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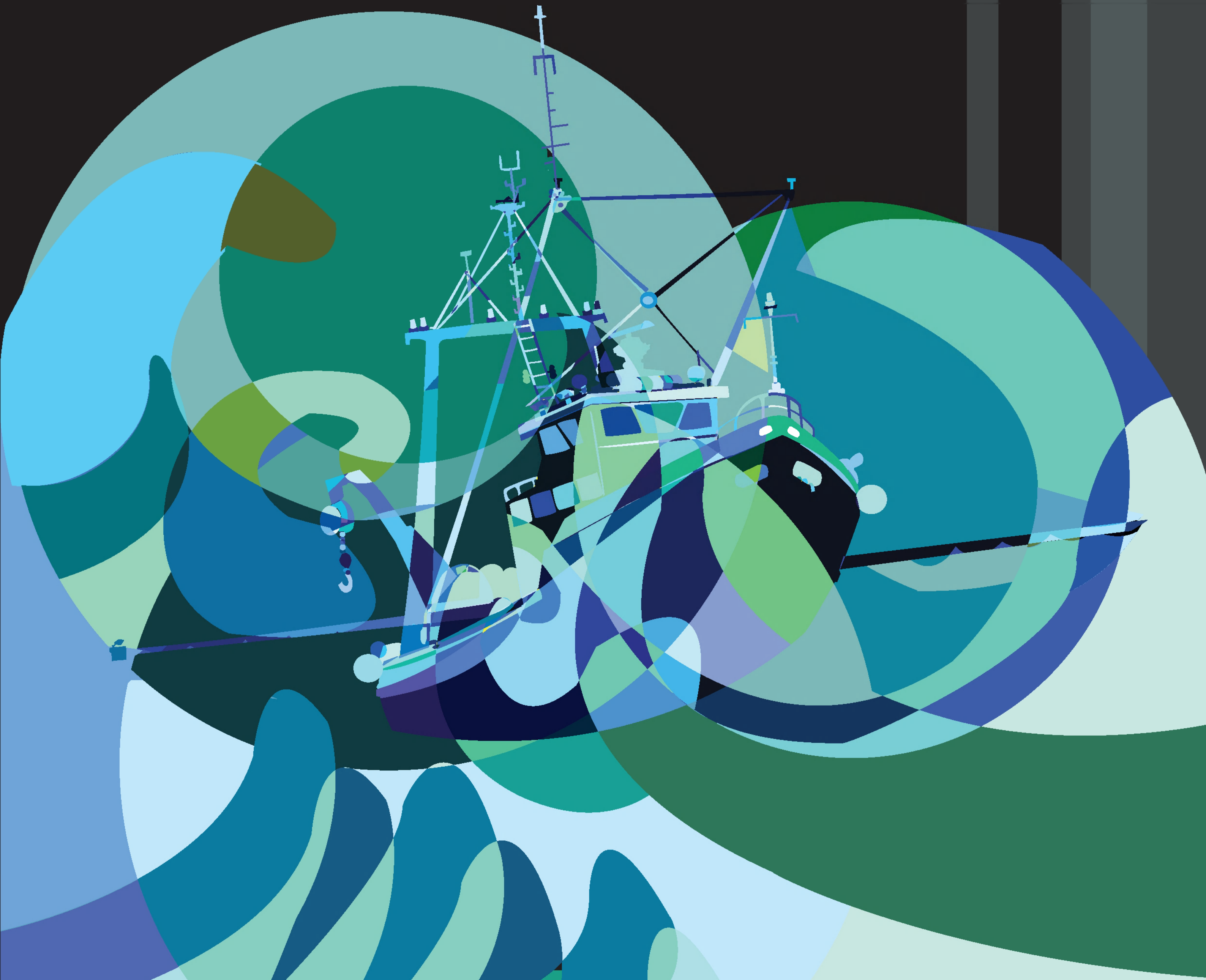
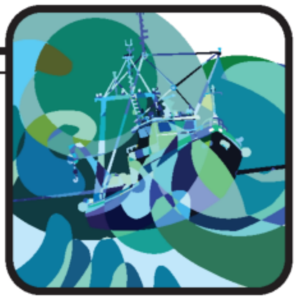
Ann-Katrien Lescrauwaet

BELGIAN FISHERIES: TEN DECADES, SEVEN SEAS, FORTY SPECIES

Historical time-series to reconstruct landings, catches, fleet and fishing areas from 1900





BELGIAN FISHERIES: TEN DECADES, SEVEN SEAS, FORTY SPECIES:

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Ann-Katrien Lescrauwaet

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Promoters:
Prof.dr.Magda Vincx
Prof.dr. Jan Mees

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Marine Biology Research Group

Campus Sterre-S8

Krijgslaan 281

B-9000 Gent

Belgium

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Co-authors to one or more chapters and published articles/book chapters:

Prof. dr. Magda Vincx, Prof. dr. Jan Mees, dr. Jan Vanaverbeke, dr. Hans Polet, dr. Els Torreele, dr. Nancy Fockedey, dr. Fien De Raedemaeker, Mrs. Heidi Debergh

Reading Committee:

Dr. Jan Vanaverbeke (Ghent University, Ghent, Belgium)

Prof. dr. Filip Volckaert (Catholic University of Leuven, Leuven, Belgium)

Dr. Jan Seys (Flanders Marine Institute VLIZ, Oostende, Belgium)

Dr. Georg Engelhard (Centre for Environment, Fisheries and Aquaculture Science CEFAS, Lowestoft, UK)

Examination Committee:

Prof. dr. Ann Vanreusel, Chairman (Ghent University, Ghent, Belgium)

Prof. dr. Magda Vincx, Promotor (Ghent University, Ghent, Belgium)

Prof. dr. Jan Mees, Promotor (Ghent University, Ghent, Belgium)

Prof. dr. Frank Maes (Maritime Institute, Ghent University, Ghent, Belgium)

Dr. Jan Vanaverbeke (Ghent University, Ghent, Belgium)

Dr. Tim Deprez (Ghent University, Ghent, Belgium)

Prof. dr. Filip Volckaert (Catholic University Leuven, Leuven, Belgium)

Dr. Hans Polet (Institute for Agriculture and Fisheries Research ILVO, Oostende, Belgium)

Dr. Jan Seys (Flanders Marine Institute VLIZ, Oostende, Belgium)

Dr. Georg Engelhard (Centre for Environment, Fisheries and Aquaculture Science CEFAS, Lowestoft, UK)

"The Common Sole formerly plentiful now very scarce,

requires immediate attention

for its preservation or propagation".

Olsen, O.T. (1883).

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WORDS OF APPRECIATION

This thesis would not have been possible without the support of Flanders Marine Institute VLIZ and in particular its director dr. J. Mees. The many contributions of colleagues and co-workers to the 'One Century of Sea Fisheries' project, are highly valued and acknowledged in the different chapters. I thank my colleagues and friends at the InnovOcean-site, and in particular R. Herman (EWI), and H. Pirlet and T. Verleye, H. Debergh, T. Verstraete and R. Pirlet (VLIZ) for the great team-work.

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Embarking in a PhD programme at this stage in life, is not a decision you take on your own and certainly not a personal project. Before deciding, I consulted with family and friends. If I had a slight idea of what this would mean, for them it was a 'blind date'. By the time they realized it might be an uncomfortable date, it was too late to change seats, and they supported me all the way. I thank my parents, brothers and sister, and my in-laws in Belgium, Venezuela and Chile who accepted my laptop as a companion during our family vacations and who supported us in this family project. My deepest thanks go to my clan who at times made me doubt whether it was worth to dedicate so much time 'looking into the past' while so much is happening at the moment in their young adult lives. I dedicate my work to them: Thorsten, Sil-Katrien and Darién Maslov for supporting their student-mother, and to my life-companion Nadimir Maslov for his endless patience and support. I promise I will not write a PhD. thesis again.

Ann-Katrien Lescrauwaet, May 2013

NEDERLANDSTALIGE SAMENVATTING

Menselijke activiteiten hebben van oudsher een invloed op de mariene ecosystemen, en de visserij wordt het vaakst gezien als de oorzaak van overbevissing en uitputting van de mariene biologische hulpbronnen (Myers en Worm 2003, Salomon 2009). Recente studies illustreren hoe onze perceptie van ongerepte omstandigheden in de zeeën en oceanen over generaties heen, is verschoven. Dit wordt vaak aangeduid als 'Shifting Baselines'. Met een groei in de bewijsvoering over (pre) historische referentiekaders is gaandeweg het besef toegenomen over de beperkingen in de huidige wetenschappelijke methoden om passende referentiekaders op te stellen waartegenover de huidige doelstellingen voor de instandhouding en het beheer worden vastgesteld, met name voor de visserij (Pinnegar en Engelhard 2008). Er wordt erkend dat, bij het opstellen van referentiekaders en doelstellingen, er moet gestreefd worden om alle beschikbare en relevante gegevens en informatie te integreren ten behoeve van betere evaluaties, en dit omvat ook de integratie van historische gegevens (Pinnegar en Engelhard 2008, McClenachan et al. 2012). Historische gegevens kunnen bijdragen in het verklaren van de onderliggende oorzaak-gevolg relaties in de veranderingen in de ecosystemen, mogelijke informatie en kennis over verleden referentiekaders onthullen (Jackson et al. 2001), en informeren bij het vastleggen van haalbare doelen voor het beheer van het mariene milieu vandaag. Dit proefschrift richt zich op de kwantitatieve gegevens om de bestaande looptijd van de huidige analyses met betrekking tot de historische visserij te verbreden en op de reconstructie van historische tijdreeksen om onze kennis inzake historische referenties voor de Belgische zeevisserij, uit te breiden.

De 'Historische Visserij Database' (HiFiDatabase) is een product van dit proefschrift. Het is een uniek product en het resultaat van een grondig onderzoek, inventarisatie, standaardisatie en integratie van gegevens voor de Belgische zeevisserij die niet eerder beschikbaar waren in het publieke domein of niet beschikbaar waren in het juiste formaat voor herverdeling. De HifiDatabase is gedocumenteerd en opgeslagen in het Marien Data Archief van het Vlaams Instituut voor de Zee en is vrij toegankelijk voor eindgebruikers. Het bevat een verzameling van tijdreeksen met gestandaardiseerde soortnamen, rapportage-eenheden, visgebieden en aanvoerhavens (Lescrauwaet et al. 2010b). Het is een 'levend' product in de zin dat nieuwe, relevante, en op kwaliteit gecontroleerde tijdreeksen kunnen worden toegevoegd naarmate ze worden geproduceerd. Gezien de relatief geringe omvang van de vloot, de korte kustlijn en het beperkt aantal visafslagen en vissershavens in België, kan men stellen dat de huidige reconstructie van de Belgische zeevisserij een vrij volledig beeld schetst van de historische omvang, waarde en samenstelling van de aanvoer, dynamiek van de vloot, visserij-inspanning en ruimtelijke dynamiek. Het werk en de gevolgde methode bieden een blauwdruk voor de opmaak van gelijkaardige reconstructie in andere landen.

De gereconstrueerde tijdreeksen geven aan dat, sinds het begin van de systematische rapportage in België in 1929, de aanvoer door de Belgische zeevisserij zowel in buitenlandse als in Belgische havens, 3,3 miljoen ton (t) bedroeg. Na een maximum van 80.000 ton in 1947, is de jaarlijkse aanvoer gestaag gedaald tot slechts 26% van deze piek in 2008 (Lescrauwaet et al. 2010a). De belangrijkste soorten over de gehele periode genomen waren kabeljauw (17% van alle aanvoer) en haring (16%), gevolgd door schol (14%), tong (8%), wijting (6%) en roggen (6%). In termen van economische waarde en gebaseerd op waarden gecorrigeerd voor inflatie, waren tong (31%) en kabeljauw (15%) de meest waardevolle, gevolgd door schol (11%), garnaal (5%), roggen (5%) en tarbot (3%). Ongeveer 73% van alle aanvoer was afkomstig uit 5 van de 31 visgebieden. Twintig procent van alle aanvoer was afkomstig uit de 'kustwateren', terwijl deze wateren bijna 60% van alle aangelande pelagische soorten en 55% van alle aangevoerde 'weekdieren en schaaldieren' produceerde. De Noordzee (zuid) en de IJslandse Zee waren de volgende in belang met respectievelijk 17% en 16% van alle aanlandingen. Het oostelijke en westelijke deel van de centrale Noordzee, droegen elk met ongeveer 10% bij aan de totale aanvoer (Lescrauwaet et al. 2010a).

De Belgische visserij kende in haar ontwikkeling 3 grote opeenvolgende fasen waarin 3 belangrijke doelsoorten of doelsoort-groepen werden geëxploiteerd, tot gebeurtenissen of processen leidden tot een overgang naar een nieuwe fase: een eerste ‘haring (en sprot) periode’ tot 1950, een ‘kabeljauw periode’ (en andere kabeljauwachtigen) tussen 1950 en 1980 en een periode die gekenmerkt werd door schol en tong tussen 1980 en 2000 (en ook daarna). Deze opeenvolgende exploitatie van doelsoorten is ook nauw verbonden met de geëxploiteerde visgronden. Dit waren achtereenvolgens de kustwateren voor haring, de IJslandse Zee voor kabeljauw, de Noordzee zuid en de Noordzee centraal (oost en west) voor de visserij op platvis (tong en schol), later ook gevolgd door de "westelijke wateren" (Engels Kanaal, Kanaal van Bristol, Ierse Zee).

Het interpreteren van de trends in de aanvoer en de veranderingen in de doelsoorten (groepen), is niet mogelijk zonder een analyse van de trends en veranderingen in de vissersvloot en de visserij-sector in een bredere sociaal-economische en politieke context. In het huidige proefschrift, wordt het resultaat voorgelegd van de reconstructie van de omvang van de Belgische zeevisserij vloot (sinds 1830), tonnage (vanaf 1842) en motorvermogen (kW vanaf 1912). De tijdreeksen tonen een daling van 85% in de omvang van de vloot en een daling van 5% in het totale motorvermogen (kW) sinds de Tweede Wereldoorlog (WOII). Deze daling werd gecompenseerd door een vertienvoudiging in de gemiddelde tonnage (GT) per schip en een verzesvoudiging in het gemiddelde motorvermogen (kW) per schip.

In slechts 10 jaar tijd na WOII is de omvang van de vloot gedaald van ongeveer 550 tot 450 schepen in 1955 (Lescrauwaet et al. 2012). Tussen 1955 en 1970 vonden grote structurele veranderingen plaats in de Belgische zeevisserijvloot. Deze veranderingen werden eerst gedreven door de verschuiving in de belangrijkste visserijactiviteiten naar IJslandse wateren in de jaren 1950 en in de vroege jaren 1960 door de overheidsubsidies voor de aankoop van nieuwe (stalen) middelgrote motortrawlers en de introductie van de boomkor (Poppe 1977, Lescrauwaet et al. 2012). Dit leidde tot minder maar krachtigere schepen: tussen 1960 en 1975 is de omvang van de vloot gedaald van 430 naar circa 250 schepen (-42%). De daling van de omvang van de vloot werd nog duidelijker toen IJsland de territoriale wateren afbakende van 12 nm naar 50 nm in 1972, en vervolgens de aanwezigheid van Belgische vissers binnen de aangegeven 200 nm in de IJslandse wateren onderworpen werd aan een 'phase-out' in 1975 (Lescrauwaet et al. under review). Als gevolg van het verlies van de IJslandse wateren rond 1980, verschoven Belgische schepen hun activiteiten weer naar het centrale deel van de Noordzee (Omey 1982) en - in mindere mate - in de richting van het Engels Kanaal, Kanaal van Bristol, Zuid-en West-Ierland en de Ierse Zee. Vanaf 2000 werden specifieke programma's opgestart, gericht op de ontmanteling van schepen met het doel om de vlootcapaciteit te verminderen. In 2012 telde de Belgische commerciële zeevisserij vloot 86 schepen, met een totale capaciteit van 49.135 kW en bruto tonnage van 15.326 BT (Roegiers et al. 2013).

De gereconstrueerde tijdreeksen suggereren dat de totale aanvoer daalde met de totale omvang van de vloot en met de totale visserij-inspanning. Op het niveau van de Belgische vloot, daalde het totale aantal dagen op zee van ongeveer 91.800 dagen in 1938 tot 15.100 dagen in 2010 (-84%). De aanvoer (kg) per vaartuig per dag op zee of per dag vissen verdubbelde tussen 1938 en 2010. De tijdreeks toont tenminste 4 opeenvolgende gebeurtenissen: een eerste event (1939-1945) is getekend door de WOII en de toename in de aanvoer van haring uit de kustwateren. De uitzonderlijk hoge aanvoer per eenheid van inspanning wordt gedeeltelijk verklaard door de stopzetting van de grootschalige haringvisserij in de Noordzee tijdens WOII in combinatie met de effecten van twee sterke jaarklassen. De tweede periode situeerde zich in 1951-1955 en viel samen met de sterke stijging van de aanvoer uit de IJslandse wateren. Ten derde wordt een toename van de aanvoer waargenomen tussen 1960 en 1967, een periode tijdens dewelke staatssubsidies werden toegekend voor de introductie van de boomkor, eerst in de garnaalvisserij (1959-1960) en later voor de visserij op platvis. Een laatste opvallende stijging betreft de periode van verhoogde niveaus in de aanvoer per vaartuig per dag tussen 1977 en 1986. Na standaardisatie van deze tijdreeks als 'aanvoer per eenheid geïnstalleerd vermogen' (LPUP) om rekening te houden met de gemiddelde stijging (x6) van het motorvermogen per schip, tonen de gegevens echter een daling met 74%, van gemiddeld 1,3 t per geïnstalleerde kW in 1944-1947 tot 0,38 t per geïnstalleerde kW in 2009-2010. Interessant is dat de gemiddelde prijs van de aanvoer (alle soorten, alle visgronden, alle visserijtakken geaggregeerd) negatief correleert met de afnemende visserij-inspanning en met de daling van de totale aanvoer. Dit wijst er op dat de Belgische zeevisserij compenseerde voor de verliezen door zich te richten op soorten met een hogere marktprijs. Hoewel de trends in LPUP illustratief zijn voor de veranderingen in de productiviteit van de visserij, kunnen ze niet worden geïnterpreteerd als een maatstaf van de verandering in de biomassa van commerciële visbestanden, omdat de Belgische visserij zich over de voorbije eeuw heen gericht heeft op verschillende soorten en vangstgebieden. Trendanalyses om verandering in de visstand te onderzoeken moeten worden uitgevoerd op het niveau van de verschillende metiers of de visserijtakken, rekening houdend met de specificiteit en de selectiviteit van het vistuig, de milieuomstandigheden in de visserijgebied, de seizoensgebondenheid van de visserij en het gedrag van de doelsoorten.

In dit proefschrift werd de impact van de zeevisserij onderzocht, en toegepast op verschillende vraagstukken. In een eerste deel werd een reconstructie uitgevoerd van de totale vangsten door de Belgische zeevisserij door het opnemen van de niet-gerapporteerde aanvoer van de commerciële en recreatieve visserij, alsmede een raming van de teruggooi. Hierbij werd een methodiek gevolgd die ook bruikbaar is als blauwdruk voor vergelijkbare reconstructies in andere landen. Het is de eerste maal dat dergelijke historische reconstructie uitgevoerd wordt en de resultaten hebben een potentiële toepassing in huidige beleidskeuzes en maatschappelijke vraagstukken. Deze reconstructie omvat 6 visserijtakken met een historisch of actuele betekenis voor België (Lescrauwaet et al. 2013). De totaal gereconstrueerde vangsten werden geschat op 5,2 miljoen t of 42% hoger dan de 3,7 miljoen t publiekelijk gemeld over deze periode. Niet-gerapporteerde aanvoer en teruggooi werden geschat op respectievelijk 3,5% (0,2 miljoen t) en 26% (1,3 miljoen t) van deze totale gereconstrueerde vangsten.

Tijdens de Tweede Wereldoorlog, ervoer de Belgische visserij een vertienvoudiging in de vangsten en een vervijfvoudiging in aanvoer per eenheid inspanning (LPUE) voor de haring visserij. In dit proefschrift werden deze toegenomen vangsten verklaard door de gecombineerde effecten van de toename in de vangstcapaciteit na WOI, de gevolgen van de beëindiging van grootschalige haringvisserij in het centrale deel van de Noordzee tijdens WOII, en het effect van sterke pre -WWII jaarklassen in het haringbestand (Lescrauwaet et al. revised manuscript under review).

Een derde deel is gericht op de plankenvisserij op kabeljauw in de IJslandse wateren. Deze visserij was van groot economisch belang in België, maar daalde met de ‘kabeljauw oorlogen’ (1958 en 1972) en kwam uiteindelijk tot een complete stop in 1996. Terwijl de daling van de totale aanvoer vanuit de IJslandse wateren begon nadat IJsland zijn EEZ uitbreidde in 1958, bleef de visserij-inspanning van de Belgische vloot stijgen tot een piek werd bereikt in 1963. De resultaten tonen aan dat de afname in de IJslandse kabeljauwbestanden zichtbaar was op verschillende niveaus met name de daling van het relatieve belang van de kabeljauw in de totale aanvoer, de daling van 75% in de LPUE (1946-1983), de daling van het aandeel van 'grote' vissen, en tenslotte het verval of de verschuiving in de definitie van ‘grote’ exemplaren in de classificatie van de aanvoer.

Als gevolg van dit proefschrift, zijn unieke gegevens gepresenteerd over de ontwikkeling in de omvang en samenstelling van de aanvoer voor het Belgische deel van de Noordzee (BNS). De wateren van het BNS worden beschouwd als het belangrijkste visgebied in termen van voedselbron voor de lokale bevolking, maar ook als de meest stabiele leverancier van voedsel. Het BNS en in het bijzonder het ecosysteem van ondiepe onderwaterzandbanken is ook belangrijk als paai- en opgroeigebied voor vis en bodemleven (Leloup en Gilis 1961, Gilis 1961, Leloup en Gilis 1965, Rabaut et. al 2007).

De HiFiDatabase verbreedt het historische beeld op de visserij en dient als basis voor verder onderzoek, toepassingen op het gebied van beheer, en ter informatie en ondersteuning van de beleidsvorming. Met name de tijdreeksen voor de visserij in het Belgisch deel van de Noordzee bieden een uniek historisch referentiekader en een potentiële basis voor het visserijbeheer in de territoriale wateren of voor de kustvisserij. Dit laatste is nuttig in het kader van de EU-Kaderrichtlijn mariene strategie, de EU Habitatrichtlijn en het voorstel voor maritieme ruimtelijke ordening op het Belgisch deel van de Noordzee. In dit proefschrift werden belangrijke inspanningen gewijd aan het benaderen van de geschiedenis van de visserij vanuit verschillende disciplines. De resultaten onderstrepen het belang van het verzamelen van economische gegevens, het inventariseren van historische archieven en historische wetgeving, historische economie en politiek, met het oog op het verfijnen en verbeteren van de interpretatie en analyse van de resultaten. Zoals bepleit door de benadering bij het huidige geïntegreerde beleid voor het mariene milieu, is de meerwaarde van zowel de methode als van de resultaten van de opdracht, afhankelijk van een multidisciplinaire aanpak.

SUMMARY

Human activity has been impacting marine ecosystems for millennia, and fishing is most often seen as the cause of overexploitation and depletion of marine biological resources (Myers and Worm 2003, Salomon 2009). There is a wealth of recent studies illustrating how our perception of pristine conditions in the seas and oceans has shifted over generations. This is referred to as 'Shifting Baselines'. A wide range of evidence about (pre) historical reference conditions and early baselines has increased the awareness on the limitations associated with the current scientific methods to determine appropriate reference conditions against which current targets for conservation and management are set, in particular for fisheries (Pinnegar and Engelhard 2008). It is acknowledged that environmental reference conditions and targets must strive to integrate all available and relevant data and information for improved assessments, including incorporating historical data into conservation and management frameworks (Pinnegar and Engelhard 2008, McClenachan et al. 2012). Historical data can contribute in explaining underlying cause-effect relations in changes in the ecosystems, potentially reveal information and knowledge from past conditions (Jackson et al. 2001), and help defining reference conditions and achievable targets for environmental management today. The present thesis focuses on quantitative data to extend the timeframe of current analyses on fisheries (landings, fleet dynamics, spatial dynamics, indexes of productivity of the fleet and impact of fishing) and on the reconstruction of historical time-series to expand our knowledge on historical references for the Belgian sea fisheries. In achieving this, it intends to counter the concept of 'Shifting Baselines' applied to the Belgian Sea fisheries.

The 'Historical Fisheries Database' (HiFiDatabase) is a product of this thesis. It is the result of a thorough search, rescue, inventory, standardization and integration of data for Belgium's sea fisheries that were not available before in the public domain or were not available before in the appropriate format for redistribution. It is documented and stored in the Marine Data Archive of Flanders Marine Institute and is freely available for end-users. It contains a unique and substantial collection of time series with standardized species names, reporting units, fishing areas and ports of landing (Lescrauwaet et al. 2010b). It is a 'living' product in the sense that new, relevant, quality-controlled time-series can be added as they are discovered or produced. Considering the relative size of the fleet, the short coastline and the limited number of fish auctions and fishing ports in Belgium, it is fair to say that the present reconstruction of Belgian sea fisheries depicts a relatively complete picture of historical volume, value and composition of landings, fleet dynamics, fishing effort and spatial dynamics. The project and its methodology offer a blueprint for similar reconstructions in other countries.

The reconstructed time-series indicate that, since the onset of systematic reporting mechanisms in Belgium in 1929, landings reported by the Belgian sea fisheries both in foreign and in Belgian ports amounted to 3.3 million tonnes (t). After a maximum of 80,000 t in 1947, annual landings declined steadily to only 26% of this peak by 2008 (Lescrauwaet et al. 2010a). The most important species over the observed period in terms of landings were cod (17% of all landings) and herring (16%), closely followed by plaice (14%), sole (8%), whiting (6%) and rays (6%). In terms of economic value and based on values corrected for inflation, sole (31%) and cod (15%) were the most valuable, closely followed by plaice (11%), brown shrimp (5%), rays (5%) and turbot (3%). Near to 73% of all landings originated from 5 of the 31 fishing areas. Twenty percent of all landings originated from the 'coastal waters', while these waters contributed nearly 60% of all landed pelagic species and 55% of all landed 'molluscs and crustaceans'. The North Sea (south) and the Iceland Sea were next in importance with 17% and 16% of all landings respectively. The eastern and western part of the central North Sea, contributed each with approximately 10% of the total landings (Lescrauwaet et al. 2010a).

The Belgian fisheries have followed a development of 3 major successive exploitation phases in which 3 major target species or target species groups were exploited until events or processes triggered a transition to a new phase: a 'herring' period between 1929 and 1950, a 'cod' (and other gadoid and roundfish) period between 1950 and 1980 and a period marked by plaice/sole between 1980 and 2000 (and after). This successive exploitation of targeted species was also associated with exploited fishing grounds, successively the Coastal waters for herring, the Icelandic Sea for cod,

the North Sea south and the North Sea central (east and west) for sole/plaice, later also complemented by the 'western waters' (English Channel, Bristol Channel, Irish Sea) for the flatfish fisheries.

To understand and interpret the trends in landings and changes in target species (groups), it is crucial to look at trends and changes in the fishing fleet and the fishing sector inserted in a wider socio-economic and political context. In the present thesis work, a reconstruction was made of the fleet size (from 1830), tonnage (from 1842) and engine power (kW from 1912) of the Belgian sea fisheries fleet. The time-series show a 85% decrease in fleet size and a 5% decrease in overall engine power (kW) since WWII. This decrease was compensated by a 10-fold increase in average tonnage (GT) per vessel and a 6-fold increase in average engine power (kW) per vessel.

In only 10 years time after WWII, the fleet size decreased from approximately 550 to 450 vessels in 1955 (Lescrauwaet et al. 2012). Between 1955 and 1970 major structural changes took place in the Belgian sea fisheries fleet. These changes were driven first by the shift in the main fishing activities towards Icelandic waters in the 1950s and in the early 1960s by the governmental subsidies for the purchase of new steel hulled medium-sized motor trawlers and the introduction of the beam-trawl (Poppe 1977, Lescrauwaet et al. 2012). This led to less but more powerful vessels: between 1960 and 1975 the fleet size declined from 430 to approximately 250 vessels (-42%). The decline in fleet size was exacerbated when Iceland demarcated its territorial waters from 12 nm to 50 nm in 1972 and when the presence of Belgian fishermen within the declared 200 nm EEZ of Icelandic waters became subject to a 'phase-out' in 1975 (Lescrauwaet et al. under review). As a consequence of the loss of the Icelandic waters towards 1980, Belgian vessels shifted their activities again towards the central part of the North Sea (Omey 1982) and - to a lesser extent - towards the English Channel, Bristol Channel, South and West Ireland and the Irish Sea. From 2000 onwards specific programmes were oriented to the decommissioning of ships with the aim to reduce fleet capacity. In 2012, the Belgian commercial sea fishing fleet counted 86 ships, with a total engine capacity of 49,135 kW and gross tonnage of 15,326 GT (Roegiers et al. 2013).

The reconstructed time-series suggest that total landings decreased with total fleet size and with total fishing effort. At the level of the Belgian fleet, the total number of days spent at sea decreased from approximately 91,800 days in 1938 to 15,100 days in 2010 (-84%). The landings (kg) per vessel per day at sea or per day fishing have doubled between 1938 and 2010. The time-series shows at least 4 successive events: a first event (1939-1945) marked by WWII and the increased landings of herring in coastal waters. The exceptionally high landings per unit of effort are partly explained by the cessation of large-scale herring fisheries in the North Sea during WWII combined with the effects of two strong year classes. The second period is situated in 1951-1955 and coincides with the steep increase in landings from Icelandic waters. Thirdly, an increase in landings is observed between 1960 and 1967, which coincides with the state subsidies to introduce the beam trawl firstly in shrimp vessels (1959-1960) and later for flatfish fisheries. A final conspicuous event concerns the period of increased levels of landings per vessel per day between 1977 and 1986. After standardization as landings per unit of installed power (LPUP) to account for the average increase (x6) of engine power per vessel, the landings have decreased by 74% from an average 1,3 t /installed kW in 1944-1947 to 0,38 t /installed kW in 2009-2010. Interestingly, the average price of landings (all species, all areas , all fisheries aggregated) is negatively correlated with the decreasing fishing effort and decrease in overall landings. This suggests that the Belgian sea fisheries compensated for the losses by targeting species that achieve better market prices. Although the LPUP are illustrative of the changes in the productivity of fisheries, they cannot be interpreted as a proxy of change in biomass of commercial fish stocks, because the Belgian fisheries have targeted different species and fishing areas over time. Trend analysis to study change in fish stocks must be conducted at the level of different métiers or fisheries, taking into account issues such as specificity and selectivity of gear, environmental conditions in the targeted fishing area, seasonality of fishing and behavior of target species.

In the present thesis, a closer look was taken at the impact of sea fisheries. In a first part, a quantitative approach was taken to reconstruct total removals by Belgian sea fisheries by including the unreported and misreported landings of commercial and recreational fishing, as well as an estimation of discards. The methodology applied in this reconstruction can serve as a blueprint for similar reconstructions in other countries. The results are useful to inform current policy issues and societal challenges. This reconstruction covers 6 fisheries with historical or current importance for Belgium (Lescrauwaet et al. 2013). Total reconstructed removals were estimated at 5.2 million t or 42% higher than the 3.7 million t publicly reported over this period. Unreported landings and discards were estimated to represent respectively 3.5% (0.2 million t) and 26% (1.3 million t) of these total reconstructed removals.

During the WWII, the Belgian fisheries benefited a 10-fold increase in catches and 5-fold increase in LPUE of North Sea 'Downs' herring. In the present thesis, these increased catches were explained by the combined effects of a major increase in catch power after WWI, the effects of the cessation of large-scale herring fisheries in the central part of the North Sea and by the effects of strong pre-WWII year classes (Lescrauwaet et al. revised manuscript under review).

A third subchapter focused on the otter trawl fishery in Icelandic waters targeting cod. This fishery was of great economic importance in Belgium but decreased with the 'cod wars' (1958 and 1972) coming finally to a complete end in 1996. While the decline in total landings from Icelandic waters started after Iceland expanded its EEZ in 1958, the fishing effort of the Belgian fleet continued to increase until a peak was reached in 1963. The results show that the decline in the Iceland cod stock was visible at different levels; the decrease in the proportional importance of cod in the overall landings, the 75% decrease in the LPUE (1946-1983), the decline in the proportion of 'large' fishes, and finally the decline or shift in the definition of a 'large' specimen.

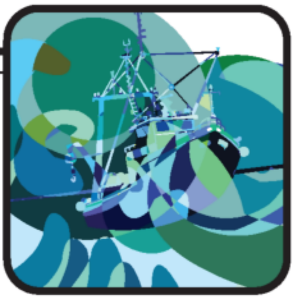
As a result of this thesis, unique data are presented on the trends in volume and composition of landings for the Belgian part of the North Sea (BNS). The waters of the BNS are considered as the most important fishing area in terms of source of food for local population, but also as the most stable provider of food. The BNS and in particular the ecosystem of shallow underwater sandbanks is also important as (post)spawning and nursery area (Leloup and Gilis 1961, Gilis 1961, Leloup and Gilis 1965, Rabaut et.al 2007).

The HiFiDatabase broadens the historical view on fisheries and serves as a basis for a range of potential research, management applications, and in support of policy-making. In particular, the time-series provide unique historical reference conditions of fishing in the Belgian part of the North Sea and a potential baseline for fisheries management in territorial waters or for the coastal fisheries. The latter is useful in the context of the EU Marine Strategy Framework Directive, the EU Habitat Directive and the proposal for Maritime Spatial Planning on the Belgian part of the North Sea. Finally in the present thesis work, important efforts were dedicated to approach the history of fisheries from different disciplines of work. The results underline the importance of collecting economic data, inventorying historical archives and historical legislation, historical economy and politics, in order to improve the interpretation and analysis of results. As advocated by the current integrated policies for the marine environment, both the challenge of the task and the richness of the results rely on a multidisciplinary approach.

List of Abbreviations in alphabetical order

ASCOBANS	Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas
BD	Biodiversity
BNS	Belgian part of the North Sea
CBD	Convention on Biological Diversity
CFP	Common Fisheries Policy
CPUE	Catch Per Unit of Effort
DB	Database
EC	European Commission
EEA	European Environment Agency
EEZ	Exclusive Economic Zone
ENSO	El Niño Southern Oscillation
EU	European Union
EUR	Euro
FAO	Food and Agriculture Organization
FH	Fishing hours
GES	Good Environmental Status
GRT	Gross Registerton
GT	Gross Tonnage
HA	Hectare
HD	EU Habitat Directive
HIFIDATABASE	Historical Fisheries Database for Belgium
HMAP	History of Marine Animal Populations
HP	Horsepower (English horsepower)
ICES	International Council for the Exploration of the Sea
ICZM – ICM	Integrated Coastal (Zone) Management
IMIS	Integrated information System
IMP	Integrated Maritime Policy
IUU	Illegal, Unregulated and Unreported Fisheries
kW	kiloWatt
LEK	Local Ecological Knowledge
LPUE	Landings Per Unit of Effort
MEA	Millenium Ecosystem Assessment

MLS	Minimum Landing Size
MPA	Marine Protected Area
MS	Member State
MSFD	Marine Strategy Framework Directive
MSP	Marine Spatial Planning - Maritime Spatial Planning
MSY	Maximum Sustainable Yield
NAO	North Atlantic Oscillation
OA	Open Access (Movement, Initiative)
OMA	Open Marine Archive
OSPAR	Oslo-Paris Convention
PK	Paardenkracht (Dutch horsepower)
SD	Sea days, days at sea
SGHIST	ICES Study Group on the History of Fish and Fisheries
STECF	Scientific, Technical and Economic Committee for Fisheries
T	Tonnes
TAC	Total Allowable Catch
TKM	Tonnekilometre
VLIZ	Flanders Marine Institute
VPA	Virtual Population Analysis (VPA) method
WFD	Water Framework Directive
WGHIST	ICES Working Group on the History of Fish and Fisheries
WKHIST	ICES Workshop on the History of Fish and Fisheries
WORMS	World Register of Marine Species
WWI, WWII	World War I, World War II



CHAPTER 1: General Introduction, Objectives, Outline of the thesis

CHAPTER 1. GENERAL INTRODUCTION, OBJECTIVES, OUTLINE OF THE THESIS

1.1 HEALTHY AND PRODUCTIVE SEAS AND OCEANS

1.1.1 INTEGRATED POLICIES AND ECOSYSTEM-BASED MANAGEMENT

The results of large scale assessments indicate that overexploitation of resources and changes in habitats are the main causes for the continued rates of loss of biological diversity (MEA 2005, EEA 2009), and that coastal and marine areas face particularly high impacts (OSPAR 2010). It is estimated that marine ecosystems provide two thirds of the value generated by ecosystems globally (Costanza et al. 1997). In terms of food production only, 128 million tonnes (t) of fish products are the primary source of protein for 17% of the world's population and nearly 25% in low-income or food-deficit countries (FAO 2012). The livelihoods of 12% of the world's population depend directly or indirectly on fisheries and aquaculture in marine waters and coastal zones. However, these ecosystems have traditionally been considered as infinite (Daly 1992) and for similar reasons, the concept of internalisation of environmental costs and the restoration and management of degraded ecosystems and resources have been scarcely applied in the marine environment.

By implementing the concept of ‘ecosystem-based management’, the European Commission (EC) sets healthy and productive marine ecosystems at the core of current and future developments in European marine waters. To comply with the objectives of marine policies, such as the EU Common Fisheries Policy (CFP), the Water Framework Directive (WFD 2000/60/EU) and the Marine Strategy Framework Directive (MSFD 2008/56/EU) as the environmental pillar of the Integrated Maritime Policy (IMP), Member States increasingly have to meet new requirements. This includes the obligation to assess the status of fish stocks and marine biological resources against the targets for sustainable management of marine resources and the protection of biological diversity in support of ‘Healthy and Productive Oceans’ (Ostend Declaration 2010). The objectives and targets of these policies also urge Member States to cooperate or extend existing cooperation in the management of marine ecosystems at the scale of regional seas, through cross-border cooperation and in agreement with third countries bordering Europe’s regional seas. Cross-border cooperation is particularly relevant for the conservation and management of habitats and species in marine waters, where physical borders cannot be implemented.

To achieve these objectives, Member States need to construct a common view and understanding of ‘healthy and productive’ conditions in marine ecosystems. In the context of the current policy frameworks these conditions are defined as a combination of quality elements or descriptors of ‘good environmental status’ (MSFD), as ‘favourable conservations status’ (Habitat directive 92/43/EEC), as ‘good ecological status’ and ‘good chemical status’ (WFD), and ‘above maximum sustainable yield’ in the case of commercially exploited fish stocks (CFP). While objectives and targets are set for separate policies, different policy targets must be translated into complementary operational objectives in the field. At the national and regional level, progress must be measured for the marine areas under the jurisdiction of Member States. These targets are often set against reference or baseline conditions, e.g. a target can be defined as ‘an increase in the area of key habitat to 50% of its reference conditions in pre-exploitation levels’. One of the issues that therefore needs to be addressed is to what extent and at what cost these reference conditions need to be restored and maintained and how these are translated as achievable targets of ‘Good Environmental Status’ or GES (Piha and Zampoukas 2001). Determining reference conditions and targets is of paramount importance for the future of the Seas and Oceans, and one that will affect society in many ways. Setting targets – for e.g. GES, Maximum Sustainable Yield MSY, and in other policies - requires a huge effort to integrate scientific knowledge, policy instruments and priority societal issues. Therefore, setting reference conditions and targets needs to be a transparent, objective and scientifically underpinned process. It must strive to integrate all available and relevant data and information for improved assessments and decision-making. There are different approaches, methods and sources to set reference conditions for current conservation and management targets. Although it may represent many challenges, incorporating historical data into conservation and management frameworks is one of the alternative methods (Pinnegar and Engelhard 2008, McClenachan et al. 2012, see also section 1.2.).

1.1.2 DATA AND INFORMATION IN SUPPORT OF AN ECOSYSTEM-BASED MANAGEMENT

Science-based assessments in the context of integrated policies increasingly need access to quality controlled and integrated data. The importance of information and integrated databases cannot be underestimated, as stated by the EC Communication 'Green Paper on Marine Knowledge' (COM(2012)473). The EC estimated that existing users would save €300 million a year if the data were properly integrated and managed (EC 2010). The first specific objective of 'Marine Knowledge 2020' is to reduce costs for industry, public authorities and researchers, and major efforts have been put in place to achieve these objectives. Although important progress is made, further improvements can still be achieved in the field of data sharing and accessing data and information.

1.2 MARINE ENVIRONMENTAL HISTORY AND THE USE OF HISTORICAL DATA IN CURRENT MANAGEMENT

It is now widely accepted that human activity has been impacting marine ecosystems for millennia, and that the concept of 'pristine' ecosystems is merely a theoretical one (Myers and Worm 2003). Fishing is considered to be the human activity with major impact (Salomon 2009) and the activity mostly associated with overexploitation in the marine environment (Myers and Worm 2003). Concern about overexploitation is not a recent phenomenon: in the 18th and 19th centuries different authors expressed their views related to overfishing in the North Sea (Mann 1777, Du Bus and Van Beneden 1866, Olsen 1883 (Figure 1.1.), Garstang 1900) and measures to regulate fishing intensity and mitigate fishing impact on the exploited stocks in the Southern North Sea were established as early as 1289 (Roberts 2007).

The impact of fishing has become evident in the first place at the level of the exploited fish stocks: worldwide almost 30% of the formally assessed commercial fish stocks today are overexploited, about 57% are fully exploited (i.e. at or very close to their maximum sustainable production) while only about 13% are non-fully exploited. These resources are therefore under increasing pressure and threats generated by the fishing activity itself, by other human-induced impacts (e.g. introduction of invasive species) and by impacts of global change (FAO 2012).

Supported by research from different disciplines (i.e. historical, genetic, archaeological, modelling) increasing evidence is being built about prehistoric reference conditions and the need to develop multidisciplinary research to improve our knowledge on these early baselines. Furthermore, this interest is fuelled by the emphasis on the precautionary approach that is embedded in many of the current policies in support of sustainable development (section 1.1.). This evidence has also increased awareness on the limitations associated with the current scientific methods in determining appropriate reference conditions against which current targets for conservation and management are set (Pinnegar and Engelhard 2008). There is a wealth of recent studies illustrating how our perception of pristine conditions in the seas and oceans has shifted over generations, and many of these refer to fisheries (Pauly 1995, Saenz-Arroyo et al. 2005, McClenachan et al. 2012). The multi-disciplinary approach, much supported by the Open Access movement, has led to the development of datasets and methods to estimate (pre)historical baseline for marine species and has demonstrated how baselines used in management have changed when historical data are included, e.g., in the management of data-poor fisheries (Pinnegar and Engelhard 2008, McClenachan et al. 2012). Awareness on the shifts in perception of the status of stocks or the health of marine ecosystems has influenced current marine ecological research and its methods and assumptions.

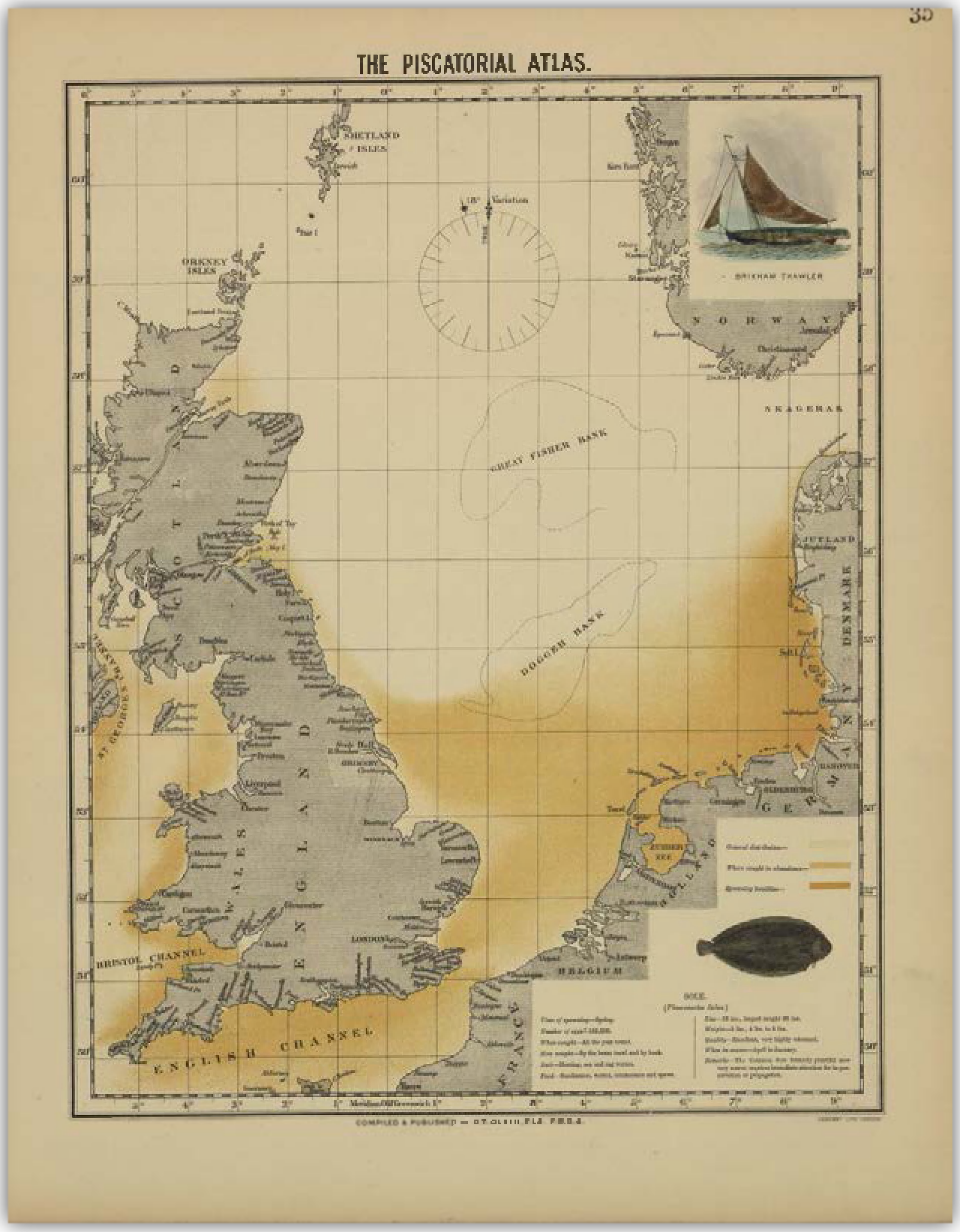


Figure 1.1.: Olsen (1883, map 35). Distribution map of sole (*Pleuronectes solea*, synonym of *Solea solea*) at the end of the 19th century. Source: Olsen, O.T. (1883). Note the text in the key to the map, as an illustration of the concept of 'shifting baselines': *"The Common Sole formerly plentiful now very scarce, requires immediate attention for its preservation or propagation".*

1.2.1 THE SHIFTING BASELINE SYNDROME

Because ecological research is often based on limited spatial and temporal scales, and conducted mostly after the 1950s (Jackson et al. 2001) much of the 'forgotten' or inaccessible historical data are of value for current and future research. Historical data can contribute in explaining underlying cause-effect relations in changes in the ecosystems, but they can also potentially reveal information and knowledge from past conditions (Jackson et al. 2001) and help defining reference conditions and achievable targets for environmental management today. In other words, historical data can counter the 'shifting baseline syndrome'.

The concept of the shifting baseline syndrome was developed by Pauly (1995) in reference to fisheries management, describing how depleted fisheries were evaluated by using the state of the fishery at the start of the careers of the experts as a baseline or reference condition, rather than the fishery in its untouched state. Pauly signposted the risks associated with this shifting perception and the challenge this represents for the management of marine ecosystems. Illustrative of the concept of shifting baselines, Sàenz-Arroyo et al. (2005) collected information over generations of fishermen, long before statistics were collected, and documented this shift in perception related to trends in abundance of target species (Figure 1.2.).

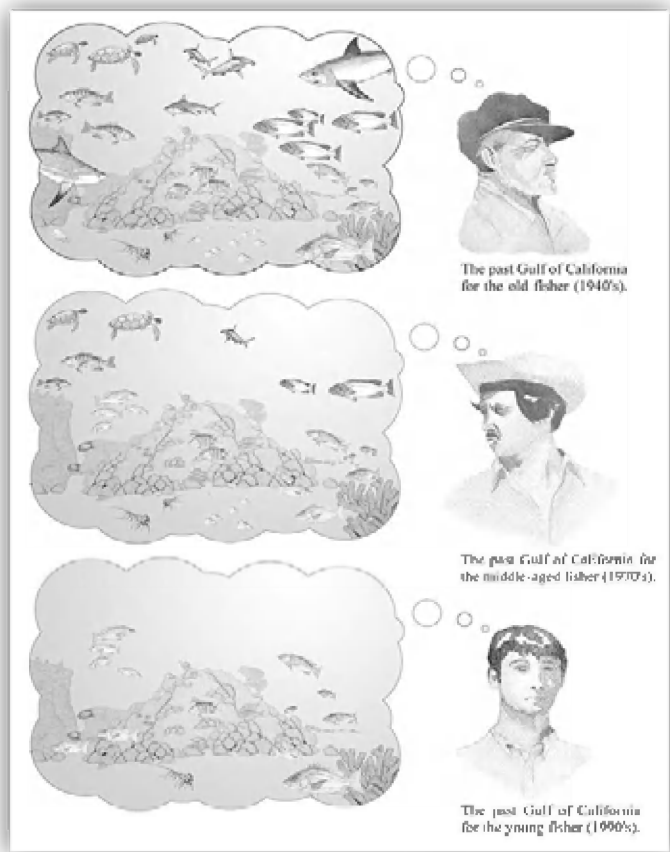


Figure 1.2.: 'Shifting baselines' translated in fisheries management (pictorial by Randall&Thiret *in* Sàenz-Arroyo et al. 2005)

In the absence of historical data, it is a widely accepted practice in ecological research to compare the impacted system with a supposedly un-impacted replica. However, with shifting baselines, much of this research is potentially based on erroneous starting points (Sheppard 1995).

Large-scale and/or long-term spatio-temporally explicit datasets collected decades ago therefore provide fundamental baselines of abundance, size structures and biodiversity patterns. These data can, among others:

- Contribute to time-series collections to feed e.g. ecosystem modeling or improved stock assessments (Cox et al. 2002)
- Support the establishment of indicators of biodiversity and geographic range
- Estimate historical population biomass and natural mortality rates of unexploited populations (Cushing 1984)
- Assist in countering the 'shifting baseline syndrome' (Pauly 1995)
- Provide early time period anchor points for meta analyses and modelling (Cardinale et al. 2009a)

Therefore, the exercise of data recovery, storage, integration and distribution is a valuable contribution to science as it allows a wider use and sharing of data by the scientific community and furthermore ensures long-term returns on funds invested by society in data gathering (Zeller et al. 2005).

1.2.2 Testing ecological hypotheses based on long term data series

Specifically related to the effects of harvesting in marine ecosystems and the shifting baseline syndrome, at least three types of hypotheses can be identified and tested by using historical data or long-term time-series:

1. Cases of temporal or permanent changes in abundance or distribution of exploited species that are caused and explained by sudden environmental changes (Corten 1999, Lindquist 2002, Poulsen et al. 2007, Eero et al. 2011). The challenge is to uncover cause-effect relationships that shape these changes and to obtain good environmental data over long-term periods or time-series on these environmental parameters, of sufficient quality to develop robust models and sound evidence.

2. Alterations in the physiological functioning of marine organisms that lead to shifts in the size structure, spatial distribution and temporal abundance of their populations, and are related to gradual or cyclic environmental changes. Examples are the gradual increase in ocean temperature (Bindoff et al. 2007) and acidity (Doney et al. 2009), rising atmospheric CO_2 and sea level rise (Hoegh-Guldberg and Bruno 2010) as well as the effects of habitat degradation, overexploitation and invasive species (Halpern et al. 2008). Examples of cyclic changes include the El Niño Southern Oscillation ENSO and North Atlantic Oscillation NAO, the cycles in solar radiation and solar energy.

3. Conditions in which the exploitation of one species has long-term effects on populations sizes and structures of other species. Examples include shifts in relative abundance of shorter-lived species lower in the food web and longer-lived species higher in the food web (e.g. Sherman et al. 1991, Steele and Schumacher 2000, Eero et al. 2011). Examination of historical and paleo-ecological data can be used as test cases to demonstrate changes in response to e.g. depletion of top predators.

Pinnegar and Engelhard (2008) and McClenachan et al. (2012) provide an overview of different types and sources of data and examples of how historical data have significantly contributed to an increased understanding of changing baselines. These may include fisheries data, fishermen logbooks, export and other economic statistics, statistics of fish consumption and transportation of fish, archaeological data, genetic studies, anecdotal information, local ecological knowledge and traditional knowledge. Even menu cards and price lists can provide a source of information for qualitative studies (Jones, *in* Starkey et al. 2000).

1.3 RECONSTRUCTING HISTORICAL DATA ON FISH AND FISHERIES

1.3.1 POLICY DRIVERS IN SUPPORT OF DATA COLLECTION

The United Nations declarations of Rio (1992) and Johannesburg (2002), the revised EU Common Fisheries Policy and the EU Marine Strategy are a few of the policy drivers that call for an integrated assessment of fishing impact. Fishing impact can be measured either as direct mortality of target and non-target species in fishing gear, or as indirect impact (Kelleher 2005). Publicly reported data and statistics on sea fisheries - which are used in conjunction with scientific surveys to produce fish stock assessments - have been typically restricted to commercial landings. However, commercial landings are only a part of the catch and hence of the total removals and impact. The difference between publicly reported versus total anthropogenic removals includes several components. Besides the unreported and misreported commercial landings (Zeller et al. 2006, Zeller et al. 2007) part of the catch is discarded at sea by fishers and dies after being thrown overboard alive (Kelleher 2005), suffers unaccounted underwater mortality e. g. in the towpath of bottom gear (Rahikainen et al. 2004, Kaiser et al. 2006, Depestele et al. 2008) or is removed by unreported recreational/artisanal fishing (Coleman et al. 2004, Zeller et al. 2008). This affects both commercial and non-commercial species such as brittle stars, seaweeds, diving birds and cetaceans. It is widely accepted that the discarding of fish at sea is unethical and represents a substantial waste of resources (Diamond and Beukers-Stewart 2011). In its resolution 57/142 of 2002 the UN have urged states and regional organizations to develop and implement techniques to reduce and eliminate bycatch and fish discards.
The impact on the sea floor can range from permanent destruction of biogenic structures (coral reefs, oyster beds) to temporary changes in sea floor cover (gravel, sediment composition) and local short-term disturbances in hydrology (suspended sediments) (Dayton et al. 1995, Turner et al. 1999, Jennings et al. 2001, Kaiser et al. 2006).

In the pursuit of an ecosystem-based approach in the marine environment, Data Collection Regulations in support of the Common Fisheries Policy CFP (EU Council Regulation 1543/2000 and Commission Regulations 1639/2001, 1581/2004 and 199/2008) require EU Member States (MS) to collect data on technical, biological and economic aspects of their national fisheries, and their impact on the marine ecosystem. The Commission Regulation 136/2007 requests member states to collect data and report on discards. Besides these measures related to data collection and the scientific stock assessments that need to advise the Council of Fisheries each year on the definition of Total Allowable Catch (TAC) and MS quota, there is a large number of technical measures to reduce fishing effort and techniques and initiatives to support the development of sustainable fishing communities throughout Europe.
In many cases, there are considerable uncertainties in stock assessments as a consequence of low stock sizes, inaccuracies in catch data (total removals) and variability in survey indices. These uncertainties add to the challenges of setting targets for the recovery of stocks in a changing natural environment. Management issues are complex and spatio-temporally explicit information becomes increasingly important to strike a right balance for a sustainable use while staying within the carrying capacity of the marine environment (Kelleher 2005).

1.3.2 FISHERIES DATA TO RECONSTRUCT FROM PRESENT TO PAST

Currently fish stock assessments are based on the data and information generated in the context of the International Council for the Exploration of the Sea (ICES). ICES stock assessment working groups meet to review the status of the principal stocks. They use three types of data to do this. First, reported data from different countries on fish landings, fishing effort and commercial catch per unit effort are combined. Secondly, independent scientific data is sampled on the fish markets and at sea (data on age structure of the landings). Thirdly the relative abundance of stocks is measured by research surveys. With these data, the fishing mortality (F)-at-age and the population number-at-age are estimated. The population number-at-age is used to estimate recruitment (R), generally the number of fish at age one or zero. Finally the total biomass (summing up the products of number x weight by age class) and spawning stock (the number x weight of fish above age of first maturity) are estimated. This Virtual Population Analysis (VPA) method is based on the principle that fishing reduces the number of fish that survive from one year to the next. With assumptions on natural mortality and selectivity of fishing gear, the actual fishing mortality can be calculated by looking at the relative number of fish of different ages by year. Using the landings-at-age data scientists can back-calculate the likely number of fish-at-age that had to be in the sea to account for the observed landings. These calculations are tuned using the commercial catch per unit of effort and the research survey data (Ricker 1975, Quinn and Deriso 1999).

Combined with landings by fishing area, the European Commission Scientific, Technical and Economic Committee for Fisheries (STECF) - established by Council Regulation EC2371/2002- produce annual stock assessments by fish stock (e.g. sole in the North Sea). The STECF then generates advice to the EC Council of fisheries on harvesting levels for these formally assessed stocks, according to precautionary principles. For most species subject to quota, stock assessments are effectuated since the 1970s, in some cases since the 1950s. However, not all stocks are formally assessed, and not for all exploited stocks TAC are determined as yet. ICES has developed a classification of fish assessment approaches that can be applied according to the amount and/or types of data these models need, and the degree of age-structured population dynamics. In data-poor environments, assessment models may need to rely on catch-only or on catch and abundance time-series models, or biomass dynamics models if a relative abundance index is available. If data are available on body growth and natural mortality, 'delay difference' models can be used. For the age-structured production and the VPA-based assessments, more complex data are required to perform statistical catch-at-age and age-structured integrated analysis models (ICES 2012-SISAM).

Fisheries management with an ecosystem-based perspective requires moving from a single-species based management to multiple-species management. It includes measures to mitigate and reduce the bycatch, discards and mortality of non-target species, while optimizing catch of target species per unit of effort based on sustainable levels of exploitation. Therefore, there is increasing interest in the reconstruction of earlier states of marine ecosystems (including non-commercial fish stocks, benthic invertebrates and ecosystem-engineering species) to understand the ecological effect of fishing in the past and support the definition of sustainable management objectives (Pauly 1995, Christensen and Pauly 1998). A considerable number of tools and data are required to achieve this. Reliable data (historical, current and forward projections) including Illegal, Unreported and Unregulated (IUU) catches and landings and reliable estimates of fishing mortality and stock assessments are one piece of the puzzle. Each of these statistics, estimates and assessments contain levels of uncertainty.

The application of the 'precautionary approach' as a principle in fisheries management has been proved promising. This may require estimating the biomass of a fish stock before exploitation, or 'virgin biomass'. According to Hilborn (2002) using recent recruitments to estimate virgin biomass in a stock that has been subject to recruitment overfishing will produce underestimations.

These assessments require datasets pre-dating exploitation, or at least before the onset of industrial or large-scale intensive fishing practices. However, historical time-series are scarce and available time-series or baselines for rebuilding depleted fish stocks typically refer to strongly exploited situations (Lescrauwaet et al. 2010a). Although highly valued, independent scientific surveys designed to estimate fish stock biomass, typically exist only for the 1970s or 1980s onwards, for some commercially important species from the 1950s. For a small number of stocks , assessments were conducted further back in time based on a variety of historical and other data sources available (Pope and Macer 1996, Rijnsdorp et al. 1996, Engelhard 2005, Cardinale et al. 2009a and 2009b).

1.3.3 FISHERIES DATA PRESERVED FROM PAST TO PRESENT

Humans have changed the marine environment and its resources ever since they started fishing. Zooarcheological evidence from the southern North Sea however, suggests that rapid changes in sea fisheries occurred around AD1000, involving large increases in catches of herring and cod (Barrett et al. 2004). The authors suggest that a rapidly increasing human population coincided with first signs of overfishing in river ecosystems due to urbanism, Christian fasting regulations, siltation and agriculture and water infrastructures (Barrett et al. 2004, Orton et al. 2011). They also suggest that commercial fishing in the marine environment was triggered by this increasing demand for fish and the declining availability of fish in nearby river and lake systems. Stable isotope analysis of archeological cod bones in England and Flanders indicates that marine catches between the 9th and the 12th centuries originated from the Southern North Sea. Later on - in the 13th and 14th centuries - the longer distance fisheries were to meet this increasing demand for fish products (Barrett et al. 2011). However, it is in particular with the implementation of fishing-enabling techniques developed during the industrial revolution that sea fisheries expanded to their current dimensions (Roberts 2007).

Fisheries in Europe have a long history and one of great economic importance. The powerful Hanseatic League in the 13th-17th centuries was built in part on the trade of herring and cod. Dutch commercial herring fisheries formed one of the best-organized and economically successful fishing ventures in the world throughout the 16th and 17th centuries (Poulsen 2008). In the 16th century, a number of towns formed the 'College van de Grote Visserij', which was granted jurisdiction over the herring industry in the Netherlands. It was operational until 1857. Poulsen (op. cit.) reconstructed time-series of catch per unit of effort of the Dutch herring fishery between 1600 and 1850, based on tax records in the Netherlands. It is the longest time-series on CPUE ever reconstructed. However, this is an exception and in spite of the strong administrative traditions of European countries, historical fish catch accounts from before the 20th century are not comprehensively available today.

Compared to other domains of human activities and in particular human activities on land such as agriculture and manufacturing, historical data on fisheries are limited and often take a narrow approach in temporal or spatial scope. Moreover, whereas historical ecological research requires a multidisciplinary approach by nature, it is still often driven by either environmental or historical research. Historical research may not take full account of the tools and theories that are instrumental to identify natural fluctuations in marine animal populations. On the other hand, fisheries ecology research questions tend to be focused on current fisheries management needs and based on the assumptions of steady state equilibria. Particular studies have incorporated climatological, oceanographic and paleontological information from historical archives to determine correlation between key environmental variables and marine animal populations (Southward and Boalch 1992, Alheit 1997) or reconstructed a historical state or evolutions in exploited marine ecosystems (Pauly 1998). In some cases, initiatives have been set up to collect and reconstruct historical reference conditions within a broader scope of developing a vision at regional sea or particular marine ecosystems, by bringing together historians, social scientists, biologists, oceanographers and fisheries managers (Holm and Starkey 1998).

Holm and Starkey (1998) distinguished three broad chronological categories of historical data and quantitative information on sea fisheries:

1. The 'statistical period': national fishery-specific records that were systematically collected by competent authorities mainly since 1900. Although much of this data - where available - may be kept and archived in printed form, quality control is needed and metadata to confirm or validate changes in data gathering procedures or changes in codes, standards, definitions, boundary classes etc. are scarce or lacking.

2. The 'proto-statistical period': often in ports and custom archives or in accountancy records of early entrepreneurship of the 18th and 19th century. Data are often quantitative but not systematically collected and hence provide a spatially and temporally restricted view on fisheries and fishing activities. The data can be used to extend the reconstruction based on statistical data from the 20th century back in

time to the mid-nineteenth century.

3. The ‘historical period’: mainly before 1850. Less extensive and mostly qualitative or anecdotal data. In some cases the data can be used to reconstruct ‘anchor points’ to extend from time-series from the proto-statistical and statistical periods.

The few available reconstructions of historical time-series are often based on indirect sources such as tax, transport and trade registers, legislation and technical fisheries measures, fishers logbooks, etc. In fact, most states in Europe did not develop a statistical approach to underpin policy development until during the first half of the 20th century (François and Bracke 2006) and standardizing fisheries statistics at the international level was certainly one of the important achievements by the ‘Statistical Committee’ of ICES.

For the present thesis, a thorough search was conducted in literature and archives, in search of quantitative information, as well as information that could prove crucial to interpret the quantitative data to be collected throughout the thesis. Chapter 2 of this thesis provides an overview of available data and time-series for the different historical periods for sea fisheries in Flanders and Belgium. Based on the findings from this extensive and in-depth - although not exhaustive - search in literature databases and archives, the existence of the three different chronological categories of data as identified by Holm and Starkey (1998) is confirmed for sea fisheries in Belgium. For particular periods, economic data was used and converted to biomass. Anecdotal information and results from studies of Local Ecological Knowledge LEK (Maes et al. 2012), proved to be valuable sources to validate outliers or support the quality control. Archaeological data and palaeo-ecological records, which use natural phenomena as ecological archives, are not the scope of the present study.

All publications, data and information sources were scanned, inventoried and described in the IMIS database (VLIZ). According to the ‘Open Access’ principles, all sources – except those for which author and other copyrights explicitly restrict access or dissemination – are made available from the Flanders Marine Institute website www.vliz.be and/or the webpages of the ‘wetenschatten’ project www.wetenschatten.be, hosted and developed by VLIZ with the support of the Province of West-Flanders.

Open Access (OA, www.openarchives.org) is the practice of providing unrestricted access via the Internet to peer-reviewed scholarly journal articles, theses, scholarly monographs, book chapters, and citable datasets. OA to research results is promoted mainly on the basis that most of the research is paid for by taxpayers through government funding of research performing organizations. The OA concept is increasingly expanding from access to journals and journal articles, to sharing data and research findings. For the marine environment and marine research in Flanders and Belgium, the OA movement is strongly promoted by the Flanders Marine Institute VLIZ. The VLIZ Open Marine Archive OMA (www.vliz.be/oma) gives free access to the digital collection of the work of Flemish/Belgian marine researchers. It holds peer-reviewed articles, pre-prints, locally published articles, press releases, reports, symposium contributions and audio-visuals. Other examples of OA resources developed and managed by VLIZ are The World Register of Marine Species (marinespecies.org), an OA inventory of all marine species names, and Marine Regions (marineregions.org), an OA inventory of Exclusive Economic Zones EEZ and marine geographic places and names which are used throughout the present study as reference databases for species and locations.

The OA movement is much in line with the ‘Digital Agenda’ for Europe which sets out an ambitious ‘open data’ policy (2003/98/EC) covering the full range of information that public bodies across the European Union produce, collect or pay for. The European Commission established OA to peer-reviewed publications as the general principle in its next framework program Horizon 2020 and promotes the OA principles to research data (experimental results, observations and computer-generated information etc.).

1.4 STATE-OF-THE ART OF RESEARCH IN HISTORICAL ECOLOGY AND FISHERIES

As argued above, there is a growing scientific and public interest to make historical data accessible in electronic format. However, the challenges to achieve this do not only refer to the digitization process. Often time-series have data gaps, limitations in temporal-spatial coverage, changes in measurement units, and the analysis and interpretation are fraught with difficulties. Acknowledging these issues led to a call from the international scientific community for a tighter collaboration between 'classic' fishery scientists, historians, and ecologists (ICES 2008). The motivation is to gain better insight into the effects of climate change, fishing, and other anthropogenic drivers on marine organisms. Data used for this purpose can refer to tax records, commercial catch statistics, catch per unit of effort (CPUE), research survey information, length and/or age compositions, biodiversity and other diverse sources (e.g. menu cards from restaurants) that can throw light on marine organisms and the dynamics of the fleet(s) exploiting them before 1960 (SGHIST 2011).

A non-exhaustive overview of some of the integrated studies and analyses that have been conducted based on the recovery of historical data is included below. They provide a context of the current state-of-the-art in historical ecology and fisheries research, in which the current research is framed (see below). An important impetus to the historical work has been provided by the History of Marine Animal Populations (HMAP) project (2000–2010) that was funded under the Census of Marine Life. Within HMAP, some 100 researchers in 12 regional focus areas and 4 global/intercontinental projects analysed marine population data before and after human impacts on the ocean became significant with the goal of enhancing knowledge and understanding of how the diversity, distribution and abundance of marine life in the World's oceans changes over the long term. Other important initiatives in this field of research are the EU project, INCOFISH (2005–2008) (hull.ac.uk/incofish/index.htm), and the Canadian-led Sea Around Us project which has a historical component digitizing historical expeditions and surveys. The European network of excellence MarBEF (www.marbef.org) also studied historical aspects in fish and fisheries studies. All projects seek to develop large-scale databases of historical relationships between ocean life and human society, and HMAP as well as INCOFISH data is archived at the University of Hull (UK).

In 2008, ICES hosted the workshop on historical data on fisheries and fish (WKHIST) in an attempt to provide links between the marine environmental history community and the marine science community. WKHIST compiled an inventory of the historical information that has been identified in locations such as national and city-archives, libraries of marine science organizations and zoological museums. The inventory is available from ICES WKHIST 2008 (www.ices.dk/workinggroups/ViewWorkingGroup.aspx?ID=629).

A few examples and case-studies from this inventory exercise are included and briefly commented below in three main categories ranging from 1) efforts to describe and make available (meta)data to large-scale digitization projects; 2) studies on spatio-temporal changes in distribution and abundance of species, fishing effort and CPUE; and 3) studies linking changes in climate with changes in population dynamics:

1.4.1 EFFORTS TO DESCRIBE AND MAKE AVAILABLE (META)DATA AND LARGE-SCALE DIGITIZATION PROJECTS

a) **Sound Toll registers project.** One of the greatest data mining exercises within history in recent years is a Dutch-Danish collaborative effort to digitize the so-called Sound Toll Registers (www.soundtoll.nl) (www.soundtoll.nl). For more than 350 years (1497–1857), the Danish king levied a toll on all ships sailing in and out of The Sound – the then main entrance point for trade between the countries around the Baltic Sea and the wider world. The preserved records from the toll, which are now being digitized, total some 1.8 million ships passages (Gøbel 2010). For future research the project will provide a unique measurement for taking stock of more than 350 years of World trade. A sizeable portion of the records relates to trade in marine resources. Common commercially caught fish include herring and cod, while dozens of other species show up in the database, such as shellfish, oysters, whale bones or sardines. While the project is running, its data become available for download online through the principles of Open Access.

b) "One-hundred Years of Change in Fish and Fisheries" (CEFAS-UK): The UK Department for Environment, Food and Rural Affairs (DEFRA), and its agency the Centre for Environment, Fisheries and Aquaculture Science (CEFAS), hold unique historical fisheries data which are highly relevant to understanding the long-term effects of fisheries, pollution, and other human impacts on marine living resources. The 100 Years of Change project collated and digitized fish and fisheries data, collected over the past 100 years by DEFRA, CEFAS, and predecessors. DEFRA commercial fisheries 'Statistical Charts' (1913–1981) provide spatially detailed (by statistical rectangle) data on catches, effort, and CPUE by fish species and fishing fleet. The historical research survey data, covering the 1890s-1970s, were conducted in the North Sea but also in the Irish Sea, north and west of Scotland, and in the Barents Sea. Based on the datasets, changes in biological characteristics in fish populations and species compositions in relation to climate and fishing were examined. The commercial data are used to examine changes in distribution of commercially important fish populations throughout the 20th and early 21st Centuries, in relation to climate change and fishing pressure. The scientific survey data serve to investigate long-term changes in stock structure, age and size compositions of key fish populations (Engelhard 2008).

c) **Online fish stomach database (1894–1915, DAPSTOM).** CEFAS scientists have collected almost 100 years worth of fish stomach content data, from the seas around the UK (North Sea, Irish Sea, and Celtic Sea). Much of these data is now available in electronic form, through the DAPSTOM data portal (www.cefas.co.uk/dapstom). The DAPSTOM project was initially financed through the 'data rescue' fund of the EU Network of Excellence EUROCEANS. The online database contains information (103927 records) on 82 predator species (most of those occurring in northern European groundfish surveys) and can be searched by predator name or by prey name for given sea areas and years (Pinnegar and Platts 2011).

d) **Fishery catch data (ICES catches from 1892 – present): reconstructing a time-series of international landings for the North Sea**. ICES collates fisheries catch data for all nations fishing in the North Sea (DK, UK, NO, NE, GE, FR, BE, SW), and makes this information available in electronic format through 'Fishstat' (1973–2005). Prior to 'Fishstat' (1903–1972) these data were available in paper format, as the annually produced publication *Bulletin Statistique*. Effort is underway (within ICES) to digitize this information and to produce a 'standard' time-series of fisheries catches for the ICES region. The data contained in *Bulletin Statistique* (Hoek and Kyle 1905) provided international fisheries data for the period 1892–1902, but only for certain key species (plaice, sole, turbot, brill, herring, haddock, cod).

1.4.2 Spatio-temporal changes in distribution and abundance of species; dynamics of fishing fleets and fishing power

a) **Northwest Atlantic: 1850s Cod Biomass Estimate on the Scotian Shelf**. This project estimated the adult cod biomass on the Scotian Shelf in 1852 by extracting daily catch records from the logbooks of 236 American fishing vessels. The total removals of cod for the Scotian Shelf were approximately 200,000 t per year or altogether 1.6 million t over 8 years (1852–1859). The Chapman-Delury method was used with the total removals and the Catch Per Unit Effort (CPUE) to derive an adult cod biomass estimate of 1.26 million t which is in stark contrast to the average annual biomass estimate of 50 000 t in the 1990s (Rosenberg et al. 2005).

b) **Changes in the North Sea cod stock.** Trends in landings, fishing mortality (F), recruitment (R), and spawning-stock biomass (SSB) were derived from analytical assessment undertaken annually by ICES extending back to 1963, as well as from earlier estimates of F and SSB back-calculated to 1920 by Pope and Macer (1996). Based on these reconstructions, relations between landings and fishing mortality, spawning stock biomass, and recruitment are analysed (Bannister 2001).

c) **Fishing and jellyfish eradicate herring…180 years ago (DTU Aqua, Univ. Aarhus, Univ Roskilde, Univ. Copenhagen-DK).** Herring has been commercially exploited for at least 400 years in the Limfjord, Denmark but its abundance has never been estimated for either historical or contemporary periods. The study developed two new estimates of herring spawner biomass for the Limfjord for a historical period of stable fisheries (ca. 1660 - 1800) following two different methods. The two independent methods produce estimates which do not differ significantly. Given these abundance estimates, the maximum carrying capacity under no-exploitation conditions (maximum spawner biomass) was calculated to be 23,000–34,000 t. These new estimates, and in particular the area-based approach, contributed to the development of reference fishing and biomass levels as well as sustainable fisheries and ecosystem management policies in situations where no other biomass estimates are available for areas such as the Limfjord, Celtic Sea and Irish Sea (MacKenzie and Poulsen 2010).

d) **Drivers of change in European Herring Fisheries, c. 1350 - present.** The European herring fisheries are one the world's biggest fisheries of the last millennium. This study analyzed how different factors played a dynamic role in how the fisheries developed over a multi-centennial scale. The focus is on i) consumer demands, ii) fishing technology, iii) environmental changes. Until the early 15th century all fisheries were land-locked in the sense that they had to return to shore with their catches for processing. Flemish fishers started to fish offshore using long driftnets deployed from converted cargo vessels, implementing an early format of 'factory vessel'. Until then, the size of catches was entirely limited by the nearshore abundance of herring. When this limitation was overcome, the output of herring was able to flourish until the ceiling of total carrying capacity seemingly was hit from the 1920s onwards (Poulsen 2008). This study evidences the need of a multidisciplinary approach in marine environmental history looking at different drivers of change (political, technological, economic, socio-cultural).

e) **Drivers influencing dominance and subsequent decline of English North Sea demersal fisheries.** Landing trends in commercial fisheries are not only influenced by natural fluctuations or fishing pressure, but also by changing drivers affecting the fishing industry. Hence, for accurate interpretation of fisheries data and revealing trends in fisheries, the historical contexts of influencing drivers have to be understood. In this study, long-term datasets covering over 100 years of international North Sea demersal fisheries were compiled, focusing on England, and relating commercial landings to historical events and political, technological and economical drivers that influenced this fishery. In the 19th and first half of the 20th century Great Britain, and in particular England, had unchallenged dominance in North Sea demersal fisheries in Europe, but lost this lead in the second half of the 20th century. For England, favourable terms of political, technological and economical drivers brought about this vast rise, but as well influenced the decline (Kerby et al. 2012).

f) **Cod moves in mysterious ways: shifting distribution in the North Sea during the last century.** The distribution of cod within the North Sea has shown major shifts over the course of the last century (Engelhard et al. 2011b). This has become evident from an analysis of almost one-hundred years of British commercial fisheries data, digitized from CEFAS archives. Combined with contemporary fisheries data, these span the period 1913-2010 (excepting both World Wars), at the spatially detailed level of ICES rectangle (0.5° Latitude, 1° Longitude). New analysis of old data reveals that from the 1920s to the 1980s cod were especially distributed in the central-west and north-western North Sea, but in the 1990s a 'hollowing out' of cod from their previous stronghold east of Scotland and Northeast England occurred, leading to an eastward shift. In the 2000s, a strong decline of cod in the south-eastern North Sea implied that cod now mostly occur in the North and Northeast North Sea. As a result, the current distribution of cod in the North Sea is almost the opposite of that during most of the 20th century (Engelhard et al. 2011b).

g) **North Sea herring: differences in fishing power between North Sea herring fishing vessels from the 16th – 20th century**. The analysis is based on a time-series from Dutch fishing vessels catching herring with driftnets in the North Sea from 1604–1966. Until 1875 the Dutch herring fisheries were still operating a fleet of hoeker type vessels using driftnets made of hemp. The hoeker was very similar to a Dutch 15th century fishing vessel. From 1866 the hoeker was gradually replaced by the faster logger whereas cotton became the preferred fabric for driftnets. Sailing luggers were in use until 1929, followed by steam from 1892 and motor propulsion from 1901. The analysis suggests that the fishing power increased more than twenty-fold over the period. However, the relative CPUE in hoeker-units suggests that the relative stock abundance of herring was ten times higher in the 1600s than in the 1950s, and that by the 1800s it had already dropped to 50–60% of the level of the 1600s (Poulsen 2008).

h) **Standardization of Catch rate and Catch per unit of effort.** In fisheries, it is a common practice to use commercial catch rate as an index of relative abundance, particularly in fisheries where no regular surveys have been conducted. The use of catch per unit of effort CPUE as an index of abundance is based on the assumption that catch, effort and abundance are related, provided catchability is constant over time. However, catchability is unlikely to remain constant over the entire exploitation history. The efficiency of the fleet, the targeted species, the environment, and dynamics of the population or fishing fleet are some of the factors that affect catchability. Therefore, CPUE data are standardized for changes or variations in catchability. However, standardization can be problematic, and results are not always proportional to abundance, in particular when methods used do not account for spatial and temporal complexity in fishing effort, or changes in fleet composition and effort creep within vessels. Methods were developed to standardize CPUE for long-term spatio-temporal analysis of population dynamics, where differing levels of technological creep need to be accounted for (Maunder and Punt 2004, ICES 2008, Engelhard 2008, Cardinale et al. 2009a, Thurstan et al. 2010)

1.4.3 RESEARCH LINKING ENVIRONMENTAL CHANGES AND DYNAMICS OF FISH POPULATIONS FROM HISTORICAL DATA

a) **Nine decades of North Sea sole and plaice distributions** (CEFAS-UK and IMARES-NL). Recent studies based mainly on research survey data suggested that within the North Sea, sole (*Solea solea)* and plaice (*Pleuronectes platessa)* have shown distribution shifts in recent decades - on average southward in the case of sole, and to deeper waters in the case of plaice. Conversely, landings data tentatively suggest a northward range expansion in sole. Various hypotheses may account for such shifts, including climate change effects and more intensive fishing effort in more southerly or shallower waters, but the relatively short time spans of datasets analyzed so far (~3 decades) have complicated the disentangling of these two effects. Extensive sole and plaice catch and effort data from the British North Sea trawlers were catalogued and digitized. These data cover nine decades and are spatially detailed by ICES rectangle (0.5° Latitude, by 1° Longitude) and allow quantifying long-term distribution changes of North Sea sole and plaice over a period of almost a century. The main conclusion from this study is that sole and plaice have shown major distribution shifts over the past 90 years and that these shifts are not the result of climate change per se, but likely also of (indirect) fishing effects and eutrophication. It would not have been evident to draw these conclusions from data coming from the last 3 decades alone (Engelhard et al. 2011a).

b) **Recreating 114 years in the North Sea using Ecopath and Ecosim**. Ecopath is a foodweb model, and includes all system fluxes from detritus and bacteria up to seals and whales. Ecosim is a time-dynamic version of Ecopath and can be used to simulate the wider ecosystem impacts of different fishing practices and to search for optimal management strategies (from an ecological or economic perspective). Ecosim can be 'tuned' to fit long-term time-series data or 'forced' using assumptions about climatic conditions and this methodology has come to be known as the 'Back to the Future' approach, whereby a model is constructed to represent a period in the past, then projected forward in time using time-series data to try to explain how events may have unfolded, prior to the current situation. Mackinson (2001) attempted to explore what the structure of the North Sea ecosystem may have looked like prior to the development of industrialized fisheries. He constructed a model for the period immediately prior to the arrival of the first British steam trawlers, Zodiac and Aries in 1881 (Mackinson 2001).

c) **Multidecadal responses of the eastern Baltic cod to human-induced trophic changes, fishing, and climate (DTU Aqua-DK).** The work builds on recent reconstructions of cod spawner biomass back to the early 1920s based on commercial CPUE, extended VPA and historical survey data (Eero et al. 2007a, Eero et al. 2007b, Eero et al. 2008, Eero et al. 2011). Combining long-term ecological datasets transcending the historical development of key human impacts, the study investigates how the onset of those impacts affected the population dynamics and productivity of cod (Eero et al. 2011). Simulations of population dynamics were conducted, 'turning off' the positive effect of one variable at a time, i.e. i) favourable climate, ii) increased nutrients, iii) reduced fishing.

d) **Shifts in spawning seasonality of sole.** This study reveals that over the past 4 decades a shift in the timing of spawning of sole has taken place, in relation to climate change. The work was carried out as an MSc project at CEFAS (Fincham et al. 2013).

e) **Historical spatio-temporal dynamics of eastern North Sea cod**. Recent analyses of historical data of fish abundance and distribution have shown promising potentialities, but pose numerous difficulties such as fragmentation and heterogeneities in the amount of available information in space and time. Using mixed-effects models in a multi-scale analysis, the appropriate spatio-temporal scale of investigation of a high-quality spatially explicit historical dataset was identified, and the long-term spatial dynamics of cod in the Kattegat-Skagerrak reconstructed along the 20th century. At the broad scale of the study area, a northern and southern main aggregation of adult cod were identified and characterized by largely independent spatial dynamics, however both suffering from a common extensive loss of coastal aggregations during the last decades. Population size widely fluctuated through the century, with a possible peak during the decade after the war. From the 1960s, a progressive contraction of the population was observed, up to the historical minimum in the 2000s when only 30% of the estimated early century cod biomass was left. The reconstruction showed that the collapse of the cod population in the area matched the peak in landings, while it anticipated the warming trend of at least two decades, supporting the major role played by the post-war development of the industrial fisheries in the decrease of local abundances and disappearance of local adult cod aggregations (Bartolino et al. 2012).

f) **Fisheries-induced evolution in fish populations**. Fishing and other anthropogenic influences can affect a species' resilience to harvesting. Fishing is thought to induce a genetic change in the populations, affecting age and length of maturity. Systematic extraction of the larger specimens of fish from a population leads to a shift in maturation to younger and smaller specimens. A decrease in the number of mature adults and recruiting individuals may lead to genetic changes in life-history traits that can be irreversible. Some studies have reconstructed parameters of somatic growth and parameters of sexual maturation. The evolution of genetic diversity and effective population size is studied based on the analysis of historical DNA from historical collections of otoliths, modeling techniques (Rijnsdorp et al. 1993, Mollet et al. 2007, Cuveliers et al. 2011, Garcia et al. 2012).

A special category of research refers to the collection of **local ecological knowledge** through which fisheries - and ecosystem related data and information is collected from oral information gathered through interviews with fishermen. The 'Yesterday's Sea' and 'LECOFISH' projects are examples of this type of research for Belgian sea fisheries covering the last 80 to 50 years. Although the research method is challenging and requires a truly multidisciplinary approach, the results show that fishermen are able to particularly recall marking events and outliers (e.g. great or unusual catches, extreme weather conditions) which can be of important value to confirm or challenge scientific knowledge and information (Maes et al. 2012).

1.4.4 The role of ICES in advancing the understanding of long-term dynamics of fish populations and fisheries

Following a recommendation from the 2008 Workshop on Historical Data on Fisheries and Fish (WKHIST), it was concluded that ICES should have a role as coordinator of the historical work on marine systems. The Study Group on the History of Fish and Fisheries (SGHIST) was created in 2009, bringing together fisheries scientists, historians and marine biologists working on multi-decadal to centennial changes in the marine environment, aiming at improving the understanding of the long term dynamics of fish populations, fishing fleets, and fishing technologies. SGHIST aims to bring together scientists working on these topics to facilitate and coordinate data recovery and digitization processes, to exchange ideas, and harmonize methodologies on spatio-temporal analysis, and to discuss methods for the analysis of technological creep and the interpretation of historical time-series of fishing power and CPUE. The results are used for setting baselines for management, restoration and conservation of marine resources and ecosystems. Several fisheries research institutes in Europe have started to make inventories of available historical information (see above).

1.5 Why we bother: the added value of integrated databases

1.5.1 Data management and integrated databases

Often marine biological data are the result of projects with a limited temporal and spatial cover (Jackson 2001). Taken in isolation, datasets resulting from these projects are only of limited use in the interpretation of large-scale phenomena. More specifically they fail to be informative on a scale commensurate with the problems of global change that humankind is confronted with (Costello and Vandenberghe 2006, Vandenberghe et al. 2009).
Databases have evolved since the 1960s with the purpose to manage increasing and complex information systems. Data integration is particularly interesting and increasingly needed in the Life Sciences: large-scale questions in science, such as global warming, invasive species spread, resource depletion, require the collection of disparate data sets for meta-analysis. This type of integration is especially challenging for ecological and environmental data because a common language of standard definitions and codes (usually referred to as metadata and standards) are not agreed upon and there are many different types produced in these fields. Such data have never been of greater importance considering the recent observation of major shifts of marine species due to global change.

There is no specific definition of the term *Integrated database*, but basically it allows to combine data that reside in different sources so as to provide the user with a unified view of these data. The advantages of creating integrated databases are many:

- Sharing of data: single files are generally owned by single users whereas a database is often owned or managed by a supporting organization.

- Control of redundancy: different users may have the same data whereas a database contains only one occurrence of the same data (version control).
- Data consistency: eliminates redundancy. In databases, the data need to be updated only once at one place, whereas in a single file system, files are distributed and data need to be updated in all of the files.
- Improved data standards: the database manager or managing authority defines organization-wide standards on how to represent data in a database (format, conventions).
- Improved data Security: single-file systems are not secure. Databases can give security to the very basic level.
- Improved data Integrity: databases give the database authority the power to define integrity constraints. e.g. question type1 cannot access information that answers question type 2.
- Faster development of new applications: a well-designed DB is modular, when a new application is purposed, the database can respond.
- Improved access to data: a query language support allows any user to get data required anytime, and there is no need for a programmer to extract the data.
- Economy of scale: cost and resources can be pooled, so a lower cost is involved per user.
- More control of concurrency: simultaneous access is possible.
- Better backup and recovery procedures: simple backup is the procedure for databases, whereas backing up the single files of all contributors is needed in a single-file-system.

The disadvantages are mainly related to the high costs of a database management system and the potential overall loss of data in case of database failure.

The global database on fisheries catches is maintained by the United Nations Food and Agriculture Organization FAO and relies on annual reports and contributions from each member country. Global data are only as good as their underlying national data. However, as described above, most national data collections are incomplete, as they focus predominantly on commercial fisheries landings and under-estimate or even ignore non-commercial (e.g., recreational) and small-scale catches (subsistence and artisanal), as well as discards. ICES is currently developing a regionally coordinated database platform for regional fisheries assessments. The database (DB) covers fisheries in the North Atlantic Ocean, the North Sea and the Baltic Sea, and addresses fishery management needs related to the European Union Common Fisheries Policy (CFP). The DB will facilitate a transparent and regional approach to the collection and processing of catch and landings data and ensure a standardized and regional approach to fisheries assessments. The database will also make it easier for countries to share data and results, and provide information to decision makers in a streamlined way.

1.5.2 HISTORICAL FISHERIES DATA: HIFIDATABASE IN BELGIUM

The efforts of reconstructing and integrating the fragmented and dispersed data sources for the period (1830)-1929-2010, led to a thematic database for Historical sea Fisheries Data or HiFiDatabase in Belgium (see Chapter 2 of this thesis). It is the most complete and integrated database for historical time-series on sea fisheries for Belgium, and contains the most detailed spatial, temporal and taxonomic data and information. It also contains unique economic information and integrated catch (landings) with effort data and with the value of catch (landings).

1.6 BELGIAN SEA FISHERIES: OVERVIEW OF A DYNAMIC SECTOR

1.6.1 BELGIAN SEA FISHERIES: THE HISTORICAL, POLITICAL AND SOCIO-ECONOMIC CONTEXT

Belgium covers a land area of 30,528 km2 and has a population of approximately 10.7 million. Historically, the area known as Belgium, the Netherlands and Luxemburg was called the 'Low Countries'. From the 16th century until the Belgian revolution (1830), the area of Belgium was occupied and ruled by Spain (1549-1713) as the 'Spanish Netherlands', by Austria (1713-1794) as the 'Austrian Netherlands', and annexed by the French First Republic (1794-1815). The 'Low Countries' were brought together as the 'United Kingdom of the Netherlands' in 1815 and ruled by the House of Orange. After the Belgian revolution of 1830 it became the independent state and Kingdom of Belgium. In this thesis, the fisheries before 1830 is therefore referred to as 'Flemish or Flanders' fisheries, whereas 'Belgian sea fisheries' is used as a correct term from 1830 onwards.

Belgium has three regions: Flanders (Dutch-speaking) in the north, Wallonia (French-speaking) in the south, and the Capital region of Brussels (officially bilingual, Figure 1.3.). A slight majority of the population (59%) lives in Flanders.

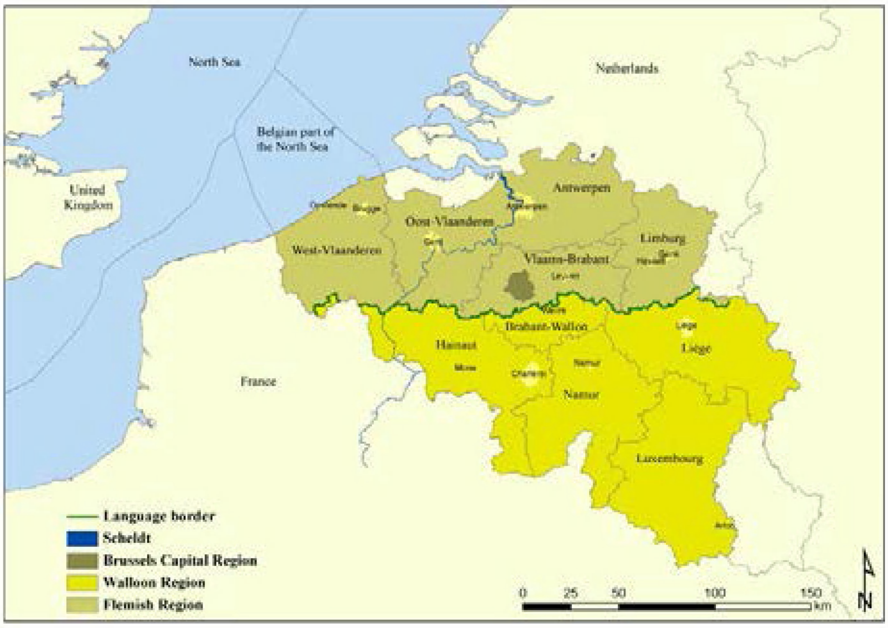


Figure 1.3.: Map of the geography and administrative structure of Belgium, and the Exclusive Economic Zone in the southern North Sea. Map by Flanders Marine Institute (VLIZ).

The Belgian coast is 67 km long and is entirely bordering the province of West-Flanders (region of Flanders, Belgium). The Belgian part of the North Sea is 3,457 km^2 (0.5% of the North Sea area), of which more than 1/3 or 1,430 km^2 are territorial sea within 12 nautical miles distance of the coastline. Belgium currently has four coastal ports (Nieuwpoort, Oostende, Zeebrugge and Blankenberge), and besides the fish auctions located in Oostende, Zeebrugge and Nieuwpoort (Figure. 1.4.) where fish is sold according to legal procedures, there are no other dispersed landing points. Although historically the port and auction of Oostende was by far the most important, today the auctions of Zeebrugge (53%) and Oostende (45%) receive the largest share of the landings of Belgian fisheries in Belgian ports.

1.6.2 Belgian Sea fisheries: an overview of the sector anno 2012

Belgium has a minor role in the European fisheries context with 0.35% of the total EU production of fish. In 2012, the Belgian commercial sea fishing fleet counted 86 ships, with a total engine capacity of 49,135 kW and gross tonnage of 15,326 GT (Roegiers et al. 2013). 45 vessels are part of the Small Fleet Segment (max 221 kW engine power) of which 2 use passive gear. The remaining 41 vessels belong to the Large Fleet Segment and have an engine power between 221 kW and a maximum of 1,200 kW. This fleet segment represents approximately 80% of the engine power capacity and 77% of the GT of the fleet. While a smaller number use trammel nets (passive gear) and otter trawl, the largest share of the Large Fleet Segment are beam trawl vessels (≥662 kW). The Belgian fleet is highly specialized: more than 68% of the effort (days at sea) and 77% of total landings are achieved by beam trawlers (2010) focusing primarily on flatfish species such as plaice (*Pleuronectes platessa*) and sole (*Solea solea*). The results of the reconstruction of the Belgian fleet dynamics since 1830 are presented and analyzed in Chapter 5.

The number of days at sea per vessel is fixed at a maximum of 265 per year and in 2011 the entire fleet realized a fishing effort of 15,855 days at sea. In 2011, the Belgian fleet landed a total of 20,138t, of which 16,905t were landed in Belgian ports. Plaice is the most important species in terms of landed weight. Eighty-eight percent of the 3233 t landed in foreign ports is sold in The Netherlands (plaice and brown shrimp). They mostly represent the catch of Dutch crews and shippers that sail under Belgian flag and are assigned Belgian fishing quota.
The landings of 2011 represented a value of €76.3 million, 14% of which was marketed in foreign ports. Sole generates 47% of the current total value of fisheries in Belgium. The Belgian sea fisheries represent 0.04% of the national Gross Domestic Product (Anon. 2008). The main fishing grounds in terms of volume of landings in 2010 were in descending order: North Sea South (IVc), Eastern English Channel (VIId), North Sea Central (IVb), Southeast Ireland/Celtic Sea (VIIg) Bristol Channel (VIIf) and Irish Sea (VIIa) (Fig. 1.5.).

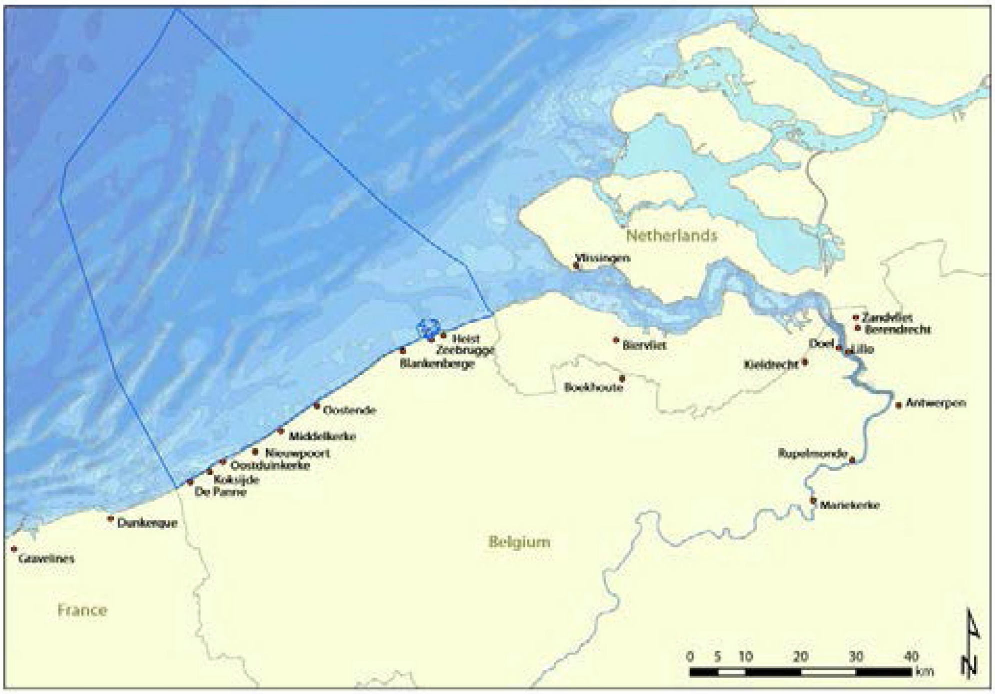


Figure 1.4.: Map of the Belgian coast with the historical coastal and estuarine fishing ports and historical fishing communities in Flanders, and the ports of Gravelines and Dunkerque in France. The blue line indicates the EEZ boundaries of the Belgian part of the North Sea. *Map by Flanders Marine Institute (VLIZ)*

In terms of direct employment, 439 fishers are registered of which approximately 350 are of Belgian nationality. Direct employment in fisheries represent approximately 0.5% of the total employment in the Belgian coastal zone. Another 1040 persons work in the fish processing industry and another 5000 persons in associated trade and services (Roegiers et al. 2013).

The Belgian fleet operates in the Belgian part of the North (BNS), in the marine waters of the European Union and in marine areas of third countries. The boundaries of the territorial sea and the BNS have been established by bilateral agreements and formalised in Belgian and international legislation. The Belgian fleet fishes in the BNS, in the southern North Sea (IVc), the central North Sea and the Western waters. The fleet is also active in the Bay of Biscay during a limited number of weeks, to fish for sole. In the framework of the EC Council Regulation (EC) No 2371/2002 of 20 December 2002 on the conservation and sustainable exploitation of fisheries resources under the CFP, the Belgian fleet also gained access to the coastal waters of other member states. Belgian fishers also legally operate in geographically demarcated areas of the coastal waters of the United Kingdom, Ireland, Denmark and France, between 6 and 12 nautical miles (nm). Furthermore, the entire coastline of the Netherlands is also accessible for the Belgian fleet in the zone between 3 and 6 nm, and the area between 0 and 3 nm according to the Benelux-agreement. Vessels that operate in the territorial sea need to observe the requirements in terms of access, fishing gear and maximum engine power, as well as minimum mesh sizes. The territorial sea is fished by coastal fishers and by a few 'eurocutters' (*eurokotters*) which are small vessels with approximately 221kW engine power being the maximum allowed power for beam trawlers within the 12nm zone. Dutch and French vessels also have access to the territorial sea of Belgium (Chapter 6).

The fishing areas to which the Belgian fleet has access in terms of assigned fishing effort and quota, include (Fig. 1.5.):

- North Sea, in area IIa (Norwegian Sea)
- North Sea areas IVa, IVb and IVc,
- Faroër in Vb
- Skagerrak in IIIa,
- West of Scotland in VIa,
- Irish Sea in VIIa,
- Western part of the English Channel VIIe,
- Eastern part of the English Channel VIId,
- Celtic Sea in VIIf,g,h,j,k
- Bay of Biscay in VIII.

Figure 1.5.: Map of the ICES Fishing areas. International Council for the Exploration of the Sea ICES (http://geo.ices.dk/viewer.php?add_layers=ices_ref:ices_areas)

Belgium is assigned fishing quota in areas considered as ‘traditional fishing areas’. These assignations refer to ‘historical use’ and are based on the spatial dynamics of the Belgian fleet after the transition to beam-trawling had taken place. The assigned quota for a number of fishing areas (I, II, IIIa, Vb (Faröer), XII, and XIV) are generally not utilized today and they are exchanged with other EU countries, for other species or fishing areas. In non-EU waters, Belgian vessels dispose of limited quota in Norwegian waters based on bilateral agreements.

1.6.3 BELGIAN SEA FISHERIES: CURRENT ADMINISTRATION AND MANAGEMENT

Since the creation of the Kingdom of Belgium in 1830, the responsibility for marine fisheries has changed between ministries such as the ‘Ministry of Mobility and Infrastructure’ created in 1884, the ‘Ministry of Mobility, Post, Telegraphy and Telephones’, the ‘Ministry of Labour and Industry’, and the Ministries responsible for Agriculture in the Belgian government. With the regionalization of Belgium, the Flemish government was created in 1980 by the Special Act of 8 August 1980. The *Lambermont agreements*, signed in 2002, finally transferred sea fisheries from the federal level to the domain of agriculture of the Flemish government. The federal government of Belgium is responsible for the environment, mobility, energy, nature conservation, heritage and spatial planning at sea.

Access to Fisheries in Flanders is managed through a collective system, by a Quota Commission which consist of representatives of the different segments of the fleet and is coordinated by the (only) producers organisation. The Quota commission also advices the Flemish government in terms of regulating the fishing effort, seasonal and spatial access to the resources, and the exchange of quota with other EU MS.

Recreational fisheries on the Belgian part of the North Sea mainly use small beam trawls (<3m wide) for flatfish and shrimp, while sea angling for cod and European sea bass are quite popular. The dimension of recreational fishing is unknown since it is not subject to licensing or reporting.

In Belgium, the Fisheries Authority (department of Agriculture and Fisheries, Flemish government) together with the producers' organization, the Fisheries Research Institute ILVO and environmental NGO have taken first steps towards a more sustainable future for fisheries through a formal Agreement and a Strategy for Sustainable Fisheries (2011), which is carried forward by its Task Force. One of the main objectives and ambitions pursued by this Task Force is to promote the transition towards more sustainable fishing by means of a general prohibition of illegal, unreported and unregulated fish and fisheries (IUU), the use of fishing gear and fishing techniques (e.g. the sumwing, eco-beam trawl, hovercran-electric pulse system) with less impact on the sea floor and benthic species and habitats, exploring passive fishing techniques, and improving the quality of the fish products. By setting these aims and objectives, Belgian fisheries are closely aligning to the EU Common Fisheries Policy.

1.7 OBJECTIVES OF THE PHD STUDY

The present PhD study focuses on the commercial sea fisheries of Belgium, both in Belgian and in foreign waters. It covers the historical evolution in terms of species composition and economic value of landings, spatial dynamics, fleet dynamics, and aspects of impact of the fisheries. In order to develop this analysis, a major effort was invested in collecting and managing data and literature sources.

The core **research questions** that are addressed in the present PhD study are two-fold:

- What are the trends in the Belgian Sea Fisheries, based on standardized quantitative parameters in terms of input (fleet, effort) and output (landings, economic value), and compared to a historic baseline of one century ago?
- What are the quantitative impacts or indications of impact of the Belgian Sea Fisheries both on the targeted commercial fish stocks and on other marine living resources (e.g. bycatch), as reconstructed from these long-term data series?

To answer these questions, the following research **objectives** were set forward:

- To identify, rescue, describe, quality control, permanently store and safeguard historical data of the Belgian sea fisheries as far back in time as achievable, and to integrate these data into a standardized Historical Fisheries database HiFiDatabase. The HiFiDatabase is a product of the present PhD study.

- To reconstruct the overall history of Belgian Sea Fisheries based on the parameters related to:
    - volume and value of landings by species, by port of landing (kg, Belgian francs, Euro)
    - spatial dynamics (by fishing area)
    - temporal information (months, seasons, years)
    - fleet (number of vessels, vessel class, tonnage, type of engine, engine power)
    - fishing effort by fishing area, by fishery (days at sea, hours at sea, fishing days, fishing hours)
- To conduct an analysis of reconstructed time-series and of the relationships between these parameters: spatio-temporal trends in landings, value of landings, diversity of landings, fleet size and power, fishing effort.
- To reconstruct indicators of impact: historical total removals (including unreported catches and discards) by the Belgian Sea Fisheries, historical catch per unit of effort, historical catch compositions
- To document cases of 'shifting baselines' in Belgian Sea fisheries for important fishing métiers: the spent herring fisheries (1930-1960), the cod fisheries in Iceland (1947-1996), a reconstruction of total versus reported catches (1929-2010), others.

The scope of this research was on the production of the Belgian fleet: officially recorded and geographically explicit reported landings by the Belgian fleet, in the fish auctions in the Belgian ports and in foreign ports. Landings from foreign fleets in the Belgian ports are not covered in the present analysis.

1.8 OUTLINE OF THE THESIS

This thesis is a compilation of research articles (published, under review or in preparation) , which are included as chapters. These articles are set in a broader research and policy context in the first introductory chapter, and the results are tied together in a general discussion in the last chapter. Although each chapter can be read on its own, there may clearly be some overlap in the introduction and description of material and methods. The cited literature is compiled as one list of references at the end of the thesis.

The general context and rationale for setting up an initiative for the collection, quality control, standardization and integration of historical data with regard to sea fisheries in Flanders/Belgium is drawn in the first introductory part. It provides the rationale for the present PhD thesis. The objectives of the study are set in context of the current situation of sea fisheries in Belgium and the framework of European and international existing and upcoming legislation. It introduces some of the important concepts that are referred to throughout the thesis. The introductory chapter also draws a state-of-the-art of similar research efforts in marine environmental history and history of fish and fisheries, in Europe and elsewhere, as a context for the present PhD study.

A study that contains an important component of data management, from inventorying to digitization, standardization, integration and quality control, requires a detailed description of how this process was conducted. The second chapter therefore gives an overview of literature sources and screened databases, the process and methodology of data inventory, metadata, quality control, graphical analysis, and other aspects of data management and issues related to the reliability of the datasets. This chapter is adapted from the published paper with reference: *Lescrauwaet, A.-K.; Debergh, H.; Vincx, M.; Mees, J. 2010b. Historical marine fisheries data for Belgium: Data sources, data management and data integration related to the reconstruction of historical time-series of marine fisheries landings for Belgium. Fisheries Centre Working Paper Series, 2010-08. University of British Columbia: Vancouver. 69 pp.*

The third chapter draws on the first and broad findings of the data-integration process: it provides overall trends and findings related to the landing statistics by species or groups of species, by fishing area, by volume and value of landings, for the period 1929-2010. It also demonstrates some of the potential applications of the database to further reconstruct the historical trends for specific species or métiers. An example of reconstructed time-series of landings for cod (*Gadus morhua*) from 1835-2010 is included. *Published as: Lescrauwaet AK, Debergh H, Vincx M, Mees J .2010a. Fishing in the past: Historical data on sea fisheries landings in Belgium Mar. Policy 34(6): 1279-1289*

The spatial dynamics of sea fisheries in Belgium are described and documented in Chapter 4. Time-series of the fishing effort and landings for the 5 most important fishing areas are complemented with an analysis of species diversity of the landings. Annual trends and seasonal variability are presented and discussed for the most important fishing areas and species (plaice, sole, cod, shrimp,..). Special attention is dedicated throughout this thesis to the ‘Coastal waters’, considering their relative importance for sea fisheries in Belgium in terms of the value and volume of landings obtained from this nearby fishing area. The ‘Coastal waters’ were historically defined as the marine waters at 20-30 nautical miles distance from the coast, stretching from northern France into the Dutch territorial sea. In practice however, in the present thesis work it was found to provide a good proxy for the fisheries on the Belgian part of the North Sea (BNS).

Trends in landings can not possibly be interpreted in the absence of data on fleet dynamics. Chapter 5 brings a detailed reconstruction of time-series related to the sea fishing fleet in Flanders/Belgium: number, average and overall tonnage, average and total installed engine capacity, and parameters related to fishing effort (days at sea and fishing days). However, an analysis of trends in abundance and biomass of fish stocks requires data of landings and fleet dynamics at the scale of specific fishing metiers and fishing areas. *Published as: Lescrauwaet, A.-K.; Fockedey, N.; Debergh, H.; Vincx, M.; Mees, J. (2012). Hundred and eighty years of fleet dynamics in the Belgian sea fisheries Rev. Fish Biol. Fish. Online first: 15 pp*

Chapters 6, 7 and 8 take a closer look at the impact of sea fisheries, both on the targeted commercial stocks and on other marine resources. In Chapter 6, a quantitative approach is taken to reconstruct total removals by Belgian sea fisheries by including the unreported and misreported landings of commercial and recreational fishing, as well as an estimation of discards. This reconstruction covers 6 fisheries with historical or current importance for Belgium. Special attention is given to the Belgian part of the North Sea (BNS) and its fishing areas, estimating unreported removals and discards for these nearby waters. An indication of data and information gaps and challenges for future work is provided. The methodology applied in this reconstruction can serve as a blueprint for similar reconstructions in other countries. The results are useful to inform current policy issues and societal challenges. *Chapter 6 accepted for publication as: Lescrauwaet, A.-K., Torreele,' E., Vincx,' M., Polet, H. and Mees, J. accepted. Invisible Catch: A Century of bycatch and unreported removals in Sea Fisheries, Belgium 1929-2010. Fisheries Research. 2013. 10.1016/j.fishres.2013.05.007.*

Special attention is given in Chapter 7, to the exceptional situation of sea fisheries in Belgium during the Second World War WWII (1939-1945) when unusually high landings of herring (*Clupea harengus*) were achieved under restricted fishing conditions. Plausible arguments to explain these historical trends are explored and validated through additional historical data and information from population parameters. *Chapter 7 included as revised manuscript currently under review: Lescrauwaet, A.-K., De Raedemaecker, F., Vincx, M., and Mees, J. revised manuscript currently under review. Flooded by herring: Downs herring fisheries in the Southern North Sea during World War II. ICES Journal of Marine Science.*

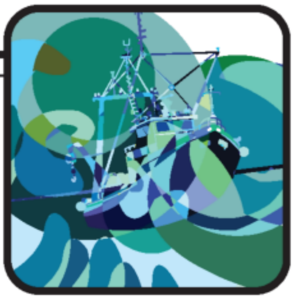
Chapter 8 focuses on the otter trawl fishery in Icelandic waters targeting cod. Iceland's fishing resources have played a major role in the economy of fishing nations around the North Sea in the 20th century and before. The 'Iceland fishery' was of great economic importance in Belgium but decreased with the 'Cod Wars' (1958, 1972 and 1975) coming finally to a complete end in 1996. While the decline in total landings from Icelandic waters started after Iceland declared exclusive access to its territorial sea in 1958, the fishing effort of the Belgian fleet continued to increase until a peak was reached in 1963. Historical data on Belgian commercial fisheries landings and fishing effort include information on vessel type and fishing rectangle. The results document the Belgian gadoid fisheries in Icelandic waters from 1929-1995 and argue that the decline in the Iceland cod stock was visible at different levels, even before the Cod Wars. *Chapter 8 is included as manuscript currently under review. Lescrauwaet, A.-K., Vincx,' M., Vanaverbeke, J. and Mees, J. manuscript currently under review. In Cod we trust: Trends in Cod and gadoid Fisheries in Iceland 1929-1996. Canadian Journal of Fisheries and Aquatic Sciences.*

The conclusions in chapter 9 are oriented to the different topics addressed by this thesis including data management, research applications and potential future research, policy issues.

All data presented in this thesis are publicly made available on-line according to the Open Access principles and following a work plan that was set out at the beginning of the study. By setting up the HiFiDatabase the purposes and multiple advantages of databases over single-file-systems are achieved. Examples of how the HiFiDatabase has contributed - both in the context of the current PhD thesis and outside- to research and applications in fisheries management, are described in Chapter 7 and listed in the Appendices. The HiFiDatabase is an illustration of the Open Access and Open Data movement.

Furthermore, as data and information are consolidated and validated, different types of outreach and communication products are developed such as factsheets, timelines, photo-gallery, search options and summary articles for the wider public. A list of these publications and products is available from the annex list of publications by the PhD candidate.

By addressing the above objectives, this PhD thesis will have hopefully achieved its aim, of describing trends in Belgian Sea Fisheries over at least Ten Decades, with shifts in relative importance of each of the Seven Seas where the fleet has been operational historically, targeting a variety of at least Forty different Species as reported in the landings; **Belgian Sea Fisheries: Ten Decades, Seven Seas, Forty Species.**



CHAPTER 2: Historical marine fisheries data for Belgium: Data sources, data management and data integration related to the reconstruction of historical time-series of marine fisheries landings for Belgium.

CHAPTER 2. DATA SOURCES, DATA MANAGEMENT AND DATA INTEGRATION RELATED TO THE RECONSTRUCTION OF HISTORICAL TIME-SERIES OF MARINE FISHERIES LANDINGS FOR BELGIUM

In spite of the €1 billion of public money spent each year in Europe on monitoring and measuring the seas (COM/2010/0461), users are still confronted with restrictions on data access. When accessible, the quality of the data may be unknown or different standards and formats may apply which make data assembling from different sources a challenging and often specialists' task. This situation seriously hampers the opportunities to develop innovative products and services, including the use of data in advanced scientific research. This is particularly true for long-term time-series. The current chapter covers the process of reconstructing time-series for different parameters that describe the sea fisheries in Belgium: landings, value of landings, species, species length classes, fishing areas, and their seasonal and annual variability. The process from source to product is explained and the main outcomes and data products of the reconstruction of historical time-series on Belgian sea fisheries are commented.

Chapter 2 modified from the publication:

Lescrauwaet, A.-K.; Debergh, H.; Vincx, M.; Mees, J.(2010). Historical marine fisheries data for Belgium: Data sources, data management and data integration related to the reconstruction of historical time-series of marine fisheries landings for Belgium. Fisheries Centre Working Paper Series, 2010-08. University of British Columbia: Vancouver. 69 pp. With foreword by Dirk Zeller, Sea Around Us project, Fisheries Centre University of British Columbia, Vancouver, Canada

The current chapter contains updates on datasets included for the analysis of the Belgian fleet dynamics.

2.1 INTRODUCTION: COLLECTIVE (DIGITAL) MEMORY DISORDER

Assuming that the Internet is a first step for the exploration and discovery of information from a general users' perspective, availability of (meta)data on sea fisheries in Belgium, was assessed on the worldwide web. The Internet was searched for references using the Dutch keywords for 'landings', 'fisheries' and 'trends' on Belgian web pages, with 692 returns (www.google.be/search?hl=nl&q=evolutie%2Baanvoer%2Bzeevisserij&btnG=Zoeken&meta=cr%3DcountryBE, consulted on 07/Jan/2009). Of the first 100 references we screened on content, only 20% contained numerical values on the landings by Belgian fisheries. Nearly half of these references compare the current fish landings with those of the previous year or provide one overall figure for the total landings of Belgian fisheries for the year in review. Ten references contain annual time-series on the evolution of total landings, starting in 1990 (4 references), or 1984 (1 reference) at the earliest. A similar literature search was conducted in Google scholar (scholar.google.com/advanced_scholar_search) and the Web of Knowledge (www.isiknowledge.com/): there were no returns that contain references to the amount (t, tonnes), composition and/or value (Belgian francs or Euros) of Belgian marine fisheries. The annual reports titled 'Aanvoer en Besomming' (Landings and value of landings) are published by the 'Dienst Zeevisserij' (Sea Fisheries Service, Flemish Government) since 1973 (on paper), and since 2000 also as electronic copies. The reports summarize the evolution of landings from 1950 onwards in a Table with one general value for total landings every 5 years between 1950 and 1975 and annual values from 1975 to date. Since 2002, the Sea Fisheries Service also publishes the annual 'Uitkomsten van de Zeevisserij' (Economic output of Belgian Sea Fisheries) on the fleet and economic parameters. These documents represent the formal fisheries statistics reports of Flanders (Belgium) and are available via the Internet: http://lv.vlaanderen.be/nlapps/docs/default.asp?id=218.

The *Integrated Marine Information System* IMIS is a specialized marine information system of Flanders Marine Institute - VLIZ. A search effort on 12/Jan/2009, based on the Dutch keywords for 'landings' and 'fisheries' yielded 27 returns. Of these, 7 are the formal annual government reports on 'Landings and value of landings' (see above); another 4 refer to total landings in 2004; 1990; 1997; 1990 and one paper on marine archaeology refers to landings of herring and cod in the 18th century. A PhD thesis on shrimp fisheries (Polet 2004) reports total annual landings of the Belgian sea fisheries from 1970 onwards. Although the IMIS collection is not exhaustive in all disciplines, it contains the largest collection of publications and documents on marine and coastal sciences in Flanders and Belgium.

We reviewed available policy documents on sea fisheries from the Fisheries authority (Agriculture and Fisheries department of the Flemish Government) and a review study on the socio-economic analysis of Belgian sea fisheries in North Sea waters (Maes 2003). The longest available time-series in the latter depict the trend in the total production of Belgian fisheries, at 5-year intervals starting in 1960. In addition, graphs with annual landings covering the time period 1990-2000 are included for the four commercially important species cod (*Gadus morhua)*, plaice (*Pleuronectes platessa),* sole (*Solea solea)* and brown shrimp *(Crangon crangon*). The historical context for landings covered in recent policy documents (e.g., National Operational Programme) to underpin strategies for (sustainable) marine fisheries in Belgium surprisingly only goes back to 1990 (ILVO 2008, Anon. 2008).
From this directed search for sources on the Internet, we concluded that our current collective memory (*sensu 'publicly available digital data and information'*) related to quantitative information on sea fisheries in Belgium does not surpass 30 years. We could think of at least two possible reasons to explain the absence or incompleteness of data on marine fisheries before 1980:

- Data were not collected/never existed or are not available (anymore) in the public domain;

- Reliable data exist and are publicly available, but data policy restrictions apply;
- Freely accessible data are not available in the appropriate format for redistribution

In the following paragraphs, these questions are addressed following the logical steps of the data production process: data inventory, data digitization and quality control, standardization, integration.

2.2 Inventories and inventorying

Starting points for inventorying potential sources of data and quantitative information on Belgian/Flemish sea fisheries were well-structured databases that allowed advanced querying on the basis of specific search terms. These databases were screened for publications, documents (including grey literature) and data on fisheries in Flanders/Belgium. Search terms included 'fishery', 'fisheries', 'fishing', 'landings' and 'fleet'. Where search options allowed, wildcards were used (e.g. 'fish*'). The search was conducted between October 2007 and February 2008.

a) **Specialized libraries and databases with digitally accessible collections (on-line index/query possibilities):**

- The Integrated Marine Information System IMIS (Flanders Marine Institute - VLIZ; www.vliz.be/imis)
- and its 'Open Marine Archive' - OMA (www.vliz.be/OMA) with full-text digital documents: screened for data and information (modules 'Publications' and 'Datasets');
- The Belgian Marine Data Centre BMDC of the Management Unit for the Mathematical Model of the North Sea MUMM (http://www.mumm.ac.be);
- The Food and Agricultural Organization of the United Nations (FAO) and the International Council for the Exploration of the Sea (ICES);
- Fishbase (www.fishbase.org/) and the *Sea Around Us* Project (www.seaaroundus.org/).

b) **Specialized libraries: physical collections:**

- The library of the Flanders Marine Institute (VLIZ) (*Oostende*, Belgium);
- The library of the Sea Fisheries Service (*Oostende*, Belgium); recent documents (after 1980) on marine fisheries are generally kept at the Sea Fisheries Service (DVZ). Older documents (>100years) were transferred to the State Archives (*Rijksarchieven-RA*), according to Belgian Law on State Archives. The responsibility for marine fisheries has changed between ministries since the creation of the Kingdom of Belgium in 1830 (e.g. the 'Ministry of Mobility and Infrastructure', 'Ministry of Mobility, Post, Telegraphy and Telephones', the 'Ministry of Labour and Industry', and the Ministries responsible for Agriculture). With the regionalization of Belgium in 1980, the Flemish government was created in 1980. The *Lambermont agreements* (2002) finally transferred responsibility for Sea fisheries from the federal level to the domain of agriculture of the Flemish Government.
- The library and archives of the Institute of Agriculture and Fisheries Research – ILVO (*Oostende*, Belgium), which are stored in the archives of VLIZ to be disclosed, documented and partly digitized. (e.g. 'Fishery atlases' and 'Stock assessments for herring').

c) **Catalogues, literature databases and internet 'harvesters'**:

- JSTOR, Web of Knowledge, Aquatic Sciences and Fisheries Abstracts, Google Scholar, Avano, Antilope and CCB (for completing reference titles).

Figure 2.1.: Image of the original Tables and fisheries reports in the Series 'Jaarverslag over de zeevisscherij', Dienst voor Zeevisscherij/ Bestuur van het Zeewezen, 1930. Source: A century of Sea Fisheries in Belgium (VLIZ 2009)Scanned images available from http://www.vliz.be/EN/Figures_Policy/Figures_Policy_Belgian_Sea_Fisheries.

d) **Historical collections**: an additional search effort was conducted in the physical collections of historical archives and documentation centres in Belgium:

- Archives of the National Institute of Statistics, Belgium (NIS), kept in the collections of the State Archives (*Rijksarchief*) of Belgium in Brussels;
- State Archives (*Rijksarchief*) of Belgium in Brussels and Bruges: contain physical collections and inventories of historical documents of the archives of the Province of West-Flanders (1795-1814, 1830-1875), the Chambers of Commerce of *Oostende* and *Brugge*, Municipal archives of *Nieuwpoort, Blankenberge, Brugge, and Heist*. The collection includes *'Bestuursmemorialen'* and *'Rapport sur l'état de l'administration de la province de Flandre Occidentale'* (Annual reports on the state of the provincial administrations) as well as *'Placcaeten van Vlaanderen'* (De Wulf 1766), which collects ancient laws and prescriptions from the local governments from the 14th-18th centuries;
- Provincial Archives in Bruges, which contain the inventories and physical collection of the archives of the Province of West-Flanders (1815-1830, 1875-present);
- City Archives of Antwerp (*ErfgoedBibliotheek Hendrik Conscience, Antwerpen*) which contain one of the most complete series of '*Landbouwstatistieken*' (Agriculture and Fisheries statistics of Belgium), Royal decrees and Ministerial decisions, official historical legislative documents.

Sources describing the history and development of early statistics in Belgium were studied and the list of official statistical publications in Belgium from 1830 to 1914 was screened for older publications and data sources. Julin (1918) and de Reiffenberg (1932) provide a review of the history of the early statistics in Belgium and the development of census and data collecting systems to underpin state policies, in particular for marine fisheries. The need to standardize the collection of fisheries data was underlined much earlier by De Zuttere (1909) and in the early volumes of the series '*Jaarverslag der commissie voor zeevisscherij*', Provincie West-Vlaanderen (see further).

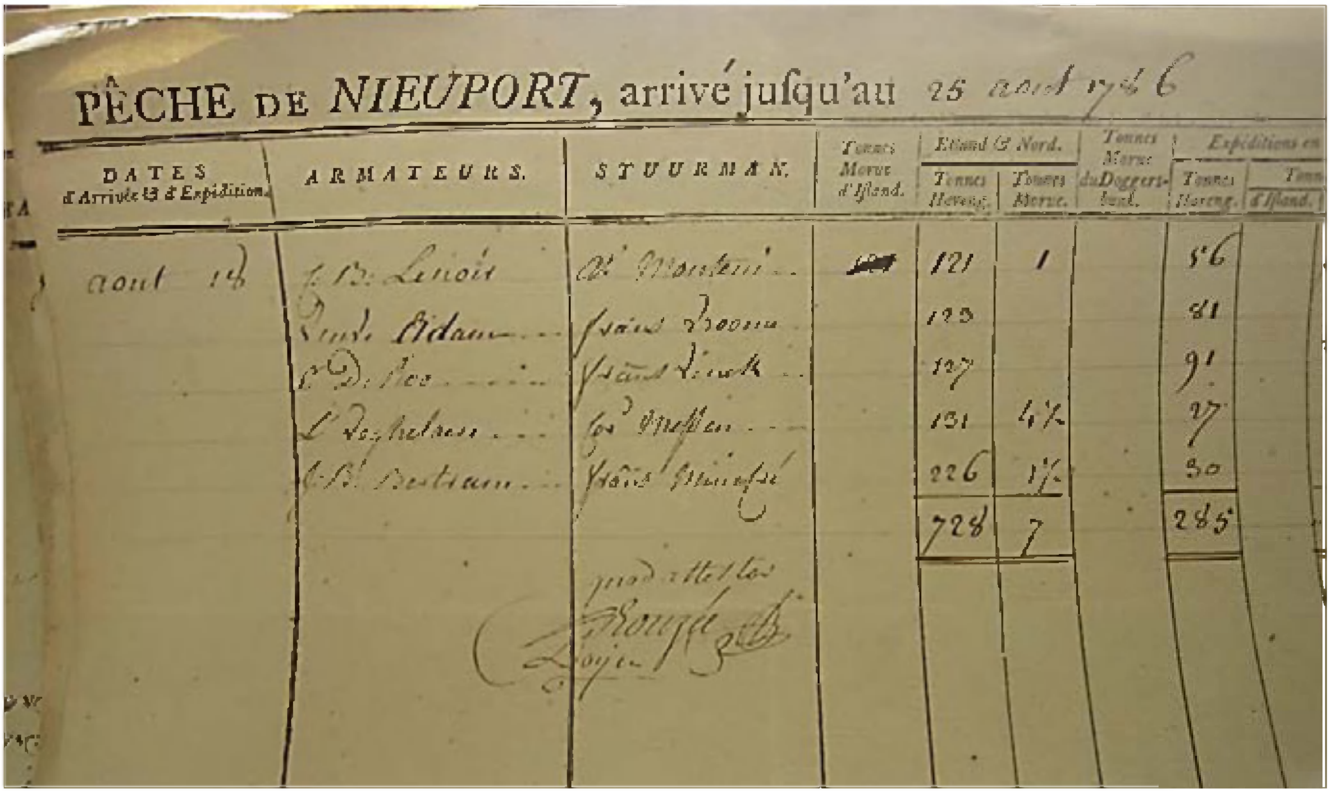


Figure 2.2.: Picture from the archives of the ancient regime of *Nieuwpoort* (INV 80 4184): fish landings register from August 25th, 1786 in the fishing port of *Nieuwpoort*. Source: A century of Sea Fisheries in Belgium (VLIZ 2009).

The methodology applied for screening and searching depended on the type and nature of the document or the series. As a general approach, the archivist was contacted previously and assisted in the search. Most promising inventories were screened based on titles (geographic and thematic).
The findings of the inventory on historical data on sea fisheries in Belgium were broadly divided into three categories or time intervals for the purpose of this paper (Table 2.1.) : 1) recent history (1900-2000); 2) the Dutch (1815-1830), early Belgian (1830-1900) and Austrian and French periods (1700-1815); and 3) the Middle Ages. Each data source was archived and described in detail in a standardised way so as to create a searchable metadata inventory, facilitating data discovery and sharing. These metadata include information needed to decide on the relevance of a dataset in a particular context (e.g. where, when and how the data was collected, where they are stored and in what format, and under which conditions they are made available). All metadata descriptions are publicly available through the VLIZ website (IMIS).

2.3 OVERVIEW OF DATA SOURCES AND FORMATS

The need for systematically collected data on marine fisheries has long been recognized, e.g. by the government commission in charge of studying the effects of state subsidies in this sector (Du Bus and Van Beneden 1866). The work of De Zuttere (1909) and of Gilson (1859°-1944†, director of the Marine Research Institute, *Zeewetenschappelijk Instituut - ZWI*) and Gilis (fisheries technician at ZWI) both participants for Belgium in the 'Statistical Committee' of the International Council for the Exploration of the Sea ICES in the early 20th century, was also crucial in consolidating structural reporting on fisheries statistics. Their efforts were hampered by the First World War (1914-1918) and fraught with financial problems. Finally, the achievement of standardized and structural reporting at the beginning of the 20th century was the work of many contributors.
The current inventory in local or foreign archives did not uncover references or data sources on sea fisheries in Flanders from the 20 years of the first French Republic (1795-1804), the French Empire (1804-1815), or from the 15 years of the United Kingdom of the Netherlands (1815-1830) (Table 2.1.). During the Dutch administration, official statistics were coordinated by the 'Bureau of Statistics' (later 'Royal Commission for Statistics'), which was established in 1826 by the Ministry of Interior Affairs in The Hague. The founder of Belgian statistics, Adolph Quetelet (1796-1874) was a member of one of the provincial commissions. In their overviews of early official statistical publications (including the period of the first French Republic) Heuschling (1843) and Julin (1918) commented briefly on the difficulties encountered for marine fisheries statistics. Although the State Archives hold documents of correspondence with the fisheries administration in The Hague dating from the Dutch period, no fisheries statistics or reference to the existence thereof were found. Further efforts are required to expand this search effort to foreign archives and working groups that focus on historical fishery statistics abroad.
A large portion of the original and prime data sources, such as logbooks and monthly statistics that were once recorded by the authorities may have been lost or destroyed during World War I (1914 - 1918) and World War II (1939 - 1945) and are now mainly available in aggregated form through secondary references (e.g. Cloquet 1842, Vlietinck 1975 (reprint from publication in 1897), De Zuttere 1909). The inventory also demonstrated that the administrative support and control associated with granting state subsidies acted as an important driver for the collection of the early fisheries statistics, as was the case for the period 1842-1868.

Finally, the beginning of this structural reporting on fisheries and landings in Belgium coincided with the period where most states in Europe developed a statistical approach to underpin policy development (de Reiffenberg 1932a, 1932b, Julin 1918, Leti 2000, François and Bracke 2006) and was triggered by the efforts of the 'Statistical Committee' of the International Council for the Exploration of the Sea ICES to standardize fisheries statistics reporting format at the international level.

Formal sources that contain data on composition and economic value of landings by Belgian fishers in Belgian and foreign ports and data on fleet parameters were inventoried from 1700 to 2010 (Table 2.1.). The Table includes an indication of the temporal resolution (period and frequency of data sampling), taxonomic resolution (level of aggregation) and spatial resolution (by area of origin or port of landing). The political-administrative situation is indicated, as well as reference to some noteworthy events in fisheries at that time.

Table 2.1.: Sources containing historical time-series (>5 consecutive years) on landings by Belgian fisheries from 1700 to 2012 with an indication of temporal, taxonomic and spatial resolution.

	Interval	Marking events of for the period	Source	Period	Frequency	Taxonomic resolution	Spatial resolution	Physical location	Digitally available in VLIZ: Data set (D) Full text (F)
1	MODERN TIMES	EU Common Fishery Policy 1972 and 1975: 'Cod Wars' in Iceland waters	Series 'De Belgische zeevisserij. Aanvoer en besomming'. Dienst Zeevisserij.*	1973 - 2012	Annual	By species, subtotals, general total	By port and by fishing area	DVZ	Available in paper format: 1973-1997 D: 1998-2006
2			Series 'De Belgische zeevisserij'. *Landbouwstatistieken*. Nationaal Instituut voor de Statistiek.	1969 – 1999	Annual	By species, subtotals, general total	By port and by fishing area	HC-Antwerp	D
3			Collection 'Monthly landings'. Archief van dr. Frank Redant, ILVO.	1967 – 1980	Annual	By species, subtotals, general total	By port	ILVO and VLIZ libraries	Available in paper format
4		1958: first 'Cod war', Iceland	Series 'Statistiek van de zeevisserij' *Statistisch tijdschrift*. Nationaal Instituut voor de Statistiek.	1957 – 1968	Annual	By species, subtotals, general total	By port and by fishing area	HC-Antwerp	D
5		World War II (1940-1945)	Series 'Statistiek van de zeevisserij' *Statistisch bulletin*. Nationaal Instituut voor de Statistiek.	1934 – 1956	Annual, no data in 1941, no data by fishing area in WWII	By species, subtotals, general total	By port and by fishing area	Heritage Library Hendrik Conscience Antwerp	D
6			Series 'Bestuurlijk Jaarverslag over de Zeevisscherij'.	1934 - 1939	Annual, no publication in 1941	By species, subtotals, general total	By port	VLIZ, DVZ	Available in paper format (1934–1936) F (1937–1939)

			Bestuur van het Zeewezen.						
7			Officiële lijst der Belgisch vissers-vaartuigen	1929-2012	Annual and semestral	By vessel	By port	VLIZ, Shipping Control offices	paper format (1929–2012) F (1929-2012)
8			Series 'Jaarverslag over de zeevisscherij', Dienst voor Zeevisscherij/ Bestuur van het Zeewezen.	1927 – 1933	Annual	By species (from 1929), subtotals, general total	By port and by fishing area (from 1929)	VLIZ library, library Province West-Flanders,	F (1927–1931) paper format (1932–1933)
9		**1914-1918:** World War I **1914:** natural ice replaced by artificial ice to conserve	Series 'Jaarverslag der commissie voor zeevisscherij', Provincie West-Vlaanderen.	1912 – 1926	Annual; no publication in WWI (1914-1918)	Subtotals, general total	By port	VLIZ library, library Province West-Flanders,	F
10	**BELGIUM** early decades (from 1830)	**1909:** the end of 'salted cod' fisheries in Belgium	De Zuttere (1909). Enquête sur la pêche maritime en Belgique.	1836 - 1907	Annual+ summer/ winter landings for cod	Salted cod, herring and 'fresh caught fish'	By port	Archives and VLIZ library	F
11		**1862**: end of state subsidies in herring fisheries, Belgium **1866**: survey on sea fisheries sector, Belgium	Rapport sur l'état de l'administration dans la Flandre occidentale fait par la Députation permanente au Conseil provincial	1836 - 1869	Annual	Cod, herring and 'fresh caught fish'	By port	State and Provincial archives	D
12		**1884:** arrival of the first steam trawler in Belgium (Oostende)	Memoriael Administratif der Provincie West-Vlaenderen. Bestuursmemoriaal van de provincie West-Vlaanderen-Section 'Pêche maritime'	1837-1875	Annual (not all volumes contain landing statistics)	Cod, herring and 'fresh caught fish'	By port	State archives	D

13	**UNITED KINGDOM THE NETHERLANDS**	1815-1830	Gazette van Gend	1814-1829	Annual and monthly	Fishing vessel movement and landings Salted cod and herring	Port of Oostende	Library of Ghent University	
14	**French Republic**	French Republic 1795-1804 And French Empire 1804-1815	Gazette van Gend				Port of Oostende	Library of Ghent University	
15	**'Austrian Netherlands'**	Oostende Compagnie (1723-1731) for stimulating Flemish trade and fisheries	Cloquet (1842). Études sur l'industrie, le commerce, la marine et la pêche nationale	1767-1780, 1783-1789		'Salted cod' and herring		UA Biblio-theek Stads-campus	F
16	**'Spanish Netherlands** (1549-1713)	**Ca. 1475**: start of Flanders *'Doggevaert'* or cod fisheries on the Doggerbank in the North sea **1547**: Flemish fleet consists of 200 vessels	Vlietinck, (1975). Het oude Oostende en zijne driejarige belegering (1601-1604)	1492-1580				VLIZ library	Available in paper format
17	**'Burgundian Netherlands**	**1396:** Technique for conservation of *herring: 'kaken'* Is applied in Flanders	Degryse & Mus (1966-1967). De laat-middeleeuwse haringvisserij	1398-1427				VLIZ library	Available in paper format

2.3.1 RECENT HISTORY: 1900-2000

Detailed digital sources for annual data on landings and their values were available as from 1998 onwards. This series of annual official reporting was available in paper format since 1973. However, predecessors of this series have been published since the early 20th century (1912). Fragmented parts of these series are kept in paper; in a few disperse province and city archives throughout Flanders.

An overview of the situation of sea fisheries in Belgium in 1909-1910 (von Schoen 1912) provided interesting information on the number of vessels and fishermen, their production and fishing areas, ports and auctions, and import and export, at that time. However, it does not refer to or contain data series on landings.

Our literature screening for time-series on landings and the economic value of these landings indicated that structurally embedded reporting in Flanders/Belgium started in 1929 with an acceptable degree of consistency and continuity ever since then, except during the war period (World War II: 1940-1945, and in particular 1941). The reports have been subject to a number of changes (e.g. responsible authority and editor, title and format of the publication). They were either published as an independent report on fisheries, or as insert chapter in agriculture statistics reporting.

2.3.2 AUSTRIAN, FRENCH AND DUTCH PERIOD, AND THE EARLY DECADES OF THE KINGDOM OF BELGIUM: 1700-1900

Data on fisheries in Flanders were reported much earlier. Cloquet (1842) and De Zuttere (1909) reported on landings of herring and cod in the ports of Oostende and Nieuwpoort from 1767-1780 during the 'Austrian Habsburgs' (1713-1794) and French period (1794-1815). The data on 18th century landings reported by Cloquet (1842) were largely based on detailed records (the remainders of which were checked in State Archives) which were presumably still intact at that time. De Zuttere reported on landings for the period 1836-1907 for herring, salted cod and for 'fresh fish' (aggregate of unidentified species). Although the author probably consulted a wider range of original documents directly obtained from fish auction authorities or Chambers of Commerce, presumably lost at present, he referred to the annual state of administration of the province of West-Flanders (Rapport sur l'état de l'administration dans la Flandre occidentale fait par la Députation permanente au Conseil provincial) and the cantons (Rapports faits par messieurs les commissaires d'arrondissement). These sources were checked, and found to coincide with the data in De Zuttere (1909) except for some minor errors which were probably due to transcription. Some of the data and Tables reported by De Zuttere (1909) were also found as draft documents while screening for historical sources (with no metadata or identification whatsoever of author and context) in the State Archives at Brussels (inventory of Vleeshouwers 1979).

In spite of the level of detail provided by Cloquet (1842) for the time periods 1767-1780 and 1783-1789, and by De Zuttere (1909) for the same intervals and for 1836-1907, neither of the authors included data or references for the 45 year time period 1790-1835. This period largely coincides with the 20 years of the first French Republic (1795-1804) and the French Empire (1804-1815), and with the 15 years of the Kingdom of the Netherlands (1815-1830). During the Dutch administration, official statistics were coordinated by the 'Bureau of Statistics' (later the 'Royal Commission for Statistics'), established in 1826 by Interior Affairs in The Hague. The founder of Belgian statistics, Adolph Quetelet (1796-1874) was a member of one of the provincial commissions. In their overviews of early official statistical publications (including the French period), Heuschling (1843) and Julin (1918) commented briefly on the difficulties with marine fisheries statistics. The absence of references and data during the French and Dutch period may be due to the fact that these were non-existent or simply not disclosed in foreign archives or brought into the public domain. During our search in the State Archives, documents of correspondence with the fisheries administration in The Hague dating from the Dutch period were encountered, but no fisheries statistics or reference to the existence thereof were found. Promising sources for this period include the newspaper of the City of Ghent *'Gazette van Gend'* (edited between 1666 and 1940), which published in-and outgoing fishing vessels in the port of Oostende (1814-1829), the volume of landings of salted cod and herring (in unit of barrels), and the fishing area of origin. Further efforts are under way to expand this search effort to foreign archives and working groups that focus on historical fishery statistics both in Belgium abroad.
The State Archives in Bruges keep original documents and records on landings of cod from the Company for trade and fishing to Iceland 'De Groote Nationale Compagnie voor zeevaart en vischvangst op IJsland (1727-1780)' (Inventory of the old regime of the City of Nieuwpoort - INV80 - 4184). In 1866, a government commission was charged with the investigation into the marine fisheries of Belgium. The report from this commission contains valuable information on marine fisheries drawn from a survey (Du Bus and Van Beneden 1866).
The landings data reported for this period were also collected and digitized in the context of this project. Although not consistently or systematically collected over the period, they provide a good idea of the fisheries during that era. Today, only fragments remain since the largest part of the archives was destroyed during World War I (1914 -

1918) and World War II (1940 - 1945). The data demonstrate the importance of subsidies in the observed trends, as was the case for the period 1842-1868. The rise and fall of cod fisheries in the 19th century could in part be explained by the existence of these subsidies. On the other hand, it was mainly the administrative support and control associated with granting subsidies that acted as the driver for the collection of the early fisheries statistics.

2.3.3 Middle Ages to 1700

Historical documents such as charters and local laws shed light on the importance of fisheries in Flanders during the Middle Ages and the Early Modern Period. The ports of Oostende and Nieuwpoort enjoyed periods of wealth and independent status for trade and fisheries. Detailed records were kept on landings, due to the tax levies on salt and particularly during years in which subsidies were granted to the herring and cod fisheries. Early documented evidence of the extent of fish trade in Flanders can be derived from taxes levied in coastal ports at the beginning of the 11th century (Degryse, 1944). Early published reports of landings in Flanders refer to herring in the port of Biervliet in 1398-1427 (Degryse and Mus 1966-1967) and to Oostende in 1492-1580 (Vlietinck 1975). The State Archives at Bruges contain valuable documents on the history of fisheries and associated trade in Nieuwpoort such as the 'Keure van Nieuwpoort' (city charter of Nieuwpoort) from 1163 which summarizes the species of fish caught, traded and taxed; a Charter of 1574 in which the king granted the city the right to exploit salt (Archive INV80 – 376); and the 'Placaetboeken van Vlaanderen' (De Wulf 1766) with reference to local laws and charters.

2.3.4 State Archives and statistics

Belgian Law on State Archives (Rijksarchieven-RA) stipulates that all governmental documents and administration archives older than 100 years need to be transferred to the State Archives. In practice, RA strives to collect archives as soon as they are freed from legal value (30 years and older). Recent documents (after 1980) on marine fisheries are generally kept at the Sea Fisheries Service (DVZ). Older documents were transferred from the respective fisheries authorities to the State Archives, and it was not clear in what conditions these transfers were conducted or how complete these archives are (M. Preneel, National Institute of Statistics, Belgium, pers. comm.). The responsibility for marine fisheries has changed between ministries since the creation of the Kingdom of Belgium in 1830, e.g., the 'Ministry of Mobility and Infrastructure' created in 1884, 'Ministry of Mobility, Post, Telegraphy and Telephones', the 'Ministry of Labour and Industry', and the Ministries responsible for Agriculture in the Belgian government. With the regionalization of Belgium, the Flemish government was created in 1980. The Lambermont agreements, signed in 2002, finally transferred Sea fisheries from the federal level to the domain of agriculture of the Flemish Government.

We also looked at the history and development of statistics in Belgium and checked the list of official statistical publications in Belgium from 1830 to 1914 to check for additional references to older publications and data sources. Julin (1918) and de Reiffenberg (1932) provide good overviews of the history of the early statistics in Belgium and the difficulties in setting up methodologically sound census and data collecting systems to underpin state policies, in particular for marine fisheries. The need to standardize the collection of fisheries data was already underlined much earlier by De Zuttere (1909) and in the early volumes of the series 'Jaarverslag der commissie voor zeevisscherij', Provincie West-Vlaanderen (Table 2.1.).

The data sources, published and unpublished references and manuscripts listed in Table 2.1. can be organized in 3 categories: data on landing statistics (volume, composition and economic value), data describing the fleet and fishing effort, data related to biological parameters of species. The data sources for these 3 categories are further described in the sections below.

2.3.5 LANDING STATISTICS

Early published reports of landings in Flanders refer to herring in the port of *Biervliet* in 1398-1427 (Degryse and Mus 1966-1967, Table 2.1.) and to *Oostende* in 1492-1580 (Vlietinck 1975)(Table 2.1.). Time-series on landings of marine fisheries in Flanders are reported as early as 1767 (1767- 1780; 1836-1906, Table 2.1.) for herring, salted cod and for 'fresh fish' (aggregate of unidentified species).
From 1836 until 1869 annual landings were reported for herring and for salted cod, in the Provincial Reports 'Mémorial administratif' and 'Rapport sur l'état de l'administration de la Flandre Occidentale fait par la Députation permanente au Conseil provinciale'. The reports also contain total economic value of landed 'freshly caught fish' (all species aggregated). In 1866, a government commission was charged with the investigation into the marine fisheries of Belgium. The report from this commission contains valuable landings statistics data information on marine fisheries drawn from a survey (Du Bus and Van Beneden 1866). Although not consistently or systematically collected over the period, they provide a good idea of the fisheries during that era. Reporting ceased when state subsidies were abolished in 1869.

De Zuttere's socio-economic survey (Table 2.1.) served as a historic baseline for the statistical data collection programme that was under scrutiny for early internationally agreed standards and formats. The programme set off in 1912 and, after an interruption during WWI, took its final format in 1929 with detailed reporting at the species level. The systematic fisheries statistics were put in place in Belgium thanks to the efforts of G. Gilson and co-worker Ch. Gilis who represented Belgium in ICES. Since then, the composition and economic value of landings is reported annually in 'Jaarverslag over de zeevisserij' and its successors. However, it must be underlined that these reports often contain highly aggregated statistics, and that most of the detailed statistics with best taxonomic, spatial and temporal resolution (original handwritten reporting sheets) were obtained by searching the storage and repository of the Sea Fisheries Service in Oostende. These original handwritten reporting sheets were organized in 'Table series' containing mostly data on composition, volume and value of landings identified by roman numbers (I-IX). The most important and complete series are: data by port of landing; data by type of fishery (e.g., shrimp fishery, demersal trawl fishery, ...); data by fishing area (fishing area 1 to 21, see also Chapter 4 on spatial dynamics of Belgian sea fisheries). Particular 'Table series' also contain annual and monthly data on fishing effort as related to the landings that resulted from this effort. These Tables are organized by type of fishery (e.g. 'shrimp fishery', 'herring drift net fishery', '(beam trawl) flatfish fishery',...) by vessel class, by year and by month. The latter are documented in the context of particular research questions (Chapters 6 to 8).

Scope of the landing statistics included in the HiFiDatabase
The HiFiDatabase is based on publicly reported statistics on landings from the commercial fleet and therefore does not cover total removals of fish and shellfish by the Belgian fleet. Publicly reported statistics on fisheries refer to commercial landings which are only a part of the catch and hence of the total removals. The difference between publicly reported versus total anthropogenic removals includes several components. Besides the unreported and misreported commercial landings (Zeller et al. 2006, Zeller et al. 2007), part of the catch is discarded at sea by fishers (Kelleher 2005), suffers unaccounted underwater mortality in the fishing gear (Collie et al. 2000, Rahikainen et al. 2004, Kaiser et al. 2006, Depestele et al. 2008) or is removed by recreational/artisanal fishing (Coleman et al. 2004, Zeller et al. 2008). There is no quantitative or qualitative assessment of the small-scale fisheries (<12m) within 12 nm or territorial sea of Belgium. Discards of the commercial fleet, landings and discards of the recreational fleet, and artisanal and land-based fishing activities are not covered in systematic reporting. Together these components are often referred to as Illegal, Unreported and Unregulated catches (IUU). Chapter 6 provides a first estimate of these components for the Belgian sea fisheries and in particular for the BNS.

The HiFiDatabase contains data on the landings (tonnes) by the Belgian fleet in the Belgian and foreign fish auctions, and on the value (Euro) of these landings at first sale, in the Belgian and foreign fish auctions. It explicitly includes landings by the Belgian fleet, both in the Belgian ports and in foreign ports. Landings from foreign fleets in the Belgian ports are reported in some of the original sources. The data rescue for the latter was covered only in terms of global annual totals and subtotals by species. For the time being – and according to priority setting – these landings from the foreign fleet were not standardized and integrated and not considered for the purpose of data analysis.

Detailed monthly landings by statistical rectangles are available for a number of species (sole, whiting, haddock, cod, plaice) and for limited years (1954-1962 and 1969-1981), and also published as 'Belgische zeevisserijatlas' (Belgian sea fisheries atlas) by the Institute of Agriculture and Fisheries Research (ILVO and its predecessors). Unfortunately, most of the recent publications (1969-1981) report values as ranges instead of absolute values (1954-1962). Exceptionally, data on fisheries practiced from the beach ('strandvisserij') were collected during WWII; these were included in the data rescue and integration.

Historical data sources on landings before 1998 were only available in hard copy. None of the data were available electronically in the public domain, except for an electronic file (spreadsheet) with landings by (the most important) species by fishing area of origin 1996-recent year provided by the Sea Fisheries Service upon personal request of researchers. In other words, landings data was available on spreadsheets for 1996 onwards. The collection of original data sources was scanned, electronically stored as PDF format, described, and data were digitized from the earliest year of consistent time-series (1929).

All data and data sources are now public and no restriction other than the acknowledgement of sources is required. A detailed list and description of digitized sources of data on the composition and economic value of landings is available from: http://www.vliz.be/cijfers_beleid/zeevisserij/pub_bijdrage.php.

2.3.6 Fleet Statistics

Since 1929 the Belgian Ministry of Transport (federal government of Belgium) publishes the annual 'Official list of the Belgian fishing vessels (OLBFV)' on the state of the national fleet, with separate lists for the fishing fleet. The OLBFV describes characteristics of individual vessels by port of registration, identifying their immatriculation number, total length (TL), capacity as gross tonnage (GT) and net tonnage (NT), engine power (Kilowatt-kW or Dutch Horsepower-HP), owner (name, address), year of construction, ship wharf, construction material (wood, steel…), fishing gear, and - however in less complete records- presence of some of the communication and technical equipment on board (VHF, sonar,...).

Table 2.2.: Overview of sources containing historical time-series (> 5 consecutive years) on landings and fleet parameters by the Belgian fishing fleet between 1830 and 2010 with an indication of temporal, taxonomic and spatial resolution.

Period	Fleet parameters	Source
1830-1841	Number of ships for the port of Oostende; total gross tonnage of ships for the port of Oostende (in registerton);	Rapport de la Commission chargée de faire une enquête sur la situation de la pêche maritime en Belgique. Séance du 17 mai 1866. Chambre des Représentants: Bruxelles. XLII, 75 pp.
1832,1836, 1839	Number of ships for the ports of Nieuwpoort, Blankenberge, Heist, De Panne/Adinkerke, Koksijde/Oostduinkerke.	Rapport de la Commission, 1866.

1842-1864	Number of ships by port (Oostende, Nieuwpoort, De Panne/Adinkerke, Koksijde/Oostduinkerke, Blankenberge, Heist); total gross tonnage of ships by port (all ports)	Rapport de la Commission, 1866
1865-1871	No data	No sources
1872, 1877, 1882, 1887, 1892-1903	Number of ships by port, including number of steam trawlers ; total gross tonnage of ships by port; open and half-open vessels for 1892-1911 estimated based on punctual reported numbers for 1892 and 1905	Hoek, P.P.C.; Kyle, H.M. (1905). Appendix J: Statistics of the North Sea fisheries. Part I: The fisheries of the various countries. Belgium *Rapp. et Proc.-Verb. Cons. Int. Explor. Mer 3*: 82-91 1905.
1905	Number of ships by port, including number of steam trawlers; Total gross tonnage of ships by port, including tonnage of steam trawlers.	De Zuttere, C. (1909). Enquête sur la pêche maritime en Belgique: introduction, recencement de la pêche maritime. Lebègue & cie: Bruxelles. 634 pp.
1910	Number of ships by port, including number of steam trawlers; total gross tonnage of ships by port, including tonnage of steam trawlers.	Von Schoen, F. (1912). La pêche maritime de la Belgique *Bulletin de la navigation et des pêches maritimes 14*: 185-205
1911-1931	Number of ships by port, including indication of number of steam trawlers; total gross tonnage of ships by port, including indication of tonnage of steam trawlers.	Provincie West-Vlaanderen. Commissie voor Zeevisscherij Jaarverslag der Commissie voor Zeevisscherij. Druk. Verbeke-Loys: Brugge: 1912, 1913, 1919-1931.
1929-2008	Number of ships by port; GT, HP, KW, total length, total width, ownership and other ship-by-ship information	Officieele lijst der visschersvaartuigen. Ministerie van Landbouw. Dienst voor Zeevisscherij: Oostende (and continued series): 1929-2010;
2008-2010	Number of ships by port; total gross tonnage of ships by port, in metric tonnes	Tessens, E.; Velghe, M. (2008). De Belgische zeevisserij: aanvoer en besomming 2008. Vlaamse Overheid. Departement Landbouw en Visserij. Afdeling Landbouw- en Visserijbeleid. Zeevisserij: Brussel. 103 pp. Tessens, E.; Velghe, M. (2010). De Belgische zeevisserij: aanvoer en besomming 2009. Vlaamse Overheid. Departement Landbouw en Visserij. Afdeling Landbouw- en Visserijbeleid. Zeevisserij: Oostende. 109 pp.

A second time-series consists of statistical Tables on characteristics of the fishing fleet and the fishermen, published as the 'statistical Tables V and VI' in the 'Landbouwstatistieken' (Agriculture statistics) from 1944 onwards. These tables contain aggregated data on number and capacity of vessels (by port, class of gross tonnage and category of engine power) and overall fishing effort (days at sea and days fishing) for steam-powered and for motor engines. Before 1929, data were obtained from disperse and fragmented sources (Table 2.2.) e.g., the report of the government's commission of 1866 and the survey conducted by De Zuttere (1909) (Table 2.1.). In spite of previously existing analyses (Polet et al. 1998, Depestele et al. 2008) where size (1905-2008) and engine power (1935-2008) of the fleet were reported with 15-year intervals (no references to sources), none of the data or time-series used in this report were available in electronic spreadsheet format or available for overviews or research analysis.

Much like the findings on historical landings, none of the data contained in the pre-1998 sources were available in electronic format or available for overviews or research analysis, with the exception of the annual reports on Belgian sea fisheries landings that are electronic formats (PDF or html) from 1998 onwards. Data on fleet parameters (number of vessels by vessel class, engine power KW) have been collected previously (e.g. IMPACT I and IMPACT II projects) starting from 1905 with time intervals of 15 years. Unfortunately these datasets seem to have been lost.

The data on fleet size, engine power, capacity and technology to reconstruct the history of fishing power and catch effort for the Belgian sea fisheries fleet was largely based on 'ship-by-ship' information. The data from the original paper copies were digitised, standardised and integrated in the 'Belgian fleet' database as part of the HiFiDatabase (Lescrauwaet et al. 2010b). Integration efforts focused on the reconstruction of the 'lifeline' of individual ships (section 2.5.2.), while standardization was mainly centered on units of power, tonnage, and of proper names.

2.3.7 Biological data and Parameters on fish stocks

Currently fish stock assessments are based on the data and information generated in the context of the International Council for the Exploration of the Sea (ICES) and data is generated according to well-agreed international sampling and survey procedures, standards (see Chapter 1). Stock assessments are used to formally assess the status of fish stocks for management purposes in the EU Common Fisheries Policy, e.g. the annual ICES advice to define Total Allowable Catches TAC and quotas. Stock assessment models are based on three primary categories of data and information:

- 'Catch' data: the biomass removed from a stock by fishing: this is often referred to as 'catch', however in practice the data used are 'commercial landings', where possible corrected by discard data and removals from recreational and artisanal/subsistence fishing
- Abundance data: a measure of the number of individuals in the stock, or their weight. This is usually based on systematic sampling conducted in fishery-independent surveys
- Biology data: information e.g. on age, size, growth rates, reproductive rates, and natural mortality

The major part of the historical reconstruction included here refers to the species composition, volume, economic value and fishing area of origin of the commercial sea fisheries, and dynamics of the fishing fleet. However, an interesting number of historical studies were identified, which provide data on population structure and biological parameters (length, weight, sexual maturity, fat contents, stomach content, number of vertebrae). Gilson, and in particularly Gilis in later years, conducted biological studies on shrimp and shrimp fisheries, on demersal fishery in the North Sea, on sole, and long-term annual assessments of the seasonal 'spent herring' fisheries. Some of these studies were not published but stored as internal reports for the purposes of the research institute. These proved very valuable and unique sources of biological information from times that typically stem from before formal stock assessments were started in the 1960s (chapter 6).

2.4 Digitization process and quality control

The sources identified in Table 2.1. and 2.2. (inventory of data sources) were scanned, described and disclosed electronically through the content management system IMIS. However, most of the actual data from the Tables contained in these sources needed manual digitalization and transcription to spreadsheets in order to allow for posterior manipulation and integration. Integrating data from different sources into one database is a stepwise process, involving basic aspects of data management such as standardization and quality control (QC). Quality control, in all its dimensions, is an essential aspect in the recovery and integration of (historical) data. The different steps of converting and controlling the quality of the converting process as well as the data are summarized below.

2.4.1 CONVERSION OF SCANNED DATA TABLES (SCANS OF ORIGINAL PAPER COPIES) TO SPREADSHEETS

Where quality of the scans permitted, the data from scanned sources were extracted by means of image/pdf reading software (ABBYY FineReader v.9.0) and converted to spreadsheets. The Table(s) were then copied and pasted in spreadsheets. Anomalies (dots, spots, etc in the printing and/or artifacts due to paper quality, storage and handling of the documents over the years) and misinterpretations of numbers or separators needed a first control during the conversion process. Still, approximately 30%-50% of the data sources needed manual conversion.

2.4.2 QUALITY CONTROL OF THE DATA CONTAINED IN THE CREATED SPREADSHEETS

A second QC focused on the quality of the data. The annual data tables are matrices which list species names in the first column and names of ports or fishing grounds in the first row, for any given year ‘x’. Each data field in the table for year ‘x’ therefore corresponds with the landings of a given species in a given port or from a given fishing ground for that year. Row subtotals should represent the sum of all landings for a given species for all ports or fishing grounds in year ‘x’. Column subtotals should sum landings of all species by the categories of (1) demersal species, (2) pelagic species and (3) molluscs and crustaceans, by port (or by fishing ground) for year ‘x’. Finally, subtotals add up to ‘Global totals’ in the last row. These annual row and column subtotals and totals were presumably tabulated on a monthly basis and calculated in the original files by the staff of the fisheries authority, after the data was collected on a daily and monthly basis in the fish auctions. The reported calculated (sub) totals were also copied in the conversion process. Row and column (sub)totals were calculated independently in the spreadsheets, and crosschecked with the reported (sub)totals in the original document. Two main types of errors were detected in the original files:

- Errors that occurred when numbers were mistakenly copied from the draft to the final version of the reported tables, by the staff
- Errors that occurred when (sub)totals in rows or columns were mistakenly calculated by the staff in the reported tables (error in the original summation);

In these two cases, the error could be located by checking the rows or columns in the original and in the copied document. The consecutive steps of the conversion of scanned tables, the quality control on the conversion process and the first data quality control on each of these ‘original’ set of spreadsheets with the set of converted tables, resulted in a number of ‘corrected files’ or spreadsheets: each file representing a report for a given year. Detectable errors in copying and/or calculations were amended in these corrected files. Each of these errors was amended and documented in the ‘metadata’ sheets of the ‘corrected files’.

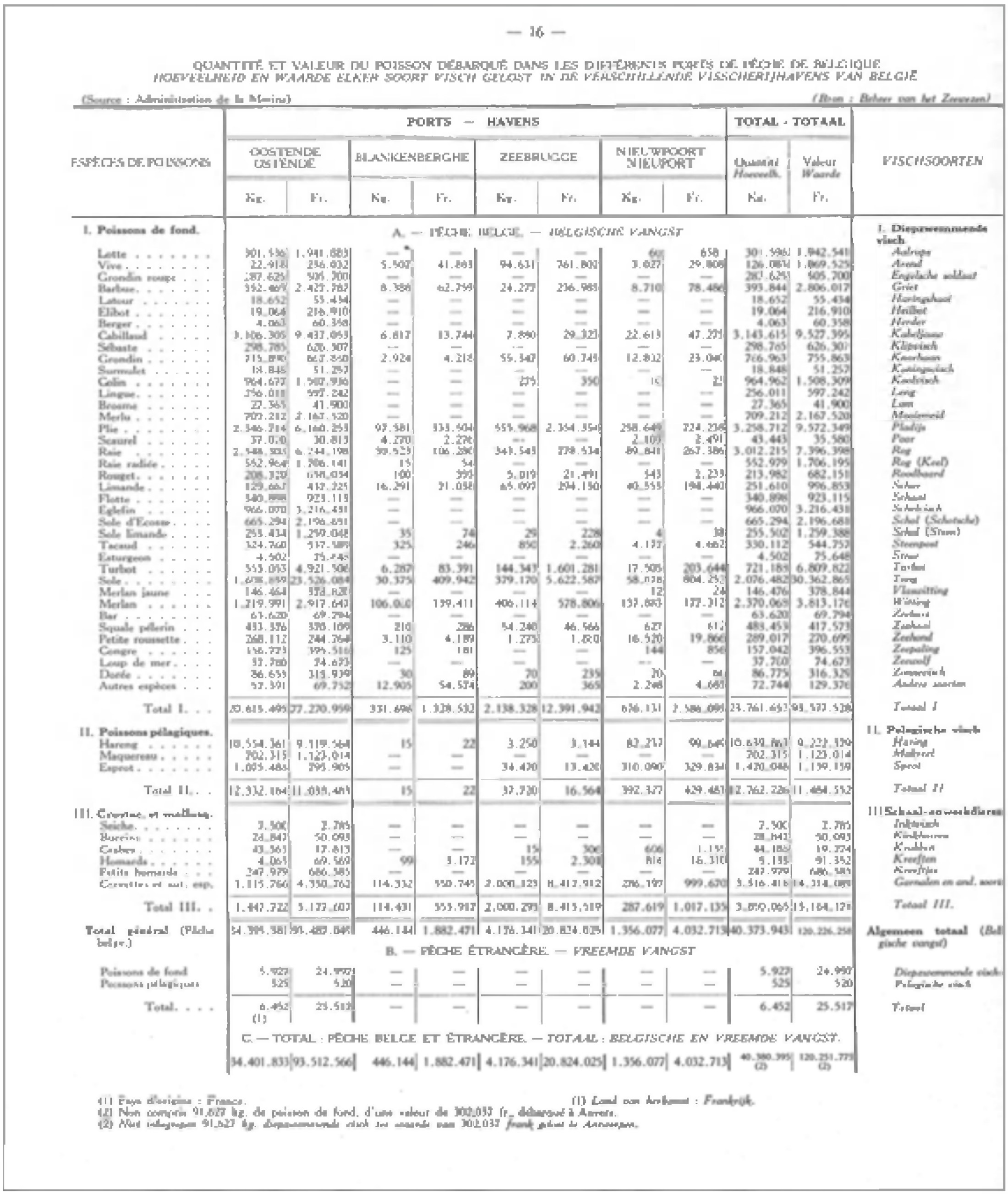


Figure 2.3.: Example of digitized original source (1936, from 'Statistisch Bulletin, 1937')

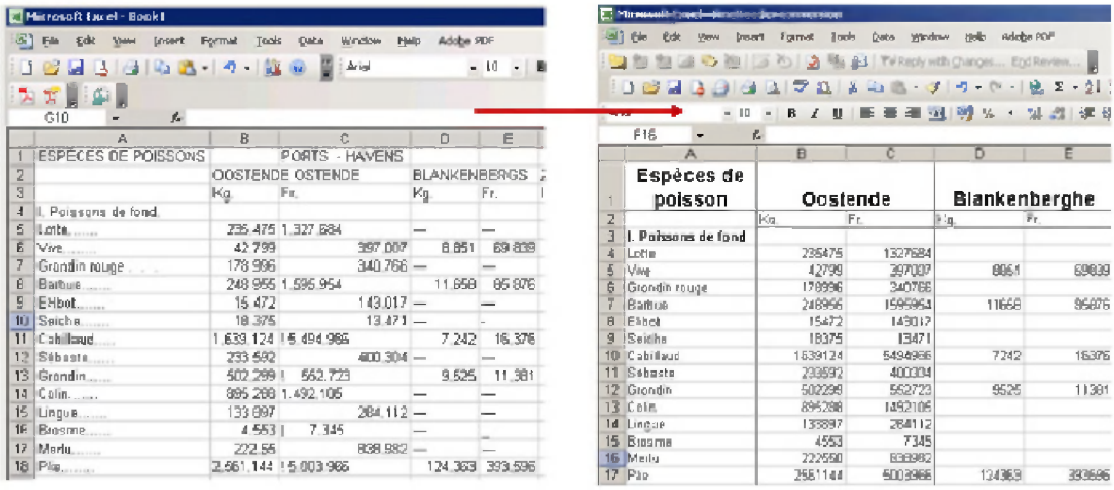


Figure 2.4.: Example of FineReader 9.0 stepwise conversion process.

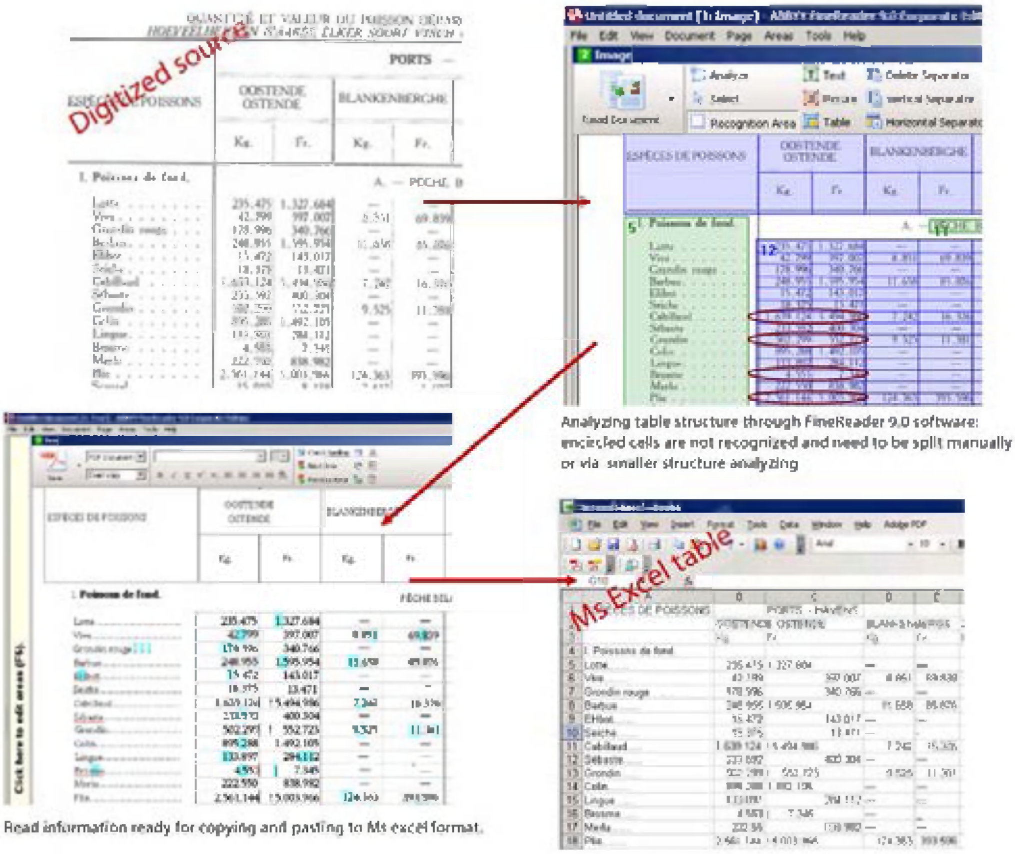
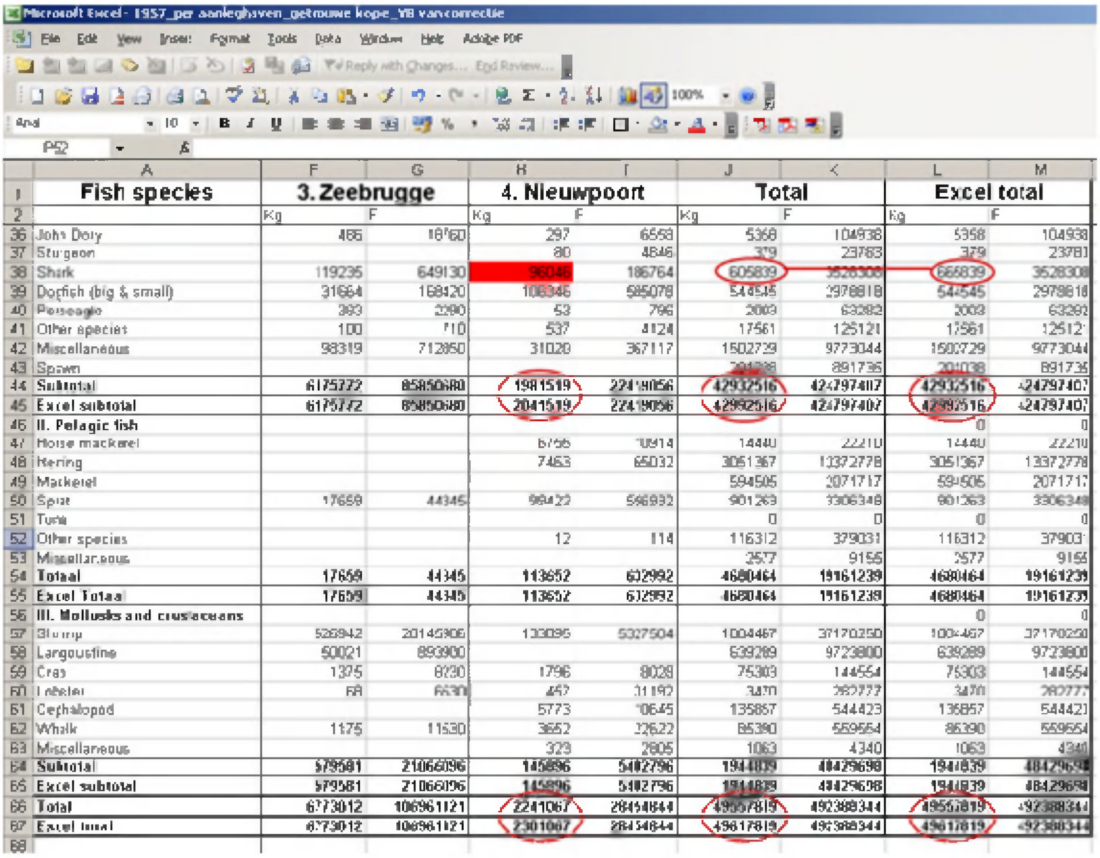


Figure 2.5.: Quality control of the FineReader conversion resulting in "clean" spreadsheet files.



Microsoft Excel - 1957_per aanleghaven_getrouwe kope_YB vancorrectie

	Fish species	3. Zeebrugge		4. Nieuwpoort		Total		Excel total	
2		Kg	F	Kg	F	Kg	F	Kg	F
36	John Dory	486	18760	297	6558	5368	104938	5358	104938
37	Sturgeon			80	4846	379	23763	379	23781
38	Shark	119235	649130	96046	186764	605839	3528308	665839	3528308
39	Dogfish (big & small)	31664	168420	108346	585078	544545	2978818	544545	2978818
40	Poiseagle	393	2290	53	796	2003	63282	2003	63282
41	Other species	100	710	537	4124	17561	125121	17561	125121
42	Miscellaneous	98319	712850	31020	367117	1502729	9773044	1502729	9773044
43	Spawn					201038	891736	201038	891736
44	**Subtotal**	**6175772**	**85850680**	**1981519**	**22419056**	**42932516**	**424797407**	**42932516**	**424797407**
45	**Excel subtotal**	**6175772**	**85850680**	**2041519**	**22419056**	**42992516**	**424797407**	**42992516**	**424797407**
46	**II. Pelagic fish**							0	0
47	Horse mackerel			6756	10914	14440	22210	14440	22210
48	Hering			7463	65032	3051367	13372778	3051367	13372778
49	Mackerel					594505	2071717	594505	2071717
50	Sprat	17659	44345	98422	546932	901263	3306348	901263	3306348
51	Tuna					0	0	0	0
52	Other species			12	114	116312	379031	116312	379031
53	Miscellaneous					2577	9156	2577	9156
54	**Totaal**	**17659**	**44345**	**113652**	**632992**	**4680464**	**19161239**	**4680464**	**19161239**
55	**Excel Totaal**	**17659**	**44345**	**113652**	**632992**	**4680464**	**19161239**	**4680464**	**19161239**
56	**III. Mollusks and crustaceans**							0	0
57	Shrimp	526942	20145906	133096	5327504	1004467	37170250	1004467	37170250
58	Langoustine	50021	893900			639289	9723800	639289	9723800
59	Crab	1375	8230	1796	8028	75303	144554	75303	144554
60	Lobster	68	6630	457	31192	3470	282777	3470	282777
61	Cephalopod			5773	10645	135857	544423	135857	544423
62	Whelk	1175	11530	3652	22622	86390	559554	86390	559554
63	Miscellaneous			323	2805	1063	4340	1063	4340
64	**Subtotal**	**579581**	**21066096**	**145896**	**5402796**	**1944839**	**48429698**	**1944839**	**48429698**
65	**Excel subtotal**	**579581**	**21066096**	**145896**	**5402796**	**1944839**	**48429698**	**1944839**	**48429698**
66	**Total**	**6773012**	**106961121**	**2241067**	**28454844**	**49557819**	**492388344**	**49557819**	**492388344**
67	**Excel total**	**6773012**	**106961121**	**2301067**	**28454844**	**49617819**	**492388344**	**49617819**	**492388344**

Figure 2.6.: Example of a case in which a figure for landings of 'shark' in Nieuwpoort was wrongly copied in the final source document: the error is reflected in the quality control calculated row and column subtotals. By replacing the '96046' by '90046' the original subtotals matched.

2.4.3 STANDARDIZATION: TAXONOMY, GEOGRAPHY, UNITS OF MEASUREMENT

One of the main difficulties in integrating and comparing different datasets from various data providers is the standardization of the data. Standardizing is a prerequisite for functional databases. Therefore an analysis was conducted of the different parameters included in the reported data sources. Single spreadsheets (one file per reported year) were integrated into one table per feature according to the defined database structure, in order to perform standardization. Standardization was performed for (1) taxonomy, (2) geography and spatial units, and (3) sampling methodology and reporting units.

- **Reporting units of landed species:** most reporting units were at the species level (e.g., 'herring'), while others were aggregates (e.g. 'lobsters' or 'pelagic species not identified elsewhere') or because the species was locally known under a generic name (e.g., 'shells' probably refers to clams *Pecten maximus and Aequipecten opercularis*). Other aggregates refer to functional groups, e.g., 'total pelagic species' reported as the sum of all species reported as 'pelagic'. Some units were reported over the entire period (1929-1999) while others appeared only for a few years. Aggregations were applied in the data for those reporting units at the species level for which some doubts were raised on the accuracy of the taxonomic identification, as species identification in the field is not always straightforward (e.g., 'rays' and 'sharks'). The overall number of different reported taxonomic 'units' for all files over the reporting period was 113 (including different naming and spelling). After standardization this number was reduced to 56 (including all aggregates).

- **Taxonomic units:** most reporting units were at unique species level. Taxonomy was checked by means of the European Register of Marine Species (ERMS), which is the European component to the World Register of Marine Species (WoRMS, http://www.marinespecies.org) and (vernacular) names linked to officially acknowledged taxa (Aphia ID codes, see right column). This authoritative taxonomic register provides a list of species occurring in the European marine environment. Spelling mistakes were corrected, and the taxonomic name as recorded in the datasets was linked to the name as included as valid in the ERMS. More information on the ERMS (Cuvelier et al. 2006) is available from the MARBEF website (www.marbef.org/data/erms).
Additional sources were consulted (e.g., literature, Fishbase http://www.fishbase.org). In cases where taxonomic identification was uncertain, such as for sharks and rays, these taxa were aggregated in the final standardised database. The original naming was maintained in the original files. Finally after standardizing and aggregation, 41 units remained at the species level.

- **Assigning species names to aggregate groups:** species or reporting units may have been erroneously assigned to the wrong or different aggregate groups over a particular period, as was the case for 'squid' (classified as demersal instead of molluscs) and horse mackerel (classified as demersal instead of pelagic). A standardised approach was applied for the entire period 1929-1999.

- **Ports**: assigning landings as disembarked in a particular port. A total of 6 ports were reported in the overall period: *Nieuwpoort, Oostende, Zeebrugge* and *Blankenberge* (Belgium) while during World War II (1939-1945), landings were disembarked in France (*Gravelines and Dunkerque*). Landings in these French ports were not included as 'Belgian ports' in the time-series because this group of ports only refers to the four Belgian ports of *Nieuwpoort, Oostende, Blankenberge* and *Zeebrugge*. However, because of their particular importance during WWII, these data were included and 'earmarked' in the reporting unit 'foreign ports' in the database. An overview of the relative importance of each port and by species, is available from the website: http://www.vliz.be/cijfers_beleid/zeevisserij/list.php (Dutch and English version; select a species and click on 'statistics').

- **Fishing area**: the overall number of different fishing areas reported was 40 (including different spellings, Table 2.3.). Standardizing fishing area names and their boundaries is not an easy task in the absence of reliable geo-referenced data sources. A detailed description of the process of standardization is available from a readers' guide and the list of fishing areas after standardization is included in the Appendix 1. To assign these standardised names, both the ICES map of fishing areas and the VLIZ Marine Gazetteer (http://www.vliz.be/vmdcdata/vlimar) database were consulted. The resulting map is included as Figure 2.7. (global) and Figure 2.8. (North Sea and 'western' fishing grounds). After standardizing, 31 standardised names of fishing grounds remained (Table 2.3.). More details on the quality control and standardization are available from the readers' guides.

- **Units of measurement**: over the time frame covered in the present reconstructions, changes in units of measurement were recorded for different parameters. An example is the unit of volume or the tonnage of a ship. In the past, the tonnage of a vessel in Belgium was expressed either in Moorsom ton or Gross Register ton GRT, or in Gross Tonnage (GT) (Chapter 5). The GT applies to new ships from 1982 although in practice, the first ships measured according to the GT system in Belgium were registered in the 1984 annual report. Before that, ships were reported as register ton GRT or in m^3. From 1984 onwards these measurements were gradually replaced by GT as new ships entered the fleet or as older ships were gradually re-measured according to the GT system. From 1994, all ships measurements were expressed as GT. Other examples of standardization of units of measurement are the Dutch PK versus English horsepower HP and the Kilowatt kW. More details are provided in the context of the specific analysis in each of the Chapters and in the readers' guides in the reference list (Lescrauwaet et al. 2009, Lescrauwaet et al. 2010c, Lescrauwaet et al. 2011).

Table 2.3.: List of standardized reporting units (local names by alphabetical order in Dutch). Source: 'A century of Sea Fisheries in Belgium' (VLIZ 2009).

	English vernacular		Local name	Scientific name(s)	WoRMS ID
Demersal fish	**Other species**	**Bodemvissen**	**Andere soorten**		
	Flounder		**Bot**	*Platichthys flesus*	*127141*
	Red gurnard		**Engelse poon**	*Aspitrigla cuculus*	*150662*
	Grey gurnard		**Grauwe poon**	*Eutrigla gurnardus*	*150637*
	Brill		**Griet**	*Scophthalmus rhombus*	*127150*
	Greater weever		**Grote Pieterman**	*Trachinus draco*	*127082*
	Sharks ('dogfish')		**Haaien**	*Squalus acanthias, Scyliorhinus canicula, Lamna nasus*	*105923,105841 105814*
	Flathead mullet		**Harder**	*Mugil cephalus*	*126983*
	Hake		**Heek**	*Merluccius merluccius*	*126484*
	Halibut		**Heilbot**	*Hippoglossus hippoglossus*	*127138*
	Cod		**Kabeljauw**	*Gadus morhua*	*126436*
	Conger eel		**Kongeraal**	*Conger conger*	*126285*
	Coal fish		**Koolvis**	*Pollachius virens*	*126441*
	Spawn (fish roe)		**Kuit**		
	Ling		**Leng**	*Molva molva*	*126461*
	Cusk		**Lom**	*Brosme brosme*	*126447*
	Red mullet		**Mul**	*Mullus surmuletus*	*126986*
	Pollack		**Pollak**	*Pollachius pollachius*	*126440*
	Tub gurnard		**Rode poon**	*Chelidonichthys lucerna*	*127262*
	Rays		**Roggen**	*Bathyraja brachyurops, Raja montagui, Leucoraja circularis, Raja clavata, Amblyraja radiata, Dipturus batis, Leucoraja naevus*	*271509,105887, 105873,105883, 105865,105869, 105876*
	Ocean perch/redfish		**Roodbaars**	*Sebastes spp (primarily S. norvegicus, S. mentella)*	*127253*
	Dab		**Schar**	*Limanda limanda*	*127139*
	Megrim		**Scharretong**	*Lepidorhombus whiffiagonis*	*127146*
	Haddock		**Schelvis**	*Melanogrammus aeglefinus*	*126437*
	Plaice		**Schol**	*Pleuronectes platessa*	*127143*

	Bib		**Steenbolk**	*Trisopterus luscus*	*126445*
	Sturgeon		**Steur**	*Acipenser sturio*	*126279*
	Turbot		**Tarbot**	*Psetta maxima*	*154473*
	Sole		**Tong**	*Solea solea*	*127160*
	Lemon sole		**Tongschar**	*Microstomus kitt*	*127140*
	Miscellaneous		**Varia**		
	Whiting		**Wijting**	*Merlangius merlangus*	*126438*
	Witch		**Witje**	*Glyptocephalus cynoglossus*	*127136*
	European sea bass		**Zeebaars**	*Dicentrarchus labrax*	*126975*
	Blackspot seabream		**Zeebrasem**	*Pagellus bogaraveo*	*127059*
	Angler		**Zeeduivel**	*Lophius piscatorius*	*126555*
	Wolf-fish		**Zeewolf**	*Anarhichas lupus*	*126758*
	John dory		**Zonnevis**	*Zeus faber*	*127427*
Pelagic fish	**Other species**	**Pelagische vis**	**Andere soorten**		
	Herring		**Haring**	*Clupea harengus harengus*	*293567*
	Horse mackerel		**Horsmakreel**	*Trachurus trachurus*	*126822*
	Mackerel		**Makreel**	*Scomber scombrus*	*127023*
	Sprat		**Sprot**	*Sprattus sprattus sprattus*	*236448*
	(blue fin)Tuna		**(blauwvin)Tonijn**	*Thunnus thynnus*	*127029*
	Miscellaneous		**Varia**		
	Salmon		**Zalm**	*Salmo salar*	*127186*
Crustaceans & molluscs	**Other crustaceans**	**Schaal- en weekdieren**	**Andere schaaldieren**		
	Other species		**Andere soorten**		
	Brown shrimp		**Grijze garnaal**	*Crangon crangon*	*107552*
	Brown shrimp (and other species)		**Grijze garnaal (en andere soorten)**		
	Cephalopods		**Inktvis**	*Alloteuthis subulata, Loligo forbesi, Loligo vulgaris, Sepia officinalis(recent years)*	*153131, 140270, 140271*
	Lobsters		**Kreeften**	*Homarus gammarus, Nephrops norvegicus*	*107253 107254*
	Edible crab		**Noordzeekrab**	*Cancer pagurus*	*107276*
	Shells		**Schelpen**	*Schelpen (probably Pecten maximus)*	*394429*
	Miscellaneous		**Varia**		
	Whelk		**Wulk**	*Buccinum undatum*	*138878*

Note: the link to the species pages in the World Record of Marine Species is achieved by adding the ID code number (right column) in the URL address, e.g. the page for 'flounder' (code 127141') is: http://www.marinespecies.org/aphia.php?p=taxdetails&id=127141

Table 2.4.: Original names of the fishing areas as reported in original statistical sources (second column), and names as assigned after standardization (right column) in the 'A century of Sea Fisheries in Belgium' (VLIZ 2009).

	Original name of fishing ground	**Standardised name**	**English name**
1	Kustzee	Kustzee	Coastal waters
2	Noordzee-Zuid	Noordzee (zuid)	North Sea (south)
3	Noordzee-Midden	Noordzee (midden)	North Sea (central)
4	Noordzee-Midden-Oost (Witte Bank)	Noordzee (midden-oost)	North Sea (central-east)
5	Noordzee-Midden-Oost	Noordzee (midden-oost)	North Sea (central-east)
6	Witte Bank	Noordzee (midden-oost)	North Sea (central-east)
7	Noordzee-Midden-West	Noordzee (midden-west)	North Sea (central-west)
8	Noordzee-Noord	Noordzee (noord)	North Sea (north)
9	Noordzee	Noordzee	North Sea
10	IJsland	IJslandzee	Iceland Sea
11	IJslandzee	IJslandzee	Iceland Sea
12	Faroe	Faeröer / Faroe	Faroes
13	West-Schotland	West-Schotland	West Scotland
14	Rockall	Rockall	Rockall
15	Moray-Firth	Moray-Firth	Moray-Firth
16	Noordzee - Moray Firth	Moray-Firth	Moray-Firth
17	Fladen	Fladen	Fladen
18	Noordzee - Fladen	Fladen	Fladen
19	Kanaal	Engels Kanaal	English Channel
20	Engels Kanaal	Engels Kanaal	English Channel
21	Bristol Kanaal	Kanaal van Bristol	Bristol Channel
22	Kanaal van Bristol	Kanaal van Bristol	Bristol Channel
23	Zuid-Ierland	Zuid-Ierland	South Ireland
24	West-Ierland	West-Ierland	West Ireland
25	Zuid- en West-Ierland	Zuid- en West-Ierland	South- and West Ireland
26	Zuid- en West-Ierland (Mine Head)	Zuid- en West-Ierland	South- and West Ireland
27	Mine-Head	Zuid- en West-Ierland	South- and West Ireland
28	Ierse Zee	Ierse Zee	Irish Sea
29	Portugal Marokko	Portugal Marokko	Portugal Morocco

Belgian part of the North Sea (BNS)

In spite of the importance of fisheries data at the scale of national EEZs or marine waters, no historical time-series were available for the BNS so far. ICES data do not contain historical statistics with spatial reference to the BNS. Only from 1996 onwards, data are available for research purposes at a spatial scale that is of relevance to the BNS. This includes Vessel Monitoring System (VMS) data which are relevant to study distribution at a micro-scale. Landings data was originally collected with reference to the rectangles of origin, however this spatial data was lost after aggregation for reporting purposes (Chapter 4). Although one of the 3 reporting ICES statistical rectangles (31F2) that are relevant for the BNS has a significant proportion of its area within the BNS, unknown but likely significant landings from the areas of 2 other rectangles (31F3, 32F2) should be taken into account (Figure 6.9.). The HiFiDatabase contains data reported for the 'coastal waters' from 1929-2010. According to the maps of Vanneste and Hovart (1959), the 'coastal waters' correspond to an area 20-30 miles from the shoreline between the line 'Griz

Nez-South Foreland' and the parallel of IJmuiden. For the purpose of quality control, the reported landings for the 'coastal waters' (1929-2010) were compared to the fragmented historical source documents that report at ICES statistical rectangle. The data for the combined rectangles 31F2 and 31F3 provide a fair match (<10% difference) with the historical time-series for the 'coastal waters'. This was confirmed by the head of the fisheries statistics 1953-1975 (pers. com. Mr. J. Depreeuw). Considering the spatial scale of the BNS, this time-series is considered to provide an acceptable representation of the landings originating from the BNS. These unique historical data were therefore used in the present thesis to reconstruct and estimate landings and total removals at the scale of the BNS (Chapter 4 and Chapter 6).

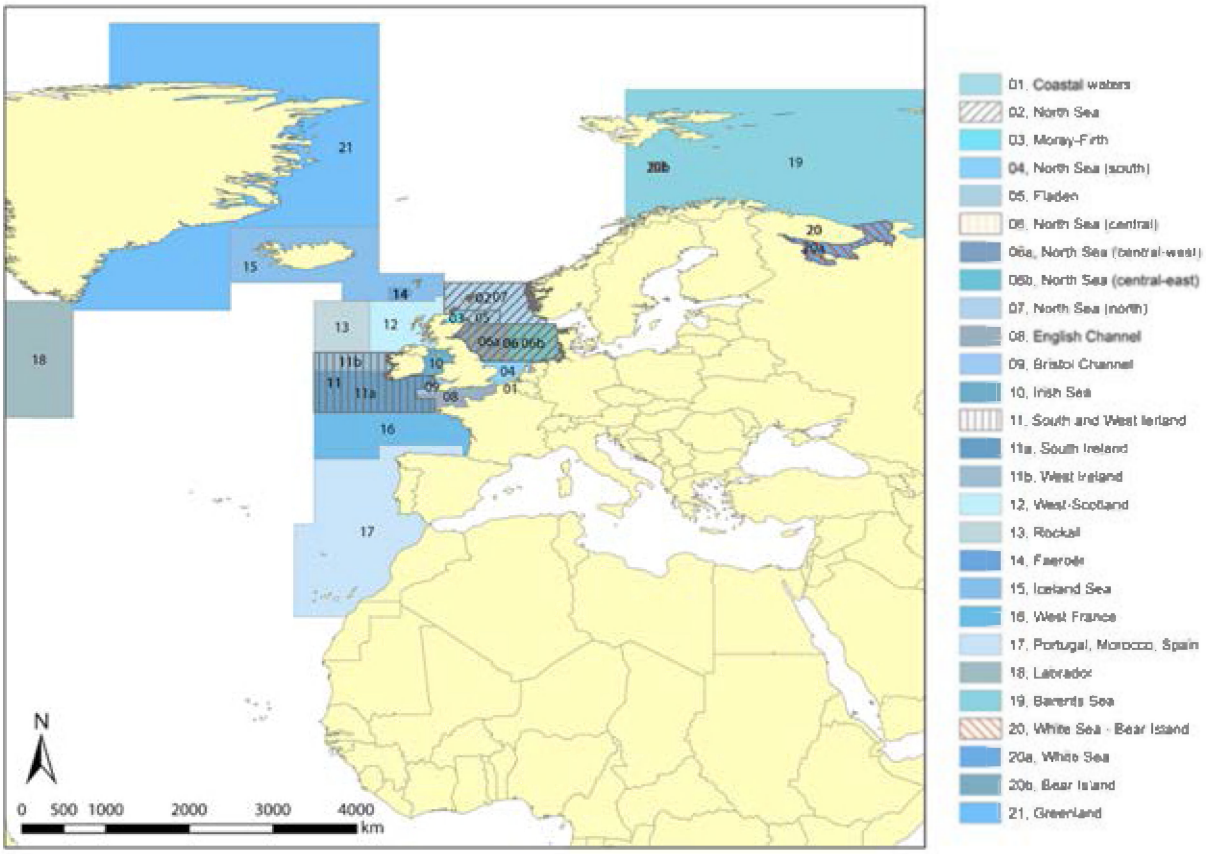


Figure 2.7.: Boundaries and names of fishing areas as reported in local data sources (HiFiDatabase), after standardization. *Source: 'A century of Sea Fisheries in Belgium' (VLIZ* 2009)

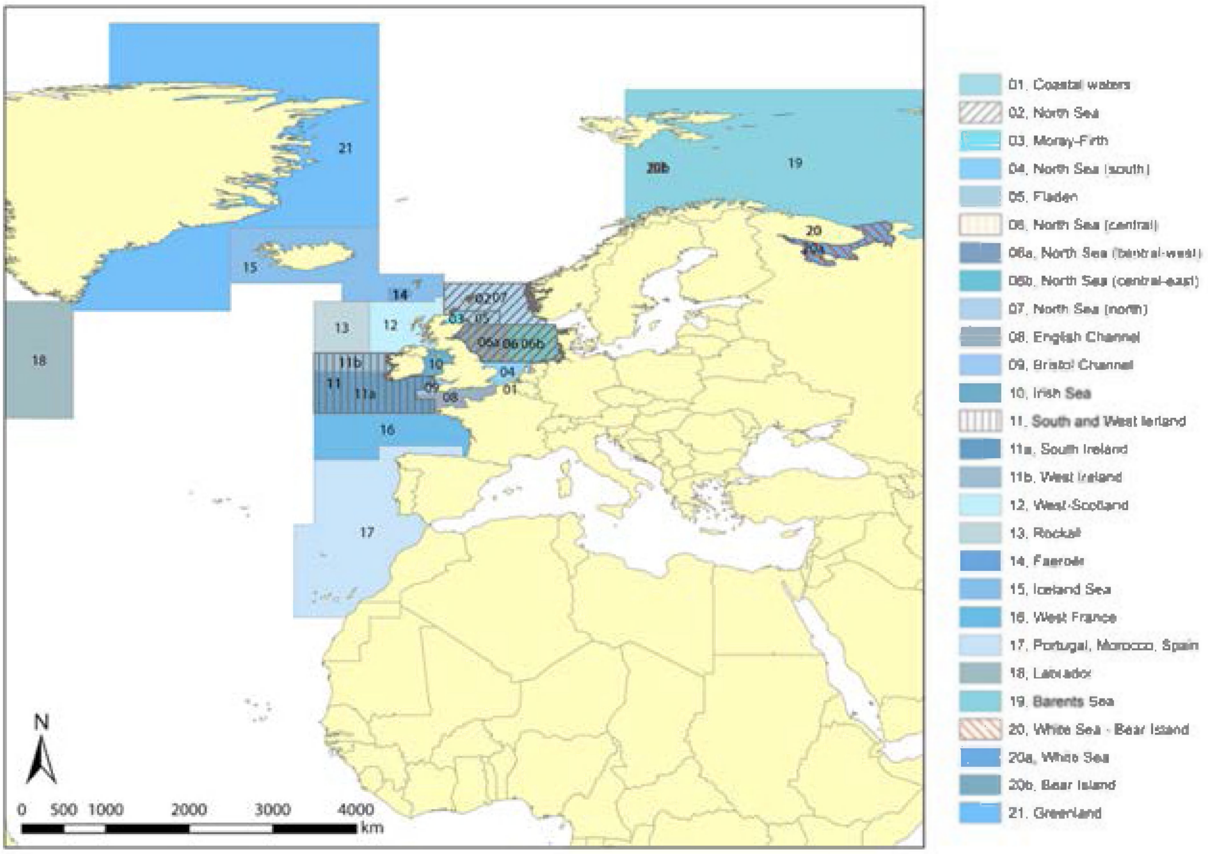


Figure 2.8: Boundaries and names of fishing areas around the North Sea and western fishing grounds, as reported in local data sources (HiFiDatabase) after standardization. *Source: 'A century of Sea Fisheries in Belgium' (VLIZ 2009*

2.4.4 Graphical analysis

After quality control and standardization, annual tables were integrated as pivot tables in spreadsheets. Pivot tables are dynamic spreadsheet tables that can easily convert data for different visualization and analytical purposes, and allow simple statistical functions. Pivot tables were based on the joining and integrating of all 'corrected files', after standardization of species names, ports and fishing grounds (see above). Since the data fields were copy-pasted manually from the individual 'corrected files' (individual spreadsheets each corresponding to a given year and a given time-series) into the pivot tables, a control of the accuracy of this copy-pasting process was conducted on each of the resulting pivot tables to check consistency with corrected files. This was achieved by checking a minimum number of randomly chosen fields for each of the categories 'demersal', 'pelagic' and 'molluscs and crustaceans' (<10% of the fields); and by crosschecking the subtotals and totals (rows and columns) from the pivot tables with those of the corrected files.

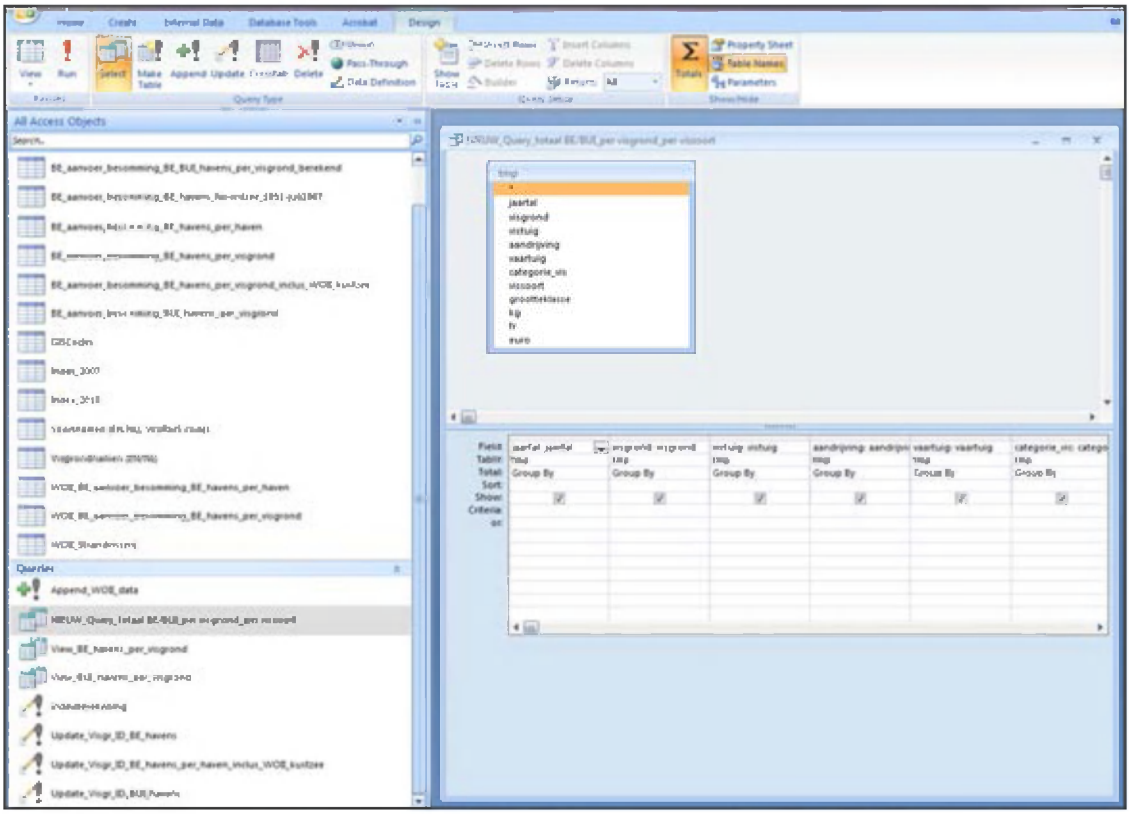


Figure 2.9.: Example of structure of the database (series II). Source: ‘HiFiDatabase: A century of Sea Fisheries in Belgium’ (VLIZ 2009).

Graphs were drawn from the pivot table reports, showing trends in the value and volume of landings over time for each of the species and aggregated units were constructed from the pivot tables, a) by port and b) by fishing ground, and for the data on the fishing fleet. Visual inspection of these graphs allowed a second quality control of errors or anomalies in the data. Special attention in the graphical analysis was given to abnormally high landings for a given species from a specific fishing ground or sudden abrupt changes in observed trends. These errors were typically not detected in the first phase of quality control of numerical values, because they were not generated by simple calculation or copy errors.

A number of problems and errors were evidenced by this visual control and plausible explanations were looked for by checking additional sources (comparing ‘row totals’ from one data-series with another). As an example, a sudden increase from 0t in 1935 and 1937 to 1200t in 1936 was reported in the landings for mackerel in Coastal waters (‘Kustzee’) (Figure 2.10.). By checking the value of subtotals for mackerel reported in a second source (subtotals of landings by species in Belgian ports), we found a difference with a value similar to this anomaly. At the same time, the subtotal reported in this same source but for another species ‘sprat’ showed a difference of exactly the same value of the anomaly for mackerel. Part of the landings of sprat from coastal waters were incorrectly assigned to the reported values for mackerel. This error may have been induced by the fact that ‘sprat’ and ‘mackerel’ were located next to each other in the tables of reporting forms and the values were probably copied in wrong fields at the moment of producing the tables. This example illustrates the importance of graphical analysis and the different steps of quality control.

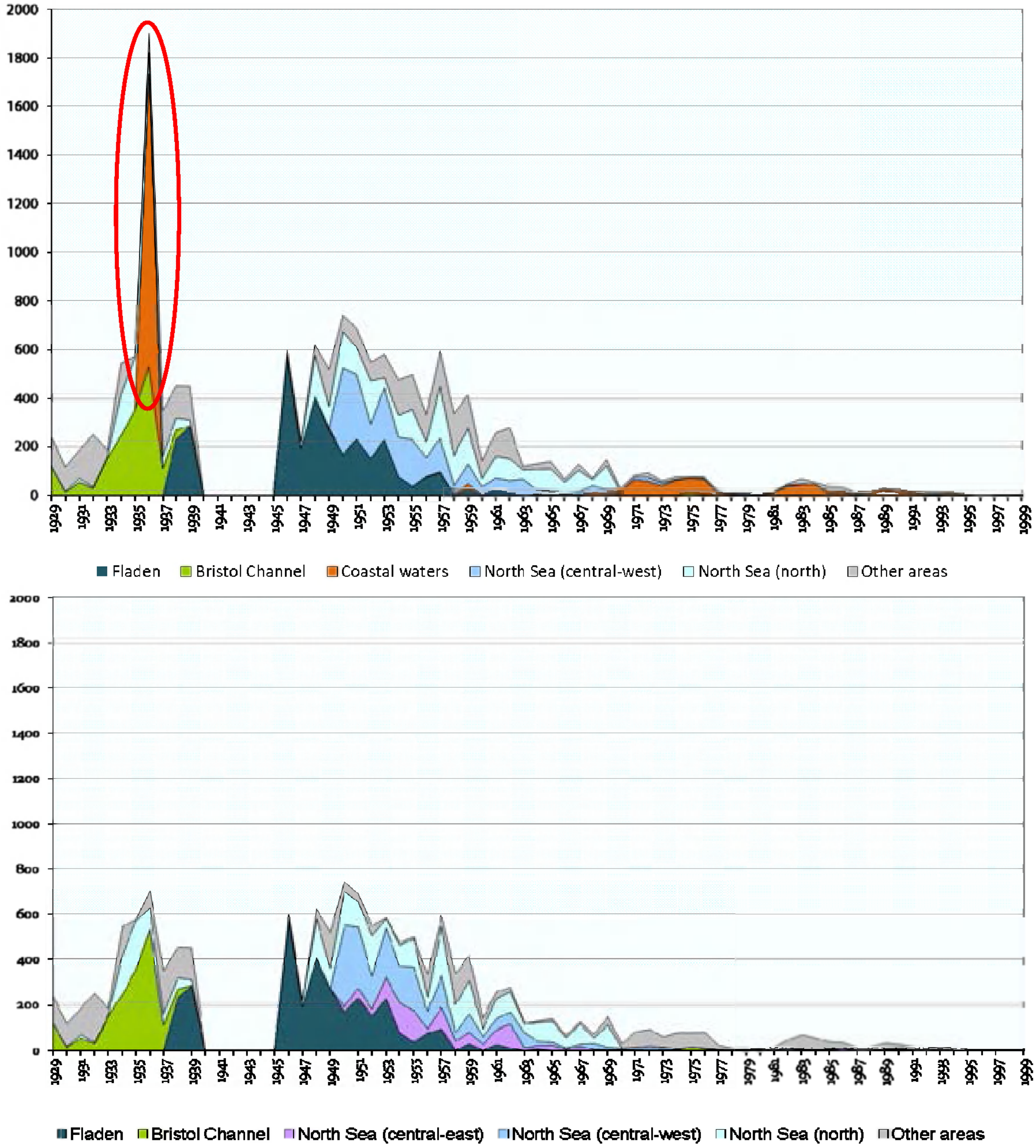


Figure 2.10.: Example of quality control based on graphical analysis of the data. Landings of mackerel by fishing area, for the 5 most important fishing areas ('Other areas' is an aggregation of the landings in the remaining fishing areas). The sudden increase in landings of mackerel (orange) originating from 'Coastal waters' from 0t in 1935 to 1,200t in 1936 (and again 0t in 1937) was attributed to an error in copying during the production of the statistics. Source: 'A century of Sea Fisheries in Belgium' (VLIZ 2009).

2.4.5 Reliability of reconstructed time-series

Reliability of fisheries data is a complex issue that starts at the moment the nets are hauled in. A combination of the selectivity of fishing gears, management regulations and socio-economic conditions affect the proportion of mortality that actually results in 'catch' and the proportion of 'catch' that is effectively reported as 'landings'. As an example, underwater towpath mortality is part of the fishing mortality that is not recorded as 'catch', and on board discarding is part of the catch that is not landed. The remaining proportion of the 'catch' is then considered either illegal, unreported, unregulated (IUU), or a combination of the previous, and may be either discarded or retained as by-catch. For an overview of terminology and estimates of these factors, see Alverson *et al*. (1994), Pauly *et al*. (1998), Gray *et al.* (2004), and Zeller *et al*. (2007). An example of unreported fisheries for Belgium is the recreational line fishing for highly valued economic species (such as cod), which is estimated to be in the range of the commercial landings for this species in recent years (Anon. 2006). Unreported catches may also include fisheries with fixed nets from the beach (for flatfish), artisanal shrimp fisheries by beach trawlers (by horse, on foot), or commercial catches of shrimp that are not landed at auction points. Illegal unreported catches include those that are landed in ports but are transferred for direct sale and consumption without passing the mandatory reporting procedures at the fish auctions.

As in many countries, the problem of incompleteness and reliability of the fisheries data in Flanders/Belgium has been persistent over time and hard to address. In fact, early publications (e.g., 'Bestuursmemoriaelen 1840-1870, De Zuttere 1909) acknowledge the fact that state subsidies were the drive for the collection of fisheries data. When subsidies in Flemish fisheries in the 19th century were abolished, data collecting stopped, as reported in *Bestuursmemoriael* (1867 in De Zuttere 1909). Still, considering the relative size of the fleet, the short coastline and the limited number of fish auctions and fishing ports, it is fair to say that the present historical reconstruction of landing statistics in Flanders/Belgium may depict a relatively complete picture of historical landings for this time period, compared to other countries.

The reconstructed time-series for volume and value of landings were tested for reliability by comparing the (sub)totals from two datasets that are part of the national reporting; one dataset reporting by fishing area (time-series I) and another reporting by fishing port (time-series II). The degree of consistency between both figures for a given species and year, can be regarded as an indication of the reliability of the data collecting process. This allowed to trace possible inconsistencies and correct remaining errors. A matrix was drawn in which the (relative) reliability of the data was expressed for each species, by year. This index was calculated as the % of difference between the absolute value (in tonnes or in Euro) for a given species and given year as reported in time-series I (value by fishing area 'F') compared to the corresponding value reported in time-series II (value by fishing port 'P'). This was achieved by combining the spreadsheet matrices (species in row headings; years in column headings) for each time-series in a new matrix and applying following formula:

*" =IF(F="error" & P; P/F *100 – 100) "*

The product is a colour-coded matrix of (relative) reliability of historical data on the composition and value of Belgian marine fisheries landings in Belgian ports (Figures 2.11. and 2.12.). Horizontal lines refer to species or aggregated taxa (e.g., rays) and vertical lines represent a given year of reporting. The green and yellow zones are considered to have excellent (0% difference) and good reliability (0% < difference <1%). The latter (yellow) is mainly due to differences in rounding. Gray zones stand for 'no data', which applies to the war period, as well as selected species such as salmon, tuna, or aggregated taxa which were not reported in specific periods. Blue codes are inconsistent reporting between the first and the second time-series (e.g. one time-series reports values for a given species in a given year, while the second time-series does not report data on that species and year). The dark-red zones are considered as having lower reliability: e.g., the earlier years (1933-1935), and certain pelagic species (herring, sprat and horse-mackerel) in more recent years. In the latter case it may be the low amount of landings of pelagic species that results in higher percentage. A similar matrix was drafted for value of landings (Figure 2.12.). Reliability as defined in the present exercise is better scored for value of landings (Euro) than for landings (tonnes). The reliability of most of the time-series data are deemed excellent to good (0% and up to 1% difference), except during the pre World War II period for the intermediate aggregated levels of taxa ('miscellaneous', 'other species') and for pelagic species (herring, sprat, mackerel, horse mackerel) after 1980. Data from the HiFiDatabase were also compared to the (sub)total values as reported by ICES (Fishstat, see further).

2.4.6 A MEASURE OF THE RELEVANCE AND IMPACT OF THE PROCESS OF QUALITY CONTROL

The results of the first quality control of the data in the 'corrected files' and the graphical analysis yielded an overall absolute correction of approximately 12,643tonnes and €2.4 million (non-indexed values). Expressed in relative terms, these corrections amount to 73% of the entire landings of Belgian fisheries in Belgian ports in 2008 (17,307tonnes). Expressed in proportional value of the current landings for 2008, this would correspond with €48,6million.
It must be noted that the impact of the corrections may increase substantially when 'zooming in' on a particular species (graphical analysis). Table 2.5. gives an overview of the amended errors (magnitude and location in the files) in the HiFiDatabase compared to the original sources.

Table 2.5.: Absolute and relative values of the magnitude of corrections on the original data after first phases of quality control

Source (time-series)	Corrections in landings in kg (%)	Corrections in value of landings in EUR (%)
Belgian fisheries in Belgian ports, by port	3,920,921 (31)	1,593,798 (66)
Belgian fisheries in Belgian ports by fishing area	7,656,687 (61)	39,505 (2)
Belgian fisheries in foreign ports by fishing area	971,730 (8)	503,253 (21)
Totals Belgian fisheries in Belgian and foreign ports	94,176 (1)	281,244 (12)
TOTAL absolute value of corrections in all files	***12,643,514 (100)***	***2,417,800 (100)***

Figure 2.11.: Reliability matrix for the landings of Belgian fisheries landed in Belgian ports. Vertical: species or reporting units; horizontal: years (1929-1999) note the clustering of inconsistent reporting for pelagic species and for certain years. Source: 'HiFiDatabase' (VLIZ 2009)

Key: Green: no difference between two time-series (0%); Yellow: up to 1% of the value in time-series; Orange: difference ranges between 1% and up to 5% of the value in time-series; Red: difference ranges between 5% and 10% of the value in time-series; Dark red: difference is higher than 10% of the value in time-series; Grey: 'no data' or '0'' reported in either of the time-series; Blue: inconsistent reporting: e.g., data (value) reported in time-series I while time-series II reports no data or '0' value.

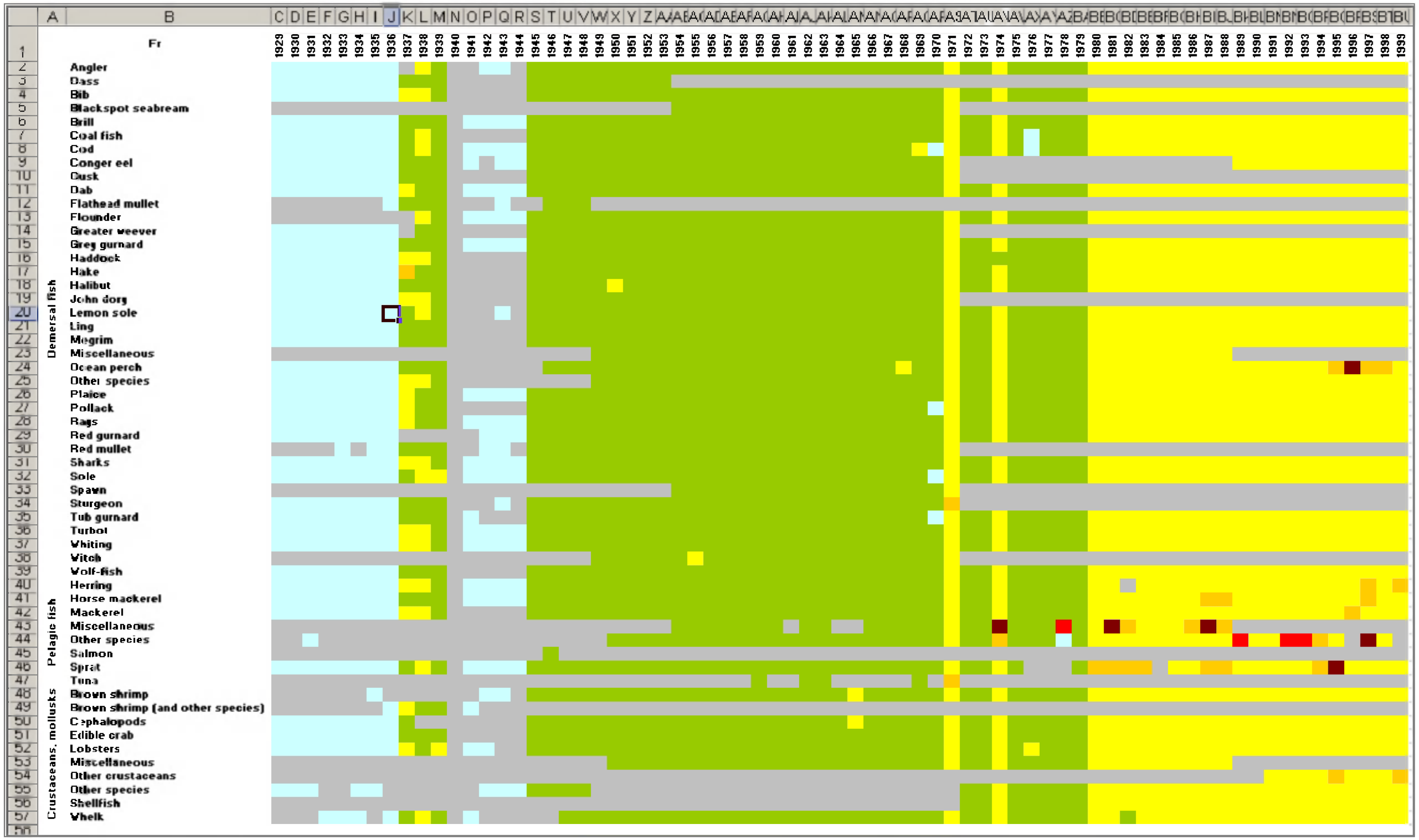


Figure 2.12.: Reliability matrix for the value of landings of Belgian fisheries landed in Belgian ports. Vertical: species or aggregate taxa; horizontal: years (1929-1999). Note the clustering of inconsistent reporting for pelagic species and for certain years.

Key: Green: no difference between two time-series (0%); Yellow: up to 1% of the value in time-series; Orange: difference ranges between 1% and up to 5% of the value in time-series; Red: difference ranges between 5% and 10% of the value in time-series; Dark red: difference is higher than 10% of the value in time-series; Grey: 'no data' or '0'' reported in either of the time-series; Blue: inconsistent reporting: e.g., data (value) reported in time-series I while time-series II reports no data or '0' value.

2.4.7 COMPARISON OF THE 'LOCAL' DATASET TO ICES/FAO LANDING STATISTICS

Hoek and Kyle (1905) gave an overview of the situation of Belgian fisheries, in a country overview published by the International Council for the Exploration of the Sea (ICES). Since 1903, ICES member states report national fishing statistics in order to build joint catch ('capture production') statistics by marine areas, which are published in the 'Bulletins Statistiques'. Currently, reporting of catch statistics to ICES by Belgium (Flanders) is twice per year: the preliminary catches for the half year and the statlant27A data by 31st may, per annum (E.Tessens, pers. comm.). These statistics are collected by the Sea Fisheries Service of the Flemish government (and its predecessors) and are based on landing statistics as reported in the fish auctions (dead weight). A comparison between the ICES database and the local integrated database was conducted to look for possible inconsistencies. ICES data were obtained from Fishstat ('capdet'-download in June 2008). The landings reported by Belgium were reported as aggregated catch from the 'Northeast Atlantic' area (Statlant27), starting in 1950.

Some terms of reference were clarified as a context for this comparison:

1. The Fishstat database contains data from 1950 onwards. Therefore the comparison with the local data (HiFiDatabase) is restricted to the period 1950-1999 and data from the HiFiDatabase 1929-1949 were excluded.
2. The Fishstat database contains aggregated landings from Belgian sea fisheries landed both in Belgian ports ánd in foreign ports. This is also the case for the HiFiDatabase, however in this case thelandings in Belgian ports and in foreign ports are reported separately and can be queried separately.
3. Fishstat data on total landings are based on landings expressed in fresh weight. These 'fresh weight' values are reported by countries after conversion of 'dead weight' as recorded in the auction, with species-specific conversion factors. Depending on the species and the processing, these factors may be further specified (with or without head, gutted, complete). The HiFidatabase contains the original non-converted data (dead weight) as recorded in the auctions.
4. The total landings from Fishstat can not be compared to the total landings from the HiFiDatabase: Fishstat data represent the sum of the total landings by species, each converted to fresh weight by a species-specific conversion factor. Therefore, the sum of the components (all species landings) of Fishstat is not equal to the landings in the HiFiDatabase.

Since HiFiData are based on landings as registered in the fish auction (dead weight), conversion factors[1] were needed to calculate and convert to fresh weight. Therefore, total landings by species per annum were multiplied by the species-specific conversion factor (see appendix, source Mr. E.Tessens-DVZ) and compared to the corresponding value as reported by ICES/FAO (Fishstat). These conversion factors are established by ICES and used by the ICES members in annual reporting to ICES/FAO.

[1] conversion factors aim to compensate for losses in biomass of the catch during transport (loss of body mass or water) or during processing (gutting or removing parts of the fish that is not commercialized).

2.4.8 Findings of comparison between ICES and HiFiDatabase

As expected, the total landings from HiFiData are consistently lower than Fishstat landings over the entire period due to the difference between dead and fresh weight (Figure 2.13).

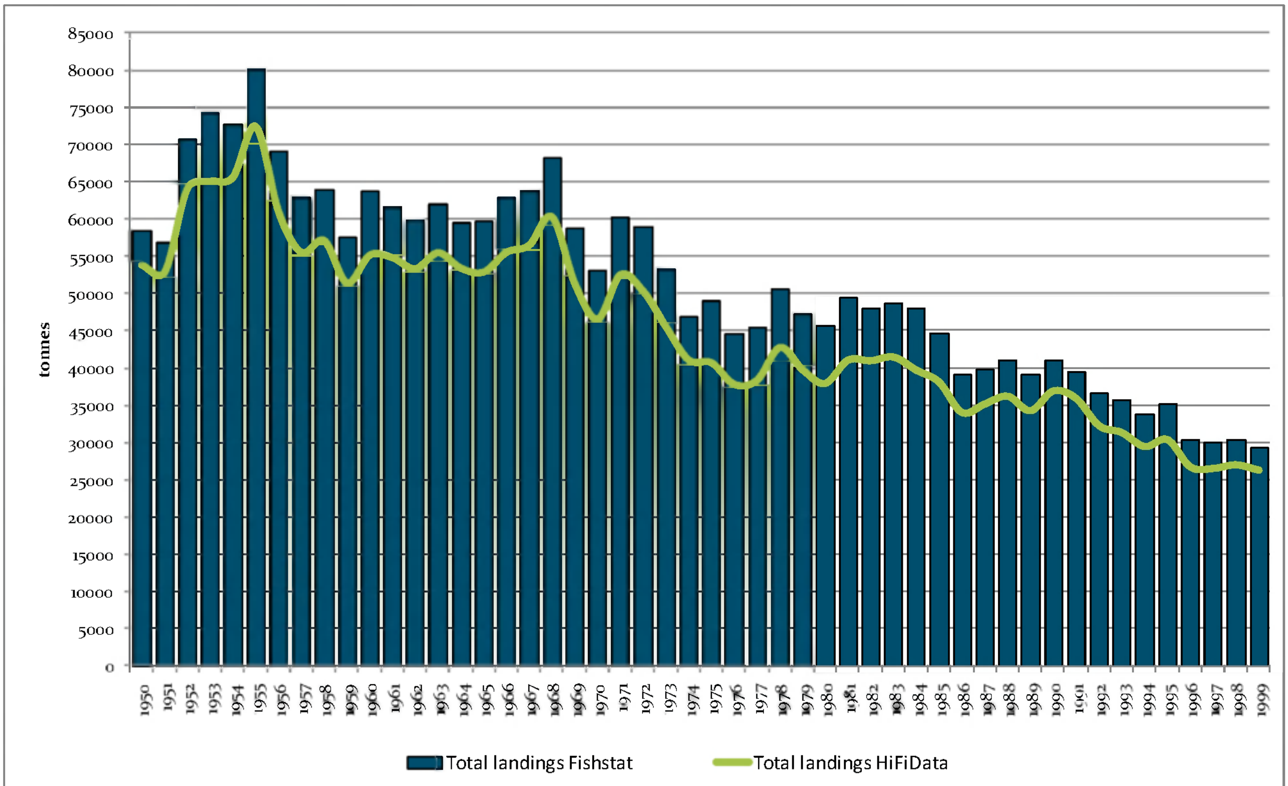


Figure 2.13.: Total annual landings (expressed in tonnes fresh weight) as reported by ICES/FAO (Fishstat) compared to the total landings (expressed in tonnes dead weight) as collected and integrated in the HiFiDatabase for Belgian sea fisheries 1950-1999. Source HIFIDatabase (VLIZ 2009) and Fishstat download in June 2008

Apparently not all species were subject to reporting, or the reported aggregations of species do not fully coincide between the two databases. Therefore, it was not feasible to conduct the conversion from HiFiData to Fishstat for the overall landings by simply adding up the converted values by single species. Subtotals (dead weight) by individual species from the HiFiDatabase were converted to fresh weight equivalents by multiplying with the corresponding species-specific conversion factor, where applicable. An example is provided for Atlantic cod (*Gadus morhua*, Figure 2.14.).

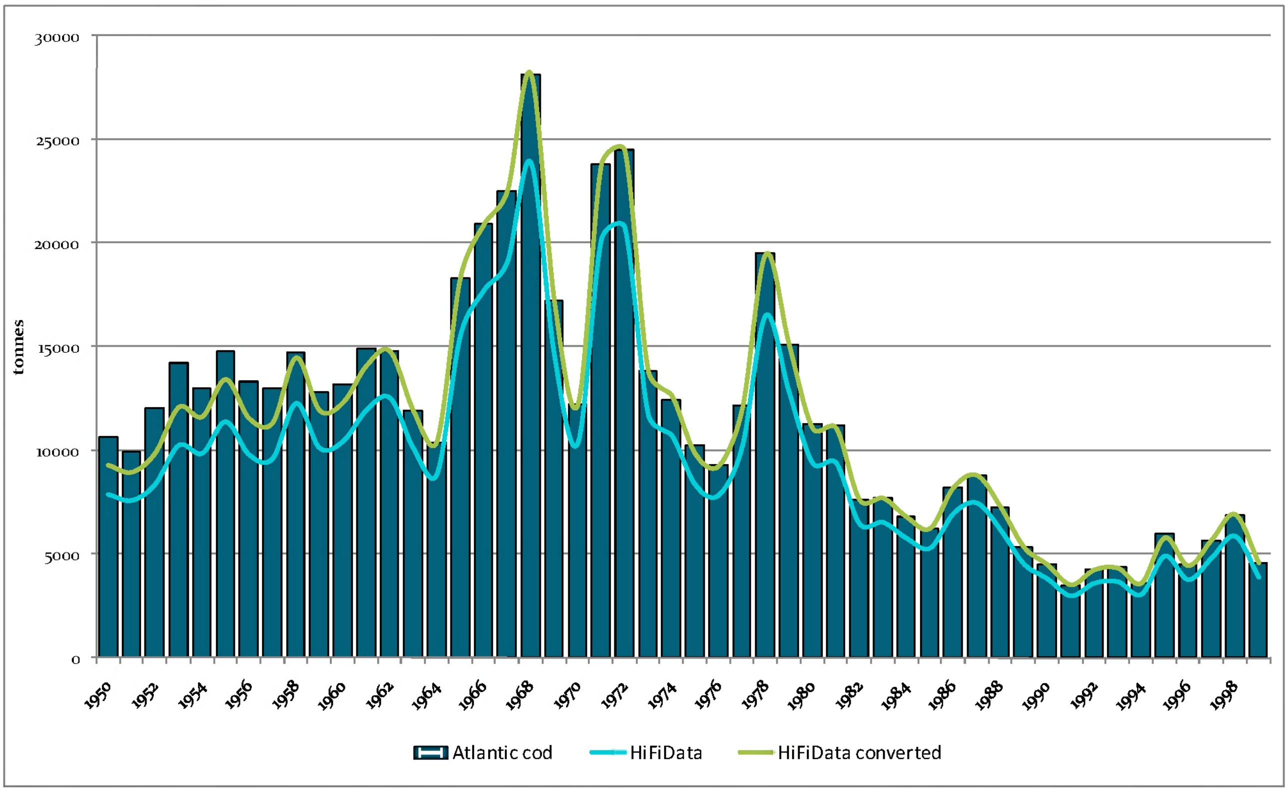


Figure 2.14.: Conversion for Atlantic cod (*Gadus morhua*) from HiFiData (dead weight) to fresh weight ('HiFiData converted') by conversion factor 1.18. Blue bars represent ICES data from Fishstat. S*ource: HiFiDatabase (VLIZ 2009) and Fishstat download in June 2008*

Annual landings for this species as provided by the HiFiDatabase (blue line), were multiplied by conversion factor 1.18. The product is 'HiFiData converted' (green line). The overall landings for the period were reported as 581,725t (Fishstat), 478,330t (HiFiData) and 564,430t (HiFiData converted). Therefore a discrepancy of 17,295t (3%) was detected for cod, in favour of the Fishstat data.

Similar conclusions were drawn for Common sole (*Solea solea)*: inconsistencies between both databases on a per annum basis for this species were noted particularly between 1950 and 1960 (up to 30%). The overall discrepancy for sole over the period 1950-1999 is 15,877tonnes (7%).
The differences may be due to changes in the conversion rates compared to earlier reporting years. However, the over- or underreporting was not systematical nor was it associated with the first decades of reporting as was clearly shown by the case of Megrim (*Lepidorhombus whiffiagonis*) for which over- and underreporting could be detected even between years (Figure 2.15.).

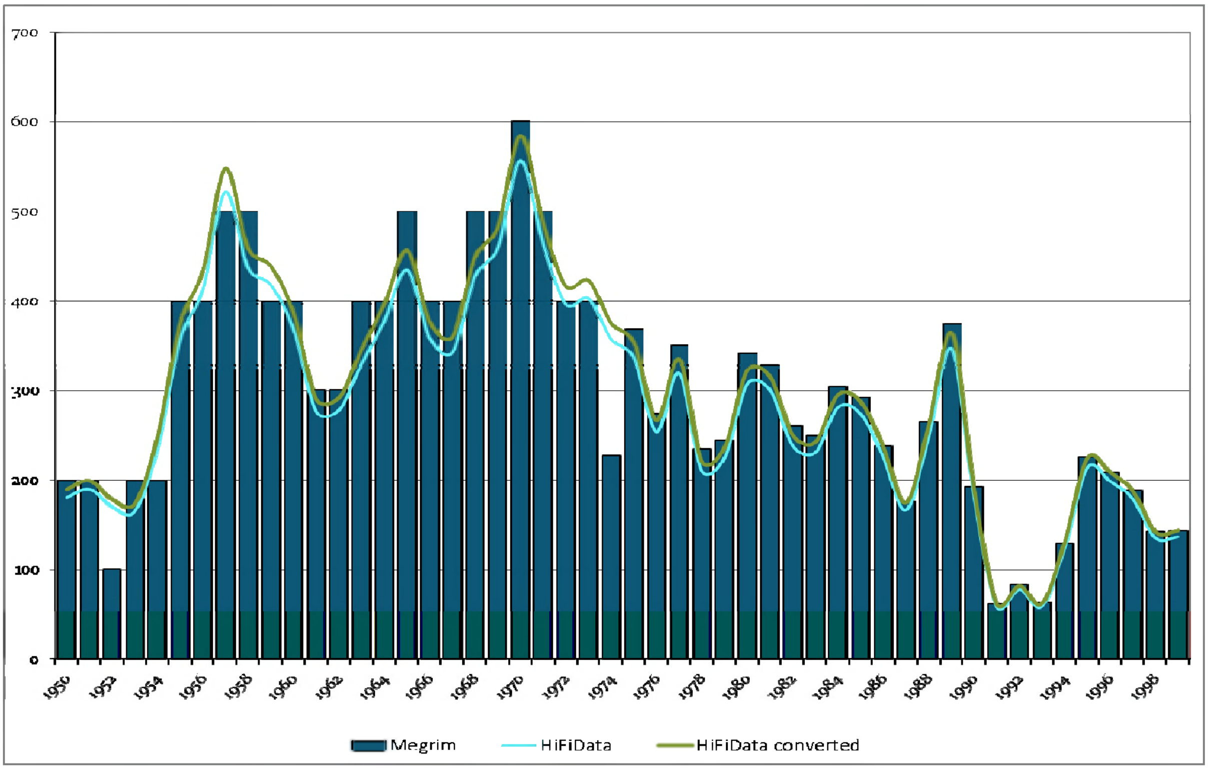


Figure 2.15.: Conversion for Megrim *(Lepidorhombus whiffiagonis)* from HiFiData (dead weight) to fresh weight ('HiFiData converted') by conversion factor 1.05. Blue bars represent ICES data from Fishstat. *Source: HiFiDatabase (VLIZ 2009) and Fishstat download in June 2008*

For some species (Atlantic horse mackerel, Atlantic wolffish, Common shrimp, European sea bass, European hake, Surmullet, Pouting, etc.- names as in the Fishstat database), the local HiFiDatabase reported overall or annual higher landings than the Fishstat data after conversion to fresh weight. For others (Atlantic herring, European plaice, European sole, Atlantic cod, European flounder, European conger, etc.) the Fishstat reports were higher (Figure 2.16). Also, the Fishstat database was not necessarily consistent in reporting higher values (or lower values if the case) for a particular species throughout the time-series 1950-1999, compared to the HiFiData. The data in Fishstat seemed to have been subject to rounding, at least in the earlier decades of reporting, and landings below 50kg were not included. However, the rounded figures do not match with converted HifiData. Also, certain species (e.g. pouting, surmullet) were not reported in the earlier years. Furthermore, the Fishstat database contained aggregations for certain groups of species, hence it was impossible to conduct a comparison at the species level. Still, even after the conversion process and in spite of the unreported species and the landings that were not accounted for, the Fishstat database seemed to report a higher total amount of landings, especially for the more abundant group of demersal fishes.

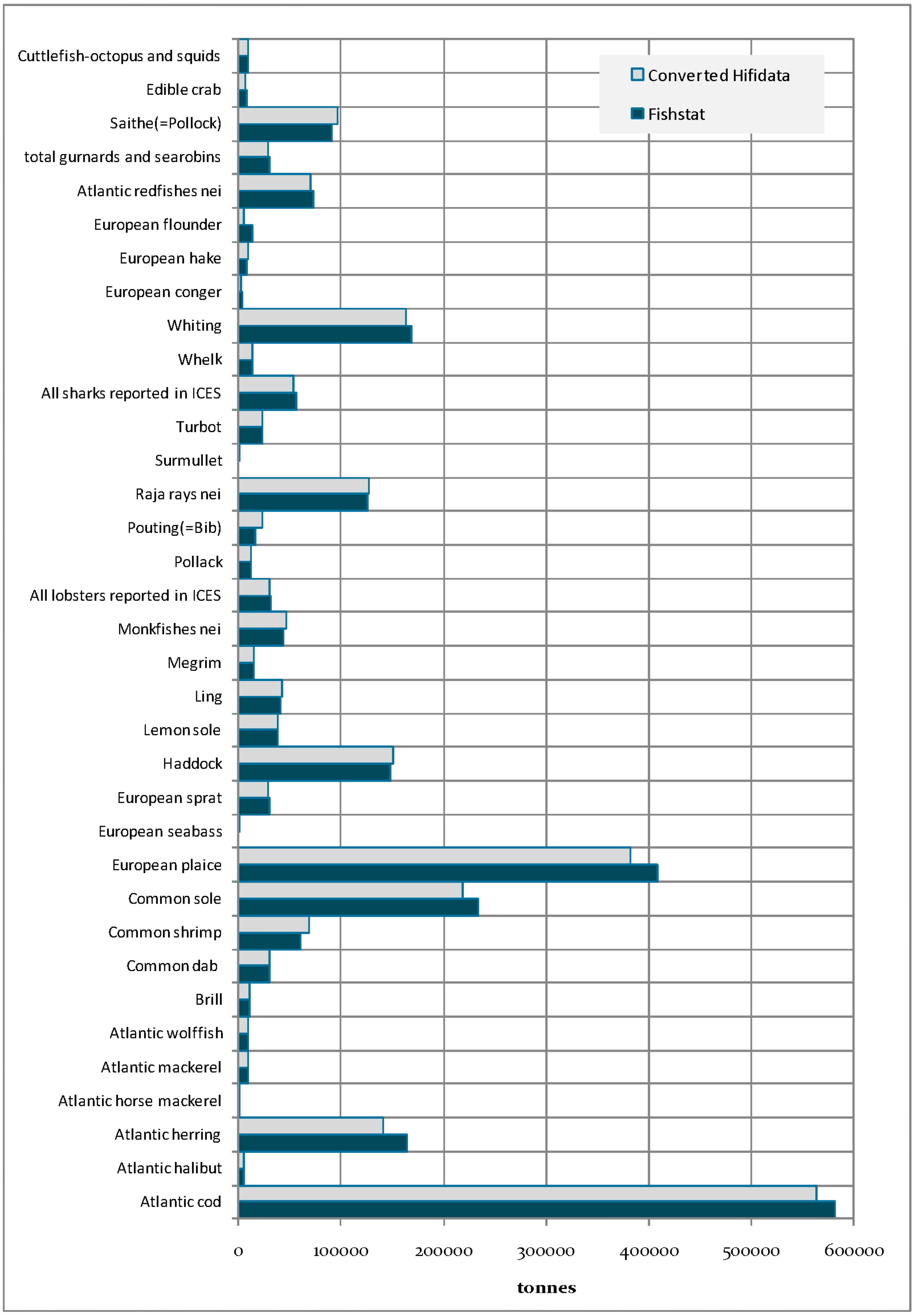


Figure 2.16.: Total reported landings (tonnes) in HiFiData (1950-1999) after conversion factors were applied, to convert dead weight or gutted weight into fresh weight (dark bars), compared with Fishstat data (grey bars). *Source: HiFiDatabase (VLIZ 2009) and Fishstat download in June 2008*

2.5 Results: Historical Fisheries Database 'HiFiDatabase' for Belgium

The results from the inventory and integrating of sources containing historical data on sea fisheries fleet and on the composition and economic value of landings in Belgium indicate that:

- Structurally embedded reporting based on detailed taxonomic and geographical resolution started in 1929 with an acceptable degree of consistency and continuity ever since. In spite of early efforts by government officials (at least since 1903) to achieve standardised collecting and centralized reporting on fisheries data in Belgium, all data on catches, landings, fleet and effort collected before 1929 are either spatially incomplete or taxonomically aggregated data. Exceptions are the surveys conducted in the context of the Commission of the Chamber of Representatives (1866) and the census conducted by De Zuttere (1909).

- At the time of initiating the present study (2008-2009), data on annual landings and value of landings collected and published before 1998 were only available in hard copy and none of the data were available electronically in the public domain. After 1998, the annual reports were published digitally and the annual data made available in spreadsheets. An electronic file (spreadsheet) with landings data from 1996 onwards was made available from the Fisheries Service.

- The International Council for the Exploration of the Sea ICES published a dataset containing data on landings (fresh weight) for reporting countries. The dataset was published in 2009 - after the onset of the present research work - and contains data from 1950-2010. The ICES data refer to fresh weight, i.e. landings as recorded in the fish auction (as dry weight), and multiplied by a factor correcting for loss of weight during transport, handling and processing. Contact was established with the project coordinators at ICES, to inform about the progress in work and next steps in the reconstruction of time-series for Belgium, and to make sure that duplication of efforts would be avoided. The 'HiFiDatabase' ('Historical Fisheries Database') is the result of the steps in data and information management described above. It contains a collection of time-series with standardised species names, reporting units, fishing areas and ports of landing.

2.5.1 Landing statistics

The datasets were partially integrated as the HiFiDatabase. HiFiDatabase allows querying data at the species level (41 species) and another 15 aggregate categories, by year (1929-1999), by fishing area (31 subareas) and by port of landing in Belgian (4 ports) and foreign ports (1 aggregate value). The main datasets include:

- Landings and value of landings **in Belgian ports, by species, by port**, and by year;
- Landings and value of landings **in Belgian ports, by species, by fishing area**, and by year;
- Landings and value of landings **in foreign ports, by species, by fishing area** and by year;
- Monthly landings and value of landings **in Belgian ports, by species, by fishing area**
- Monthly landings and value of landings **in Belgian ports, by species, by fishing area** by length class for 7 species
- Monthly landings and value of landings **in Belgian ports, by statistical rectangle (1946-1983),** by type of fisheries and vessel class

The HiFiDatabase is further complemented with other datasets that could not be fully integrated because of changes in spatial reporting units or aggregation levels. The overview of the reconstructed time-series is included in Table 2.6., with the name of the dataset, a description, and an indication of its extent (number of rows and columns) and size (MB).

The timeframe of the reconstruction focuses on 1929-1999. Recent data from 2000 onwards were also collected to complement the historic data. For particular species (Atlantic herring *Clupea harengus* and Atlantic cod *Gadus morhua*) additional data was collected to extend the time-series further in the past.
The added value of the reconstructed time-series can be described in multiple aspects:

Spatial Coverage:
All fishing areas where the Belgian fleet has operated between 1929 to present. This includes at least 4 fishing areas not covered by ICES reporting: Fladen, Belgian coastal waters (part of ICES fishing area 'North Sea south' IVc), North Sea central-east, North Sea central-west (part of ICES fishing area 'North Sea central' IVb).

Spatial resolution:
All fishing areas and reporting units at the smallest available scale (=highest resolution). This includes datasets in which landings are reported by statistical rectangle (monthly values between 1946-1983).

Temporal resolution:
Monthly values

Temporal Coverage:
1929-1999

Taxonomic coverage:
41 species and 15 aggregated taxa

Thematic Scope:
Economic data

- Value of landings (in Belgian francs and converted into Euro, nominal values and values corrected for inflation)
- Average price of landings (in Belgian francs/kg and converted to Euro/kg, nominal values and values corrected for inflation).

Economic data have not been collected previously for the purpose of reconstructing historical time-series. All economic values were also expressed as values 2010 to allow for comparison of trends over time.

Coverage of ports :
In total, 6 ports/fish auctions where the fish was landed and sold, were included in the reporting since 1929. These are Blankenberge, Zeebrugge, Oostende, Nieuwpoort (Belgium) and the ports of Gravelines and Dunkerque (France). The 4 Belgian ports were included in reporting since 1929, although reporting for Blankenberge ceased in 1958 (last reported landings in 1957). The port of Nieuwpoort was the most important during WWII, while Gravelines and Dunkerque were also used to disembark the landings during WWII (Chapter 3).

Table 2.6.: Overview of reconstructed time-series for landings, value of landings, fishing effort, with the name of the dataset, a description, and an indication of its extent (number of rows and columns) and size (MB)

Title sheet	Content	Number of rows	Number of columns	MB
BE_aanvoer_besomming_BE_BUI_havens_per_visgrond_ber_incl_WOII_	This dataset combines the data of landings and value of landings per fishing ground in Belgian ports 'BE_aanvoer_besomming_BE_havens_per_visgrond_inclus_WOII_kustzee' with the data of landings and value of landings per fishing ground in foreign ports 'BE_aanvoer_besomming_BUI_havens_per_visgrond' into one value	44816	20	4,47
BE_aanvoer_besomming_BE_havens_Noordzee_1951-juli1967	This dataset integrates 17 individual reporting sheets based on handwritten documents obtained from the archives of the 'Dienst Zeevisserij' (Fisheries Service, Flanders Government). It contains data on landings (kg) and value of landings (in BEF and EUR) for different pelagic and demersal fish species, mulluscs and crustaceans, landed by Belgian fishing vessels in the different belgian fishing ports/fish auctions, and caught from the North Sea. The data are reported by month and per year. For a limited number of species (7), landings were reported by length classes. Average price per kg is calculated in the file and reported in BEF en EUR, as well as in current prices (corrected for inflation, expressed as values 2007 and values 2010). For particular years and months, data is available on number of catches, number of vessels, total HP (PK), number of fishing days, number of days at sea, hours at sea, hours spent fishing, HP(PK)*hours fishing, HP(PK)*hours at sea. This dataset was validated by comparing the values contained herein with those contained in 'BE_aanvoer_besomming_BE_havens_per_visgrond' and considering the reporting unit 'North Sea' was constructed by adding the values for the fishing areas 'Fladen', 'Coastal waters', 'Moray Firth', 'North Sea (central-east)', 'North Sea (central-west)', North Sea (north)(, 'North Sea 'south)'.	15680	32	2,02
BE_aanvoer_besomming_BE_havens_per_haven	This database is the result of the integration of 70 different datasets. It contains data on landings (kg) and value of landings (in BEF and EUR) of different pelagic and demersal fish species, crustaceans and molluscs landed by Belgian fishing vessels in Belgian ports, by port, per year. For a limited number of species (7), landings were reported by length classes for a number of years (1929 - 1933, 1935). Average price per kg is calculated in the file and reported in BEF en EUR, as well as in current prices (corrected for inflation, expressed as values 2007 and values 2010)	11735	18	1,82
BE_aanvoer_besomming_BE_havens_per_visgrond	This database integrates 66 different sub-components or datasets. It contains data on landings (kg) and value of landings (in EUR and EUR) of different pelagic and demersal fish species, crustaceans and molluscs landed by Belgian fishing vessels in Belgian ports, by fishing ground, per year. For a limited number of species (7), landings were reported by length classes for a number of years (1929 - 1933, 1935). For the period 1929 - 1933 a breakdown by type of fishing gear and vessel type is available. Average price per kg is calculated in the file and reported in BEF en EUR, as well as in current prices (corrected for inflation, expressed as values 2007 and values 2010)	45988	23	5,34
BE_aanvoer_besomming_BE_havens_per_visgrond_inclus_WOII_kustzee	This database combines data from "BE_aanvoer_besomming_BE_havens_per_visgrond" with the annual data from the database "WOII_BE_aanvoer_besomming_BE_havens_per_visgrond"	46132	23	4,27

BE_aanvoer_besomming_BUI_havens_per_visgrond	This database integrates 49 different sub-components or datasets. It contains data on landings (kg) and value of landings (in EUR and EUR) of different pelagic and demersal fish species, crustaceans and molluscs landed by Belgian fishing vessels in foreign ports, by fishing ground, per year. Average price per kg is calculated in the file and reported in BEF en EUR, as well as in current prices (corrected for inflation, expressed as values 2007 and values 2010)	46511	23	3,86
GISCodes	Codes for every fishing ground, to be able to present data on a map using a GIS application	30	3	
Index_2007	Factor for indexation 2007 (calculated using the consumptionpriceindices with basis 2004)	71	3	
Index_2010	Factor for indexation 2010 (calculated using the consumptionpriceindices with basis 2004)	71	3	
Soortnamen (EN/NL), WoRMS codes	Dutch (standardized), English and scientific fish species names, including species code from the World Register of Marine Species	54	5	
Visgrondnamen (EN/NL)	Dutch (standardized) and English fishing ground names	32	3	
WOII_BE_aanvoer_besomming_BE_havens_per_haven	This database is the result of the integration of 68 different subcomponents or datasets (4 files, 68 spreadsheets). It contains data on landings (kg) and value of landings (in BEF and EUR) of different pelagic and demersal fish species, crustaceans and molluscs landed by Belgian fishing vessels in Belgian ports, by port, per year, per trimester and per month during WWII. For a limited number of species (5), landings were reported by length classes. Average price per kg is calculated in the file and reported in BEF en EUR.	7207	19	0,71
WOII_BE_aanvoer_besomming_BE_havens_per_visgrond	This database is the result of the integration of 68 different subcomponents or datasets (4 files, 68 spreadheets). It contains data on landings (kg) and value of landings (in BEF and EUR) of different pelagic and demersal fish species, crustaceans and molluscs landed by Belgian fishing vessels in Belgian ports, by fishing ground, per year, per trimester and per month during WWII. For a limited number of species (5), landings were reported by length classes. Average price per kg is calculated in the file and reported in BEF en EUR.	2086	20	0,24
WOII_Strandvisserij	This database is the result of the integration of 54 different subcomponents or datasets (4 files, 54 spreadsheets). It contains data on landings (kg) and value of landings (in BEF and EUR) of different pelagic and demersal fish species, crustaceans and molluscs landed by Belgian fishing vessels in Belgian ports, per beach of the Belgian coast, per year, per trimester and per month during WWII. For a limited number of species (5), landings were reported by length classes. Average price per kg is calculated in the file and reported in BEF en EUR.	2615	19	0,22
BE_aanvoer_besomming_BE_havens_per_visgrond_per_maand_incl_groottkl	Data for 1947 - 1981 in this database are the result of the integration of 254 different sub-components or datasets (188 files and 254 spread-sheets). It contains data on landings (kg) and value of landings (in EUR and EUR) of different pelagic and demersal fish species, crustaceans and molluscs landed by Belgian fishing vessels in Belgian ports, by fishing ground, per year and month. Average price per kg is calculated in the file and reported in BEF en EUR, as well as in current prices (corrected for inflation, expressed as values 2007 and values 2010). Annual data for 1929 - 1933 were taken from the database "BE_aanvoer_besomming_BE_havens_per_visgrond". The data (year, month, trimester) for 1941-1944 were taken from the database "WOII_BE_aanvoer_besomming_BE_havens_per_visgrond"	353768	23	53,28

BE_aanvoer_besomming_effort_per_visgrond_per_visserij_gestandaardiseerd	This database is the result of the integration of 43 different datasets or files based on handwritten and typed documents from the archives of the 'Dienst Zeevisserij' (Fisheries Service, Flanders Government). Depending on the time period following information is available in the database: • 1946 - 1949: Annual and monthly data by fishing ground, by fisherytype and vessel class with information on number of vessels, number of trips, days at sea, fishing days, hours at sea, fishing hours, HP (PK) x days at sea, HP (PK) x fishing days, HP (PK) x hours at sea, HP (PK) x fishing hours, total landings and value of landings • 1950 Annual and monthly data by fishing ground, by fisherytype and vessel class with information on number of vessels, number of trips, days at sea, fishing days, hours at sea, fishing hours, HP (PK) x fishing days, HP (PK) x hours at sea, HP (PK) x fishing hours, average HP (PK) per vessel, total landings and value of landings • 1956 - 1964 Annual data by fishing ground, by fishing rectangle, per fisherytype and per vessel class with information about number of vessels, number of trips, days at sea, fishing days, hours at sea, fishing hours, HP (PK) x hours at sea, HP (PK) x fishing hours, total landings and value of landings • 1965 - 1968, 1971 - 1983 Annual and monthly (from 1968) data by fishing ground, by fishing rectangle, per fisherytype and per vessel class with information on number of vessels, number of trips, days at sea, fishing days, hours at sea, fishing hours, HP (PK) x hours at sea, HP (PK) x fishing hours, total landings and value of landings and from 1972 onwards aslo GT x hours at sea, GT x fishing hours	18119	31	4,82
BE_aanvoer_besomming_effort_ijsland_per_scheepsklasse_incl_soortgegevens	This database is the result of the integration of 33 different sub-components or datasets (10 files, 33 spreadsheets) based on handwritten documents from the archives of the 'Dienst Zeevisserij' (Fisheries Service, Flanders Government). For fishing ground nr. 12 (Iceland), it contains annual and monthly data by fishery type, by vessel class with information on number of vessels, number of trips, days at sea, fishing days, hours at sea, fishing hours, HP (PK) x days at sea, HP (PK) x fishing days, HP (PK) x hours at sea, HP (PK) x fishing hours, average HP (PK) per vessel, total landings and value of landings, landings and value of landings per fish species (pelagic and demersal fish, crustaceans and molluscs, some of which information for length classes is available e.g.: plaice, sole, cod, ..)	18573	21	1,69
BE_aanvoer_besomming_effort_kustzee_per_scheepsklasse_incl_soortgegevens_garnaalvisserij 6-7	This database is the result of the integration of 46 different sub-components or datasets (10 files, 46 spreadsheets) based on handwritten documents from the archives of the 'Dienst Zeevisserij' (Fisheries Service, Flanders Government). For fishing ground nr. 1 (Coastal waters), it contains annual and monthly data by fishery type (shrimp fisheries nr. 6 & 7), by vessel class with information on number of vessels, number of trips, days at sea, fishing days, hours at sea, fishing hours, HP (PK) x days at sea, HP (PK) x fishing days, HP (PK) x hours at sea, HP (PK) x fishing hours, average HP (PK) per vessel, total landings and value of landings, landings and value of landings per fish species (pelagic and demersal fish, crustaceans and molluscs, some of which information for length classes is available e.g.: plaice, sole, cod, ..)	26776	21	2,09

BE_aanvoer_besomming_effort_kustzee_per_scheepsklasse_incl_soortgegevens_overige visserijen	This database is the result of the integration of 124 different sub-components or datasets (10 files, 124 spreadsheets) based on handwritten documents from the archives of the 'Dienst Zeevisserij' (Fisheries Service, Flanders Government). For fishing ground nr. 1 (Coastal waters), it contains annual and monthly data by fishery type (other fisheries nr. 1, 2, 3, 4, 5, 8), by vessel class with information on number of vessels, number of trips, days at sea, fishing days, hours at sea, fishing hours, HP (PK) x days at sea, HP (PK) x fishing days, HP (PK) x hours at sea, HP (PK) x fishing hours, average HP (PK) per vessel, total landings and value of landings, landings and value of landings per fish species (pelagic and demersal fish, crustaceans and molluscs, some of which information for length classes is available e.g.: plaice, sole, cod, ..)	72304	21	6,69
BE_aanvoer_besomming_effort_overige visgronden_overige visserijen	This database is the result of the integration of different sub-components or datasets (10 files) based on handwritten documents from the archives of the 'Dienst Zeevisserij' (Fisheries Service, Flanders Government). For all fishing grounds (except fishing ground nr. 1 -coastal waters and nr. 12 – Iceland), it contains annual and monthly data by fishery type, by vessel class with information on number of vessels, number of trips, days at sea, fishing days, hours at sea, fishing hours, HP (PK) x days at sea, HP (PK) x fishing days, HP (PK) x hours at sea, HP (PK) x fishing hours, average HP (PK) per vessel, total landings and value of landings, landings and value of landings per fish species (pelagic and demersal fish, crustaceans and molluscs, some of which information for length classes is available e.g.: plaice, sole, cod, ..)	51718	21	4,41
TOTAL		764286		95,93

By querying the database, the change in landings of a particular species over time can be analyzed by port or by fishing area. Alternatively, changes in the species being landed in a particular port, or the shifts in species landed from a particular fishing area, can be analyzed. Trends in seasonal landings by species or by fishing area can also be studied. Detailed analyses related to specific research hypothesis are presented and discussed in Chapter 4. However, the main findings are described and commented in Chapter 3.

2.5.2 FLEET, FISHING EFFORT AND FISHING GEAR

As is the case for reported landings of fish and fish products, structurally embedded reporting on the fleet size and features in Flanders (Belgium) started in 1929 with a good level of consistency and continuity ever since then. The beginning of structural reporting on the fleet coincided with the period where most states in Europe developed a statistics approach to underpin policy development (Lescrauwaet et al. 2010a).

The Belgian fishing fleet has had an interesting evolution: vessels, boats and ships changed owner, immatriculation number (unique identifying code) or port of registration. A unique number or unique letter-number combination for each fishing vessel is required by law since the Royal Decree of January 6, 1884 (Official Journal March 31, 1884). These numbers must be listed on the hull on both sides of the bow. The letter stands for the port of registration. The format of the immatriculation number of ships of the Belgian fishing fleet has undergone some changes since then: Before 1947 the individual ports of call registered the immatriculation numbers. Each local port authority registered ships and assigned codes starting with the number '1'. Thus it was possible to find two identical codes within a given year, for two different ships, depending on the lists of different ports of call. E.g. number 5 was assigned in a given year in the list of Nieuwpoort, Oostende, as well as in De Panne and in Heist. Originally, no letters were assigned before the number until after 1941. Generally, a letter.nummer combination is found on the bow, the sail or the stern of the ship, depending on the port of call or port of registration. From 1947 onwards, the registration of fishing vessels became a matter of centralized informationkeeping and many ships were reassigned new codes and numbers. In Oostende, ships were numbered from nr 1 and upwards, in Zeebrugge numbering started from nr 400, in Blankenberge ships were assigned numbers above 600, and in Nieuwpoort the lowest possible number on a ship was 700. The immatriculation number of a vessel is maintained when it is sold, unless the ship will change port of call after changing owner. In that case, the first port of call can keep the number and use it to register a new vessel.

Table 2.7.: List of ports of call or registration and the letter codes assigned to the Belgian Scheldt ports and coastal ports

Sea ports	**Scheldt ports**
B: Blankenberge	A: Antwerpen
DP: De Panne	BDR: Berendrecht
H: Heist	BOU: Boekhoute
N: Nieuwpoort	D: Doel
O: Oostende	K: Kieldrecht
OO: Oostduinkerke	L: Lillo
Z: Zeebrugge	M: Mariekerke
	R: Rupelmonde
	ZV: Zandvliet

Over time ships were converted to or equipped with more efficient technology: sailing ships were replaced by steamers and later the entire fleet was gradually motorized. Data on characteristics of individual fishing vessels, boats and ships were collected from official sources and inventoried (section 2.3.6). After digitization and quality control, the data were standardized and integrated in a database on the 'Belgian fishing fleet'. Based on (a combination of) attributes of a given '*casco*' (i.e. the floating hull of a ship as the structure is taken to the water without propulsion or rigging) the lifetime of a ship was derived from this database and reconstructed. This reconstruction allows documenting the changes that a vessel has undergone e.g. in its name and immatriculation number but also in type of drive gear and even in the ships'owner. The resulting database counts 50 columns by 28,370 rows (10MB).

Data and time-series on fleet and fishing effort were reconstructed by vessel class, by type of fisheries, by fishing area and fishing rectangle. Historical time-series on fishing effort have not been reconstructed previously for the Belgian sea fisheries.

Data on total fishing effort of the Belgian sea fisheries fleet were obtained from the 'statistical tables V and VI' in the 'Landbouwstatistieken' (Agriculture statistics) from 1944 onwards. For specific research purposes, data on fishing effort for particular fisheries or vessel classes were collected. The resulting time-series and analysis on fleet dynamics are discussed in detail in chapter 5. A detailed analysis on the role of the Belgian fishing fleet fishing for Downs herring during the Second World War is available in Chapter 7, and on the Iceland otter trawlers fishing for gadoid, in Chapter 8.

Fishing gear

In Belgium the transition from sail to motor engines was near to completion by 1929 and after WWII the commercial fleet consisted mainly of motor engine-powered vessels. The last steamer disappeared in 1964 (Lescrauwaet et al. 2012, Chapter 5). As was the case for the steamers, the motor engine-powered vessels used the otter trawl to catch fish. Before 1950, the otter trawl was the main fishing gear, together with drift nets (for pelagic fisheries). After 1960, the otter trawl was mainly used for roundfish (e.g. whiting and cod) fisheries and for shrimp (*Crangon crangon*). The pelagic trawl for herring and sprat was used from 1950 onwards and remained important until 1965 in terms of effort (SD) and landings (Gilis 1962). After 1960, the (re)introduction of the beam trawl (*boomkorvisserij*) – the most efficient gear for catching targeted flatfish – and the subsequent technological improvements to increase catch efficiency of the beam trawl required an increasing average engine power (Polet et al. 1998). The installment of the beam trawl was subsidized by the Belgian government and supported by royal decree 1/03/1958 (Lescrauwaet et al. 2012). In 1985 otter trawling targeting herring and sprat, shrimp, and other species represented respectively 1%, 11% and 21% of effort in SD while beam trawl targeting sole and plaice represented 62%. The remaining 5% effort was realized by twin trawling (‘*spanvisserij*’) for cod. With the increasing cost of diesel, recent interest has been given to the otter trawl (10% of SD) compared to the shrimp beam trawl (14% of SD) the flatfish beam trawl (68% of SD) and passive gear (1% of SD) in 2010. Passive forms of fishing that recently (re)gained importance are angling (handlines) for cod and sea bass, trammel- and gillnetting.

2.5.3 Biological data and Stock management

Due to the scarcity and the fragmentary and anecdotic nature of the historic sources related to species biology, it was not possible to integrate the data from these sources. Whereas the data on sea fisheries (landings, spatial dynamics, fleet dynamics) were systematically collected and described, the historical data and information on biology and stock assessments were collected in view of the scope of the specific research questions. These sources are identified and described in the different subchapters of chapter 6 (Impact by sea fisheries).

However, the literature sources were documented and described in IMIS, and in a next step screened for the purposes of biological databases (biogeographical databases e.g. OBIS, taxonomic databases e.g. ERMS and WoRMS, …).

2.6 CONCLUSIONS

The present chapter reports on the process of inventory, data capture, data integration and quality control of historical sea fisheries data for Belgium. It gives an overview of the process, the methodologies applied and the metadata required for correct interpretation of the data integration. The results can be summarized in three main areas:

2.6.1 Digitized inventory (IMIS) and annotated bibliography

The results of literature screening and inventory are available from the bibliography. All data and literature (context) sources were digitized, linked to context (‘Historical Fisheries Data - *HiFiData*’) and are now available in the public domain. They can be queried (by author, by keyword(s), by year of publication, other) through the modular *Integrated Marine Information System IMIS* managed by Flanders Marine Institute VLIZ.

2.6.2 INTEGRATED DATABASE

Datasets from single paper sources (different Tables from single annual reports) were digitized (to spreadsheet formats), standardized, quality controlled and integrated into one 'HiFiDatabase'. This database was stored according to professional data management standards and is available for further research purposes. The efforts of data mining have yielded a significant increase in readily available and high resolution data (by species, by fishing area, per annum). In practical terms this means that a continuous time-series is available in digital format since the first year of detailed and systematic reporting (1929) until 1999 (and can be extended up to current year). It improves the availability of digital information with approximately 60 years (from 1989 back to 1929) and the availability of data (previously available on paper and/or not in the public domain) with approximately 40 years. The data represent approximately 800,000 rows (96MB of file sizes). To our knowledge, and as far as the screening of literature, sources and archives have indicated, the present data rescue and integration of historical fisheries data is the first attempt in Belgium to collect, archive and integrate the available historical sea fisheries statistics and make these time-series publicly available. To our knowledge, it is also the first time that a country digitized to such a complete extent its historical fisheries data.

2.6.3 ACCESSIBLE RESULTS IN AN APPROPRIATE FORMAT FOR POLICY LEVEL, SCIENCE AND THE INTERESTED PUBLIC

Data were summarized in factsheets, timelines, articles for the general public, and web applications. A list of these products is available in the appendices. They contribute to awareness raising about the historical importance of fisheries, the dynamic features of the fleet, fishing areas and target species, the historical potential of sea fisheries as providers of proteins from wild fish stocks, and demonstration of the concept of 'shifting baselines'.
The data rescue process and metadata (standards, methods) are described in an on-line 'Users Guide'. The following products of the HiFiData are now available on-line or in preparation:

- Website:
    a. Key message on the absolute and relative importance of a given species in Belgian sea fisheries (Dutch and English)
    b. Links to further relevant sources for taxonomy and ecology of the species in a wider thematic and geographical context
    c. Graphs: a total of 500 graphs were produced on a fixed number of parameters (landings, values, average price, in Belgian and foreign ports, by fishing area of origin, by port of landing)
    d. Maps: reconstruction of the historical fishing areas based on available source in literature
    e. Users guides: with detailed description of the standardization of the spatial data (published in Dutch and English) and the overall process of data integration
- Informative sheets: digitally published information sheets on Belgian sea fisheries. Contain key information on landings and value of landings by species in Belgian and foreign ports, by port of landing or by fishing area (available on-line in Dutch and English, work in progress)
- Context: IMIS collection of literature related to historical data on Belgian sea fisheries (most sources in Dutch)

The HiFiDatabase and the approach and methodology can serve as a blueprint for similar initiatives in other countries or regions. In the UK, a similar initiative is conducted through the '100 Years of Change project' which collated and digitized fish and fisheries data, collected over the past 100 years by DEFRA, CEFAS, and predecessors. DEFRA commercial fisheries 'Statistical Charts' (1913–1981) provide spatially detailed (by statistical rectangle) data on catches, effort, and CPUE by fish species and fishing fleet. The commercial data are used to examine changes in distribution of commercially important fish populations throughout the 20th and early 21st Centuries, in relation to climate change and fishing pressure (Engelhard 2005, Engelhard 2008). In both projects (UK and Belgium) a broad approach was taken, incorporating information from different fields of work (legislation, social, cultural, economic, ecological). Exchange of data, information and experiences should be of great benefit to both projects.

Finally, the data collection and integration disclosed data on the early 20th century that can be further used for basic research on fisheries and historical ecology of the (southern) North Sea. As an example, time-series were constructed from the data found in older sources for the period 1836-1907 (De Zuttere 1909, Cloquet 1842) for herring and salted cod. The original sources for these older data were identified and the data quality controlled. Although these datasets can not be fully integrated with the HiFiDatabase, they provide good insights into the importance of fisheries in the 19th century since associated data on the extent of the fleet is available for that period.

2.6.4 Potentialities and limitations of the HiFiDatabase

There is an increasing demand for a historical baseline of marine ecosystems, in particular fish stocks, to evaluate them and set goals for sustainable management (Pinnegar and Engelhard 2008). However this requires a historical perspective, at least before the onset of industrial or large-scale intensive fishing practices, and estimations of historical biomass and fishing mortality to set baselines and evaluating the state of the marine ecosystems (Rijnsdorp et al. 1996, Cardinale et al. 2009a and 2009b, Roberts 2007, Pauly 1995). Historical time-series are scarce and available time-series typically date from after the start of intensive exploitation. Hence the baselines for rebuilding depleted fish stocks typically refer to strongly exploited situations (Pitcher 2001).
In the absence of catch statistics, data on landings have been used in a number of applications and models as a proxy for fishing mortality (Zeller and Pauly 2007, Eero et al. 2008, Walker and Heessen 1996, Daan et al. 1994). Landing statistics can serve as the basis for the estimation of total catch by involving diversity of sources and data (surveys, oral history and interviews, historical population data, consumption data etc.) and for further analysis related to the setting of historical baselines. Of particular interest are the datasets in which landings are reported in conjunction with fishing effort for particular segments of the fleet (by vessel type or engine power), fisheries type, and/or high temporal (by month) and spatial resolution (by fishing rectangle). In this sense, the HiFiDatabase offers an interesting basis for further research and analysis.
However, some limitations apply to the HiFidatabase, a number of which have been described above:

- Unlike with current landings, it is not possible to validate taxonomic identity of the landed species reported in earlier years. This is a limiting factor for interpretation and taxonomic validation of reported species that may not be straightforward to determine in the field (e.g. rays).
- It is not known what proportion of the catch was actually landed in the 4 ports that are included in historical landing statistics and if actually/what proportion was landed informally in other sites along the coast.

- No data were found on landings in foreign ports before 1950, in spite of the thorough screening of potential sources. Therefore, the data before 1950 may give an incomplete picture, although the landings from 1950 onwards did not indicate the existence of large amounts of landings in foreign ports.
- In some years and some sources, landings were rounded to '000kg.
- Except for the landings that were reported by statistical rectangle, the larger spatial units of reporting - although more detailed than the Fishstat data - remain quite coarse
- Uncertainty remains concerning the discrepancy between HiFiData and Fishstat[2] which could not be fully explained by converting to fresh weight equivalents.

2.7 Next steps

To achieve the present historical reconstruction and data integration, a thorough search and literature study was conducted in archives and physical collections. Though not all-encompassing, this exhaustive search disclosed data that was previously not known or accessible to the public domain. The current effort of data rescue and data integration will include these sources and be complemented with the following next steps:

- Conduct a detailed trend analysis of the HiFiData, by type of fisheries (métier) species and by fishing area of origin.
- Collect data and information that allow for a calculation of indices of catch per unit of effort (CPUE) or landings per unit of effort/power (LPUE/LPUP) and trends herein over time
- Collect evidence and indications that allow for an estimation of Illegal, Unreported and Unregulated catch (IUU) in Belgian sea fisheries, to complement the current landing statistics
- Explore the relevance of collected data, in combination with other time-series, for further use in policy making, i.a.:
    - for the description of historical baselines for the Belgian part of the North Sea and the wider North Sea area;
    - for inferences related to trophic level of sea fisheries, and the concept of fishing down the food web (Pauly et al. 1998).
- Explore with neighbouring countries (The Netherlands, UK, France), the feasibility of reconstructing historical sea fisheries by spatially defined area, in particular for the reconstruction of reported and unreported removals (which include discards) in the Belgian coastal waters (spatial unit which is not reported in the ICES database).

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[2] After the date of publication of the current Chapter, an update of the Fishstat database was released (2012). For Belgium, among others, French-language footnotes to the original data tables and other information was included. The discrepancies between HiFiDatabase and the updated Fishstat were checked (2013) and now found to be smaller.

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CHAPTER 3: Fishing in the past: Historical data on sea fisheries landings in Belgium

CHAPTER 3. HISTORICAL DATA ON SEA FISHERIES LANDINGS IN BELGIUM

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ABSTRACT

In Belgium, centralized reporting on landings of sea fisheries at the species level started in 1929. This paper summarizes the process and the results of integrating time-series, based on fragmented and disperse data sources for the period 1929-1999. The resulting database contains data by species (41), by port of landing in Belgium (4) and in 'foreign ports', and by fishing area of origin (31). After quality control, total reported landings over the period 1929-2008 amounted to 3,320,518 tonnes (t), of which 90% was landed in Belgian ports. After a maximum of 75,370 t in 1947, annual landings declined steadily to only 26% of this peak by 2008. Currently, landings are below those achieved in 1929. The most important species in terms of landings (1929-1999) were cod (17% of all landings) and herring (16%). In terms of economic value, sole (31%) and cod (15%) were the most valuable. Close to 73% of all landings originated from 5 of the 31 fishing areas. Twenty percent of all landings (1929-1999) originated from the 'coastal waters', while these waters contributed nearly 60% of all landed pelagic species and 55% of all landed 'molluscs and crustaceans'. Compared to the currently available ICES data, this local database offers advantages in temporal coverage (data from 1929 onwards), temporal scale (monthly values), and at the taxonomic level. It also provides more detailed information at the spatial scale of the southern and central North Sea, and it is the only source of historical information on landings originating from the coastal waters. Given the importance of the shallow and productive 'Flemish banks' as a local source of food in historical and recent times, this data is valuable for further research on the productivity of the coastal ecosystem and the local impact of fisheries. The database broadens the historical view on fisheries, underlines the decline in landings since reporting started, and serves as a basis for further (fisheries) research and policy-making in Belgium.

Keywords: Sea fisheries, History, Belgium,

3.1. INTRODUCTION

SEA FISHERIES IN BELGIUM: A HISTORICAL PERSPECTIVE

The Belgian coast is 67km long and located in the province of West-Flanders (region of Flanders, Belgium). The Belgian part of the North Sea is 3,457km² (0.5% of the North Sea area). Belgium has 4 coastal ports (*Nieuwpoort, Oostende, Zeebrugge* and *Blankenberge*), and besides the fish auctions currently located in *Oostende, Zeebrugge* and *Nieuwpoort* (Figure 3.1.) there are no other dispersed landing points today[1]. Belgian sea fisheries represent 0.04% of the national Gross Domestic Product (Anon. 2008). In January 2009, the Belgian fisheries fleet counted 100 ships, with a total capacity of 60,620kW and 19,007 GT (Flanders Sea Fisheries Service, accessed May 2009). In 2008, the Belgian fleet landed a total of 20,012t, of which 17,307t were landed in Belgian ports. The landings represented a total value of €76.3million, 14% of which was marketed in foreign ports. Fisheries today provide direct jobs for approximately 550 fishermen (full time equivalents, FTE) and another 1,370 FTE indirectly employed in the processing sector (Platteau et al. 2008). The Belgian fleet is highly specialized: more than 95% of the total landings is achieved by beam trawlers, focusing primarily on flatfish species such as plaice (*Pleuronectes platessa*) and sole (*Solea solea*). Sole generates 48% of the current total value of fisheries in Belgium (Anon. 2008, Mees 2001).

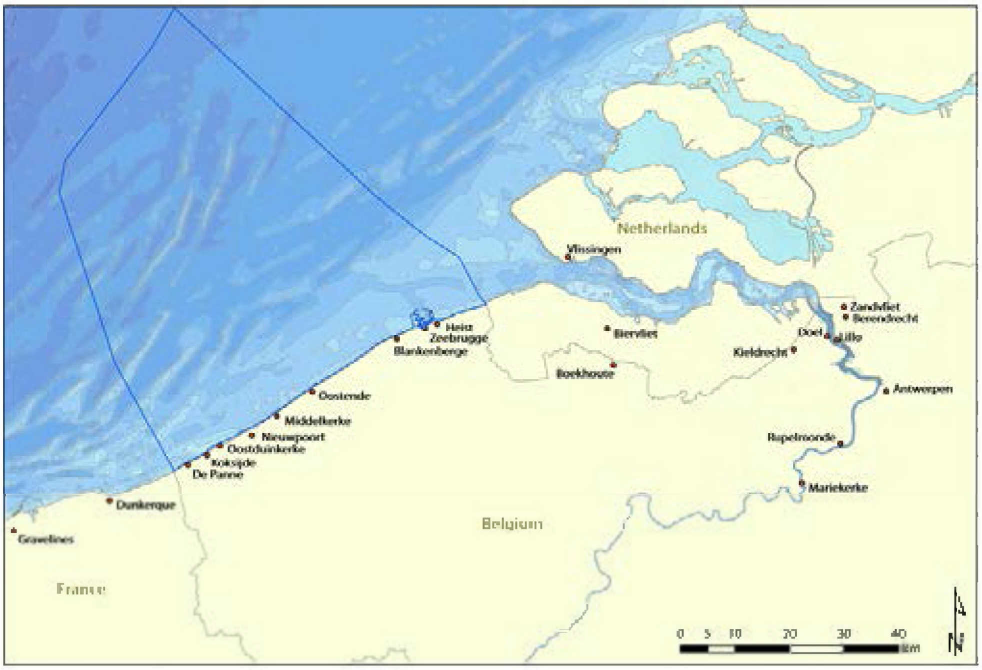


Figure 3.1.: Map of the Belgian coast with the historical fishermen's settlements in Flanders, the ports of *Gravelines* and *Dunkerque* in France, and the current coastal (fishing) ports of Oostende, Zeebrugge, Nieuwpoort and Blankenberge. The line indicates the boundaries of the Belgian part of the North Sea. Source: A century of Sea Fisheries in Belgium (VLIZ 2009).

[1] Before WWII, an important number of vessels sailed from other coastal settlements, where (unreported) amounts of (day)fresh fish was landed (Fig.3.1. and Chapter 5: Fig. 5.2. - 5.4. and 5.6.). During WWII, the ports of Dunkerque and Gravelines were mainly used to disembark the exceptional landings of herring (Chapter 7). After WWII, vessels were registered in the current 4 coastal ports.

Considering the limited extent of the fleet, the short and simple coastline and the limited number of fish auctions and fishing ports, a historical reconstruction of landing statistics in Flanders/Belgium may yield a fairly complete picture of the historical situation, compared to other fishing nations.

There is an increasing demand for a historical baseline of marine ecosystems, in particular fish stocks, to evaluate them and set goals for sustainable management (Pinnegar and Engelhard 2008). Recovering the historical context of our fisheries is necessary to document the cultural heritage of our coastal society and to tackle the issue of 'shifting base-lines' in a marine ecology context (Pauly 1995, Pauly et al. 1998, Roberts 2007). This requires a historical perspective, at least before the onset of industrial or large-scale intensive fishing practices, and estimations of historical biomass and fishing mortality to set baselines and evaluating the state of the marine ecosystems (Pauly 1995, Rijnsdorp et al. 1996, Roberts 2007, Cardinale et al. 2009a). However, historical time-series are scarce and available time-series mostly date from after the start of intensive exploitation. Hence the baselines for rebuilding depleted fish stocks typically refer to strongly exploited situations (Pitcher 2001).

Lescrauwaet et al. (2010b) searched the Internet for historical references on landings and their values, based on selected keywords, and concluded that the collective memory (*cfr. publicly available data and information*) in terms of Belgian sea fisheries does not surpass 30 years. The authors proposed 5 plausible reasons to explain the absence or incompleteness of data on sea fisheries before 1980:

- data were not collected/never existed;
- data exist/existed, but are not available (anymore) in the public domain;
- data exist and are publicly available, but data policy restrictions apply;
- data exist and are freely accessible, but not available in the appropriate format;
- data exist and are freely accessible, in appropriate format, but of insufficient reliability.

To address these questions, an integrative approach was needed and a thorough data rescue based on the best available historical data and information was conducted, with the questions raised above as guidance.

3.2. OBJECTIVES

The objectives of the data rescue were to identify, describe, quality control, permanently store and safeguard formal and centralized reports on historical data of Belgian sea fisheries, to integrate these data into a standardised database, and to make time-series available to end-users. The scope of this effort was on the production of the Belgian fleet: officially recorded landings by the Belgian fleet, in the fish auctions in Belgian ports and in foreign ports. It did not cover landings from foreign fleets in Belgian ports. Lescrauwaet et al. (2010b) give a complete overview of the methodology used for the data rescue. The present paper briefly refers to methodology, and focuses on the results and main findings in the context of the above questions.

3.3. METHODOLOGY

3.3.1. Question 1: do data exist, were data collected?

Structured databases that allowed advanced querying on the basis of specific search terms were screened for publications, documents (including grey literature) and data on fisheries in Flanders/Belgium. A thorough - although not exhaustive - search was conducted in specialized libraries (physical and digital collections), literature databases, catalogues, internet 'harvesters' (e.g. JSTOR, Web of Knowledge) and historical collections (archives and documentation centres in Belgium). Most 'promising' inventories were screened based on titles (geographic and thematic). A complete list of historical sources consulted in the context of this review, is available from: http://www.vliz.be/cijfers_beleid/zeevisserij/pub_bijdrage.php (click on 'Collection of publications and other sources').

Historical documents such as charters and local laws shed a light on the importance of fisheries in Flanders during the Middle Ages and the Early Modern Period. One of the early documented evidences of the extent of fish trade in Flanders can be derived from taxes levied in coastal ports for the beginning of the 11th century (Degryse 1944). Documents such as the '*Keure van Nieuwpoort*' (city charter of Nieuwpoort) from 1163 refer to the species of fish that were caught, traded and taxed. Early published reported data on landings in Flanders refer to herring in the port of *Biervliet* in 1398-1427 (Degryse and Mus 1966-1967) and to *Oostende* in 1492-1580 (Vlietinck 1975). Historical reviews and bibliography on sea fisheries in Belgium are available elsewhere (Vilain 1962, Poppe 1982, Hovart 1994), the focus of this review is on data and time-series at the species level.

3.3.2. Question 2 and 3: are data (still) publicly available and if yes, what data policy restrictions apply?

Except for the annual reports on Belgian sea fisheries which are electronic formats (pdf or html) from 1998 onwards, none of the time-series contained in the pre-1998 sources were available electronically in the public domain. Through the present exercise, data were digitised from the earliest year of consistent and detailed time-series (1929). The collection of digitised data sources and data on the composition and value of landings are now public, available on-line, and no restriction other than the acknowledgement of sources and authors is required.

3.3.3. Question 4: data exist and are publicly available and freely accessible, but are not in the appropriate format

Data were not available before in the appropriate format for overviews or research analysis. The present data integration process included digitisation (from paper copies), quality control of the digitisation process, taxonomic and geographic standardisation, data integration and graphical analysis.

The resulting integrated database on historical fisheries data ('HiFiDatabase') allows querying data at species level (41 species) and another 15 aggregate categories, by year (1929 until present), by fishing area (31 subareas) and by port of landing in Belgian (4 ports) and foreign ports (aggregated value), and 2 ports in France (during World War II 1940-1945). Detailed landings of the Belgian fleet in foreign ports were covered for the period 1950 until present. Lescrauwaet et al. (2010b) describe the details of geographic standardisation.

3.3.4. Question 5: data exist and are freely accessible, in appropriate format, but of insufficient reliability

The problem of incompleteness and reliability of the fisheries data in Flanders/Belgium has been, as in many fishing nations, persistent over time and hard to address. In fact, early 19th and 20th century publications (e.g. Annual reports of the Province of West-Flanders or '*Bestuursmemoriaelen*' (Anon. 1837-1909) and a thorough investigation on the Belgian sea fisheries by De Zuttere (1909) acknowledge the fact that state subsidies were the drive for the collection of fisheries data. Still, considering the limited extent of the fisheries (fleet and ports) and the short and simple coastline, the present historical reconstruction of landing statistics in Flanders/Belgium may depict a fairly complete picture of the historical situation as compared to other fishing nations, especially from the beginning of the 20th century onwards.

A first quality control of the data sources (including graphical analysis on the integrated database) yielded an overall absolute correction of approximately 12,643t and €2.4million (nominal values, not corrected for inflation). These corrections amount to 73% of the landings of the Belgian fleet in Belgian ports in 2008. Expressed as a proportion of current value of landings (2008), this would correspond with €48.6million. The impact of this quality control may increase substantially when 'zooming in' on a particular species.

In a second quality control, the total annual landings as reported in two different datasets were compared. The degree of consistency between both values provided a relative indication of the reliability of the data. Most of the time-series were evaluated as excellent to good (0% to <1% difference), except for the earlier years (1933-1935) of reporting, for the World War II period (1940-1945), for aggregated levels of reporting units ('miscellaneous, 'other species') and for some pelagic species after 1980. Finally, the data from the HiFiDatabase were compared to the values reported by ICES (Fishstat) (Section 3.4.9.).

The previous assessment indicated that historical fisheries data was unavailable for science and policy-making so far, mainly because of fragmented and poorly accessible data sources, and their (paper) format.

3.4. Results and Discussion

Our literature screening for time-series on landings and the economic value of these landings indicated that structurally embedded reporting at the species level in Flanders (Belgium) started in 1929 with an acceptable consistency and continuity ever since then. The beginning of structural reporting on fisheries and landings coincided with the period where most states in Europe developed a statistic approach to underpin policy development (Julin 1918, de Reiffenberg 1932a and 1932b, François and Bracke 2000, Leti 2000). Time-series on (value of) landings of sea fisheries in Flanders were reported at least as early as 1767 (1767-1780; 1836-1906) for 'small herring fisheries' (values), 'large herring fisheries' (values), 'salted cod' (landings) and for 'fresh fish' (total values for the aggregate of unidentified species). These fragmentary data are valuable when attempting to reconstruct landings per unit of effort (LPUE), socio-economic importance, etc. in combination with other datasets. Lescrauwaet et al. (2010b) provide details on data sources.

3.4.1. Total value and landings of the Belgian fisheries, in Belgian and foreign ports

The data integration covered the period 1929-1999. This time-series was extended with the data for the period 2000-2008 currently stored at the *Dienst Zeevisserij-DVZ* (Flanders Fisheries Service). The total amount of reported landings from 1929-until present (2008) amounted to 3.3 million t, of which 3,0 million t (90%) were landed in Belgian ports and 0,3 million t in 'foreign ports' with an additional 20,256t in *Dunkerque* and *Gravelines* (France) during World War II. Since the peak in 1947 (75,370t), annual landings have continuously declined to represent only 26% of this '1947 peak' by 2008. Since the mid 90s, total landings have not exceeded the landings achieved in 1929 (Figure 3.2.): the landings in 2008 are approximately 60% of those in 1929.

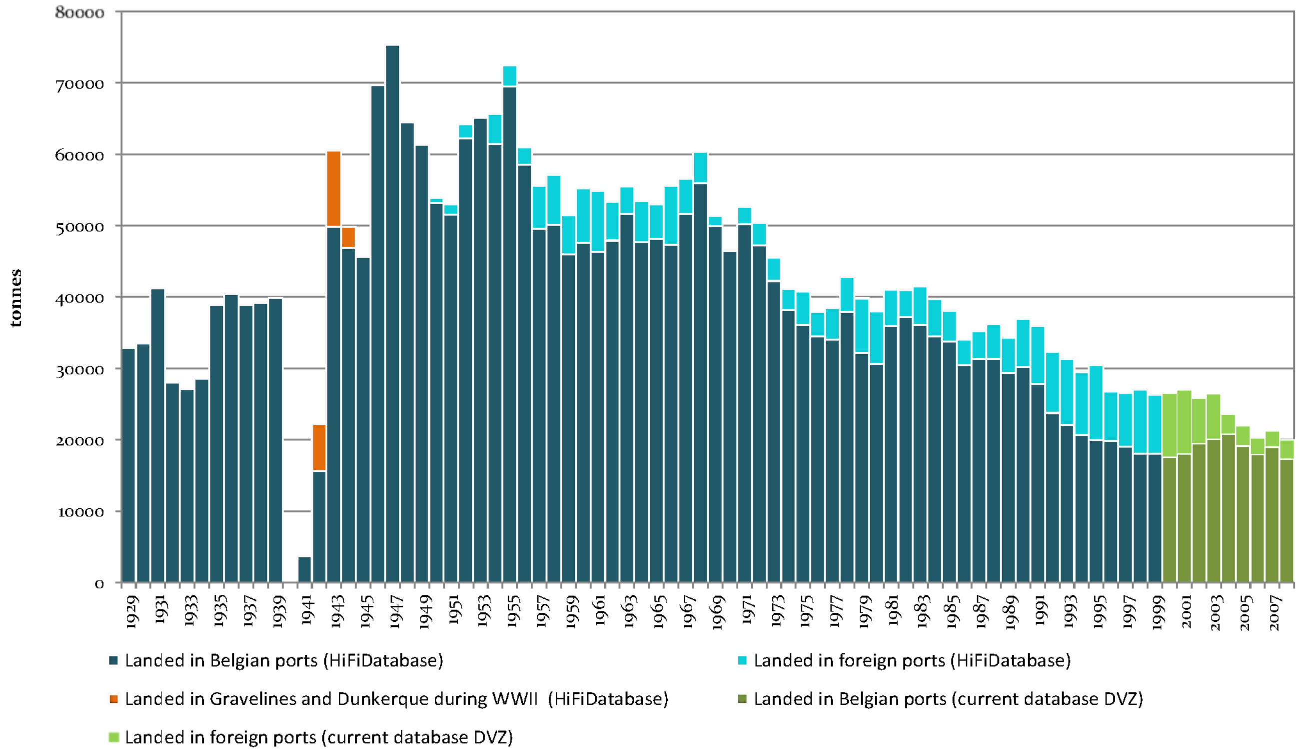


Figure 3.2: Landings of Belgian fisheries in Belgian (dark) and foreign (light) ports in the period 1929-2008, including *Dunkerque* and *Gravelines* (France). Data for 2000-2008 were kindly provided by the Flanders Fisheries Service. Source: 'A century of Sea Fisheries in Belgium' (VLIZ 2009).

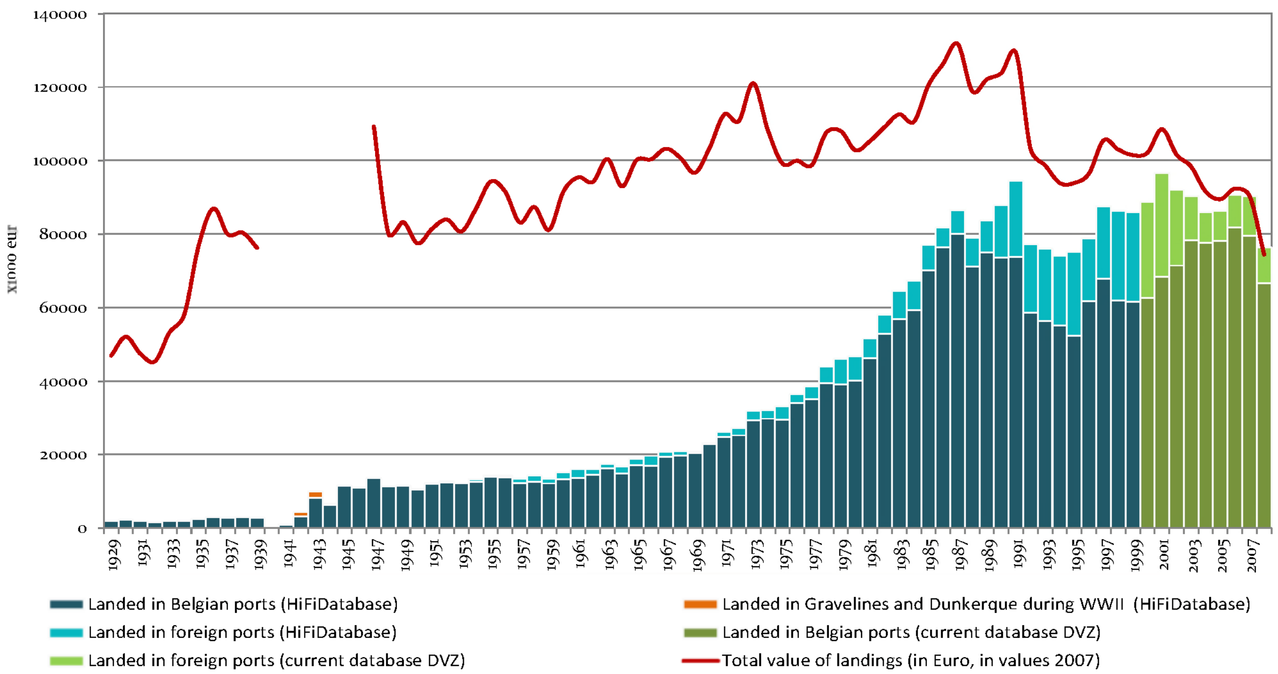


Figure 3.3.: Value of landings (x €1,000) of Belgian fisheries in Belgian (dark) and foreign (light) ports between 1929-2008. Value of landings in Gravelines and Dunkerque during World War II are inconspicuous. The line indicates the trend of value of landings corrected for inflation (values 2007).

The total nominal value of these landings (1929 until 2008) amounted to €3,075 million which corrected for inflation (values 2007) represented €6,923 million (excluding World War II for which no indexes are available to correct values) (Figure 3.3.). While the peak in landings occurred in 1947, the gross income (corrected values) generated by Belgian fisheries steadily increased after 1950, peaked in 1987 and 1991 and declined afterwards. In spite of the decline in landings, the Belgian fisheries have compensated gross income thanks to the increase in market value for some species, and by focusing on selected and higher-priced species such as common sole (*S. solea*). The increase in gross income however was not co-linear to (increase in) net or real income, in particular considering the proportional importance of increasing fuel prices in the total production goods of fisheries.

3.4.2. Demersal, pelagic and 'molluscs and crustaceans' fisheries: value and landings in Belgian and foreign ports

Demersal fisheries

Since the 1950s, Belgian fisheries is mainly focused on demersal species, with the use of beam trawlers, and targeting flatfish such as sole and plaice. The figures for demersal fisheries showed a maximum in 1968 with landings of 57,767t, of which 4380t were landed in foreign ports (Figure 3.4.). While the landings of demersal fish by Belgian fishermen in Belgian ports steadily decreased from 1968, the landings in foreign ports slightly increased, especially during the 1990s.

This peak in landings was supported by the rich fishing areas of the Iceland waters. From 1972 onwards, access to these fishing grounds became restricted when Iceland further demarcated its territorial sea from 12nm to 50nm (also known as the 'cod wars', see Chapter 8). From 1975 presence of Belgian fishermen within the 200nm became subject to a 'phase-out'. Flatfish fisheries were forced to turn towards other fishing grounds (Figure 3.5.). Besides the traditional fishing areas for Belgian fisheries (coastal waters, southern and central part of the North Sea), the 'western waters' (English Channel, Bristol Channel, Irish Sea,..) gained importance.

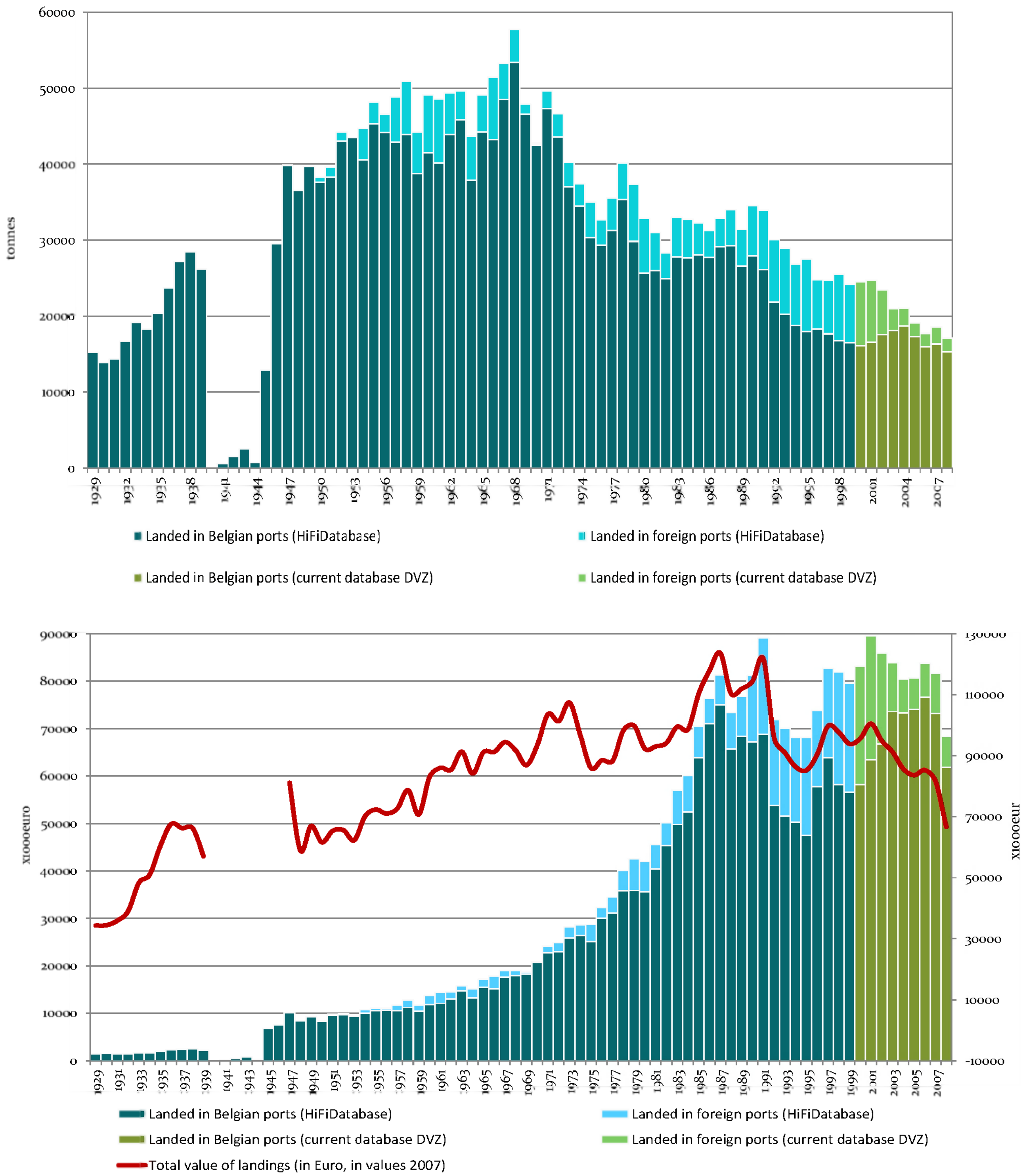


Figure 3.4: Upper panel: Landings (tonnes) of demersal fish in Belgian fisheries in Belgian ports (dark) and foreign ports (light) between 1929-2008. **lower panel:** Value of landings (x1000euro) of demersal fish in Belgian fisheries in Belgian ports (dark) and foreign ports (light) between 1929-2008. Data for 2000-2008 were kindly provided digitally by the Flanders Fisheries Service DVZ. Source: 'A century of Sea Fisheries in Belgium' (VLIZ 2009).

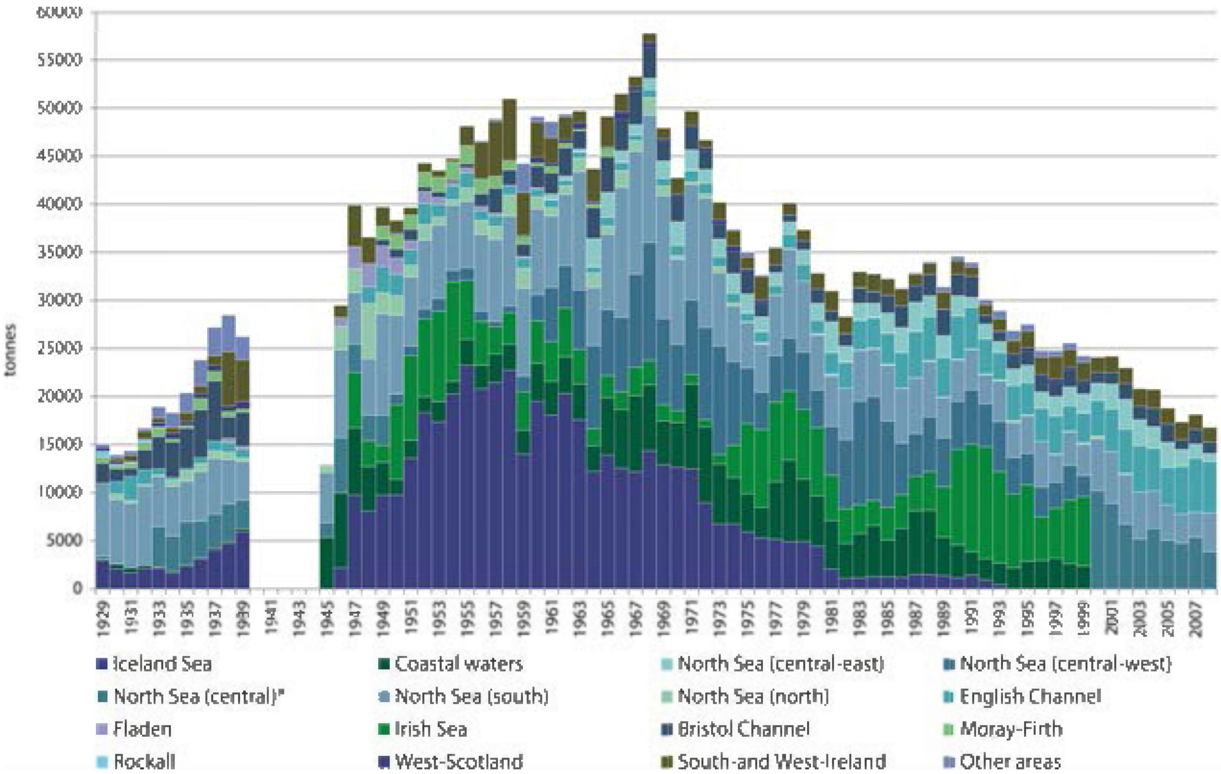


Figure 3.5.: Landings (t) of demersal fish in Belgian fisheries by fishing area of origin. Data for 2000-2008 were kindly provided digitally by the Flanders Fisheries Service DVZ.

3.4.3. Pelagic fisheries

During and after World War II, unusually high landings of pelagic fish were reported with up to 58,000t (mainly herring) in 1943, of which the larger part was sold in the fish auction of *Nieuwpoort*. Pelagic fisheries focused on the coastal waters, the southern North Sea and Fladen (northeastern UK). During the Second World War, Belgian fishermen landed an important part of the herring catches in French (border) ports. In *Gravelines* and *Dunkerque* alone, more than 10,000t of 'Flemish herring' was sold in 1943 Besides herring, also sprat, mackerel and horse mackerel were targeted. Important landings of pelagic species were achieved in the early 1950s (21,402t in 1955), but after the last peak in the early 1980s (9254t in 1982) pelagic fisheries in Belgium became part of history (Figure 3.6.).

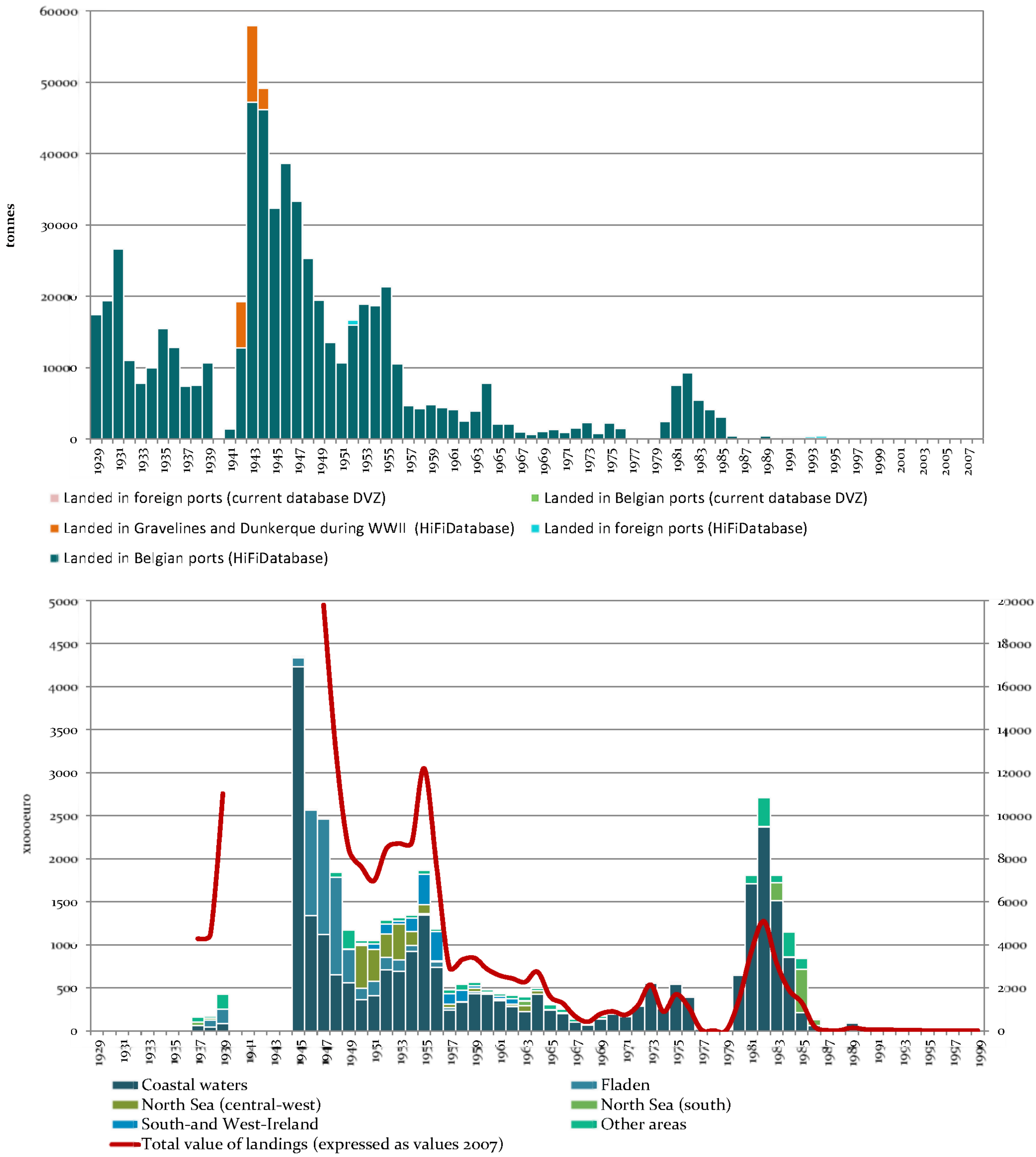


Figure 3.6: Upper panel: Landings (t) of pelagic fish in Belgian fisheries in Belgian ports (dark) and foreign ports (light) between 1929-2008. Data for 2000-2008 were kindly provided digitally by the Flanders Fisheries Service DVZ.
Lower panel: Value (nominal) of landings (x1000euro) of pelagic fish in Belgian fisheries by fishing area between 1929-1999. Total value expressed as values 2007 is indicated in red line. Source: 'A century of Sea Fisheries in Belgium' (VLIZ 2009).

3.4.4. MOLLUSCS AND CRUSTACEANS FISHERIES

Since the early 20th century, Belgian fisheries on 'molluscs and crustaceans' focused on a few target species: brown shrimp (*Crangon crangon*), whelk (*Buccinum undatum*), lobsters and cephalopods. Landing statistics showed a peak value of 4343t in these seafood species in 1937 (Figure 3.7.). Although a gradual decline was visible between the mid-1970s and the end of the 1990s, landings have increased again over the last decades. The largest proportion of molluscs and crustaceans originated from coastal waters (section 3.4.6.).

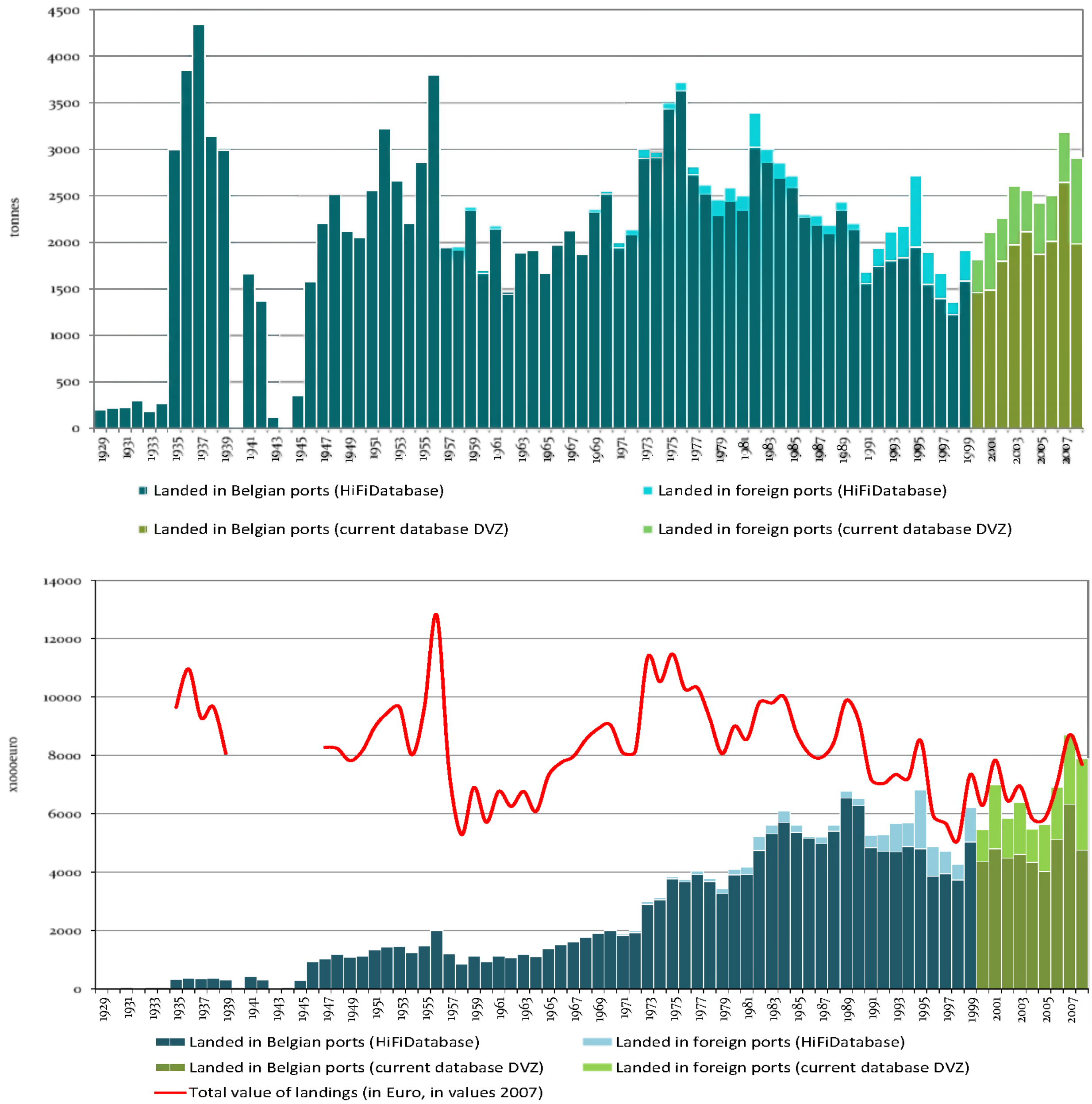


Figure 3.7.: upper panel: Landings (t) of 'molluscs and crustaceans' in Belgian fisheries in Belgian ports (dark) and foreign ports (light) between 1929-2008. **lower panel:** Value of landings (x1000euro) of 'molluscs and crustaceans' in Belgian fisheries in Belgian ports (dark) and foreign ports (light) between 1929-2008. Data for 2000-2008 were kindly provided digitally by the Flanders Fisheries Service DVZ.. Source: 'A century of Sea Fisheries in Belgium' (VLIZ 2009).

3.4.5. Most important species

The level of detail available in the integrated database allowed scoring the most important species in Belgian sea fisheries in terms of landings (t) and value (€) for the period 1929-1999, landed in Belgian and foreign ports.
In terms of landings, cod and herring were the most important species. They respectively made up 17% and 16% of the total landings of Belgian fisheries (1929-1999), closely followed by plaice (14%), sole (8%), whiting (6%) and rays (6%) (Table 3.1. and Figure 3.8.). These species made up 67% of the total amount of reported landings (3.1 million t) covered by the HiFiDatabase over the period 1929-1999.

Table 3.1: Most important species in terms of landings of Belgian sea fisheries 1929-1999

Species	Landings (kg) in Belgian ports	Landings (kg) in foreign ports	Total landings (kg)	Percentage of overall landings (%)
Cod	475,830,707	63,452,890	539,283,597	17
Herring	494,349,106	1,073,844	495,422,950	16
Plaice	340,577,079	87,748,584	428,325,663	14
Sole	225,630,204	12,057,095	237,687,299	8
Whiting	170,484,151	9,930,878	180,415,029	6
rays (aggregated class)	169,506,117	8,265,576	177,771,693	6
Sum	1,876,377,364	182,528,867	2,058,906,231	67

In terms of nominal value of landings, sole and plaice were the most important species. However, cumulated nominal values were negatively biased for species which generated income in the earlier years of fisheries and therefore contributed with lower nominal values. After accounting for the inflation, sole and cod appeared as the two most important species. They represented, respectively, 31% and 15% of the total (corrected) value of Belgian fisheries (1929-1999) and were closely followed by plaice (11%), brown shrimp (5%), rays (5%) and turbot (3%). These species made up 70% of the total corrected value of reported landings (€6,075 million) covered by the HiFiDatabase over the period 1929-1999 (Table 3.2.).

Table 3.2.: Most important species in terms of value of landings of Belgian sea fisheries 1929-1999: nominal values and values corrected for inflation (reference year 2007)

Species	**Nominal value of landings (€) in Belgian ports**	**Nominal value of landings (€) in foreign ports**	**Total nominal value (€)**	**Total value (€) corrected for inflation**	**Percentage of overall corrected value (%)**
Sole	720,891,297	69,546,672	790,437,969	1,882,646,185	31
Cod	249,700,409	48,225,963	297,926,372	888,249,043	15
Plaice	234,873,098	107,266,892	342,139,990	695,269,398	11
Brown shrimp	79,152,943	11,069,718	90,222,661	310,118,469	5
rays (aggregated class)	70,172,223	3,207,275	73,379,498	279,556,322	5
Turbot	63,317,885	13,111,290	76,429,175	208,450,538	3
Sum	**1,418,107,855**	**252,427,810**	**1,670,535,665**	**4,264,289,955**	**70**

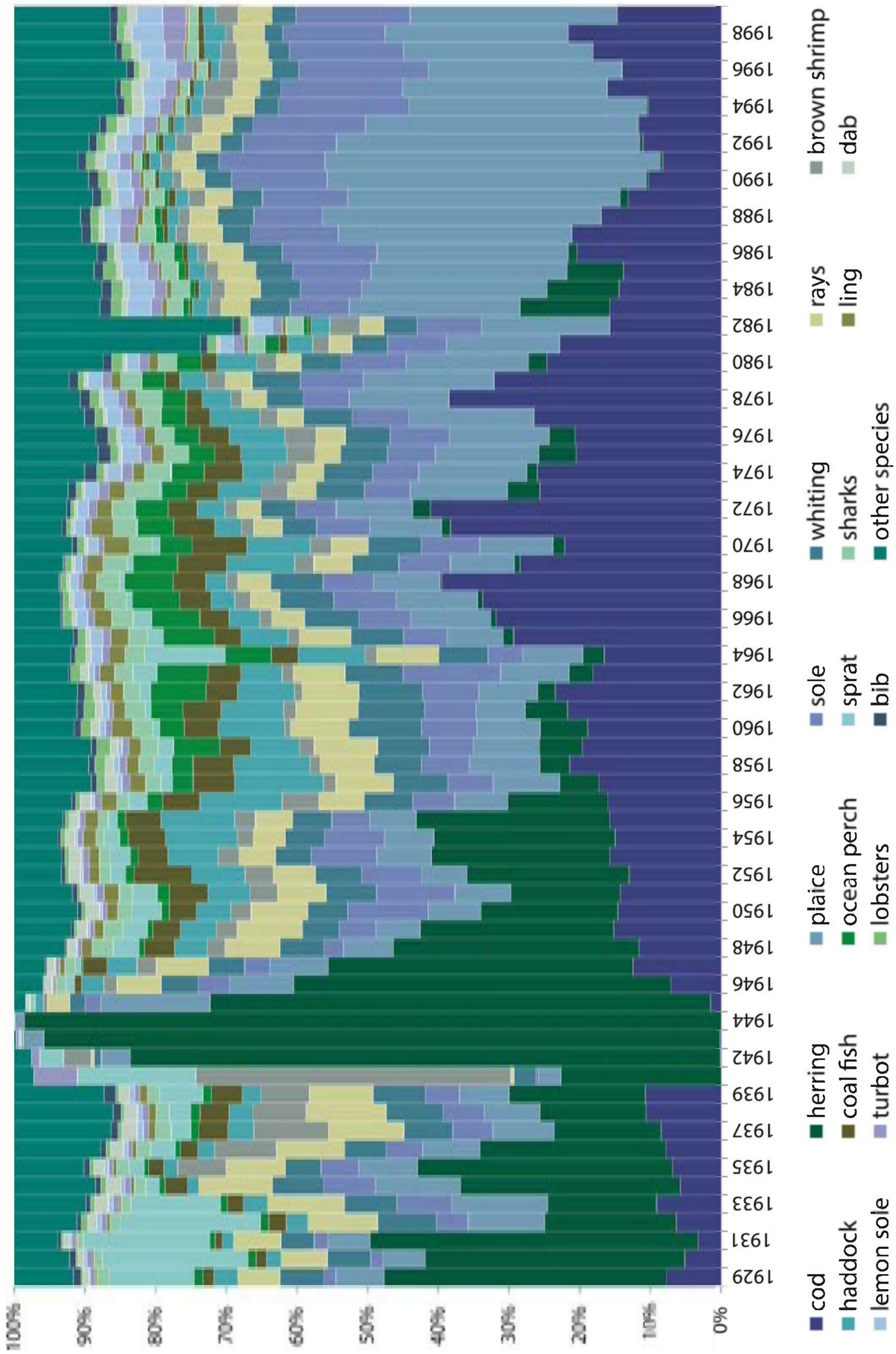


Figure 3.8.: Proportion of annual landings (in %) by species (or aggregation of species) from Belgian fisheries, landed in Belgian and in foreign ports (1929-1999). Source: 'A century of Sea Fisheries in Belgium' (VLIZ 2009).

3.4.6. MOST IMPORTANT FISHING AREAS

Similar to the scoring of the most important species (see above), the most important fishing areas for the period 1929-1999 were identified from the database. They were listed in order of importance in terms of landings (kg), in Table 3.3.

Table 3.3.: Five most important fishing areas for the Belgian sea fisheries (1929-1999) in terms of landed species (kg), in order of importance.

Fishing area	Total landings (kg) in Belgian ports	Total landings (kg) in foreign ports	Total landings (kg)	Percentage (%) of overall landings
Coastal waters	600115224	15806841	615922065	20
North sea (south)	515370304	17381122	532751426	17
Iceland Sea	462469753	37893907	500363660	16
North Sea (central-west)	220023736	77493755	297517491	10
North Sea (central-east)	206814279	78356942	285171221	9

Close to 73% of all landed species originated from five fishing areas: Coastal waters, North Sea (south), Iceland Sea, and North Sea (central-east and central-west) (Table 3.3. and Figure 3.9.). The data underlined the importance of the Coastal waters: considering the entire period 1929-1999, 20% of all landed species originated from the coastal shallow waters. The North Sea (south) and the Iceland Sea followed closely with 17% and 16% respectively. The eastern and western part of the central North Sea, contributed each with approximately 10% of the total landings. Twenty percent of all landings originated from the central North Sea, if early reports on the spatially aggregated fishing area 'North sea (central)' are included. Compared to the vast extension of the central North Sea, the coastal waters were an important source of fish products throughout the time span 1929-1999, and in spite of their limited extent contributed nearly 60% of all landed pelagic species and 55% of all landed 'molluscs and crustaceans' reported in this period.

3.4.7. MOST IMPORTANT FISHING PORT

The landings in foreign ports were reported as one aggregated value (except for the ports of *Dunkerque* and *Gravelines* during World War II). It was therefore not possible to look at trends in landings of Belgian fisheries for individual foreign ports. Over the period covered by the HiFiDatabase, the fish auctions of *Oostende* and *Zeebrugge* were the most important. Although since 1985 *Zeebrugge* has taken the lead in terms of annual landings in Belgian ports, *Oostende* was the most important port when considering overall landings reported in Belgian ports for the entire period 1929-1999: 68% of all landings were reported in *Oostende*, versus 24% in *Zeebrugge*, 8% in *Nieuwpoort* and 0.35% in *Blankenberge*. The decline of Oostende as main fishing port is among others related to the disappearance of the large steam-trawlers after WWII and the gradual loss of traditional distant water fishing grounds (e.g. Icelandic waters). Also, the port Zeebrugge was of more recent construction and offered improved port facilities, to which new investments were attracted (Chapter 5).

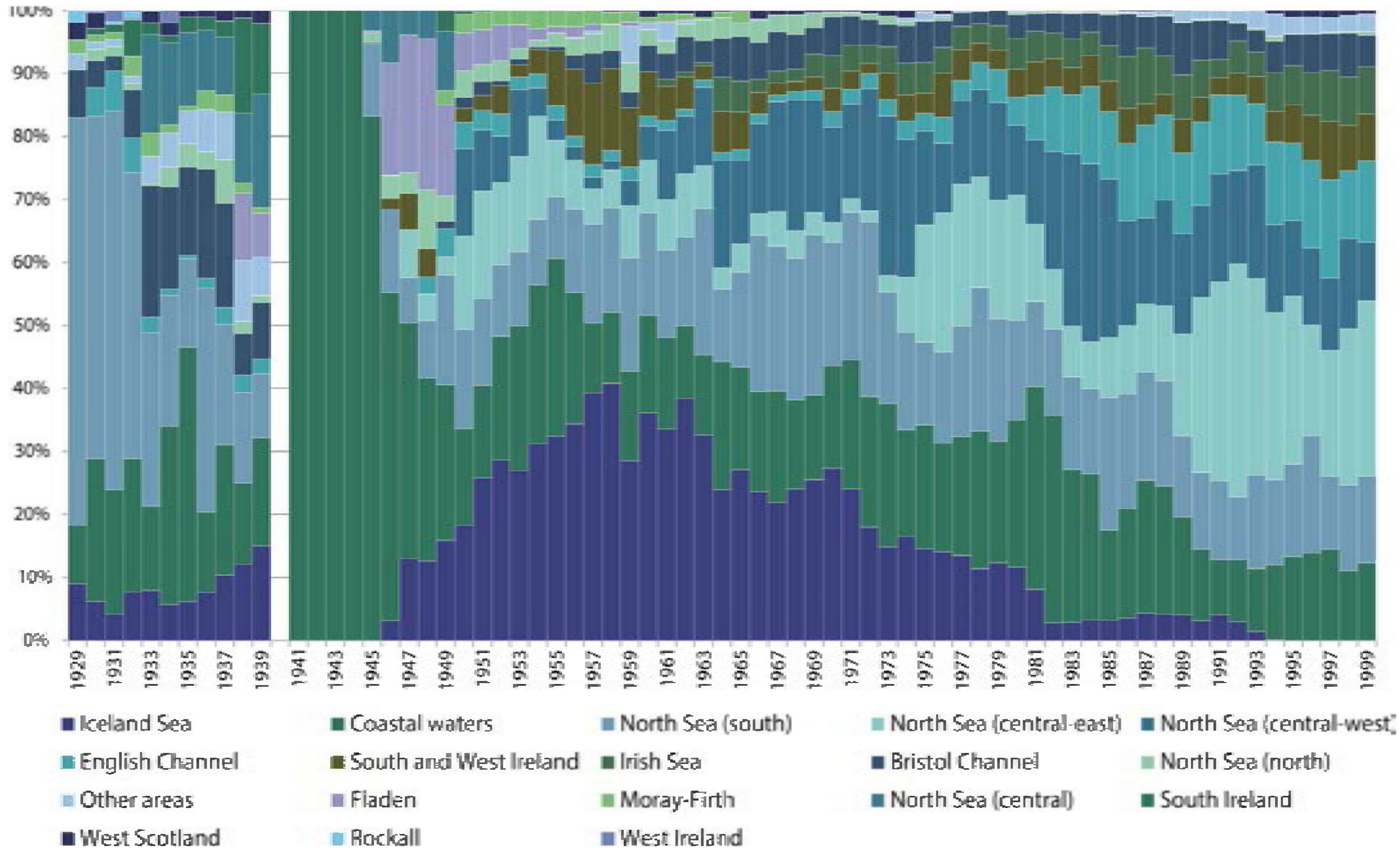


Figure 3.9.: Proportion of annual landings (in %) from Belgian fisheries by fishing ground of origin, as landed in Belgian and in foreign ports (1929-1999). Source: 'A century of Sea Fisheries in Belgium' (VLIZ 2009).

3.4.8. Historical landings time-series by species by fishing area of origin

Finally, for each of the reported species, graphs were reconstructed from 1929 onwards at the species level, visualizing the annual landings (t), annual value of landings (nominal and current values in €) and annual average value (€/kg), by fishing area of origin. Figure 3.10. is an example of this reconstruction for Atlantic cod (*Gadus morhua*), historically the most important species in terms of landed weight. In the dataset for 2000-2008, the fishing areas 'North Sea (central-east)' and 'North Sea (central-west)' were reported as one aggregated value for 'North sea (central)', and 'Coastal waters' was included as part of 'North Sea (south)'. Current catches are compliant with the Belgian EU quota for Atlantic cod, imposed as conservation measures in the context of the depletion of fish stocks. The current landings of cod are contrasted with the well-documented landings of 'salted cod' fisheries in the 19th century (1836-1907), mainly originating from the Doggerbank and the Faroe Islands (De Zuttere 1909, after Anon. 1837-1909) (Figure 3.10.). These total landings of salted cod from the ports of *Antwerpen, Brugge, Oostende* and *Nieuwpoort* fluctuated around 2300t before the 'cod subsidies' were abolished after 1867. 'Fresh fish' landings were reported for the same period (1836-1907) by De Zuttere (1909), however in terms of their values (Belgian francs) and as one aggregate class. It is logical to assume that 'fresh cod' was part of these 'fresh fish' landings. However, there was no direct indication of the proportion of Atlantic cod in these 'fresh fish' landings, as data at the species level was not reported again until 1929 (see above). Possibly the missing part of the 'cod history' can be reconstructed by assembling piecemeal information from local newspapers, individual logbooks, company records.

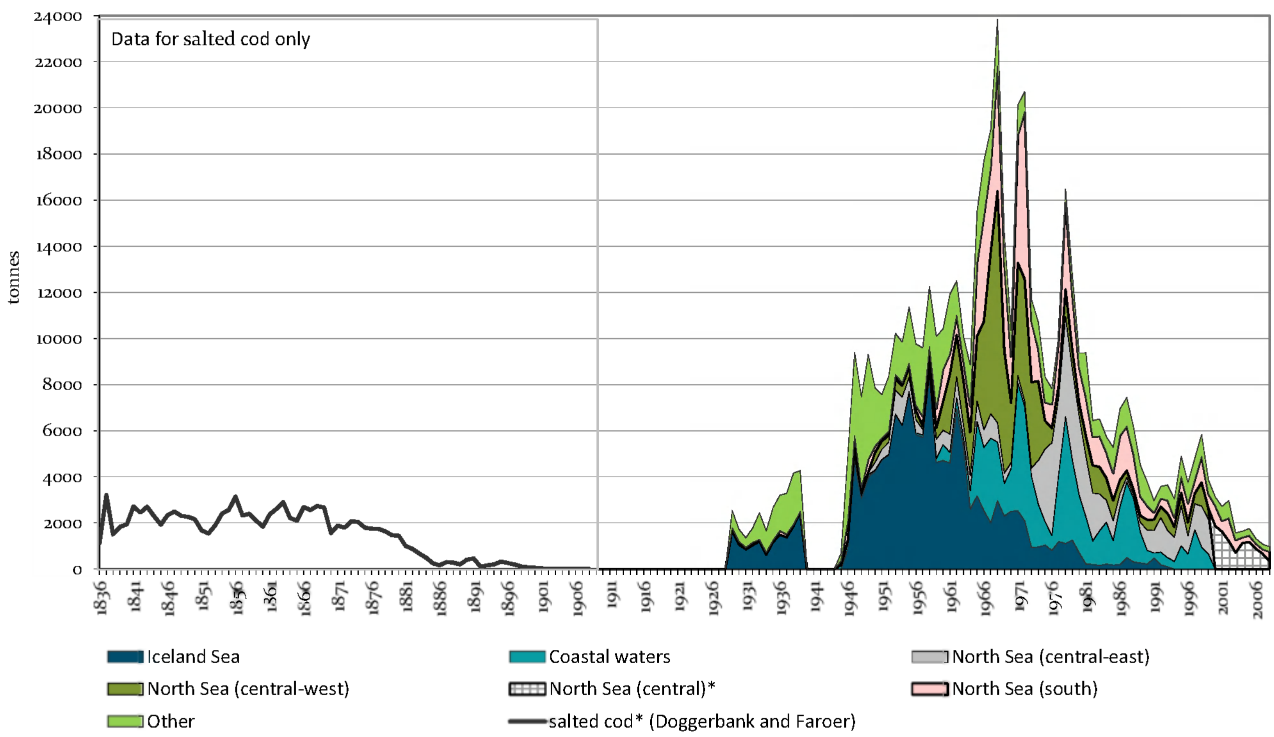


Figure 3.10: Landings (t) of Atlantic cod in Belgian fisheries in Belgian and foreign ports, by fishing area between 1836-1907 (salted cod) and 1929-2008. No data between 1908 and 1929. Data from 2000 onwards were kindly provided digitally by the Flanders Fisheries Service DVZ. See text for notes on 'salted cod*' and 'North Sea (central)*. Source: 'A century of Sea Fisheries in Belgium' (VLIZ 2009).

3.4.9. COMPARISON OF THE HIFIDATABASE TO ICES LANDING STATISTICS

A comparison between the ICES database and the local database was conducted to look for possible inconsistencies. ICES data were obtained from Fishstat (ICES 2008). For Belgian sea fisheries, Fishstat contained aggregated landings from the 'Northeast Atlantic' area (Statlant27), landed both in Belgian ports and in foreign ports from 1950 onwards, expressed as 'fresh weight equivalents'. These 'fresh weight' values were reported by countries after conversion of 'dead weight' as recorded in the auction, with species-specific conversion factors. The HiFiDatabase contained the original non-converted data (dead weight) as recorded in the auctions. Therefore, the sum of the components (ICES data by species) was not necessarily co-linear to the landings in the HiFiDatabase. Moreover, not all species were subject to reporting since the beginning of ICES reporting, or the reported aggregations of species did not allow a 'species to species' comparison between the two databases.

As expected, the annual values for total landings from HiFiData were consistently lower than ICES data over the entire period due to the difference between dead and fresh weight. Subtotals (dead weight) by individual species were converted to fresh weight equivalents by multiplying with the corresponding species-specific conversion factor, where applicable.

The over- or underreporting was not systematical between years nor was it associated with the first decades of reporting. Therefore it could not be explained by changes in the conversion rates compared to earlier reporting years. For some species (Atlantic horse mackerel, Atlantic wolffish, common shrimp, European sea bass, European hake, surmullet, pouting, etc.), the HiFiDatabase reported overall higher landings than the ICES data after conversion to fresh weight. For others (Atlantic herring, European plaice, European sole, Atlantic cod, European flounder, European conger, etc.) the Fishstat total reports were higher. Our calculations indicated that, for the demersal species which were reported both by HiFiData ánd by ICES, the sum of the HiFiData landings by species converted to live weight was still approximately 288,000t lower than that reported in ICES. More details on the outcome of this comparison are available in Chapter 2.

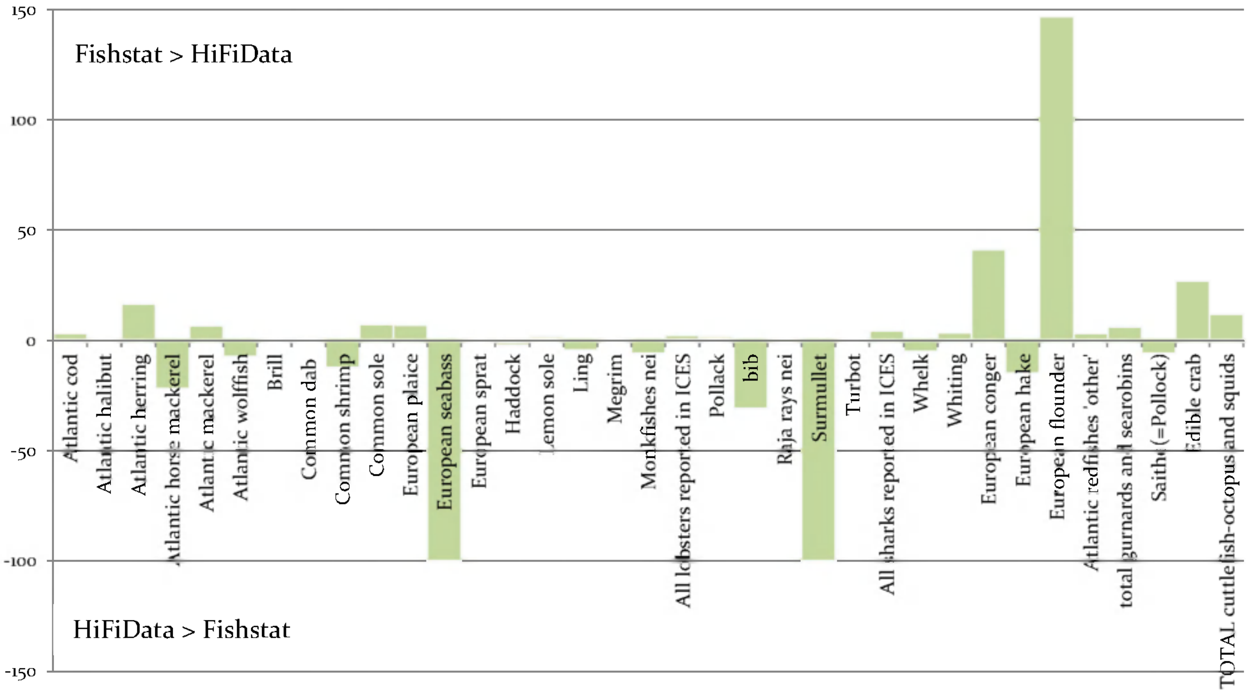


Figure 3.11: Discrepancy (%) between reported landings (t) in HiFiData and Fishstat, by species or aggregated groups of species (1950-1999). Positive values indicate higher reported landings in Fishstat, while negative values mean that the national HiFiDatabase (after conversion for fresh weight) reported higher landings (VLIZ 2009).

3.5. CONCLUSION

The efforts of data integration extended digitally available and detailed time-series on landings (by species, by fishing area, by port, per annum) with approximately 60 years. To our knowledge, and as far as the screening of literature, sources and archives have indicated, it was the first attempt in Belgium to collect, archive and integrate the available historical sea fisheries statistics. The added value for science and policy is summarized as:

3.5.1. DIGITISED INVENTORY AND ANNOTATED BIBLIOGRAPHY

The results of literature screening and inventory are digitally available and can be queried (by author, by keyword(s), by year of publication, other) in the online catalogue through the modular *Integrated Marine Information System IMIS* managed by Flanders Marine Institute VLIZ (VLIZ).

3.5.2. INTEGRATED DATABASE

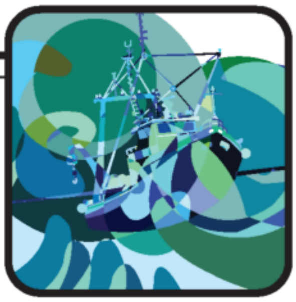
Data, graphs, maps and other products are accessible for end-users. In spite of the limitations inherent to the HiFiDatabase - many of which also apply to current data - it offers interesting advantages compared to the current ICES database: the temporal coverage (from 1929 onwards), the temporal scale (data on monthly landings and length classes available between 1941 and 1967) and the taxonomic level (few aggregated groups in reporting). The database contains data on the evolution of value (€) and average price (€/kg) at the species level, since 1929. The data rescue process and metadata (standards, methods, quality control) were described in an on-line 'Users Guidelines' and the integrated database made available for further research purposes. Reliability maps provide users with an indication of the relative reliability of the data. In the absence of catch statistics, integrated and quality controlled landing statistics can be used in a number of applications and models as a proxy for fishing mortality (Daan et al. 1994, Walker and Heessen 1996, Zeller and Pauly 2007, Eero et al. 2008) and for further analysis related to the setting of historical baselines.

3.5.3. ACCESSIBLE RESULTS IN AN APPROPRIATE FORMAT FOR POLICY LEVEL, SCIENCE AND THE INTERESTED PUBLIC

Data integration showed that total annual landings have continuously declined since 1947 to reach only 26% by 2008.The annual landings in 2008 were approximately 60% of those achieved in 1929. Being the only source of information on origin of landings, the database quantified the coastal waters as the most important fishing area for the Belgian sea fisheries (1929-1999). Given the importance of the shallow and productive coastal 'Flemish banks' as a source of food for Flanders in historical and recent times, this data is valuable for a qualitative and quantitative study of the historical and cumulative productivity of the ecosystem and the ecological impact of fisheries. The HiFiDatabase can serve as a basis for further research and analysis of fish stocks and provide background information for research on fisheries ecosystems.

ACKNOWLEDGEMENTS

The support of a many persons who contributed to this project by digitizing data, drawing maps, developing web applications is acknowledged on the Internet webpages of this project. P. Rogiest (Heritage Library Hendrik Conscience Antwerpen, Belgium), M. Vandermaesen, F. Strubbe and L. Vandeweyer (State Archives Belgium), provided expert assistance with the Archives. Prof. F. Volckaert (Catholic University of Leuven, Belgium), H.Polet (Institute of Agriculture and Fisheries Research-ILVO, Flanders), E. Tessens and M. Velghe (Sea Fisheries department, Flanders), W. Versluys (company owner), provided valuable references and expert advice.



CHAPTER 4: Fishing in the Past: the spatial dynamics of the Belgian sea fisheries during the 20th century

CHAPTER 4. THE SPATIAL DYNAMICS OF THE BELGIAN SEA FISHERIES DURING THE 20TH CENTURY

ABSTRACT

Historically, fleet dynamics have received less attention than the aspects of population dynamics in fisheries research. However, to understand trends in the volume of landings and changes in the catch per unit of effort and in the economic returns by the fleet, spatio-temporally explicit information is needed. The integration of historical time series on the landings and value of landings of Belgian sea fisheries, by fishing area, allows for a spatial analysis of broad-scaled historical preference of different Belgian fisheries for specific fishing areas. It documents changes in the relative importance of fishing areas for the Belgian fisheries as well as changes in composition of landings from within fishing areas over 8 decades (1929-2009) and underlines the historical importance of the 'coastal waters' to the Belgian fisheries. Finally, qualitative and quantitative statements about the spatial dynamics of Belgian fisheries in published sources are validated and, where not supported by our data, challenged. Some of the cause-effect relations that may explain the spatial dynamics of Belgian sea fisheries, are explored.

Key words:

Fisheries, Belgium, sea use, spatial dynamics

Manuscript, not submitted for publication

4.1. INTRODUCTION

In spite of being a relatively small fishing nation, Flemish fishers have exploited a diversity of fishing areas and travelled over long distances to increase their economic competitiveness and explore new opportunities. The cod fisheries to the Dogger Bank from the end of the 15th century, to the Faroer and Iceland from the 17th century, the fisheries in the Labrador and Barents Seas and in the waters of Portugal, Morocco and Spain in the early 20th century (Cloquet 1842, De Zuttere 1909, Poppe 1977) are examples of the long distance fisheries by a small nation's fishing fleet.

It has been documented that fisheries and their investments shift towards more distant areas once the stocks in nearby areas start to show signs of decline. This is the concept of expansive behaviour in fisheries, as described by Pauly et al. (1998), where unsustainable forms of fisheries tend to deplete one stock or area and move to the next in consecutive stages. The relation between fishing effort and the status of fish stocks however is complex, and environmental variables have a demonstrated effect on the recruitment and biomass of fish stocks, in particular in conditions of low biomass (Planque and Fredou 1999, Brander 2005, Payne et. al. 2009)

Reconstructions of historical biomass of stocks of commercial species through stock assessments typically go back until the 1960s (ICES Stock assessments and Annual Advice). Studies covering a wider temporal range mostly focus on particular species e.g. Atlantic cod, herring or plaice (Gulland 1968, Daan et al. 1994, Hislop 1996, Pope and Macer 1996, Bannister 2004, Cardinale et al. 2009a and 2009b) and fishing areas of interest, e.g. the North Sea or the Baltic Sea (Pope 1996, Rijnsdorp et al. 1996, Bannister 2004, Poulsen et al. 2007, Eero et al. 2008, Cardinale et al. 2009a and 2009b).

Historically, fleet dynamics have received less attention than the aspects of population dynamics (Hilborn 1985, Poos 2010). However, to understand trends in the volume of landings, in the catch per unit of effort and in the economic returns by the fleet, spatio-temporal explicit data on the fleet dynamics and fishing effort are required. Ideally the landings and fishing effort are known at the smallest spatial scale, by seasonal/monthly basis, and by métier (i.e. type of fisheries, target species, fishing gear and vessel class). Fishers use the seasonal variability in patterns of the target species' abundance and distribution to adapt their strategies of fishing effort in space and time, at the larger-spatial scale (Poos 2010). In the fisheries of the countries that operate under the EU Common Fisheries Policy CFP, it is safe to say that the quota system is an important determining factor that affects the way fishing effort is allocated at the scale of subdivisions in fishing areas. The quota also affect the rates of discarding, since vessels need to optimize their annual net revenues by continuously adjusting strategies on where to fish and what part of the catch to retain (Poos 2010). However, before the onset of quota, decision making probably relied on less complex management constraints in which indexes of catch rates per unit of effort, broad economic incentives and traditions played a proportionally more important role.

The objective of the present chapter is to document changes in the relative importance of fishing areas for the Belgian fisheries over time, as well as changes in composition of landings from within fishing areas over 8 decades (1929-2009). Potential cause-effect relations that may explain the dynamics of the Belgian sea fisheries at broader spatial scale are explored.

4.2. METHODOLOGY

4.3.1. DATA SOURCES AND DATA INTEGRATION

For Belgian fisheries, data on composition and value of landings at the species level were standardized and integrated for the period 1929-present (Lescrauwaet et al. 2010a). Earlier quantitative information with a spatial reference (e.g., Bestuursmemorialen 1815-1875, Cloquet 1842, De Zuttere 1909) is generally fragmented and disperse, and at a higher level of taxonomic or spatial aggregation. The resulting database (HiFiDatabase) spans 80 years of data by 41 species and 15 aggregated taxa, by month, by port of landing in Belgium (4 ports) and in 'foreign ports', and by fishing area of origin (21 georeferenced fishing areas plus the reported category 'other areas'). Lescrauwaet et al. (2010b) provide a detailed account of the data management, the quality control and the resulting data products. The HiFiDatabase also contains data on fishing effort and corresponding landings by fishing rectangle and data by fisheries type and by vessel class, from 1947-1983. Unique historical economic data on income and average price by species and by fishing area of origin, as well as by fish auction/port of call, are also included in the database. The economic data were standardized in Euro (40.34 Belgian francs per Euro) and expressed as values 2010 to account for inflation by correcting the data with the annual index. This allows comparing gross income and gross average prices spanning a period of nearly one century and taking into account economic parameters when interpreting trends in spatial dynamics of the fleet and fishing effort. The HiFiDatabase is managed by Flanders Marine Institute VLIZ and the data are available in the public domain through the Marine Data Archive (MDA, VLIZ).

4.3.2. COLLECTING SPATIAL INFORMATION ON THE BELGIAN SEA FISHERIES IN THE 19TH AND 20TH CENTURY

The spatial information related to effort and landings collected in the 20th century was recorded on paper logbooks kept on board, similar to the (electronic) logbooks that currently keep track of the activities of fishing vessels. Fishermen were obliged by law (the Royal decree of 26/05/1937 for vessels operating outside territorial sea, extended to fishing activities in all waters by the regent's decision of 20/10/1945) to register the catch by species and the catch was assigned to ICES statistical rectangles at least from 1947 onwards (1° longitude x 0.5° latitude corresponding to 30nmx30nm, Figure 1). Fish was classified on board, by species and length category and assigned to the main fishing rectangle of origin. A representative of the local maritime police ('*waterschoutsambt*') recorded the dates and hours of departure and arrival of fishing vessels in the ports by their immatriculation number. In this manner, effort (expressed as number of days at sea) was collected per vessel. In the fish auction, municipal officers kept accounts of all sale transactions as well as of landings that were rejected or withdrawn from the market. In this manner, detailed statistics were produced of the fish landings by species and length class, by statistical rectangle of origin, number of days and hours at sea and actively fishing, engine power (horsepower), vessel class, and number of vessels (Gilis 1959).

For reporting purposes this detailed spatial and temporal information was then later aggregated by month and by year and by fishing area. Finally the aggregated data was reported to ICES by year and by ICES subdivision (e.g. North Sea South IVc). Therefore the rich spatial information was unfortunately lost forever in the aggregation process (pers. comm. 25/01/2011 personal interview with Mr. J. Depreeuw, statistical officer at the National Institute of Statistics between 1953 and 1980s, in charge of Sea Fisheries Office from 1967). However, the efforts to reconstruct historical time series on Belgian sea fisheries disclosed previously uncovered monthly reports by statistical rectangle in the repositories of the Sea Fisheries Service. These statistical tables are available from 1947 to 1983 in 2 different reporting formats: one referring to rectangle, effort, fishing gear or type of fisheries and overall landings, and a second one providing general data on effort but detailed data on landings by species, per month and – for the commercially most important species – by weight class.

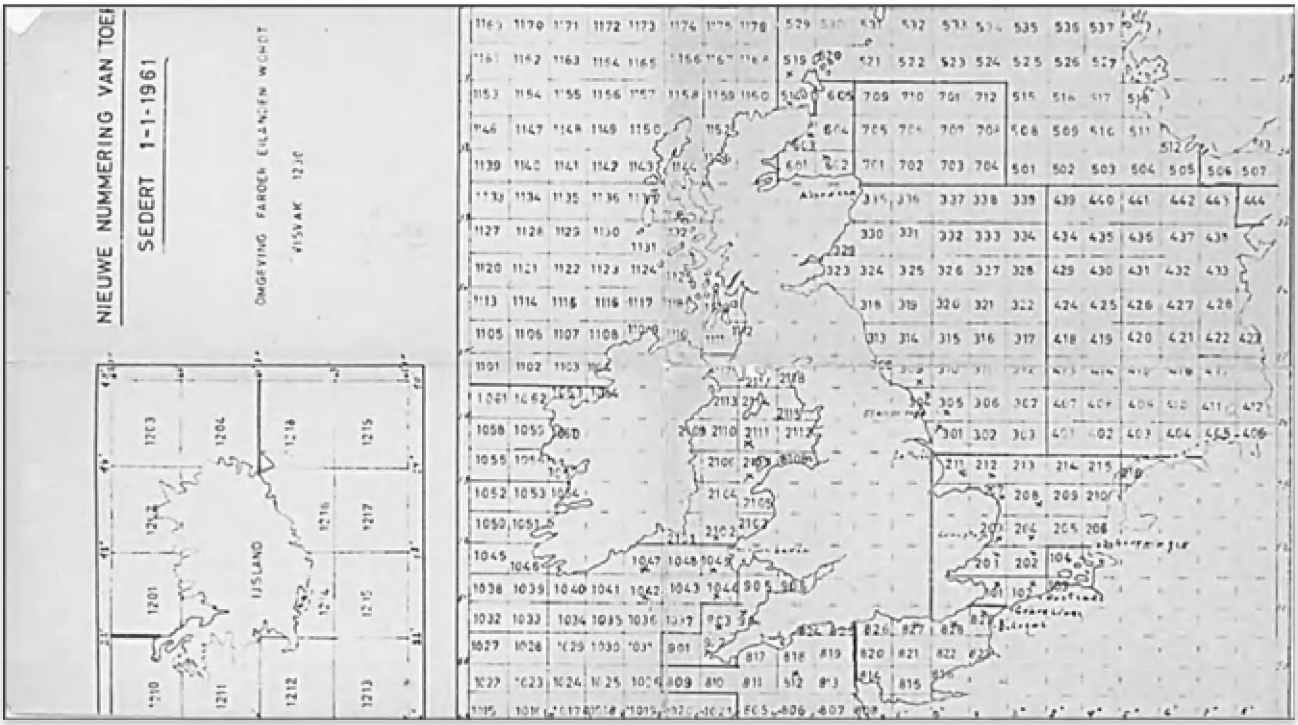


Figure 4.1.: Geography and boundaries of the statistical rectangles as reported in the national data uncovered and integrated in the HiFiDatabase (1947-1983).

4.3.3. The geography of reported spatial data on Belgian sea fisheries in the 20th century

Standardization of fishing areas and boundaries is a prerequisite for the integration of data at the spatial scale. However, in the historical reports on sea fisheries, the coordinates of the larger aggregated spatial units or 'fishing grounds' are not explicitly identified and fishing areas changed names over time or disappeared (temporarily) from the statistics. Maps and metadata issued for specific years were used as anchor points to reconstruct the boundaries of these spatial reporting units. After standardizing, 29 areas (including the non-spatially-explicit 'other areas') of the 41 different fishing areas that were reported in the period 1929-1999, remained. The geography of these fishing areas during the 20th century was reconstructed on the basis of formal reports and historical maps that explicitly refer to the sea fisheries context (Figure 4.2. and Table 4.1., see Manual for a summary http://www.vliz.be/imis/imis.php?module=ref&refid=141768). The fishing areas coincide largely with the ICES subdivisions. However, a number of important differences and advantages are noted:

The 'Coastal waters' (located in ICES subdivision IVc), the North Sea central-east and the North Sea central-west (located in ICES subdivision IVb), Moray-Firth and Fladen (located in ICES subdivision IVa) are not separate ICES spatial reporting units and they provide a unique level of spatial resolution in historical Belgian sea fisheries statistics. The boundaries of the fishing area 'Coastal waters' were delineated at 20-30 nautical miles (37 km) from the shoreline since they broadly coincide with two ICES statistical rectangles 102 and 103 (Figure 4.1.). These unique and additional spatial reporting units situated in the subdivisions IVc, IVb and IVa in the HiFiDatabase also represent the historically most important fishing areas as sources for fish products.

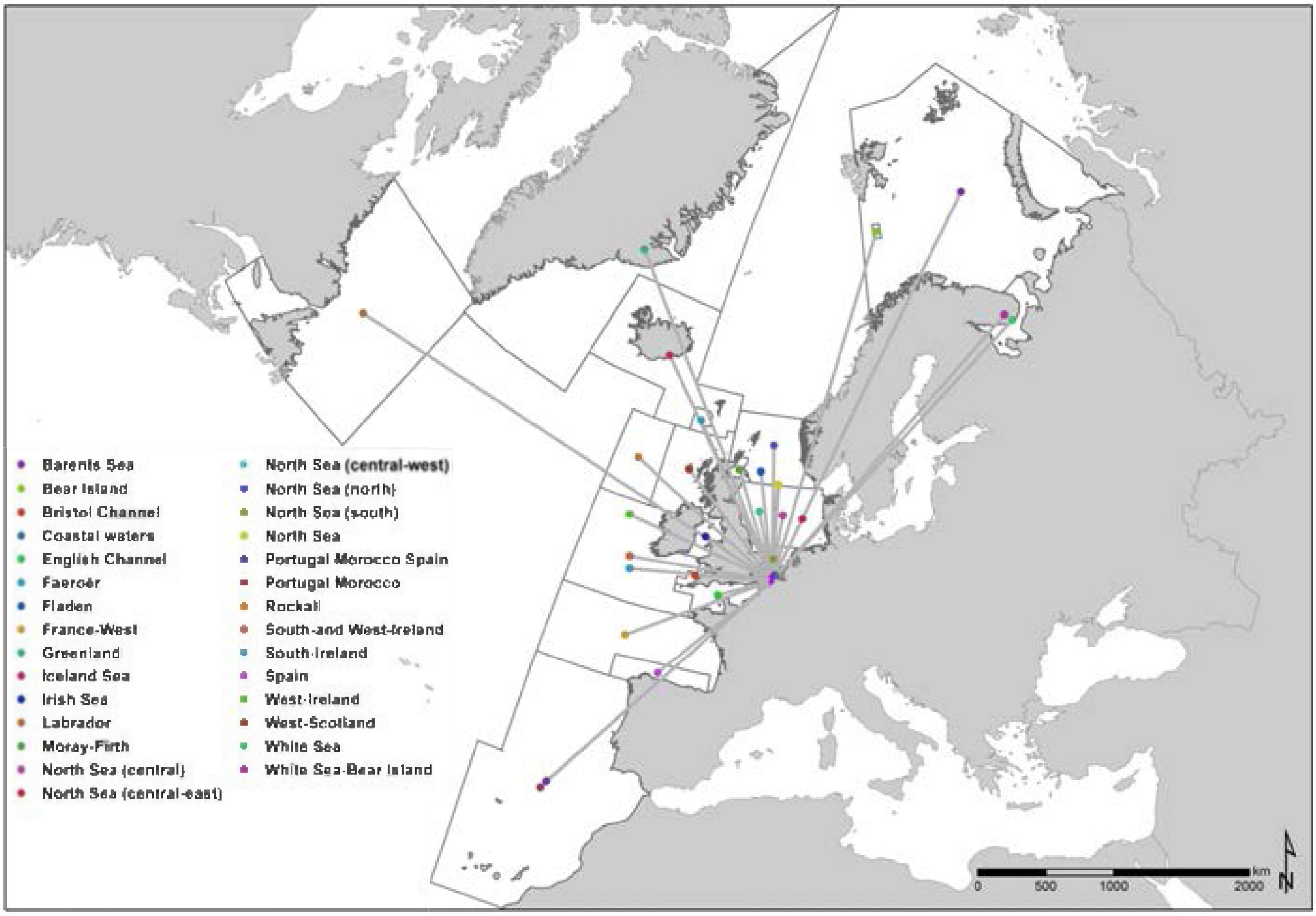


Figure 4.2.: Geography and boundaries of the 29 reported fishing areas of Belgian sea fisheries (1929-1999) with centroïds of the shapes. Note: in historical sources in the UK, Barents Sea and White Sea were used as synonyms to indicate the same fishing area.

To look at the evolution of 'distance from port', an indicative value of overall tonne-kilometres (tkm) was calculated as an indicator of 'sustainability' of the fishing activities (Figure 4.9.). For each year, the annual landings (t) from each fishing area (all species) were multiplied by the average distance (km) to the centre of the Belgian coast (Oostende). Distances are calculated as a straight line between the centroid of the fishing area (shape) and Oostende, probably inducing an underestimate for the tkm from distant waters.

The landings from the Belgian fleet sold in foreign ports are reported as an aggregated unit 'foreign ports' and can not be pinpointed to a particular 'foreign port'. Therefore, no distance to fishing area can be calculated for these landings and they were not included in the calculation. Landings in foreign ports make up for an average 10% of all landings by the Belgian fleet.

Table 4.1.: Overview of the 29 reported fishing areas (shapes), centroïds of the shapes and their coordinates, distances (km) from the centroïds to the centre of Belgian coastline (Oostende) and area (km^2). (*) Note: to view the areas in the VLIZ Marine Gazetteer VLIMAR, replace the ID number in the link of the Marine gazetteer in the example below (Coastal waters) http://www.vliz.be/vmdcdata/vlimar/vlimar.php?p=details&id=24504, by the ID number of the fishing areas as in the table.

Fishing areas, Standard Names	Latitude	Longitude	Distance (km)	Area (km^2)	Gazetteer link *
Bristol Channel/Kanaal van Bristol	50,81	-5,20	570	18726	24503
West-Ireland/West-Ierland	53,53	-13,78	1159	123641	24517
Irish Sea/Ierse Zee	53,46	-4,92	587	49937	24501
Portugal Morrocco Spain/Portugal Marokko Spanje	35,02	-13,82	2227	1803322	24514
West-Scotland/West-Schotland	57,49	-8,63	1020	235785	24518
Rockall	57,20	-15,00	1335	220423	24515
North Sea (north)/Noordzee (noord)	60,06	1,41	988	215673	24511
Fladen	58,28	0,17	805	35259	24498
Moray-Firth	58,17	-2,54	849	15837	24506
English Channel/Engels Kanaal	49,80	-2,47	412	89388	24496
Coastal waters/Kustzee	51,62	3,16	48	8411	24504
North Sea (south)/Noordzee (zuid)	52,66	2,84	160	55138	24512
North Sea (central-east)/Noordzee (midden-oost)	55,46	5,73	508	151456	24508
North Sea (central-west)/Noordzee (midden-west)	55,69	0,65	520	127090	24509
Faeröer / Faroe	60,77	-8,84	1285	20750	24497
Bear Island/Bereneiland	74,44	19,01	2678	5414	24495
White Sea/Witte Zee	66,20	39,08	2605	87362	24519
Barents Sea/Barentszzee	75,27	42,44	3180	2012754	24494
Labrador	53,99	-52,33	3592	1460267	24505
Spain/Spanje	43,97	-6,76	1081	92775	24516
Portugal Morrocco/Portugal Marokko	34,53	-14,16	2289	1710547	24513
Iceland Sea/IJslandzee	64,17	-16,21	1816	553305	24502
North Sea (central)/Noordzee (midden)	55,59	3,42	488	278546	24510
White Sea-Bear Island/Witte Zee – Bereneiland	66,73	38,30	2596	92776	24520
North Sea/Noordzee	57,60	2,44	710	494219	24507
South-Ireland/Zuid-Ierland	50,16	-11,97	1053	415734	24522
South-and West-Ireland/Zuid- en West-Ierland	50,94	-12,37	1065	539375	24521
France-West/Frankrijk-West	45,88	-10,58	1152	581938	24499
Greenland/Groenland	69,56	-28,78	2607	1322045	24500

Indices of biological diversity are used to measure and compare biological diversity between samples to compare e.g. areas or periods. Hill (1973) developed a suite of diversity indicators in which the importance of rare species declines as the order of the index increases. The index N_0, refers to the number of species irrespective of their relative abundance in the sample, whereas N_{infite} is the inverse (1/x) of the relative abundance (x) of the most abundant species, hence assigning no importance to less abundant or rare species. N_1 (exponent of Shannon-Wiener index) and N_2 (inverse of Simpson's index) provide intermediate measurements. Applied to landings by fishing area, the indices reflect fisheries preference behaviour rather than measuring a relative biological diversity of an area. The landings are to be considered as subsample of the true diversity and one which is 'biased,' i.a., by the fishing gear and the behaviour and decisions of the fisher.

Box plots were used to compare relative importance of fishing areas over the study period, or compare the relative importance of species within particular fishing areas, and to conduct an exploratory analysis of outliers, medians and quartiles. The TWINSPAN program was used to explore distinctive features or species diversity between fishing areas.

4.3. Results: Spatial analysis of the Belgian fisheries in the 20th century

4.3.1. The relative importance of fishing areas as source of food and income over the years

Fishing areas were exploited with different degrees of intensity (fishing effort, gear and technique) and over different time slots (annual and seasonal fluctuations). While larger areas were disaggregated in the reports as their commercial importance increased, others were merged or disappeared from the statistics as they became less important. The nearby fishing areas (Coastal waters, North Sea south, North Sea central-west, North Sea north) and the western waters (Bristol Channel and English Channel, South-and West-Ireland) appear almost continuously throughout the reporting period. The activities in the Iceland Sea, which dated from at least the 16^{th} century (De Zuttere 1909) ceased completely in 1995 (Lescrauwaet et al. 2013 under review). The Barents Sea and the waters off Rockall were reported for 6 years, whereas other areas did not appear in more than 5 annual reports, e.g. Greenland, Faroer, Labrador, West-France and White Sea - Bear Island. In historical sources in the UK, Barents Sea and White Sea were used as synonyms.
Besides the overall number of reported calendar years of exploitation since 1929, it is also interesting to look at the continuity in the fishing activity in a certain area, i.e. the number of periods of uninterrupted fishing in the area (Figure 4.3.).

While 5 areas were exploited for less than 5 years, 10 fishing areas were reported during more than 50 years. From these, 5 areas have provided fishing products continuously except during the Second World War (WWII, 1939-1945). When taking into account the WWII statistics (Lescrauwaet et al. 2013 under review) the 'Coastal waters' were the only continuous providers of demersal and pelagic fishes, molluscs and crustaceans. Although e.g. the Fladen and the Irish Sea both appeared in the statistics in 39 years, Fladen was discontinuously exploited while the Irish Sea was continuously exploited during 39 years from 1961 (Figure 4.3.).

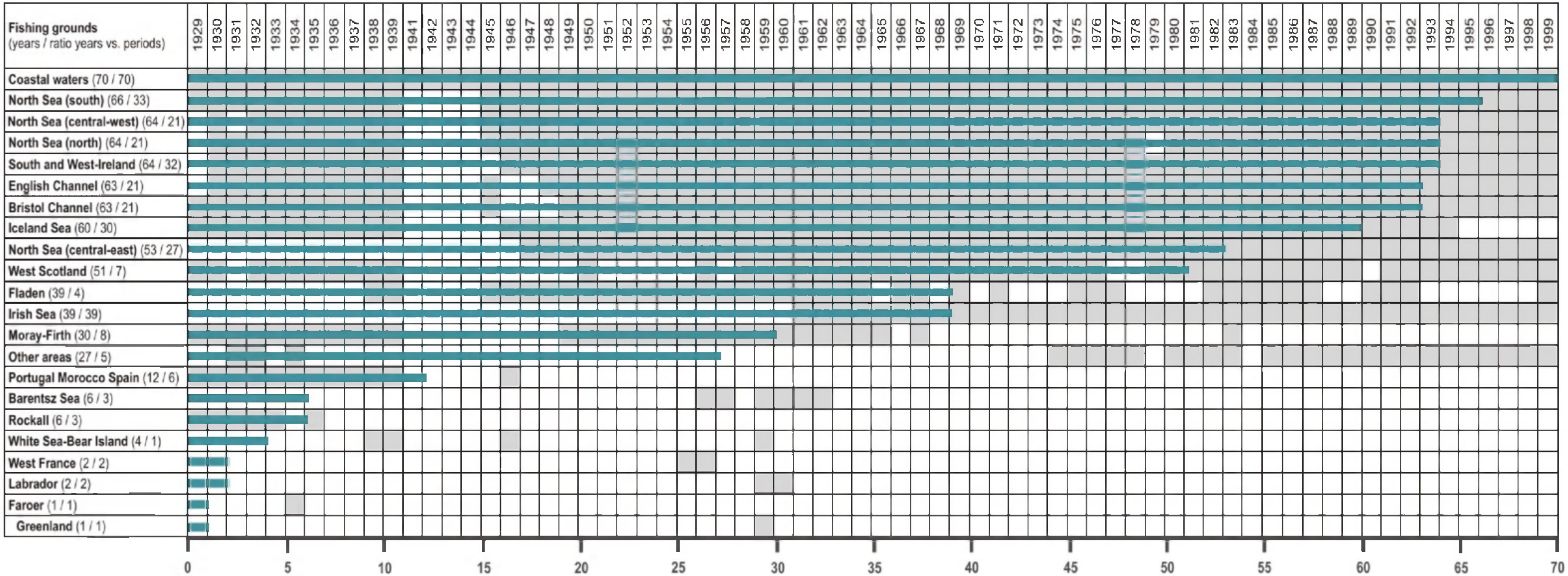


Figure 4.3.: Fishing areas as reported by year (black rectangles, by chronological order in upper x-axis, 1929-1999) in the official annual landing statistics and the total number of years in which landings were reported for a fishing area (white horizontal bars, bottom x-axis 1-70 years, see also the numbers between, brackets in the first column).

4.3.2. Observed trends in annual landings of the Belgian fishing fleet by area of origin (1904-2010)

In the reconstruction of the time series of landings of the Belgian sea fisheries by fishing area of origin for the period 1904-2010, data from 1904-1929 are incomplete and not standardized and therefore not integrated in the HiFiDatabase. However, for the purpose of visualization of the main trends, they are included (Figure 4.4.). From the beginning of the 20th century until the outbreak of the First World War (WWI, 1914-1918), reported landings originated mainly from the 'North Sea' (sic) and to a lesser extent from the 'southern coast of Ireland', the 'Iceland Sea', the 'Gulf of Biscay' and the 'English Channel'. Total annual landings in the pre-WWI times fluctuated between 10,000 and 15,000 t.

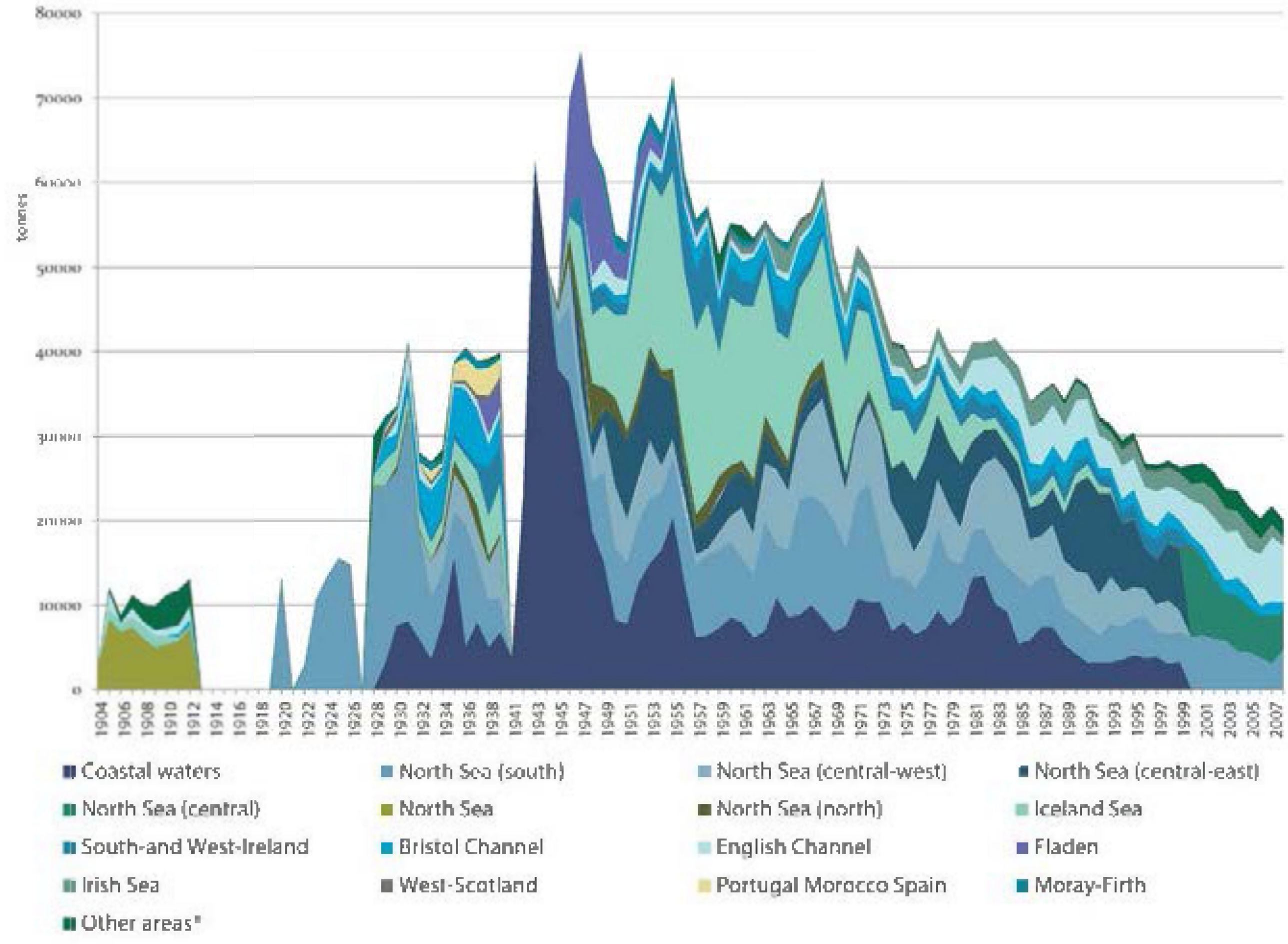


Figure 4.4.: Annual total landings (t) of Belgian sea fisheries in Belgian and foreign ports by fishing area of origin in the 21 fishing areas (+'other areas') in the period 1904-2010. Data 1929-1999 are provided by the HiFiDatabase (2009) and complemented with partial information for the period 1904-1913 (ICES Annual reports; De Zuttere 1909). Data for the period 1920-1928 are based on the surveys conducted by Gilson and reported to ICES. Flanders Fisheries Service (Dienst Zeevisserij) provided the recent data 2000-2010.

During the WWI, information on fishing activity is anecdotal: a witness reports that fishing in Belgian waters was practically impossible between October 15, 1914 and May 19, 1916 (Vermaut 1998). After WWI, landings quickly increased again to the pre-war levels of 12,000-15,000 t. Data for this period (1920-1926) are preliminary statistics limited to the port of Oostende only. However, in the first decade of the 20th century other data sources confirm that Oostende accounted for approximately 70% of all Belgian landings of fresh fish and 100% of salted cod (De Zuttere 1909). The 1920-1926 data confirm that landings were predominantly from the fishing grounds of the 'North Sea south', without distinction of the 'coastal waters' as separate reporting entity (Figure 4.4.). The scarce metadata suggest that before 1929, landings from coastal waters were not reported as such but either aggregated as 'North Sea' or 'North Sea (south)'.

From 1928 onwards the importance of the nearby fishing areas (North Sea south) gradually declined and fishing areas diversified to Iceland and the 'western waters' (West-Scotland, South-and West-Ireland, the Bristol Channel) between 1934 and 1939 (Figure 4.4.). With the outbreak of WWII, fishing was exclusively restricted to the 'Coastal waters' and yielded unprecedented quantities of herring, besides sprat, and to a lesser extent plaice, and brown shrimp. The WWII data were obtained from previously unknown government reports with detailed monthly statistics and are not available from ICES or other sources (Lescrauwaet et al. 2013 under review).
By the end of the WWII, 10% of the landings originated from the North Sea (south) and after WWII fishermen quickly turned to the 'western waters' again. Between 1950 and the mid 1970s, the most important observed trend was the increase of landings from the 'Iceland Sea'. The 'North Sea central-west', the 'North Sea central-east' and the western waters could not make up for the losses once fishing in the 'Iceland Sea' was restricted through the 'modern cod wars' and enforced by law after 1972 (Omey 1982). The instalment of fishing restrictions and quota through the EU Common Fisheries Policy CFP from 1983 onwards leaves less room for fluctuations in the relative importance of fishing areas.

The exploitation of the fishing areas follow different patterns. In terms of total landings for 1929-1999, the 'Coastal waters', 'Icelandic Sea' and 'North Sea-south' show bell-shaped curves. Note the gradual increase and decline in the 'Iceland Sea' and the outliers in the 'Coastal waters' and 'Fladen' (Figure 4.5., Upper panel). The patterns of fishing effort are expressed as 1000HP*Fishing Hours (Figure 4.5., Lower panel). They suggest the proportionally high fishing effort conducted in the southern North Sea compared to the landings obtained from it. Note the increase in fishing effort in the Irish Sea and the English Channel towards the mid 1980s

The evolution of the total landings by fishing area does not reflect the underlying trends at the species level. These trends are determined by a complex mechanism driven by market and fleet dynamics for each of the different fisheries and is flavoured by the fishermen's tradition, the state of the fish stocks and –especially after 1983 also by fisheries management and quota setting. These complex relationships are broadly explored in the current paper and the economical data that were integrated in the HiFiDatabase are made accessible for further research, from the website: http://www.vliz.be/cijfers_beleid/zeevisserij/list.php

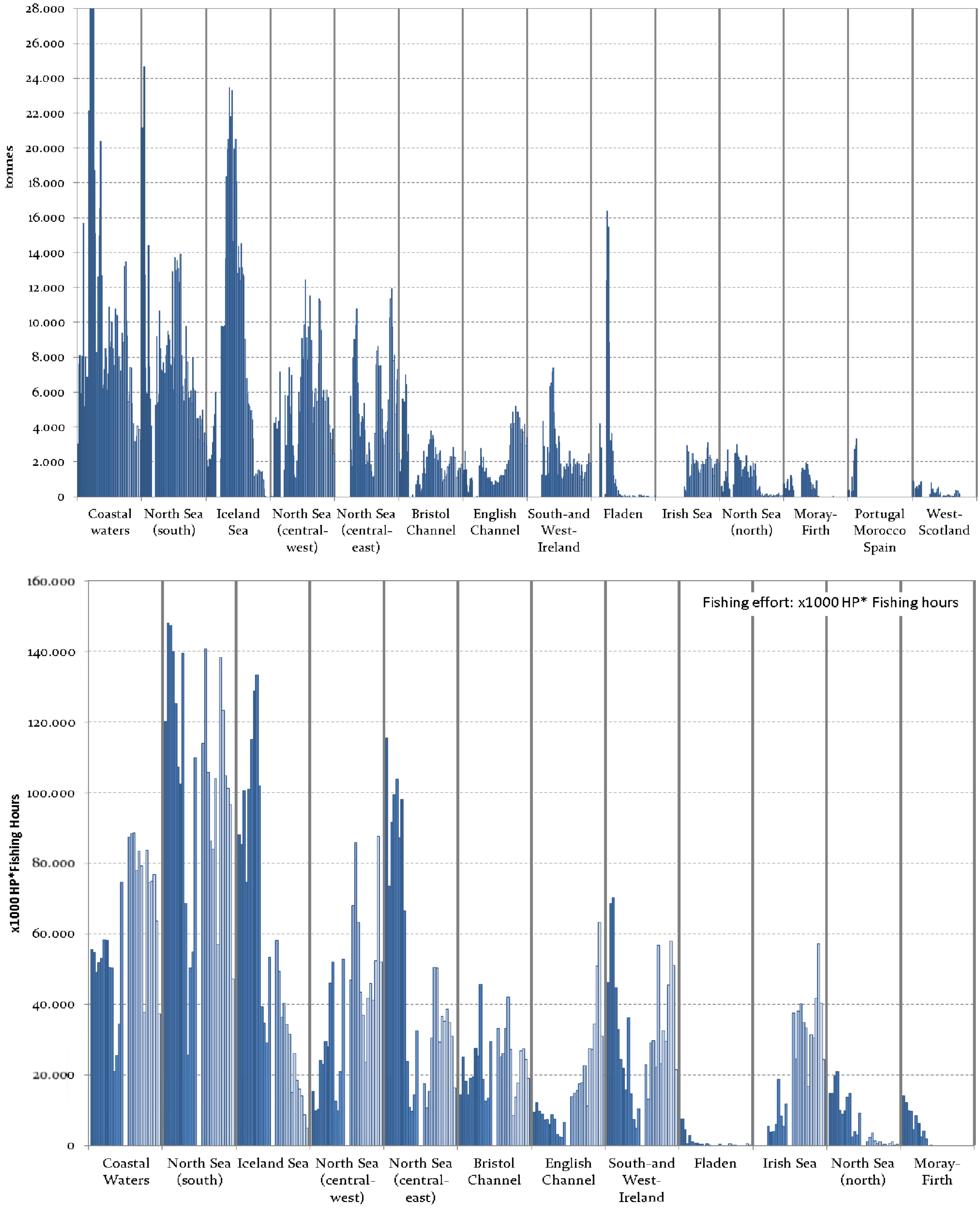


Figure 4.5.: Upper panel: Trends in total reported annual landings (t) for the 14 most important fishing areas, Belgian sea fisheries (1929-1999). Fishing areas are ordered according to decreased overall landings, x-axis denotes years, by fishing area. Note that the y-axis is cut off at 28,000t for improved visualisation of scale. Landings from Coastal waters peaked in 1943 with approximately 62,000t. **Lower panel**: Trends in fishing effort (x1000 HP*Fishing hours) from 1950 to 1983. Note the decrease in Icelandic waters and the increase in the English Channel and Irish Sea.

4.3.3. ECONOMIC IMPORTANCE OF FISHING AREAS

Gross value (Euro) of income

A fishing area may have acquired a relatively higher economic importance over time because of the absolute volume of landings it generated, because of the high proportion of high-valued species obtained from it, or a combination of both. Examples of the first are the Coastal waters or the North Sea south with important landings of herring and plaice while the Irish Sea and the English Channel are examples of the latter, with important catches of sole. The total nominal value of these landings (1929 until 2010) amounted to 3.1 million EUR which corrected for inflation (expressed as Euro values 2010) represented 6,9 million EUR. This excludes the value of income during World War II, a period for which no indexes are available to correct nominal values and calculate these in current values (Lescrauwaet et al. 2010). While the peak in landings (t) occurred in 1947, the annual gross income (expressed as Euro values 2010) generated by the Belgian fisheries steadily increased after 1950, peaked in 1987 and 1991 and declined afterwards (Figure 4.6.). In spite of the decline in landings, the gross value of income was compensated by the increase in market value for some species, and by increasingly targeting higher-priced species such as common sole (*S. solea*).

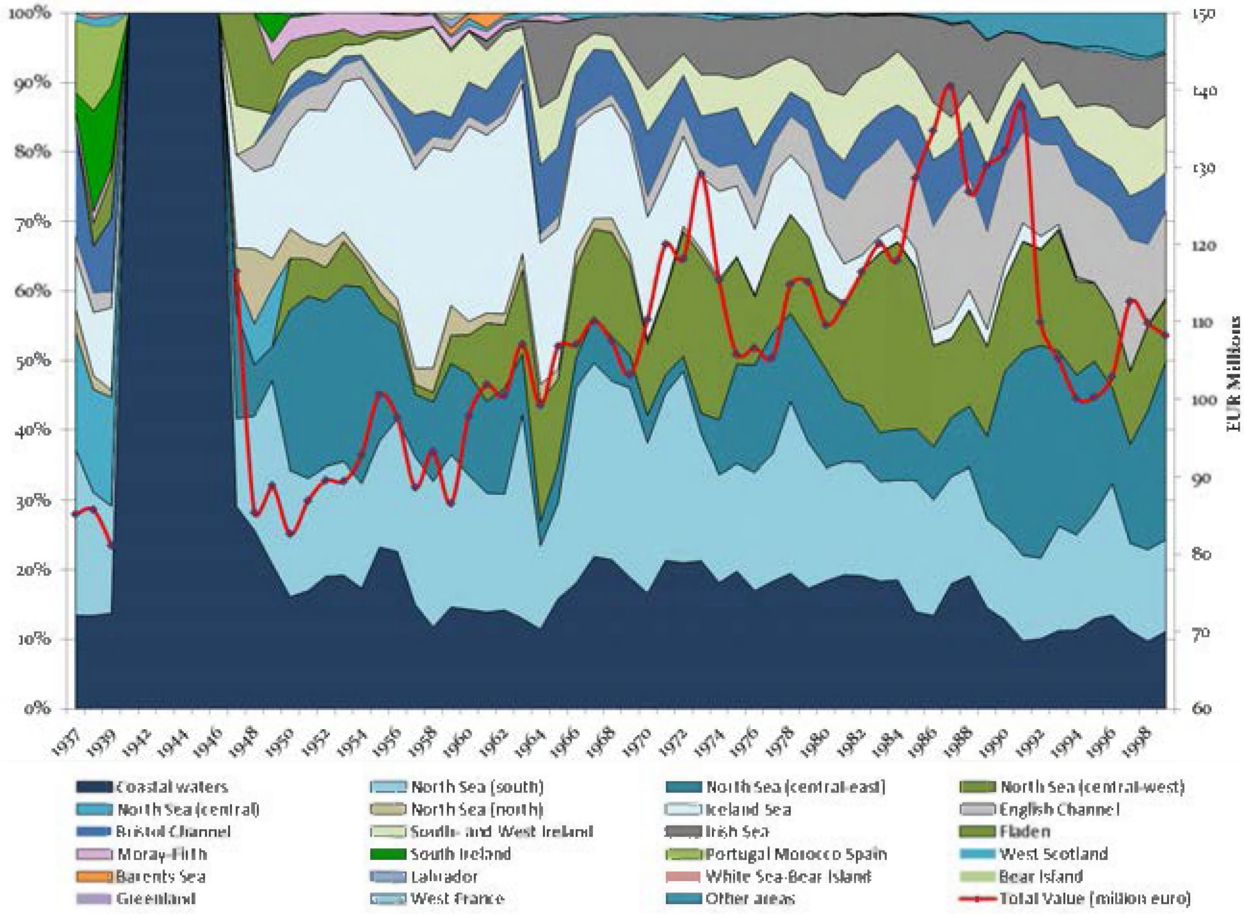


Figure 4.6.: relative economic importance (%) of fishing areas 1937-1999, based on the values of gross value of income (Euro values 2010), and trend in gross value of income (red line, Euro values 2010).

The 5 economically most important areas make up for 70% of the total income over the observed period: North Sea south (18%), Coastal waters (17%), North Sea central east (12%), Iceland Sea (11%) and North Sea central west (11%). The total generated gross value of income (x1,000 Euro values 2010) and total generated volume (t) by fishing area are placed in perspective by visualizing the proportion (%) of the total landing/value they represent over the entire period.

The summed absolute volumes (t, white bars) and values (grey bars) for the 14 most important fishing areas are compared (Figure 4.7.). In a relative perspective, the white squares indicate the proportion of the total landings that were obtained in each of the areas, while the triangles refer to % of total value (expressed as Euro values 2010).

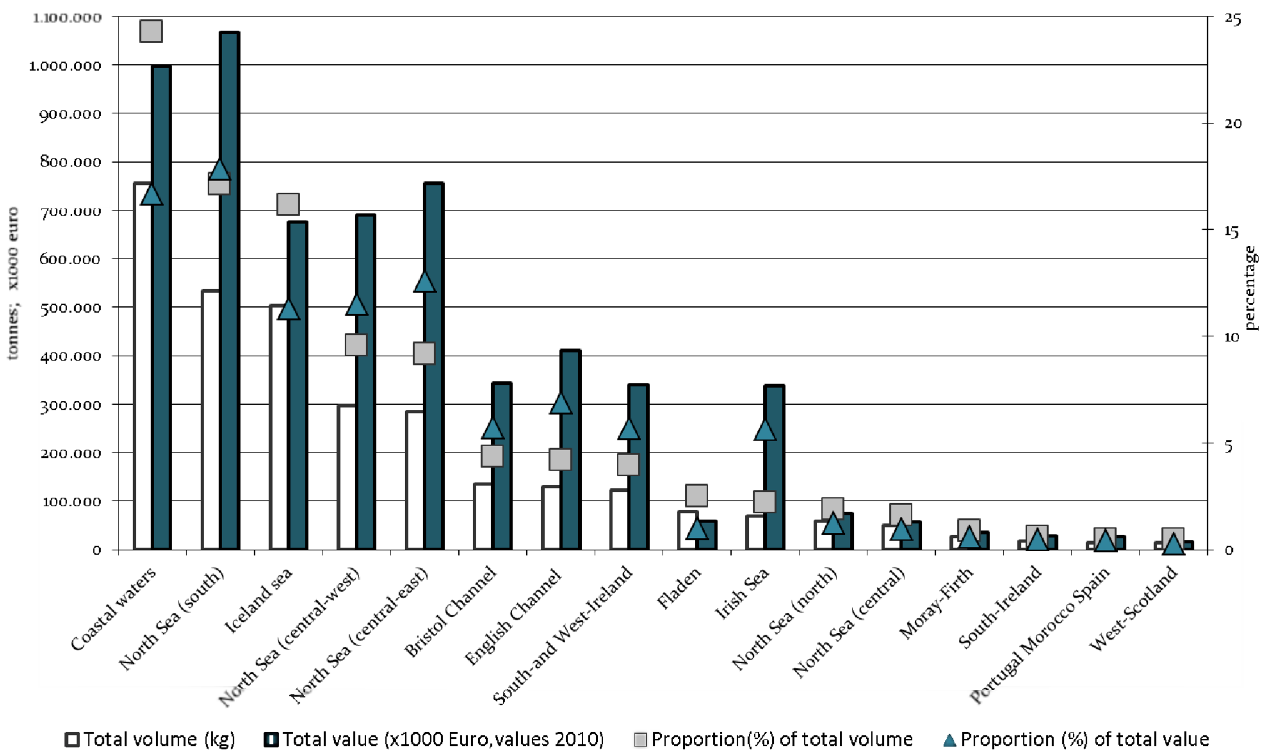


Figure 4.7.: Relative importance of the fishing areas in terms of landings (tonnes) (white bars, left axis) and gross values (x1.000Euro corrected for inflation, values 2010, blue bars, left axis). Gross values of income and landings are also shown as a proportion (%) (volumes as grey squares and values as blue triangles). Values for Coastal waters are underestimated because of their economic importance during WWII, a period for which no indexes are available to correct for inflation.

The graph suggests that some areas have generated relatively higher value by unit of volume. Fishing areas for which triangles are above boxes (e.g. Irish Sea), typically sustain fisheries on higher-values species such as sole, turbot.

4.3.4. MARKET VALUE (EURO/KG) AS A DRIVER FOR HAULING LONG DISTANCES

In terms of average market value of species, the Irish Sea (4.9€/kg), the English Channel (3.2€/kg), the Bristol Channel (2.5€/kg), South-West Ireland and the North Sea (central-east) (2.6€/kg) overall have generated higher-valued species (Figure 4.8., all species averaged, all years). The opposite is true for the Coastal waters (1.3€/kg), Fladen (0.8€/kg), North Sea north (1.3€/kg) and the Iceland Sea (1.3€/kg) where proportionally larger volumes were obtained from species that at that time had a proportionally lower value (herring, cod).

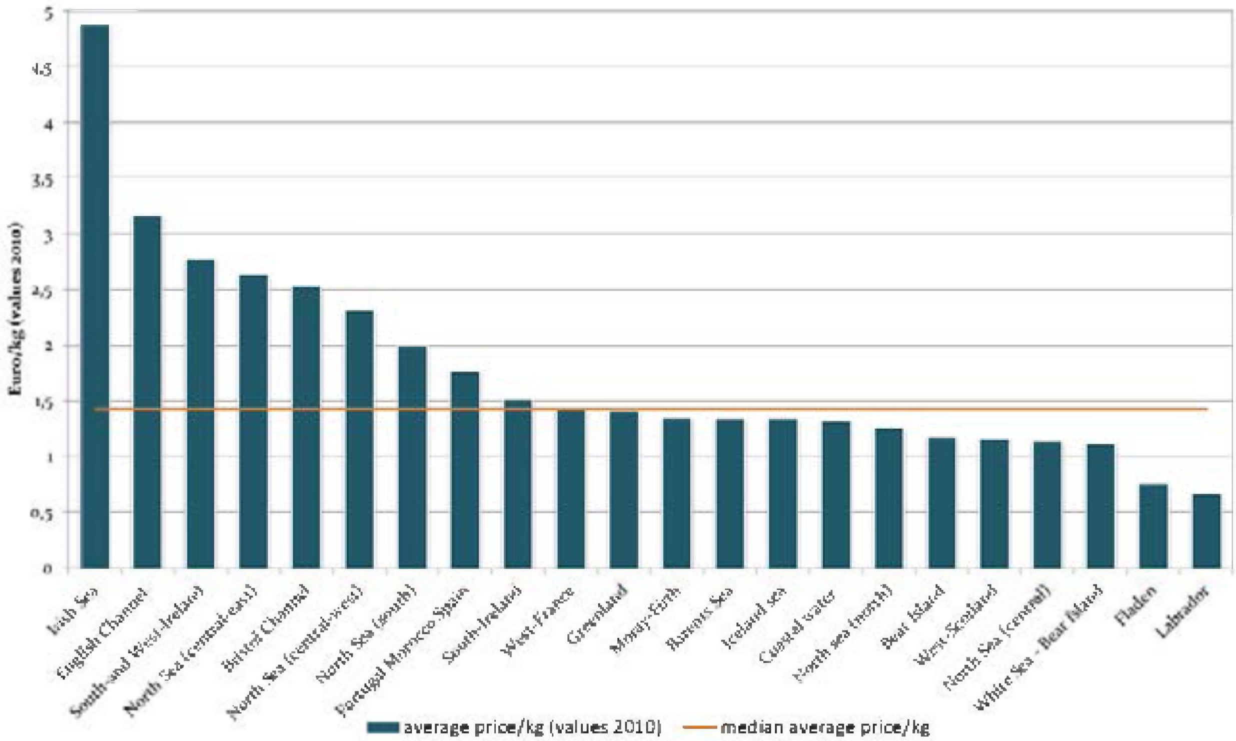


Figure 4.8.: Average value €/kg (prices 2010) of all species for all years (1929-1999) by fishing area.

As the cost of fishing increases with the distance to the harbour e.g. the cost of transit time and fuel (Sampson 1991) one would expect that at increasing distances successful fisheries either pursue a landings-maximization driven by higher catch rates per unit of effort, or a profit-maximization strategy driven by higher or increasing species market value (Hilborn and Walters 1987, Gillis et al. 1995). A graphical analysis of the trends of single species market values (€/kg) for the most important species (sole, plaice, cod, herring) in the HiFiDatabase over the observed period suggests that inter-annual differences in market values within specific fishing areas, exceed or at least compare with the differences between fishing areas within a specific year. Also there is no observed relation between years with higher market values (€/kg) for a particular fishing area and increases in landings from that area or vice versa. With the present spatio-temporal resolution, the data do not seem to indicate differential pricing mechanisms that could stimulate fisheries in a way to prefer a particular fishing area over another for a particular species. Therefore, at least at the spatio-temporal scale of the present analysis - and before the on-set of the EU quota system - market value does not seem to fully account for

observed spatial dynamics of fisheries. Future analyses of monthly statistics and statistics for differential pricing of length classes by species in the HiFiDatabase may shed more light on decision strategies in fishing.
There are particular cases however where the data quantitatively confirm sources that indicate an offer-demand mechanism (see Discussion). In general however, the dynamics of spatio-temporal allocation of fishing effort within a particular type of fishery is expected to be explained mostly by mechanisms related to optimizing indices of catch per unit of effort, in particular in the current conditions of stringent output control (Poos 2010, van Ginkel 2007).

4.3.5. TONNE-KILOMETRES AND TONNES PER HECTARE: MEASURES OF SUSTAINABILITY AND PRODUCTION

The cost of fishing in distant fishing areas is translated as additional costs of days at sea (staff cost, insurance, food, engine hours) and the increased cost of fossil fuels. Distance to fishing areas is therefore expected to be one of the important factors in the decision making of allocating fishing effort in space and time.

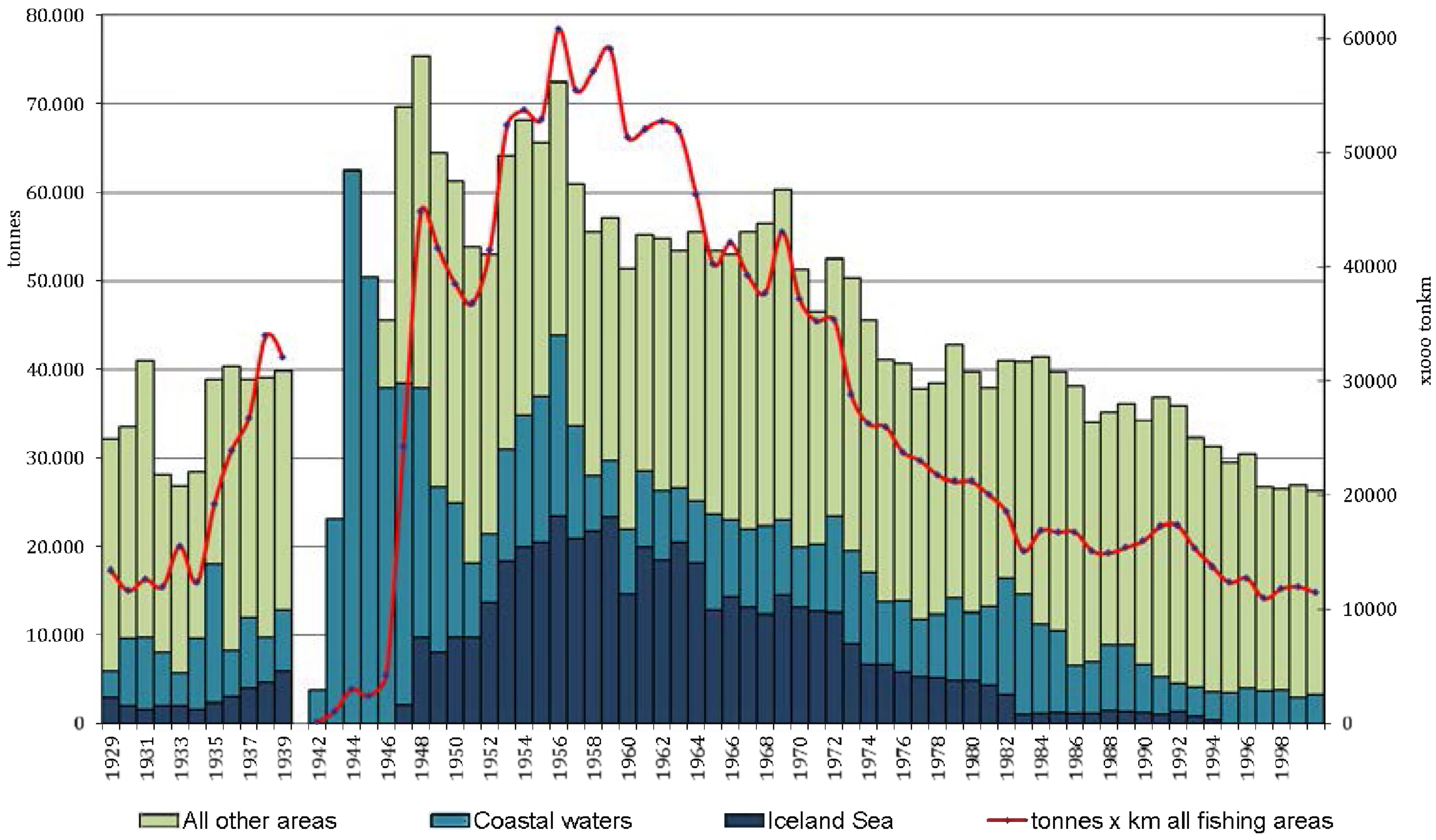


Figure 4.9.: The annual tonne-kilometres of the Belgian sea fisheries, red line (values in right-hand axis), calculated as the sum of the annual landings per fishing area *a* (tonnes) multiplied by the km distance to the centre of the fishing area *a*. The columns represent the overall annual landings per year (tonnes, left-hand axis)) for the distant 'Iceland Sea' (dark blue), the nearby 'Coastal waters' (median blue) and the remaining reported areas as 'all other areas' (light green).

The tonne-kilometre (tkm) is a unit of measure of goods transport which represents the transport of one tonne by road or overseas, over one kilometre (EUROSTAT definition). Although it is used as a measure of expenditure to transport, it is also used as an indicator in a context of moving towards sustainable development. Total tkm show a steep increase from an average 13 million up to 33 million tkm per year just before the outbreak of WWII, in a period in which overall landings remained stable, indicating seafood was increasingly being caught in distant waters (Figure 4.9.). In effect, up to 1933 most of the landings originated from the Coastal waters and the southern North Sea whereas other fishing grounds (e.g. Iceland Sea and the areas around Portugal Morocco and Spain) became more important from 1934 onwards. The importance of the nearby 'Coastal waters' during WWII generated a remarkably high amount of landings with an unprecedented low tkm (1-3 million tkm). Interestingly, the second peak in overall landings (1955, see Figure 4.4.) was generated by a proportionally much higher tkm (61 million tkm) than the similar first peak in landings in 1947 (45 million tkm). Whereas the first peak is still largely explained by the exploitation of nearby fisheries in the southern North Sea and coastal waters, the second peak is mainly explained by the increased landings from the Iceland Sea. After 1955, the proportional 'over-investment' of efforts in distant waters maintained the tkm at high levels while the overall landings already started an irreversible decline. The fisheries on distant grounds (e.g. 'Iceland Sea') however, remained important until the middle of the 1960s. From the end of the 1960s the overall tkm continuously declined and since the beginning of the 1980s, under the influence of the CFP, tkm are more closely correlated with the landings. By the end of the 20th century, and in spite of the considerable technological development in fleet and gear, the situation looked quite similar to that in the years after the First World War.

Fishing areas are also compared for their 'production', expressed as kg landings per unit of area (hectares). Smaller fishing areas such as the 'Coastal waters' (1.000kg/hectare), the 'North Sea 'south' and the 'Bristol Channel' (100kg/ha) have supported substantially more productive fishing as compared to other areas (Figure 4.10.). These values do not take into account the extent of years during which a fishing area was exploited, the dedicated fishing effort in, or the nearness of the fishing ground.

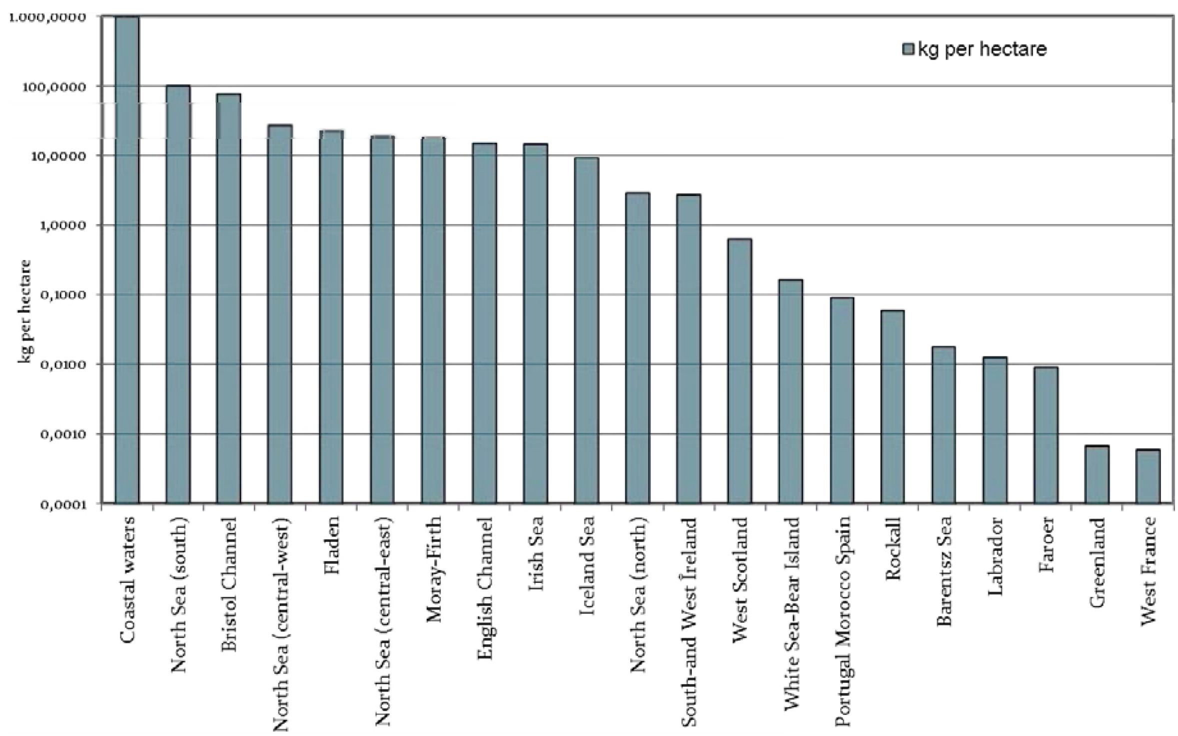


Figure 4.10.: An index of historical 'production' of fishing areas (expressed as the total amount of harvested kg per unit of hectare) (bars). Note the primary axis is in logarithmic scale.

4.3.6. DIVERSITY OF CATCH AND LANDINGS FROM DIFFERENT FISHING AREAS

Fishing areas were also compared by looking at the diversity and relative abundance of species in the landings originating from these areas, and the trends in this diversity over the years. While some regions may attract particular fisheries because of their characteristics as habitat for particular species or groups of species, others may be exploited because of commercial commodities (e.g. nearness of processing facilities and servicing). Still, provided the necessary cautionary approach in interpretation, the trends in the species diversity in the landings from specific fishing areas may indicate latitude/longitudinal shifts of species over time (Pinnegar et al. 2010, Kerby et al. 2013), as well as patterns of exploitation over time, e.g. an initial phase of highly selective fisheries may be followed by a diversification.

For 13 of the 22 fishing areas, overall species richness (N_0) in the landings is above 40 species out of a maximum 46 species. The areas that generated landings with significantly lower species richness N_0 (West-France, White Sea-Bear Island, Barents Sea, Faroer, Labrador and Greenland) were exploited for 6 years or less. Although the landings from the fishing areas 'Bristol Channel' and 'South- and West-Ireland' have similar number of species compared to other areas (e.g. North Sea south, North Sea central-east and central-west), they have higher N_1, N_2 and N_{inf} indices values and therefore the composition of landings was more diversified. This is also confirmed by the K-dominance plot (not included here). It is important to underline that the indices reflect fisheries preference behaviour rather than measuring a relative biological diversity of an area, as they are measuring the diversity of a subsample of the true diversity and one which is 'biased,' i.a., by the fishing gear and the behaviour and decisions of the fisher.

A similar comparison was conducted over 4 periods, the boundaries of which were chosen based on exploratory data analysis. Each period consists of 11 years: the 'pre WWII' (1929-1939), the 'post WWII' (1946-1956), the period marked by strong changes in technology of fleet and fishing gear and in particular the transition to beam trawlers (1965-1975) and finally the 'post-Common Fisheries Policy' (1985-1995) in which a more static approach is taken to fishing areas and catches through the establishment of quota.

The number of reported fishing areas decreased from 16 (pre-WWII) to 13 (post CFP). The median number of species in the landings increased over the first three periods from 37 to 41.5 but decreased again in the last period. The indices that take account of relative abundance suggest that, although in the 'post-WWII' a higher volume (t) was landed (see also Figure 4.4.) and more species were reported (N_0) than during the pre-WWII, it are a few 'dominant' species that provide proportionally higher volumes therefore making fishing less diverse. The third period is marked by a decrease both in reported areas and landings (t), however the number of reported species increased and the landings are less marked by dominant species. Finally, in the post CFP period, the total number of species reported and the volume of landings continued to decrease while the proportion of the most abundant species in the catch remained the same, therefore suggesting an increasing importance of 'dominant' species N_{inf}.

The results of a similar analysis of landings, detailed by fishing area, show that overall herring was the most important species both before (28% of all landings) and after WWII (29% of all landings) (Table 4.2.).

Before WWII, 'North Sea (south)' was the most important fishing area yielding 33% of all landings, and herring the most important species with 28% of all landings. While 'South-and West-Ireland' was the most diverse area (highest N_1) during this decade, Fladen was the less diverse with 83% of its landings composed of herring.

After WWII (1946-1956), the 'Coastal waters' accounted for 27% of all landings and were characterized by a 'dominance' of herring making up 61% of the production in 'Coastal waters'. 'Bristol Channel' was the most diverse while the 'Barents Sea' was the less diverse: 92% of its landings consisted of Atlantic cod.

Table 4.2: Overview of the most important fishing area and species in terms of volumes (t) and the most diverse and less diverse fishing areas based on N_1, for each of the 4 decades considered in this analysis. For the less diverse fishing area, the dominant species (in terms of % landed volumes) is indicated between brackets, with the proportion of landings of this dominant species landed from this area over the decade.

	Most important fishing area	***Most diverse fishing area***	***Less diverse fishing area (and dominant species)***	***Most important species***
Pre WW II 1929-1939	North Sea (south) (33%)	South- and West Ireland	Fladen (Herring 83%)	Herring (28%)
Post WW II 1946-1956	Coastal waters (27%)	Bristol Channel	Barents sea (Atlantic cod 92%)	Herring (29%)
Technology boom 1965 – 1975	Iceland Sea	South- and West Ireland	Moray-Firth (Atlantic cod 60%)	Atlantic cod (31%)
Post CFP	North Sea (central-east)	Bristol Channel	North Sea (central-east) (European plaice 65%)	European plaice (37%)

Atlantic cod (31% of all landed weight) and the Iceland Sea (22% of all landed weight) ruled the Belgian sea fisheries in the decade 1965-1975, a time marked by fast technological progress. But this position was completely taken over by the European plaice (37% of all landed weight) and the 'North Sea (central-east)' (21 % of all landed weight) once quota were established and the trade for fishing rights was installed. The Bristol Channel was the most diverse fishing area in the decade 1985-1995. European plaice can be considered as a 'dominant' species marking the period 1985-1995: this species did not only make up the most important volume of landings, it also made up 65% of all landed weight from the North Sea central-east (the less diverse fishing area).

In fact, the landings from the Central and southern North Sea over the entire period 1929-1999 show that in the colder period after the 1960s and before the mid 1980's, mainly Atlantic cod was obtained from these areas, whereas this changed to European plaice from the warmer mid 1980's (1983) onwards. This change also coincided with the fleet shifting from targeting roundfish to flatfish, a transition which was facilitated by subsidies to install the beam-trawl on existing vessels and later invest in purposely built medium-sized steel-hulled trawlers which were also equipped with beam-trawls. An EEC subsidy scheme implemented from 1980 onwards stimulated the construction of these new '*Eurocutters*' or vessels with engines <221kW and LOA < 23.99m..Also, after the gradual loss of access to the Icelandic waters, Belgian vessels shifted their activities again towards the central part of the North Sea (Omey 1982) and - to a lesser extent - towards the English Channel, Bristol Channel, South and West Ireland and the Irish Sea.

Overall, a gradual increase in N_1 is observed during the 2 decades from the early 1950s to the early 1970s, followed by a stagnation or downward trends. The southern North Sea was the most diverse of the four most important fishing areas with an average N_1 of 13 (Fig. 4.11.). While the landings from the coastal waters were initially least diverse due to the targeted sprat and herring fisheries (average $N_1 = 3$), the diversity of landings has gradually increased and from the 1970s even surpassed (average $N_1 = 8$) that of Icelandic waters and the North Sea central-east.

The diversity of species in the landings from the Icelandic waters and the North Sea central-east followed similar trends and fluctuated less over time, but with lower N_1 (Figure 4.11.). After 1995, fishing in Iceland comes to a complete halt; after 1999 the statistical information reports landings on the North Sea central –east and central-west in aggregated way.

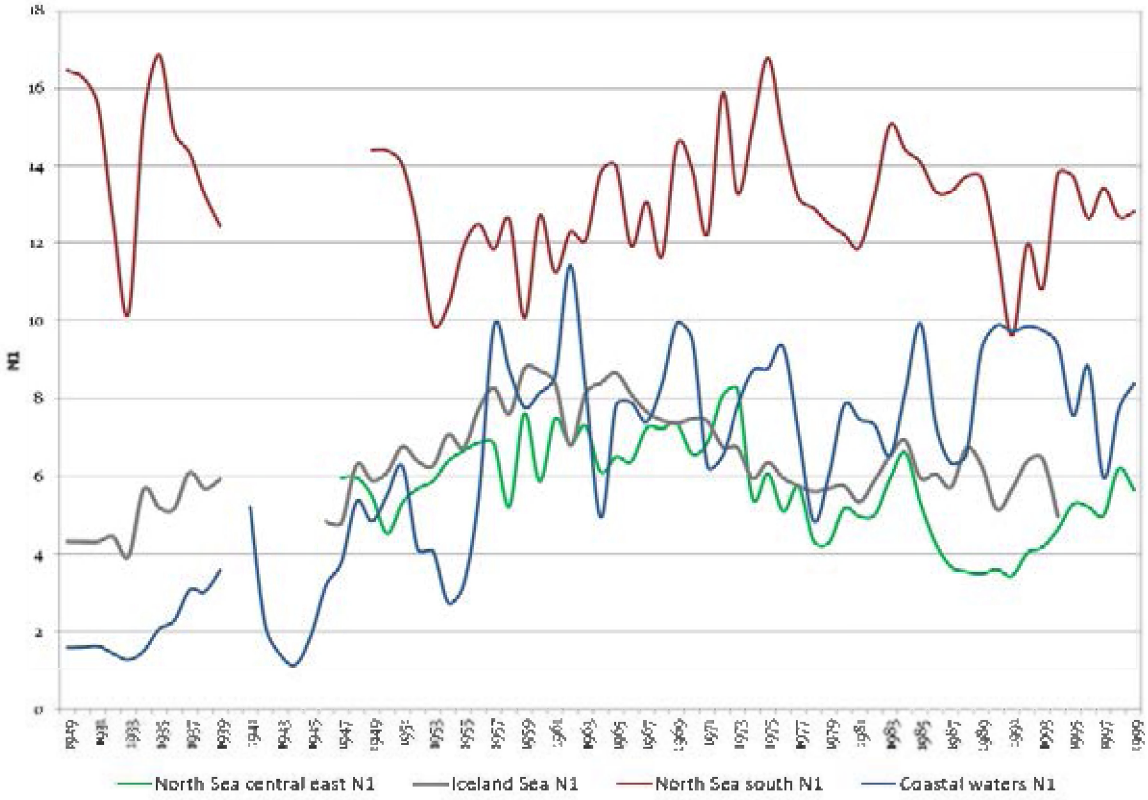


Figure 4.11.: diversity of species (N_1) in the composition of commercial landings from the 4 most important fishing areas, Belgian landings in Belgian ports 1929-1999.

4.3.7. Relative importance of the Coastal waters as fishing area for the Belgian sea fisheries (1929-1999)

The Belgian coast is 67 km long and the Belgian part of the North Sea or BNS is 3,457 km² (0.5% of the North Sea area; Figure 6.9.). The unique historical data reported for the 'Coastal waters' for 1929-2010 (HiFiDatabase) can serve as a proxy to quantify total landings and income from the commercial fisheries on the BNS, and the trends in species composition of the landings (Chapter 6). In terms of overall landings it is historically the most important fishing area for Belgian fisheries representing over 20% of the total Belgian landings, while these waters contributed nearly 60% of all landed pelagic species and 55% of all landed 'molluscs and crustaceans' (Lescrauwaet et al. 2010, Lescrauwaet et al. 2013). This suggests also that a variety of fishing gear is deployed in this fishing area compared to other areas.
The reported landings from the 'Coastal waters' amount to 0.8 million t (dead weight) and the trends in volume and composition of landings follow a similar pattern as that for the fisheries as a whole (Lescrauwaet et al. 2010a, see Figure 6.10.). The median of annual reported landings is 8100t with a peak value of 60,500t in 1943 and a minimum of 1900t in 2007 (Figure 4.12.). A first period (1929-1940) characterized by pelagic and shrimp fisheries, is followed by a peak in landings of pelagic species during and after WWII (1942-1964).

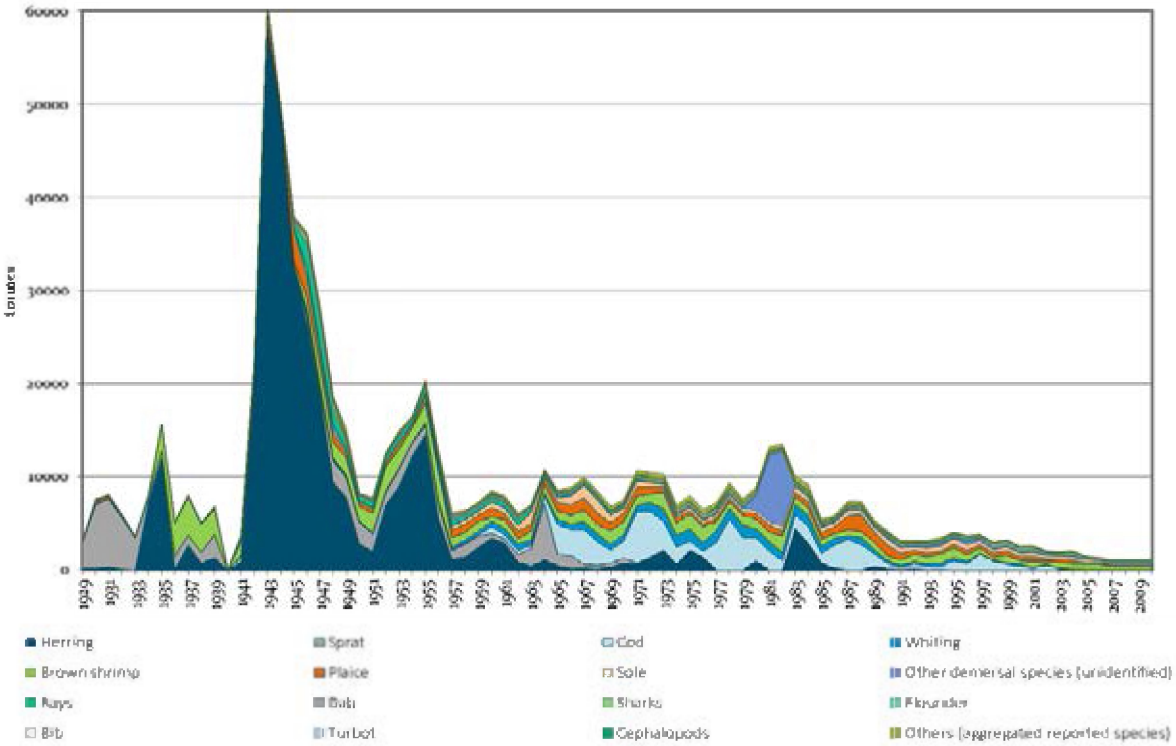


Figure 4.12.: Annual landings from the Coastal waters, by species. Based on annual landings in Belgian and in foreign ports

Cod is the dominant species in the reported landings from 1965-1980. After the mid 1980s the composition of the reported landings is less dominated by a single species although plaice and sole are the most important component. Herring and sprat (49%), brown shrimp (12%), cod (9%), plaice (6%), whiting (4%) and sole (3%) represent the most important species over the entire period. Commercial pelagic fisheries by Belgian fishermen have virtually completely disappeared from Coastal waters after the mid 80s. Interestingly, the five most important species landed from the Coastal waters, are from four different groups or fisheries: pelagic species (herring and sprat), flatfish (plaice), roundfish (cod), crustaceans (brown shrimp).
In spite of the numerous outliers, which in fact correspond to the exceptional ‘herring years’ during the WWII, the upper and lower quartiles for the data in the box plot for the Coastal Waters are relatively evenly distributed around the median, and the minimum and maximum values. If the outliers are excluded from analysis, the Coastal waters are considered not only by far as the most important fishing area in terms of overall landings and as source of food for local population, but also as the most stable provider of food.

4.5. Discussion

Historical sources sometimes refer to spatio-temporal information on fishing activities but these are generally qualitative and rarely based on quantitative evidence. Of the few historical references made about the geography of fishing, cited statements with temporal or spatially explicit information, were tested against the collected data and findings described (Results section 4.4.). A detailed overview of spatial dynamics of the fisheries by target species and fishing gear (brown shrimp fisheries, Norway lobster fisheries, roundfish and gadoid fisheries, flatfish fisheries, others) is available from Chapter 6.

Rapid expansion of the fleet after World War I stimulated long-distance destinations

According to Poppe (1977) many of the Belgian trawlers had fled to the UK with the outbreak of WWI, from where they turned towards the western waters (English Channel, Bristol Channel, St. George, south of Ireland and the coastal waters of Spain and Portugal). Although these areas were known to them from well before WWI, Belgian fishermen specialised in those regions during the WWI alongside their British fellows. Poppe (1977) explains that upon their return home after the WWI, Belgian trawlers continued fishing in these areas for a few decennia during the inter-war period. From the statistics however, the importance of 'the west' and the long-distance fishing grounds is not evidenced until after 1932. This may in part be due to the fact that expatriated fishermen did not return immediately in the years following the war and therefore these landings were not registered as 'Belgian landings'. Before 1950, there are no records of the landings by Belgian fishermen in foreign ports. However, we argue that it is possibly the instalment of credits to support the construction of new vessels (Royal Decision of July 1923) that was crucial for the fast expansion of the fleet after 1923 and until 1938 (Vanneste and Hovart 1959). As pointed out by Poppe (1977) when the engine made its appearance in the Belgian fishing sector, more fishermen shifted their activities and began travelling longer distances to the West and off the coast of Spain and Portugal. Also in other European countries – England, Scotland, Germany, the fishing fleet moved increasingly to distant waters in the 1930s (Ashcroft 2000, Robinson 2000).

Coastal fisheries achieve exceptional catches during WWII

The smaller vessels that stayed in Belgian ports during WWII, were to witness the most productive fishing (herring) seasons ever documented in Belgium and Flanders (Poppe 1977, Lescrauwaet et al. under review, Chapter 7). The presence of marine mines and other threats caused by imminent war had created a major decline in fishing in the North Sea already from autumn 1939. In the UK during WWII, the fleet moved to the safer, western waters (MAFF 1946). Some authors claim that the absence of the large-scale herring fisheries of the Doggerbank, Fladen and the east coast of England and the Channel (Gillis 1946) during the war, generated spectacular herring catches on the post-spawning areas on the Flemish Banks (De Mulder 1984, Lescrauwaet et al. under review). In spite of the severe damage the Belgian fleet suffered during the WWII, this success triggered an expansion of the coastal fishing fleet (Poppe 1977) and the post-WWII recovery was – again – quite fast. The reconstructed monthly statistics (HiFiDatabase) quantify these exceptional catches in 'Coastal waters' with up to 62,500 t in 1943 and demonstrate that these were in part explained by the absence of large-scale fishing during the war and influenced by two strong year-classes 1936 and 1938 (Lescrauwaet et al. 2013 under review). The coastal waters remained the most important provider of sea food until at least 1947, with 37% of annual landings (Figure 4.4.).

Western waters 'revisited'

The recovery of the North Sea fish stocks during WWII stimulated Belgian fishermen to shift their activities again to the North Sea - and Icelandic waters- after the war, until fisheries were hit by a crisis (in 1948) from which they would not recover until the end of the 1950s (Poppe 1977). According to this author, a combination of the effects of overfishing in the traditional North Sea fishing grounds and economic measures that failed to protect the internal market from foreign import, forced a large part of the fleet to head their activities again further northwards to the Iceland waters. Although the HiFiDatabase confirms and quantifies this increase in landings (t) from the Iceland Sea, it further expands on Poppe's hypothesis by showing that also the central-east part of the North Sea gained particular importance during the 1950s (mainly for plaice and sole), and this especially in monetary terms. Hovart (1994) probably refers to this trend when describing a second important shift during the 1950s, regarding the sole fisheries that were lured by the increased abundance of fish in the North Sea fishing grounds just after WWII, and in particular on the White Bank to the east of the central North Sea. After the decline in landings from the waters of the White Bank, according to Hovart (1994) the sole fisheries were forced to move again to the western fishing grounds from 1955 onwards. The HiFiData confirms this 'sole boom' in the North Sea (central-east) between 1949 and 1962, and shows a shy and gradual increase

in the sole landings from the Bristol Channel and South- and West-Ireland afterwards. It was however not until after 1964 that the western waters really became important fishing areas for Belgian sole fisheries. A similar 'westwards 'shift reported for the herring fisheries (Poppe 1977, Hovart 1994) needs to be put into perspective: during the second half of the 1950s, the herring fisheries already started the general decline which continued through the 1970s and 1990s (Lescrauwaet et al. under review, Chapter 7). Therefore, although areas like South-and West Ireland did gain some importance compared to traditional herring grounds e.g. Fladen and the Dogger Bank (Poppe 1977), these landings were quite limited in terms of weight (t).
In 1959 beam trawl fishing was introduced to increase profits in the shrimp fisheries and according to Hovart (1994) this system was also applied in the sole fisheries in the English Channel from the 1960s. Although an increase in the importance of sole fisheries (landings) from the English Channel is not visible from the HiFiDatabase until after 1970, Belgian trawlers were operating in the Bristol Channel (Horwood (1993).

The 1960s and the promise of growth through unprecedented technology
The sixties announced an era of structural changes in the fleet: while the last steam trawler (the O298 'Van Dyck') sailed out to England in January 1964, according to Poppe (1977) the fleet was already entirely renewed by motorized beam trawlers. A Royal decision (29 November 1961, nr.799) installed a system with governmental bounties for the demolition of larger old ships (>30 years) and the introduction of medium-sized steel trawlers (Poppe 1977). These trawlers moved to the Irish Sea, the fishing grounds around the Isle of Man and around the Smalls, 40-50nm off the southeast coast of Ireland - for the sole fisheries. New rich fishing grounds near Yorkshire caused a real 'codfish boom' (cfr. The 'gadoid outburst') in the second half of the 1960s and probably explain the increased landings from the North Sea (central-west) in the HiFiDatabase. Haddock off the central-east coast of England was sold at a higher price on the English markets (Grimsby, 1963-1964) and this is clearly quantifiable in the increased landing statistics from the North Sea (central-west) fishing area (1963-1964) in the HiFiDatabase.

There are particular cases where our data confirm sources that suggest an inverse offer-demand effect in the price of landings: e.g. the two-fold increase in sole landings in the peak year 1963 generated a 50% decrease in prices that year (witness interviews 'Yesterday's Sea' p. 191, validated by HiFiDatabase). Similarly, the sudden 'oversupply' of herring during the WWII caused the price on the formal market to exceed that of the black market (Beke 1985).

In spite of the energy crisis (1973-1974) and the renewed interest in passive fishing methods like fixed nets, long liners and twin-rig trawling (Hovart 1994) the effects of overfishing became more evident and quota were established for herring and later also for sole and plaice. As a result of Iceland's extended territorial sea and exclusive jurisdiction on fisheries up to 200 nm, Belgian fisheries in Iceland declined and shifted to nearby areas in the North Sea (Omey 1982). According to these authors, in 1980 the coastal waters and the southern part of the North Sea again became important fishing areas for the Belgian fisheries. A similar patter, for UK fisheries, is described by Kerby et al. (2012).

The HiFiDatabase confirms this statement and also expands it to include the fishing areas in the North Sea central east and west. Although Belgian vessels fished smaller amounts from the English Channel, Bristol Channel, South and West Ireland and the Irish Sea, these fishing grounds yielded high-valued fish products. This coincided with the introduction of an (EEC) temporary measure for subsidies to improve the structure of the shrimp fishing fleet and the coastal fleet. With the subsidies, new Euro-cutters were built, that were more efficient than the vessels they were replacing (De Wilde 1998). Although the subsidies were conceived to improve the segment of the coastal fleet fishing for brown shrimp, cod and whiting, the vessels targeted flatfish at least part of the year. A peak is observed in the total landings from the coastal waters from the early 1980s until the mid 1980s, however, a closer look at the composition of these landings from coastal waters shows that – although the landings of plaice and sole gradually increased from the beginning of the 1980s - the peak in landings of flatfish occurred around 1995.

Finally, in 1983 the Common Fisheries Policy (CFP) was put in place and with it the EU practice of setting annual TAC's established by Article 3 of the EU Regulation 170/83. Since then national fisheries are somehow 'fixed' according to this international context of quota by fishing area within which spatio-temporal dynamics of fishing is mostly explained by a profit-maximization strategy (Gillis et al. 1995).

4.7. CONCLUSION AND RECOMMENDATIONS FOR FURTHER WORK

The spatial dynamics of Belgian fisheries in the 20th century were marked by distinct periods. After 'stable' volumes of mostly herring from nearby fishing areas (coastal waters and the southern North Sea) before WWII, a rapid expansion followed, stimulated by the unprecedented local productivity during the war. Fisheries and their investments shifted towards more distant areas once the stocks in nearby areas started to show signs of decline, and with the development of larger, motorized fishing vessels. Investments, fishing efforts and spatial expansion of the fisheries continued well after Belgian fisheries had reached their historical peaks in landings in 1947 and 1955. The gradual loss of cod yields from the Iceland Sea was partly compensated by production from fishing areas in the western part of the North Sea.

The instalment of restrictive quota and the shift to targeted sole and plaice fisheries both in the eastern part of the North Sea and more recently in the western waters, coincided with a period characterised by warming temperatures through the beginning of the 1980s in the (southern) North Sea. This is in line with the hypothesis that the ecology of the North Sea has shifted between two different ecological states with the coincident decline of cod and the increase in sea surface temperature (SST) in the mid 1980s as the tipping point (Frid et al. 2000, Brander 2005, Callaway et al. 2007, Kirby et al. 2009). These authors claim that following the decline of North Sea cod, the abrupt ecosystem shift and onset of warmer temperatures resulted in a series of changes in trophodynamics of the plankton and benthos. The HiFiDatabase shows a change in the North Sea landings dominated by Atlantic cod between the 60's until the mid '80s, to predominantly plaice from 1983 onwards. This trend was also strongly related to the transition to beam-trawling (Poppe 1977, Hovart 1994). However, the landings data need to be correlated to fishing effort and LPUE of the commercial fleet in order to further test this hypothesis.

Fishermen use the general patterns in seasonal variability of target species to select spatio-temporal strategies of fishing effort at the larger-spatial scale. However, as Poos (2010) demonstrated for sole and plaice fisheries in the North Sea, local aggregations of limited persistence in time are superimposed on these large-scale patterns. Fishermen use empirical knowledge about these small scale concentrations of fish within the selected fishing areas to optimize landings and/or profit. As Poos stated, restrictive TAC's affect the effort allocation and the discard rates at the national fleet level, since vessels need to optimize their annual net revenues by continuously adjusting strategies on where to fish and what part of the catch to retain. Before the onset of quota and other management constraints in fisheries however, these strategies probably relied on less complex decision making in which indices of catch rates per unit of effort, broad economic incentives and traditions played a proportionally higher role.

The integration of historical time series (Lescrauwaet et al. 2010) increased the accessibility of quality-controlled data on the landings and value of landings of Belgian sea fisheries and particularly allows a quantitative dimensioning of the spatial dynamics of the Belgian fisheries in the 20th century. The present paper brings the outlines on the spatial information covered by this database. It provides quantitative evidence to support or challenge some of the statements from historical literature, underlines the historical importance of the 'coastal waters' to the Belgian fisheries and provides a picture of decades of diversity changes in fish species and fishing grounds, before the onset of the CFP. Finally, it provides a potential source to test hypotheses in ecosystem ecology and fisheries biology. Moreover, it allows contrasting the history of Belgian fisheries with that of other European countries that share the same fishing grounds.

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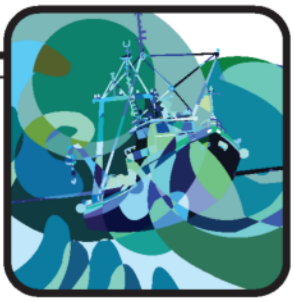

CHAPTER 5: Hundred and eighty years of fleet dynamics in the Belgian sea fisheries

CHAPTER 5. HUNDRED AND EIGHTY YEARS OF FLEET DYNAMICS IN THE BELGIAN SEA FISHERIES

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ABSTRACT

Understanding the impact of fisheries on the commercial fish stocks requires detailed catch statistics and data on the dynamics of fleet and catch effort, at least before industrial fishing started. Most time series on the fleet dynamics start after the 1980s, at times when major changes in fleet characteristics had already taken place. In the present paper, the results of the integration of data on fleet size (from 1830), tonnage (from 1842) and engine power (kW, from 1912) of the Belgian sea fisheries fleet are presented. The decrease in fleet size and changes in overall tonnage and engine power since the beginning of the reconstructed time series, are quantified. The data show that the decrease in fleet size (-85%) and in overall engine power (-5%) was compensated by an increase in average tonnage per vessel (x10 increase) and in average engine power per vessel (x6 increase). The overall fishing effort of the fleet expressed as the total number of days spent at sea has decreased by approximately -84% between 1938 and 2010, while the average amount of fish landed per day per vessel (1,000 kg in 2008-2010) has at least doubled in the same period. The data reconstruction provides a unique view on the dynamics in the sea fisheries fleet of Belgium over 180 years and the political and social events associated to these changes.

Keywords: Fleet dynamics, Historical reference, Belgium

5.1 INTRODUCTION

5.1.1 SEA FISHERIES IN BELGIUM: A HISTORICAL PERSPECTIVE ON CATCH AND EFFORT

The failure to manage fisheries sustainably in the present has triggered concern over 'shifting base-lines' in a marine ecology context (Pauly 1995, Pauly et al. 1998, Roberts 2007, Finley 2011) and stimulated research into the historical context of fisheries. The true nature of change in abundance of commercial fish species however can only be grasped if we take into account the impacts of fisheries at least since the onset of industrial fishing. In particular, time series of catch and effort before the widespread changes in fisheries towards the end of the 20th century are needed. In the absence of catch statistics, integrated and quality controlled landing statistics can be used as a proxy for fishing mortality and for further analysis related to the setting of historical baselines (Zeller and Pauly 2007, Lescrauwaet at al. 2010a). However, time-series on landings mostly date from after the start of intensive exploitation. Similarly, time series on fishing power and fishing effort typically do not go further back in time than 30-40 years. Hence, the currently available baselines for rebuilding depleted fish stocks typically refer to strongly exploited situations (Pitcher 2001) and reconstructions of historical time-series are needed to improve our understanding on the impacts of fishing. The North Sea was one of the first areas to adopt non-human mechanical power in fisheries. The invention of the steam engine and the appearance of the first steam trawler in the UK (1877) symbolize the start of industrial fishing, which started in Belgium with the arrival of the first steam trawler in Oostende in April 1884 (02/04/1884, the 'Prima 071').

The Belgian coast is 67km long and located in the province of West-Flanders in the region of Flanders, Belgium (Figure 5.1.). Today, Belgium has four coastal ports (Nieuwpoort, Oostende,Zeebrugge and Blankenberge), although historically the fishing communities of Heist, Blankenberge, De Panne, Oostduinkerke and Koksijde, and the locations along the Scheldt estuary harboured an important number of vessels. Besides the fish auctions located in Oostende, Zeebrugge and Nieuwpoort (Figure 5.1.) there are no other dispersed landing points today. In 2011, the Belgian commercial sea fishing fleet counted 89 ships, with a total engine capacity of 44,025 kW and gross tonnage of 15,733 GT (Anon. 2012). 46 vessels are part of the Small Fleet Segment (max 221 kW engine power) of which 2 use passive gear. The remainder 43 vessels of the Large Fleet Segment have an engine power between 221 kW and a maximum of 1,200 kW. This fleet segment consists of 5 vessels using trammel nets, 4 using otter trawl and 34 large beam trawl vessels (≥662 kW). The Belgian fleet is highly specialized: more than 68% of the effort (days at sea) and 77% of total landings is achieved by beam trawlers (Anon. 2012) focusing primarily on flat fish species such as plaice (*Pleuronectes platessa*) and sole (*Solea solea*). The landings represent a total value of € 76 million, of which € 65 million are sold in Belgian ports, € 11 million in foreign (mainly Dutch) ports. Sole generates 48% of the current total value of fisheries in Belgium (Anon. 2008). In 2010, the Belgian fleet landed a total of 19,683 tonnes (t), of which 15,970 t were landed in the Belgian ports (Anon. 2012).

Around the turn of the 19th century major changes took place in the Belgian fleet, as it moved from sailing vessels (with trawl and drift nets) and rowing boats (mainly passive gear) to steam vessels (with otter trawls) and later on the diesel engine powered vessels mainly deploying beam trawls (Hovart 1994) in particular from the 1960s. Lescrauwaet et al. (2010a) addressed the absence of historical time-series on sea fisheries production in Flanders (Belgium) at the species level by conducting a data rescue and integration (Lescrauwaet et al. 2010b) reaching back to the beginning of the 20th century. The authors quantified an overall decline of 75% in the total landings since the peak in 1947 and provided trends by species and by fishing area from 1929 till the present. From an environmental perspective however, trends in landings and catch statistics need to be interpreted in the context of fishing effort and fishing power, shifts in targeted species and fishing grounds (Kerby et al. 2012) and considering economic and political drivers. Therefore, the dynamics of the fishing fleet and the increase in fishing power which started at the end of the 19th and continued throughout the 20th century (motor engines, beam trawling, tickler chains, geographic positioning systems etc.) need to be quantified as a first step towards interpreting trends in fish landings statistics. In the current paper, the results of a historical reconstruction of the size and capacity of the Belgian sea fishing fleet (1832 until present) are presented and trends are described.

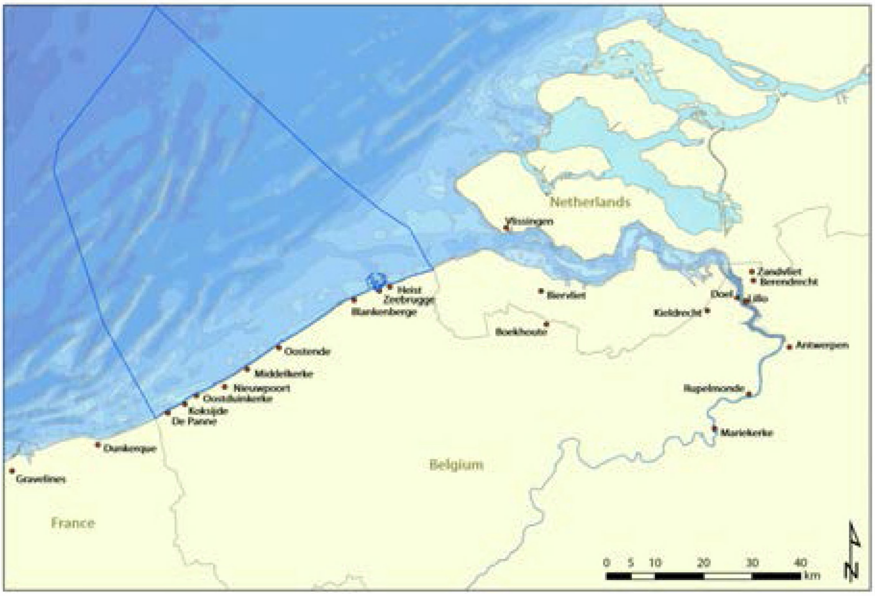


Figure 5.1. Map of the Belgian coast with the coastal (fishing) ports and auctions, including historical fishermen's settlements in Flanders, and the ports of Gravelines and Dunkerque in France. The line indicates the boundaries of the Belgian part of the North Sea. Source: a century of Sea Fisheries in Belgium (VLIZ 2009).

5.2 Methodology

A number of independent data sources were used to reconstruct the characteristics of the Belgian fleet from 1830 onwards. First, the annual 'Official list of the Belgian fishing vessels' OLBFV (section 5.2.1) is published by the Ministry of Transport (federal government of Belgium) since 1929. The second important source consists of statistical tables (1944-present) published by the National Institute of Statistics NIS (5.2.2) in cooperation with the Ministry of Agriculture and Fisheries. The information in the statistical tables is continued in the current annual series 'Landings and value of landings' and 'Analysis of the economic efficiency of the fleet' published by the department of Agriculture and Fisheries (Flemish government) until today. Before 1929, data were obtained from different disperse and fragmented sources (Table 5.1.).

5.2.1 Ministry of Transport, annual fleet statistics

The data on fleet size, engine power, capacity and technology to reconstruct the history of fishing power and catch efficiency for the Belgian sea fisheries fleet is largely based on 'ship-by-ship' information. Since 1929 the Belgian Ministry of Transport publishes annual reports on the state of the national fleet, with separate lists for the fishing fleet. The annual 'OLBFV' describe characteristics of individual vessels by port of registration, identifying their immatriculation number, total length (TL), capacity as gross and net tonnage (register ton – RT or tonnage T), engine power (Kilowatt-kW or Dutch Horsepower-HP), owner (name, address), year of construction, ship wharf, construction material (wood, steel), fishing gear, and - however in less complete records- presence of some technological equipment (VHF, sonar, etc.). The data from the original paper copies were digitized (28,000 individual records) standardized and integrated in the 'Belgian fleet' database (Lescrauwaet et al. 2010c) as part of the HiFiDatabase (Lescrauwaet el al. 2010b). Integration efforts focused on the reconstruction of the 'lifeline' of individual ships, while standardisation was mainly centered on units of power and of proper names. The series starts in 1929, coinciding with the first detailed and formalized reporting on fish landings (Lescrauwaet et al. 2010b). For more information on the 'Belgian fleet' database and to consult information by individual ship, access the online search tool: http://www.vliz.be/cijfers_beleid/zeevisserij/fleet.php

5.2.2 Ministry of Agriculture and Fisheries, annual agriculture statistics

A second time-series (1944 to present) was constructed based on governmental statistics published as the statistical tables V and VI (extent and activity of the fishing fleet, by port, by class of gross tonnage) in the 'Agriculture statistics' (Landbouwstatistieken), which also report on fishing effort, landings and their values. These tables contain aggregated reports on total number and overall capacity (gross tonnage) of vessels by fishing port, number of vessels by category of engine power, for steam powered (2 categories) and motor engines (5 categories). Advantage of this data is the reference to fishing effort and landings. Fishing effort is expressed as days at sea (SD) and days fishing. A day at sea is defined as any continuous period of 24 hours (or part thereof) during which a vessel is present within an area and absent from port. Disadvantage of this second source is the level of aggregation, the discontinuity in category boundaries, and the restricted time coverage (starting in 1944). Also, the tables refer to the active fleet only and do not include the 'open and half-open' ships. Although the latter contributed less in overall gross tonnage of the fleet, they were important in number at least in the beginning of the time-series. This second database was used as a control to the first and more detailed 'Belgian fleet' database.

5.2.3 Additional sources

Additional data and information on the fleet were obtained from punctual historical surveys, publications and reports commissioned by authorities to provide input e.g. the report of the commission in charge of studying the situation of fisheries in Belgium in 1866 (Chambre des Représentants 1866) to provide advice to the authorities on the question of abolishment of subsidies, and the thorough survey conducted by De Zuttere (1909).

The data integration covers the period from 1830 to present. An overview of sources is included in table 5.1. For a detailed description of the digitization, standardization procedures and quality control, the authors refer to Lescrauwaet et al. (2010b). Our literature screening indicated that structurally embedded reporting on the fleet size and features in Flanders (Belgium) started in 1929 with a good level of consistency and continuity ever since then. Much like our findings on historical landings – with the exception of the annual reports on Belgian sea fisheries landings that are electronic formats (pdf or html) from 1998 onwards – none of the data contained in the pre-1998 sources were available in electronic format or available for overviews or research analysis. As is the case for reported landings of fish and fish products, the beginning of structural reporting on the fleet coincided with the period where most states in Europe developed a statistics approach to underpin policy development (Lescrauwaet et al. 2010a).

Table 5.1.: Overview of sources used for the reconstruction of time-series on the Belgian fishing fleet

Period	Fleet parameters	Source
1830-1841	Number of ships for the port of Oostende; total tonnage of ships for the port of Oostende	Rapport de la Commission chargée de faire une enquête sur la situation de la pêche maritime en Belgique. Séance du 17 mai 1866. Chambre des Représentants: Bruxelles. XLII, 75 pp
1832,1836, 1839	Number of ships for the ports of Nieuwpoort, Blankenberge, Heist, De Panne/Adinkerke, Koksijde/Oostduinkerke.	Rapport de la Commission 1866 see above
1842-1864	Number of ships by port (Oostende, Nieuwpoort, De Panne/Adinkerke, Koksijde/Oostduinkerke, Blankenberge, Heist); total tonnage of ships by port (all ports)	Rapport de la Commission 1866 see above
1865-1871	No data	No sources
1872, 1877, 1882, 1887, 1892-1903	Number of ships by port, including number of steam trawlers; total tonnage of ships by port; open and half-open vessels for 1892-1911 estimated based on punctual reported numbers for 1892 and 1905	Hoek, P. and Kyle, H. (1905) Appendix J: Statistics of the North Sea fisheries. Part I: The fisheries of the various countries. Belgium *Rapp. et Proc.-Verb. Cons. Int. Explor. Mer 3*: 82-91
1905	Number of ships by port, including number of steam trawlers; Total tonnage of ships by port, including tonnage of steam trawlers	De Zuttere, C. (1909) Enquête sur la pêche maritime en Belgique: introduction, recencement de la pêche maritime. Lebègue & cie: Bruxelles. 634 pp
1910	Number of ships by port, including number of steam trawlers; total tonnage of ships by port, including tonnage of steam trawlers.	Von Schoen, F. (1912) La pêche maritime de la Belgique *Bulletin de la navigation et des pêches maritimes 14*: 185-205
1911-1931	Number of ships by port, including indication of number of steam trawlers; total tonnage of ships by port, including indication of tonnage of steam trawlers.	Provincie West-Vlaanderen. Commissie voor Zeevisscherij Jaarverslag der Commissie voor Zeevisscherij. Druk. Verbeke-Loys: Brugge: 1912, 1913, 1919-1931.
1929-2011	Number of ships by port; tonnage in GRT until 1983, in GRT and GT between 1984 and 1994, in GT from 1994 onwards, HP, kW, total length, total width, ownership and other ship-by-ship information	Officieele lijst der visschersvaartuigen. Ministerie van Landbouw. Dienst voor Zeevisscherij: Oostende (and continued series): 1929-2010
2008-2010	Number of ships by port; total tonnage (GT) of ships by port	Tessens, E. and Velghe, M. (2008) De Belgische zeevisserij: aanvoer en besomming 2008. Vlaamse Overheid. Departement Landbouw en Visserij. Afdeling Landbouw- en Visserijbeleid. Zeevisserij: Brussel. 103 pp Tessens E and Velghe M (2010) De Belgische zeevisserij: aanvoer en besomming 2009. Vlaamse Overheid. Departement Landbouw en Visserij. Afdeling Landbouw- en Visserijbeleid. Zeevisserij: Oostende. 109 pp Anon. (2012). FIVA Activiteitenverslag 2011.

Metadata are rarely provided in historical sources. Graphical analysis of the result of the integration of the data extracted from fragmented sources and covering different periods uncovered two main breaks in the observed trends. A first break was identified in the total number of ships reported for Oostende in 1892-1911. Literature study (Hoek and Kyle 1905, Commissie voor Zeevisscherij 1912, 1913 and 1919-1931) confirmed that 'open and half-open vessels' were not included in the total number for this period, whereas they were identified and included in the data from OLBFV (time-series after 1929). An estimation of 'open and half-open' vessels for the period 1982-1911 was included based on reported numbers for 1892 and for 1905 as anchor points (Table 5.1.). Graphical analysis uncovered a second important break in the integrated time-series on tonnage. Historically, different measurements to calculate vessels cargo capacity were in place in different countries. The standardised system of gross register ton (GRT) became British law in 1854. In Belgium GRT was established in 1876 and transcribed in Belgian law as Royal Decree in December 1879. In practice however, both the GRT and the cubic volume (m^3) co-existed for administrative purposes in Belgium. GRT was established internationally by the Convention for a uniform system of tonnage measurement of ships, signed in Oslo in 1947. Subsequently, the system of gross tonnage (GT) was defined by the International Maritime Organization in 1969 and it came into force on July 18, 1982. Gross tonnage is an index related to a ship's overall internal volume. It is calculated by using the formula GT=K*V, where *V* = total volume in m^3 and K=0.2+0.02*log10V (K is a figure between 0.22 and 0.32) depending on the ship's size. GT is therefore tied to the cubic meter unit of volumetric capacity, but it is a unit-less entity. Although the time-series on tonnage was standardised to obtain coherence over time, problems persist with the data on tonnage for the early years for which metadata is very scarce.

5.3 Results and Discussion

During the period of the French Republic (1795-1814) the province of West-Flanders was under the French administration of the 'Departement de la Lys-Leie'. Due to the political turmoil and wars, Flemish fishermen were often recruited and fisheries could not prosper as they did during the Austrian empire (1713-1795). During the Austrian period Flemish fisheries flourished thanks to the establishment of direct subsidies and indirect tax levies on imported fish. Between 1815 and 1830, the Flemish provinces became part of the United Kingdom of the Netherlands. As soon as 1816 the administration in Brussels issued a system of subsidies to stimulate fisheries, however this system did not take into account the particular fishing gears and techniques used in Flanders. The Flemish fisheries therefore could not fully qualify to receive the subsidies that favoured the fisheries in the northern Dutch provinces (De Zuttere 1909).

With the independence of Belgium in 1830, the Dutch system of subsidies was adjusted to the conditions of the Flemish fisheries for salted herring and cod, by a complex system of laws e.g. the Law of 27/05/1837 to promote national fisheries, or the Law to assign credits and subsidies to promote national fisheries (*XLI(132)*: 411; http://www.vliz.be/imis/imis.php?module=ref&refid=203467). An interesting side effect of this system of subsidies was the setting up of detailed statistics on the fleet and fishing effort, since the payment of subsidies throughout this period (1836-1866) was subject to reporting. In summer, Belgian fishermen travelled to the Dogger Bank, the Faroe Islands, the Shetland Islands and the Icelandic Sea for cod fishing, mainly from the ports of Oostende, Nieuwpoort and Antwerpen. In the winter there was also a smaller number of vessels travelling from Nieuwpoort and Antwerpen to the Doggerbank to catch cod (Chambre des Représentants 1866). The landings of fresh fish at that time were not subject to subsidies and reporting, although the overall income value was recorded (in Belgian francs BEF). Fresh fish fisheries were restricted to inshore or coastal waters and during the winter months (Poppe 1977). The introduction of creels (seawater tanks within the ship's hold) in 1820 and the use of artificial ice from 1874 were important steps to improve quantity and quality of the fresh fish landings. The combined introduction of the steam engine vessels (1884), the employment of otter trawl nets (1894) and the use of donkeys (1882) to raise the heavy trawl gear mechanically, were technological improvements which allowed a significant increase in catches and profits and a fast expansion of the fresh fish fisheries towards new fishing grounds (Vanneste and Hovart 1959). From 1905, steam trawlers moved offshore Portugal and Spain and in 1908, the first Belgian trawlers reached the White Sea. Another important renewal in the fishing industry was the application of an auxiliary engine from 1910 (Vanneste and Hovart 1959) and finally the widespread introduction of the motor engines after the Second World War (WWII, 1939-1945).

5.3.1 Trend in total number of fishing vessels of the Belgian fishing fleet since 1830

The data integration covers the period from 1830 to 2010. In spite of the data gaps (1865-1871 and 1915-1918, Table 5.1. and Figure 5.2.) and the inter-annual differences in coverage of ports and types of vessels, the time-series reconstructs the overall trend in total number of fishing vessels. From the beginning of reporting, the total number of vessels increased from 145 in 1832 to 274 in 1864, nearly duplicating in 3 decades (Figure 5.2.). This increase was explained by De Zuttere, who was a member of the government commission of 1866, as a direct effect of the system of subsidies (see above). Oostende remained the most important port throughout this period and the next period of reporting (1892-1911, Figure 5.2.), as it was more apt to receive larger vessels. The facilities of the new port of Zeebrugge were inaugurated in 1907. The fishing port of Nieuwpoort, the settlements of Heist and Blankenberge to the east, and De Panne/Adinkerke and Oostduinkerke/Koksijde to the west also harboured an important number of vessels. Most of these stranded on the beaches to disembark the produce, or used the neighbouring ports of Nieuwpoort, Blankenberge and later Zeebrugge to do so. By the end of the 19th century, Oostende increasingly focused on 'fresh fish' catches during winter, in particular with the appearance of steam trawlers from 1884-1887 onwards. De Panne/Adinkerke, Oostduinkerke/Koksijde, Heist and Blankenberge were home to vessels of coastal fisheries and fishing areas at shorter distances.

A maximum total number of 630 fishing vessels was reported in 1913 (Commissie voor Zeevisscherij 1913), at the outbreak of the First World War (WWI, 1914-1918). At the eve of WWI, the new port infrastructure of Zeebrugge was harbour to 20 sailing vessels, Oostende to 327 of which 29 steamers, followed by De Panne (87), Heist (67), Blankenberge (67), Nieuwpoort (37) and Oostduinkerke/Koksijde (26).
While the fleet size quickly recovered from the destruction suffered during WWI, a revolution took place in fishing power of the fleet as they moved from sail or steam as driving power, to motor engines during the inter-war period (1919-1939). Motors were first installed as donkeys (to lift the nets) and as auxiliary power (propelling power) on sailing vessels and progressively as central driving power (Commissie voor Zeevisscherij 1912, 1913, 1919-1931) (Figure 5.5. and section on driving power and tonnage).

These shifts also required considerable investments and after WWII, fishing moved from a more family-oriented business to shipping companies. Fishing activities became concentrated around only 4 (Oostende, Zeebrugge, Nieuwpoort, Blankenberge) of the previously mentioned ports or fishing communities.

The fish stocks in the North Sea showed a recovery after the cessation of the fishing activities during WWII and a historic maximum of 75,370 tonnes (in 1947) was reported in overall landings of the Belgian sea fisheries. However, the sector was severely hit by an economic crisis in 1948 and by 1950 the North Sea showed marks of depletion again. In only 10 years time, the fleet size decreased from approximately 550 to 450 vessels (-20%). The larger otter trawling vessels were forced to shift their fishing activities to the Icelandic waters to ensure profitability. By 1958, the landings from the Icelandic Sea represented 40% of all fish disembarked by Belgian fishermen (Lescrauwaet et al. 2010a). Another segment of the fleet targeted the rich concentrations of flatfish (mainly sole) on the White Bank (eastern part of the central North Sea). When the catches of sole decreased on the White Bank after 1955 the Belgian fisheries returned to the western fishing grounds (South-West Ireland, Bristol Channel), which they had left 10 years before in favour of the North Sea.

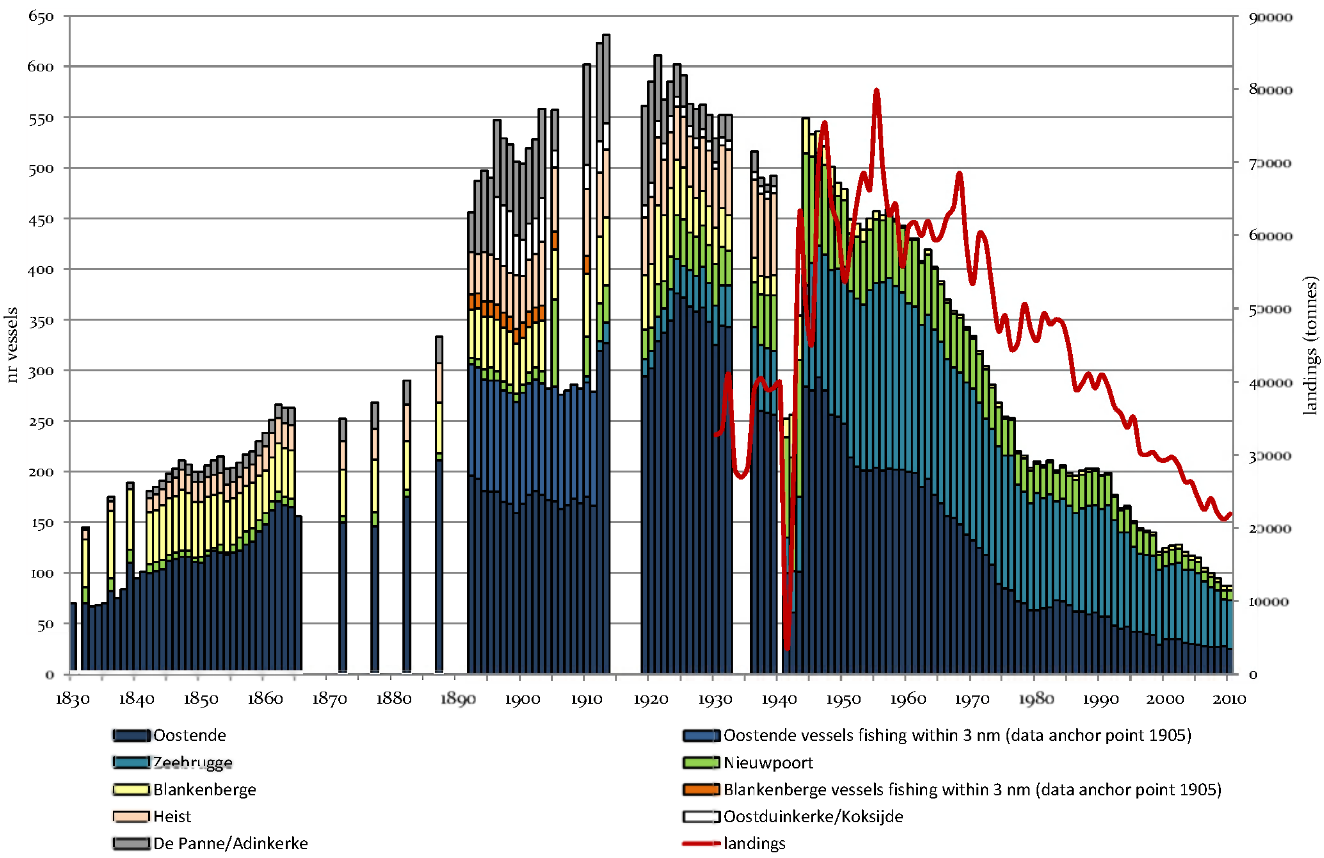


Figure 5.2.: Trend in number of vessels of the Belgian fishing fleet in the period 1830-2010. Source: VLIZ HIFIDatabase, reconstructed from historical sources Table 5.1.

In the 1960s, major structural changes took place in the Belgian sea fisheries fleet. The large shipping companies which had invested in steam trawlers disappeared (e.g. the Ostend Shipping Company): the last Belgian steam trawler sailed out to England on the 14th of January 1964 exactly eighty years after the first steam trawler entered in the port of Oostende. Between 1961 and 1969, governmental subsidies were issued for the renewal of the fleet with bounties for the demolition of older ships and for the purchase of new steel hulled medium-sized motor trawlers (Poppe 1977). Although the beam-trawl was introduced in 1822 in Oostende, it went nearly unnoticed until the 1960s. In 1959, the paired beam-trawl fishery (‘*bokkenvisserij*’, a ship pulling one beam-trawl on each side of the vessel) was implemented from the port of Zeebrugge: first for the brown shrimp (*Crangon crangon*) fisheries, and later also for the sole fisheries. Also from Zeebrugge, succesful ventures for pair-otter trawl (‘*spanvisserij*’, two ships pulling one otter trawl) fisheries for cod were implemented which increased the relative importance of Zeebrugge as fishing port. Whereas the port of Oostende had kept its reputation of first fishing port since at least the 18th century (Cloquet 1842, De Zuttere 1909) Zeebrugge definitely took over in 1968 as the most important port in terms of fleet size and in 1985 in terms of landings.

Between 1960 and 1975 the gradual decline in the overall fleet size, from 430 to approximately 250 vessels (-42%), was particularly evident in the port of Oostende with a decrease of -58% (from 200 to 85). The traditional fisheries from Oostende were further affected in 1972 because access to the distant and rich fishing grounds became restricted for all foreign fishing fleets when Iceland demarcated its territorial waters from 12 nm to 50 nm. From 1975 the presence of Belgian fishermen within the declared 200 nm exclusive economic zone of Icelandic, became subject to a ‘phase-out’. As a consequence of the loss of the Icelandic waters towards 1980, Belgian vessels shifted their activities again towards the central part of the North Sea (Omey 1982) and - to a lesser extent - towards the English Channel, Bristol Channel, South and West Ireland and the Irish Sea. The gradual decline in the total number of vessels continued and in January 2011 the Belgian fleet that operates from coastal ports counts 87 ships. The structural changes as a consequence of technological developments in the 1960s, the loss of access to the Icelandic waters as fishing grounds, the energy crisis in the early 1970s and the increasing fuel costs, and the specific programmes of the European Commission Common Fisheries Policy oriented to the decommissioning of ships with the aim to reduce fleet capacity, have contributed in different degrees to this gradual decline in fleet size.

5.3.2 FISHING PORTS AND VESSELS IN THE ESTUARY OF THE RIVER SCHELDT (1930-2010)

Although the present paper focuses on reconstructing the landings and fishing capacity of the fleet operating from the coastal ports, time-series on the number of vessels operating from ports located along the estuary of the river Scheldt were also reconstructed on a ship-by-ship basis (Lescrauwaet et al. 2010c), many of which were small open or half-open decked boats. The Scheldt has a long tradition of inshore fisheries on the estuary in particular for brown shrimp and some flatfish species. However, historical data on landings from the Scheldt estuary are currently unavailable so it is not feasible to relate the landings to the fleet or its fishing effort.

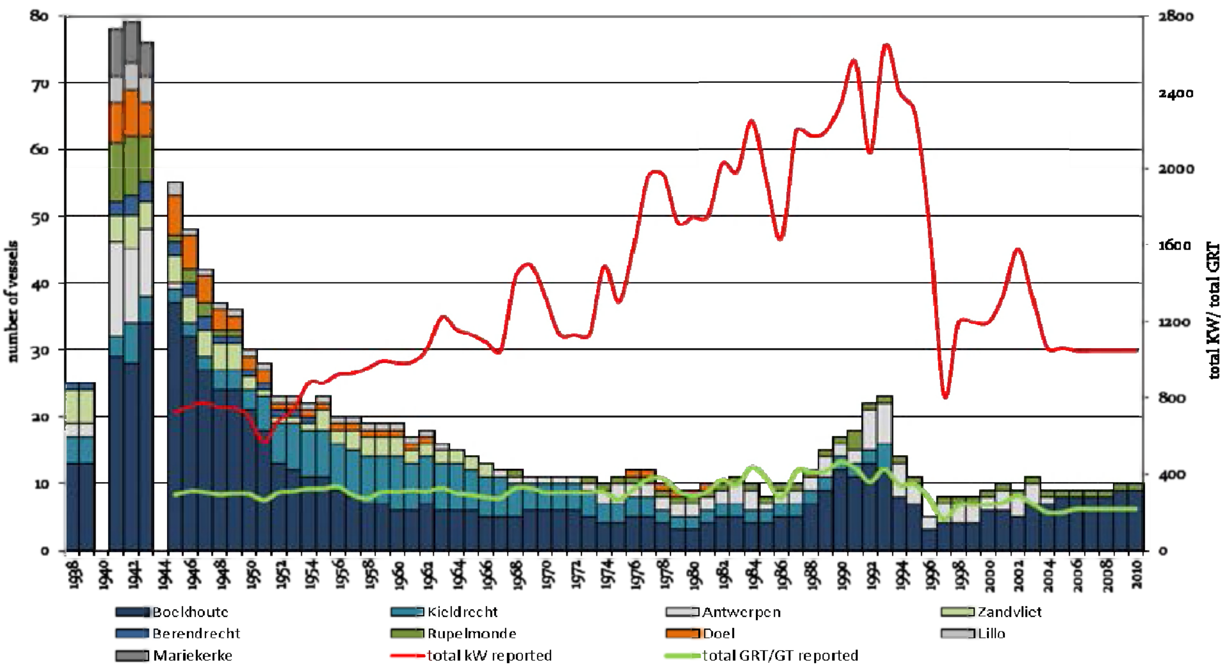


Figure 5.3.: Trend in number of vessels, total fishing power (kW) and Gross tonnage (GRT and GT) of the Belgian estuarine and inshore fishing fleet operating from ports along the river Scheldt in the period 1930-2010. Source: VLIZ HIFIDatabase, reconstructed from historical sources Table 5.1.

Similar to the case for the coastal ports, the fleet on the Scheldt has declined from 79 in 1942 to less than 10 today and total fishing power (kW) is comparable to that of the 1960s (Figure 5.3.). More strikingly, 7 of the former 9 fishing ports and their fishing communities along the Scheldt estuary have disappeared e.g. Zandvliet, Mariekerke and Doel.

5.3.3 TREND IN TOTAL TONNAGE OF THE FLEET AND AVERAGE TONNAGE OF FISHING VESSELS OF THE BELGIAN FISHING FLEET SINCE 1842

The tonnage is a measurement of the overall volume of a ship's enclosed spaces. It is closely linked to the vessel's storage capacity and to its driving power (engine or sail), and is an expression of the ambition of a vessel's owner. In the past, the tonnage of a vessel in Belgium was expressed either in Moorsom ton, in Gross Register ton GRT, or in Gross Tonnage (GT) which applies to new ships from 1982 (section 5.2.). In Belgium, in practice, the first (2) ships measured according to the GT system were registered in the 1984 annual report. Before that, ships were reported as register ton GRT or in m^3. From 1984 onwards these measurements were gradually replaced by GT as new ships entered the fleet or as older ships were gradually measured according to the GT system. From 1994, all ships measurements were expressed as GT. The data integration covers the period from 1842 to present and shows the same data gaps as in the reconstruction of the fleet size (Figure 5.2.).

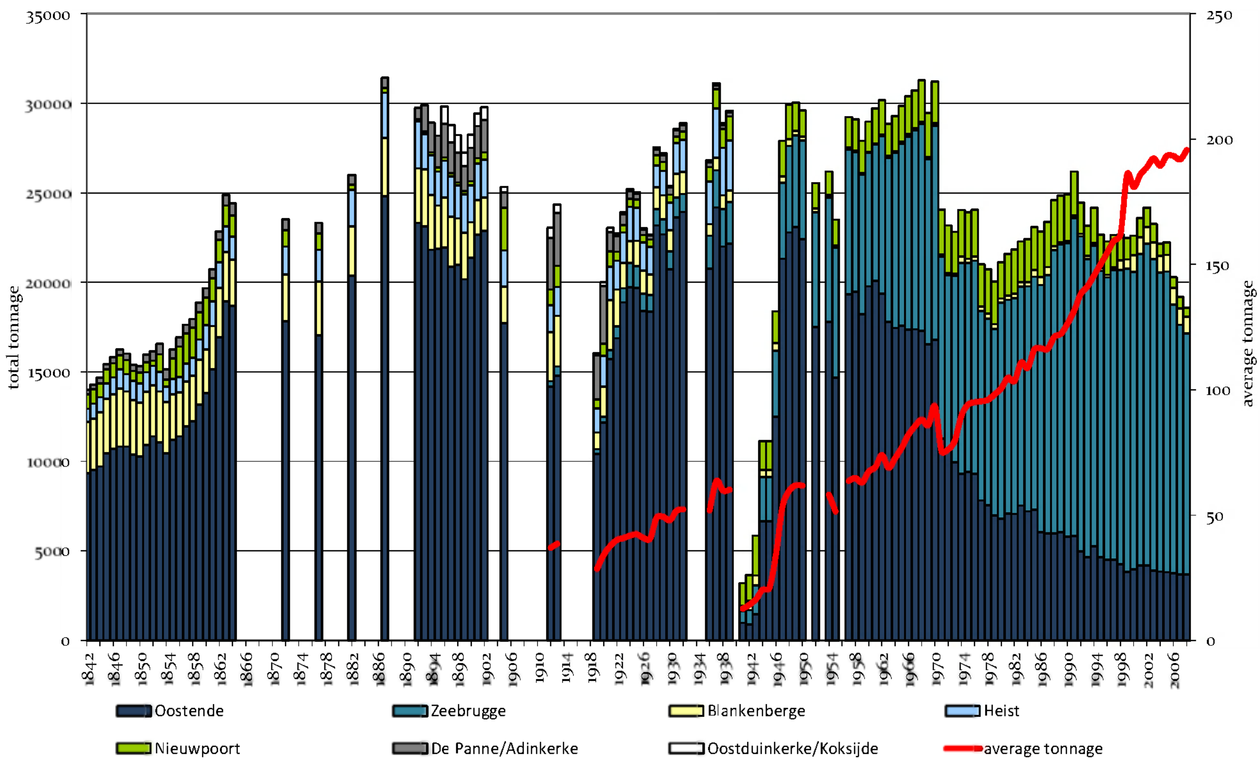


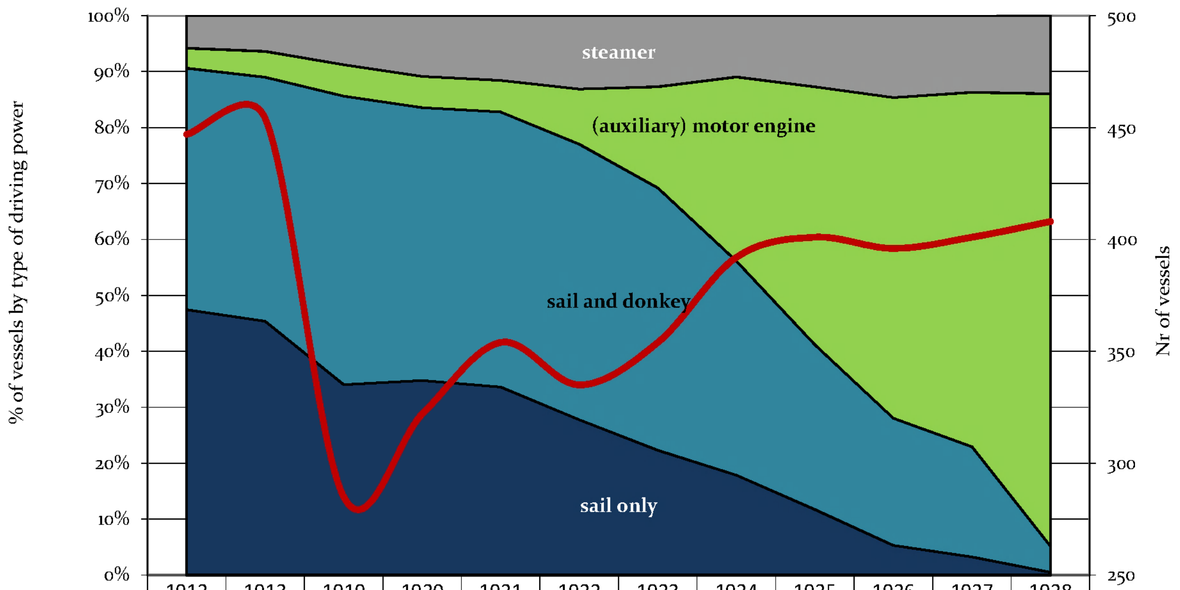
Figure 5.4.: Trend in total gross tonnage and average tonnage of vessels of the Belgian fishing fleet in the period 1842-2010. Source: VLIZ HiFiDatabase, reconstructed from historical sources Table 5.1. From 1984 to 1994, tonnage measurements were gradually replaced by the GT. After 1994 tonnage is expressed as the unit-less GT (see text).

Overall gross tonnage of the fleet increased from 1842 to 1864 (Figure 5.4.), the period during which subsidies were granted by the government for new ship constructions (e.g. Royal Decree 07/01/1837) and for cod and herring fisheries (e.g. Royal Decree 19/06/1837). Average tonnage increased in Oostende and in Nieuwpoort, with offshore fisheries for cod and herring, whereas the other locations operated smaller vessels for inshore fisheries and short distances (Chambre des Représentants 1866).

The arrival of steam vessels in 1884 affected the overall nature of the fleet, in particular the average size of the sailing vessels. From 1884 until 1905 the tonnage decreased in all ports except in Oostende where the core of the fleet of steamers was located. The larger sailing vessels could no longer compete with the efficiency and haul-out of the large steamers and specialized in inshore fisheries (Commissie voor Zeevisscherij 1913). In 1912 the steamers represented 6% of the ships with covered decks (see also Fig. 5.5.), but contributed 25% of the total tonnage and 60% of the total fish production (reported in Belgian francs BEF). In particular just after WWI, when total tonnage had fallen substantially (16,043 GRT in 1919, Figure 5.4.), the recovery of GRT was most notorious in Oostende where steamers increased from 25 (4,899 GRT) in 1919 to 58 in 1926 (9,812 GRT). After WWI, total gross tonnage over all ports grew from 16,043 GRT in 1919 to 31,205 GRT in 1970, an increase interrupted only by the destruction of the fleet during WWII (Figure 5.4.). The reverse trend in Oostende however set in from the 1960s and is particularly visible at the beginning of the 1970s when a number of larger ships registered in this port were taken out of service and registered tonnage decreased from 16,800 GRT to 11300 GRT (-33%). Meanwhile, the increase of the overall tonnage in the port of Zeebrugge - especially between 1980 and 1990 - could not compensate for the overall decline. Finally total tonnage dropped from 24,175 GT in 2002 to 15,812 GT in 2010. Although the fleet size has downsized to about 17% compared to the post WWII situation, the near 10-fold increase in average tonnage, from approximately 20 GRT in 1945 and 70 GRT in 1950, to near 200 GT (approximately 277 GRT) in 2010, has partially compensated the overall decrease in tonnage of the fleet (Figure 5.4.).

5.3.4 Trend in total installed engine power (Kilowatt-kW) of the fleet and average engine power (kW) of fishing vessels of the Belgian fishing fleet since 1928

The arrival of the first steam vessel in Belgium (Oostende 1884) triggered a period marked by major changes in the fishing power of the fleet, which until then had remained dependent on the sail as only driving force. In only 16 years' time (1912-1928) a major transition would take place. In 1912, 90% of the fleet consisted of sailing vessels of which nearly half deployed a motorized donkey to haul out the nets (Commissie voor Zeevisserij 1913, Figure 5.5.). In 1928 however, 10 years after WWI, this segment of the fleet represented only 5%. Figure 5.5. shows the evolution in total number of the fleet before and after WWI and the major changes in numbers (Figure 5.5. data table) and proportion (Figure 5.5.) for the different types of driving force of the fleet. In 1928, 95% of the vessels (not including the smaller 'open and half-open' vessels) were using (auxiliary) motor or steam engines (14% from the total) as driving force.



	1912	1913	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928
steamer	26	29	25	35	41	44	45	43	51	58	55	57
(auxiliary) motor engine	16	21	16	18	20	33	64	129	185	227	254	330
sail and donkey	193	198	147	157	174	165	166	150	118	90	79	19
sail only	212	206	97	112	119	93	79	70	47	21	13	2
number of vessels	447	454	285	322	354	335	354	392	401	396	401	408

Year

Figure 5.5.: Change in driving force (1912-1928) of the Belgian fishing fleet by type of driving force: sailing vessels with 'sail only', sailing vessels using donkeys to haul out the nets 'sail and donkey', vessels with motors or auxiliary motors, and steam vessels. The figures in the graph are expressed as % of the total fleet size (left axis); the red line and the data table give absolute numbers. Data reconstructed from historical sources listed in Table 5.1. Note: data in the table do not include 'open and half-open' decks, only vessels with closed-covered decks.

The reconstruction of the time-series of engine power (Horsepower HP and/or Kilowatt kW, Figure 5.6.) is based on the OLBFV from 1928 until present, covering a period with comparable fleet characteristics (>95% of the fleet is motorized in 1928). Engine power was reported in sources as 'effective Horsepower' or in kilowatt, integrated on a ship-by-ship basis and standardized to Kilowatt (1HP= 0,745699 kW). The engine power measurements were provided by the Maritime Inspection and reported as 'effective engine power', which differs from the theoretical engine power by taking into account the friction losses. As a general note however, the statistics on engine power must be interpreted with care since declared engine power may differ from true installed engine power, because of taxes or licensing issues.

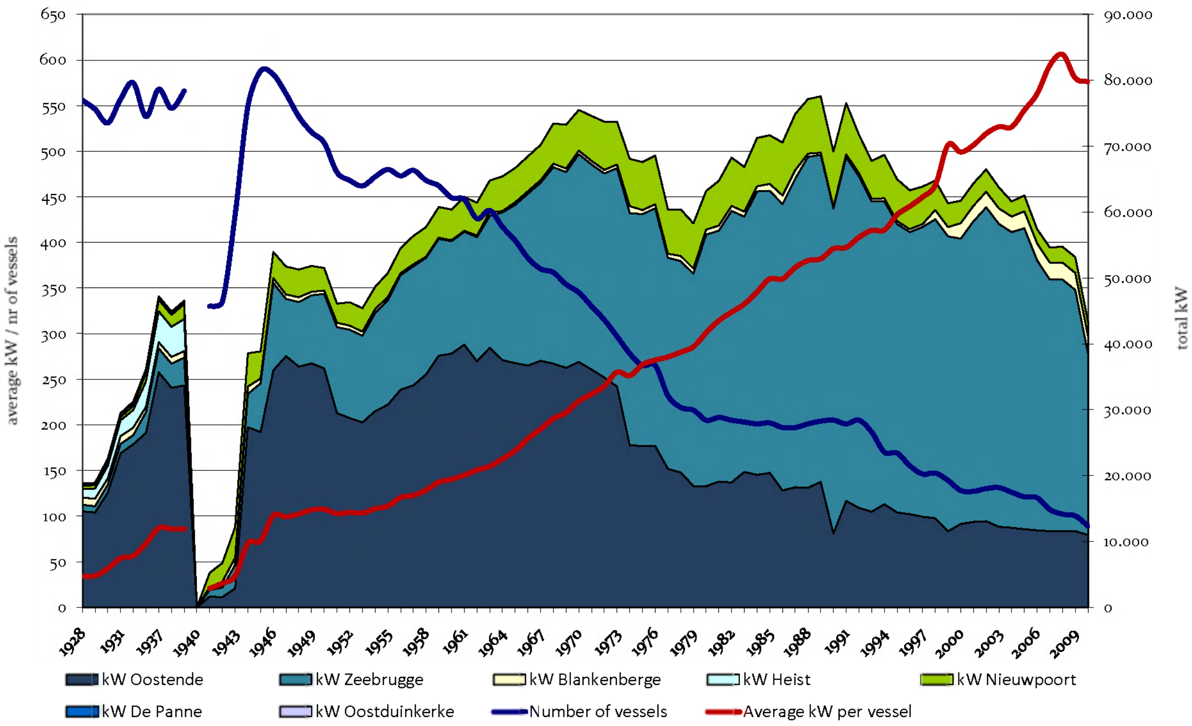


Figure 5.6.: Trend in total installed motor capacity (Kilowatt kW) of the Belgian fleet, by port, and average installed engine power of vessels in the period 1928-2010. Source: VLIZ HiFiDatabase reconstructed from Official List of the Belgian fishing vessels on a ship-by-ship data integration.

Total installed Kilowatt (kW) of the fleet amounted to 54,000 kW in 1946 compared to 51,200 kW in 2011 (Figure 5.6., figures in the text are rounded). Peaks in total engine power of the fleet were reached in 1970 (75,500 kW) and in 1989 (77,500 kW). Whereas the total kW of the fleet in Oostende reached a maximum of 39,800 kW in 1961 and decreased since then, total kW in Zeebrugge increased up to 52,100 kW in 1991 before declining (Figure 5.6.). In summary, in 2011 a fleet size of only 15% of the size of 1946 operated a total engine power of 95% compared to that of 1946. In opposite wording, the fleet size decreased by 85% while overall engine power decreased by 5% only. On average, a fishing vessel has become 5.7 times more powerful in terms of engine capacity compared to 1946. This comparison does not take into account other relevant enabling technologies that have significantly enhanced fishing power, and are commonly referred to as 'technological creep'. Marchal et al. (2003) estimated an annual increase in catchability as a consequence of 'technological creep' of up to 10% in North Sea surveys, while Rijnsdorp et al. (1996) reported an annual increase of 1.8-2.6% in beam trawl fisheries for sole and plaice in the North Sea. For the case of the Belgian fleet, this increase in average engine power is related to the subsidised (re)introduction of the beam trawl in the 1960s and to the introduction of tickler chains (an example of technological creep) rigged in the net-mouth and which required more engine power (Polet et al. 1998).

This positive trend in average tonnage (GRT or GT) and average engine power (kW) in a declining fleet size was legally capped by measures establishing a maximum of 1,200 kW per vessel, and a maximum of 221 kW for beam trawlers fishing within the 12-miles territorial waters. The decline in total engine power (kW) in recent years is both due to the decline in the fleet size and the gradual replacement of larger vessels by smaller ones.

5.3.5 TREND IN EFFORT OF THE FLEET: NUMBER OF DAYS SPENT AT SEA AND FISHING SINCE 1938

Figure 5.7. shows the evolution of the total number of days the fleet spent at sea or days spent fishing. The annual number of days spent at sea by the entire fleet has decreased from approximately 91,800 in 1938 to 15,100 days in 2010 (-84%, Figure 5.7.). Crews spent on average 88% of the days at sea as effectual fishing days, and a vessel spent on average 171 days per year at sea. Only during WWII, when fishing was allowed during daytime breaks and in coastal waters, a day spent at sea was actually spent fishing.

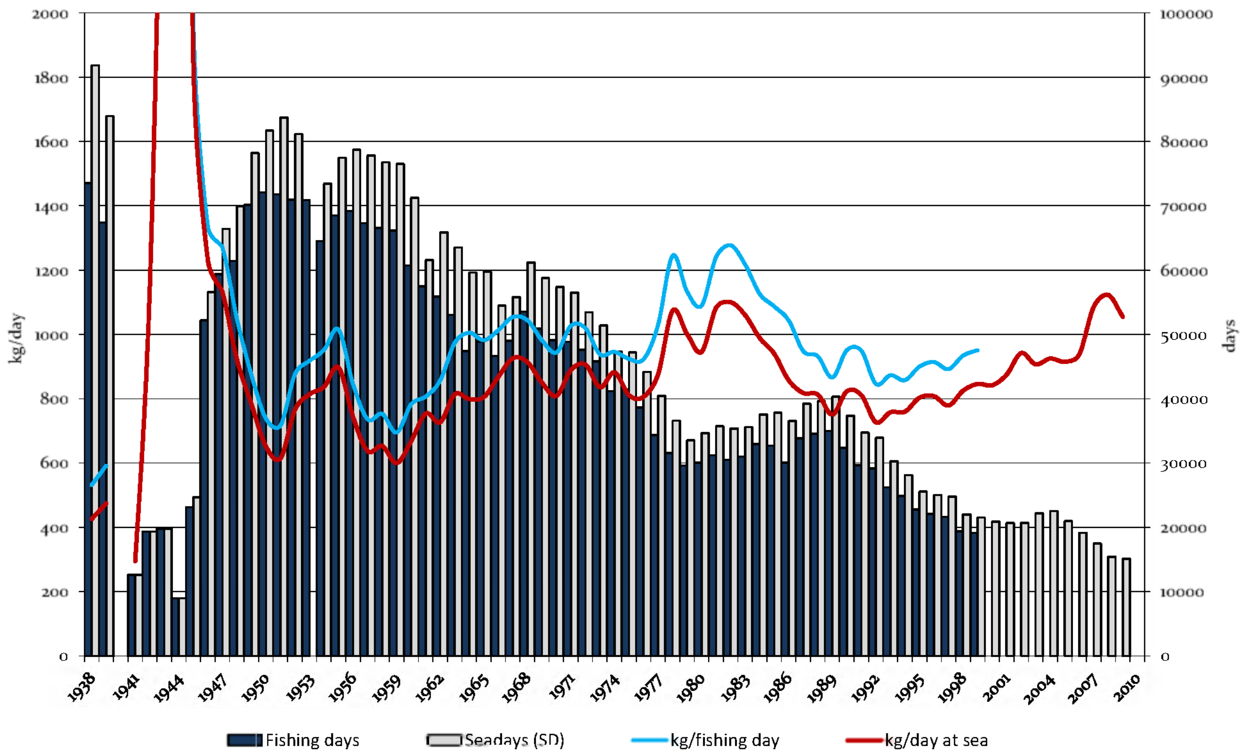


Figure 5.7.: Trend in total number of days spent at sea or fishing by the Belgian fishing fleet 1938-2010 (left axis). Reported landings of fish per day by the Belgian fishing fleet 1938-2010 (kg/day, right axis). The extremely high values kg/day in 1943-1945 are not visualized to optimize scale (see text). Source: VLIZ HiFiDatabase, reconstructed from historical sources Table 5.1.

Considering the entire period – excluding WWII - an average of 850 kg fish were landed per day spent at sea. In 1942-1943 this was 5,500 kg per day (Lescrauwaet et al. 2013 under review). The average amount of fish landed per day in 2008-2010 (1,000 kg, Figure 5.7.) was similar to that in 1978-1983 and 1946-1947 (the peak years of landings for Belgian fisheries since 1929). These values however are not indicative of relative abundance of fish due to the shifts made by the Belgian fleet in targeted species and fishing grounds on the one hand, and also because of the profound changes in the fleet size, capacity, engine power and fishing power of the vessels and fishing gear employed. Also, the average tonnage and engine power of vessels have increased 10 and 6 times respectively since 1938 and technology creep has not been accounted for in the figures presented here.

5.4 Conclusions

The recovery and integration of historical data on the characteristics of the Belgian sea fisheries fleet allowed reconstructing time-series from 1830 until present. Time-series show a decrease in the current fleet size (-85%) and overall kW engine power (-5%) since 1946 and demonstrate that this smaller fleet compensated by more powerful vessels with a 10-fold increase in average tonnage and a six-fold increase in average kW per vessel. The present analysis is based on the aggregated data for all types of commercial vessels and fishing gear in Belgian fisheries and does not reflect changes in specific fisheries over time. As it is not straightforward to compare the fishing power or fishing effort between different fisheries, the available data on fleet and fishing effort need to be disaggregated by fishing 'métier' (i.e. the combination of target species, fishing gear, season and fishing areas) in order to develop an analysis of the trends in landings per unit of effort LPUE. In a next step, it is important to expand the current analysis to develop distinct indexes of LPUE for different fishing 'métiers' in Belgian fisheries (e.g. shrimp beam trawl fisheries in coastal waters, beam trawl fisheries for flatfish plaice and sole in the North Sea or in the western waters). As these indexes of LPUE are widely accepted as indicators of changes in fish stock biomass (Christensen et al. 2003, Myers and Worm 2003, Cardinale et al. 2009a and 2009b, Thurstan et al. 2010) they can support current fisheries management and provide reference points for the definition of good environmental status in the context of the European Marine Strategy Framework Directive.

The time-series built a unique view of 180 years of dynamics of the Belgian sea fisheries fleet and its response to some of the major local events and international trends. It also demonstrated the significant changes in the fleet as a consequence of the introduction of new technologies (steam engines, motor engines), legislation (subsidies, tax levies, exclusion zones) and its responses to changes in the availability of fishing resources (target species and fishing areas). Some of the most drastic changes, such as the transition from sail and steam engines to motor engines or the shift from otter trawl to beam trawl as main fishing gear, took place over a time interval of one decade. This reflects the difficult conditions in which fisheries operate, but also suggests that the sector is able to adapt to quickly changing economic, technological and environmental conditions and newly emerging societal challenges. The time-series is unique in revealing how the decline in the fleet size – less ships concentrating in a few ports with specialized facilities - is linked to the disappearance of numerous fishing communities both along the coast and along the estuary of the river Scheldt, drastically changing the sight and social fabric of the coastal communities in Belgium. It also raises the question of whether a minimum fleet size should be observed to ensure economic viability and resilience of the sector, a question that is also of particular strategic importance to smaller EU fishing nations.

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CHAPTER 6: Invisible Catch: A century of bycatch and unreported removals in Sea Fisheries, Belgium 1929-2010

CHAPTER 6. INVISIBLE CATCH: A CENTURY OF BYCATCH AND UNREPORTED REMOVALS IN SEA FISHERIES, BELGIUM 1929-2010

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Lescrauwaet, A.-K., Torreele,' E., Vincx,' M., Polet, H. and Mees, J. 2013. Invisible Catch: A Century of bycatch and unreported removals in Sea Fisheries, Belgium 1929-2010. Fisheries Research (in press, 2013). 10.1016/j.fishres.2013.05.007

Note: A summary of this chapter will be included in the Global Atlas of Fisheries Total Catch Reconstruction as the contribution for Belgium. Publication by the 'Sea Around Us Project', dr. Daniel Pauly, Fisheries Centre, University of British Columbia UBC , Canada. No citation available yet.

Abstract

Publicly reported statistics on the production of fisheries available refer to 'landings' as opposed to 'catch'. However, well-informed decisions and evaluation of the impacts of fisheries on ecosystems must be based on total removals, so including the part of the catch that is discarded at sea or not reported as landings. Total removals by Belgian fisheries from all ICES fishing areas and from the Belgian part of the North Sea (BNS) from 1929-2010 were reconstructed by including unreported and misreported landings of the commercial fleet, unreported landings by the recreational and artisanal/subsistence fisheries and by estimating discards for the most important fisheries. Total reconstructed removals were estimated at 5.2 million t or 42% higher than the 3.7 million tonnes (t) publicly reported over this period. Unreported landings and discards were estimated to represent respectively 3.5% (0.2 million t) and 26% (1.3 million t) of these total reconstructed removals. The reconstructed total removals on the BNS were estimated to be 55% higher than the 0.8million t publicly reported over this period. In terms of percentages, discards on the BNS represent an average annual of 34% over the entire period. The results suggest that since the 2000s, approximately 50% of all Belgian removals from the BNS are unreported landings and discards (IUU). The unreported landings and discards are increasingly taken by non-commercial, small-scale (<12m) vessels that are not subject to reporting and not taken into consideration in planning, monitoring and enforcement. While the present paper provides a first attempt to reconstruct historical total removals for Belgium's sea fisheries, it also addresses the gaps in data and information that need to be resolved to improve the reliability of the estimates of unaccounted removals. The reconstructed time series provides a context for the wider debate about how to move to more sustainable fisheries, what the role of small-scale fisheries are, how to achieve the agreed policy targets in Belgian marine waters and in particular in the marine areas protected under the EU Habitat and Bird directives.

Key words: Catch reconstruction, IUU, Belgium, EEZ

6.1 INTRODUCTION

Well-informed decisions in support of ecosystem-based resource management in the marine environment must be based on total removals by fishing activities and not just on officially reported landings (Zeller et al. 2009). The total removals by fishing can be summarized as the publicly reported plus the total of *illegal, unreported and unregulated catches* or IUU (Pauly 1998, Bray 2000). Publicly reported statistics on fisheries generally refer to commercial landings which are only a part of the catch and hence of the total removals.
The difference between publicly reported versus total anthropogenic removals includes several components. Besides the unreported and misreported commercial landings (Zeller et al. 2006, Zeller et al. 2007), part of the catch is discarded at sea by fishers (Kelleher 2005), suffers unaccounted underwater mortality in the fishing gear (Collie et al. 2000, Rahikainen et al. 2004, Kaiser et al. 2006, Depestele et al. 2008) or is removed by recreational/artisanal fishing (Coleman et al. 2004, Zeller et al. 2008). It is widely accepted that the dumping of fish at sea is unethical and represents a substantial waste of resources (Diamond and Beukers-Stewart 2011). Resolution 57/142 (2002) of the United Nations urges states and regional organizations to develop and implement techniques to reduce and eliminate bycatch and fish discards. In many cases, there are considerable uncertainties in stock assessments as a consequence of low stock size, inaccuracies in catch data (total removals) and variability in survey indices. These uncertainties add to the challenges of setting targets for the recovery of stocks in a changing natural environment.

In the pursuit of an ecosystem-based approach in the marine environment, it has become increasingly important to document and quantify total removals. Data Collection Regulations in support of the Common Fisheries Policy CFP (EU Council Regulation 1543/2000 and Commission Regulations 1639/2001, 1581/2004 and 199/2008) require European Member States to collect data on technical, biological and economic aspects of their national fisheries, and their impact on the marine ecosystem. Regulation COM(2007) 136 requests member states to collect data and report on discards. As a follow-up of this regulation and the outcomes of the revised CFP regarding the so-called 'discard-ban', it is anticipated that from 2015 formal reporting on commercial landings will be extended with commercial discards and removals from non-commercial fishing so as to obtain a more complete view on total removals from the marine ecosystem by fisheries and improve stock assessments. Moreover, for the establishment of criteria and definition of good environmental status (GES) for the Marine Strategy Framework Directive MSFD (2008/56/EG), both the current information on total removals and the historical reference conditions are important. Besides the gaps in historical information, there is no quantitative or qualitative assessment of the small-scale fisheries (<12m) within 12 nautical miles or the territorial sea of Belgium. Historical time-series are scarce and available time-series mostly date from after the start of intensive exploitation. In Belgium, centralized reporting on landings of sea fisheries at the species level started in 1929 (Lescrauwaet et al. 2010a). As is the case for most fishing nations, the routine data collection requirements related to sea fisheries production in Belgium were - until recently - limited to landings of the commercial fleet. Discards of the commercial fleet, landings and discards of the recreational fleet, and artisanal and land-based fishing activities are not covered in systematic reporting.

The present work contributes to the reconstruction of total present and historical removals by Belgian fisheries by estimating the unreported catch and the discards, based on the best available scientific data and information. These estimates help to better inform the public on current and historical levels of fisheries removals and underline the importance of unaccounted components of total removals. They can support informed decision making towards more sustainable catch levels, in particular for the Belgian part of the North Sea. The paper also provides an overview of relevant historical sources reporting on bycatch, discards and unreported catch that can be of use for similar exercises in other countries. Finally, remaining gaps and uncertainties that need to be removed in order to fully reconstruct the historical total removals by Belgian fisheries in the eighty-two years from 1929 until 2010, are identified.

6.2 Sea Fisheries in Belgium: current and past situation

Fleet, ports and employment

Belgium today has four coastal ports (Nieuwpoort, Oostende, Zeebrugge and Blankenberge) and besides the fish auctions located in Oostende, Zeebrugge and Nieuwpoort there are no other or dispersed commercial landing points. Before World War II (WWII, 1939-1945) there were important settlements in Heist and Blankenberge to the east, in the Scheldt estuary, and in De Panne, Adinkerke, Oostduinkerke and Koksijde to the west. Together with the current fishing ports they harboured more than 500 vessels of which approximately 100 had open and half-open decks. In 2011, the Belgian commercial sea fishing fleet consists of 86 ships, with a total engine capacity of 49,135 kW and a tonnage of 15,326 GT (Tessens and Velghe 2012). 46 vessels are part of the Small Fleet Segment (SFS; max 221 kW engine power) of which 2 use passive gear and the others are beam trawlers for shrimp and flatfish. Of the SFS, 21 are inshore vessels that make fishing trips of less than 48 hours within the range of 12 nautical miles. 43 vessels compose the Large Fleet Segment (LFS) with an engine power between 221 kW and a maximum of 1,200 kW. The LFS consists of 5 vessels using trammel nets, 4 using otter trawl (*bordenvisserij*) and 34 large beam trawl vessels (≥662 kW). The Belgian commercial fishing fleet has no vessels under 10m or above 40m. According to the EU definition (EC Council Regulation Nr 1198/2006), none of the vessels or fisheries operating in the Belgian fleet can be considered as small-scale fisheries, except for one 11.8m vessel operating drift and/or fixed nets. Reconstructed time-series on fleet dynamics since 1830 (Lescrauwaet et al. 2012) show a decrease of 85% in the fleet size between 1946 and today, while the fleets' overall engine power has decreased by only 5% in that same period. This 85% decrease in fleet size was compensated by a 10-fold increase in average gross tonnage and a six-fold increase in average kW per vessel. The Belgian fleet today is highly specialized: more than 68% of the effort (expressed as seadays or SD) and 77% of total landings are achieved by beam trawlers in 2010, focusing primarily on flatfish species such as plaice (*Pleuronectes platessa*) and sole (*Solea solea*).

Origin, value and composition of landings

In 2010, the Belgian fleet landed a total of 22,000 t (fresh weight), of which 80% was landed in the Belgian ports. After a maximum of 81,000 t reported (fresh weight) landings in 1947, annual landings declined steadily to only 26% of this peak today. Currently, landings are below those achieved in 1929. Considering the period 1929-2010, the most important species in terms of landings were cod (*Gadus morhua*, 17% of all landings), herring (*Clupea harengus*, 16%), plaice (14%), sole, whiting (*Merlangius merlangus*) and rays. In terms of economic value, sole (31%) and cod (15%) were the most valuable (Lescrauwaet et al. 2010a). Since reporting started, 20% of all reported landings have originated from the 'coastal waters' (section 6.4. i), while these waters contributed nearly 60% of all landed pelagic species and 55% of all landed 'molluscs and crustaceans'. The boundaries of the reporting unit 'coastal waters' approximate the area of the Belgian part of the North Sea (part of ICES subdivision IVc). North Sea (south) (ICES fishing subdivision IVc, Figure 6.1.), Iceland (Va), North Sea (central-west) and North Sea (central-east) (the last two aggregated as IVb in FAO/ICES fisheries statistics) were the next most important fishing areas in terms of reported landings. Overall, 73% of all landings originated from only 5 of the 31 fishing areas where the fleet operated historically.

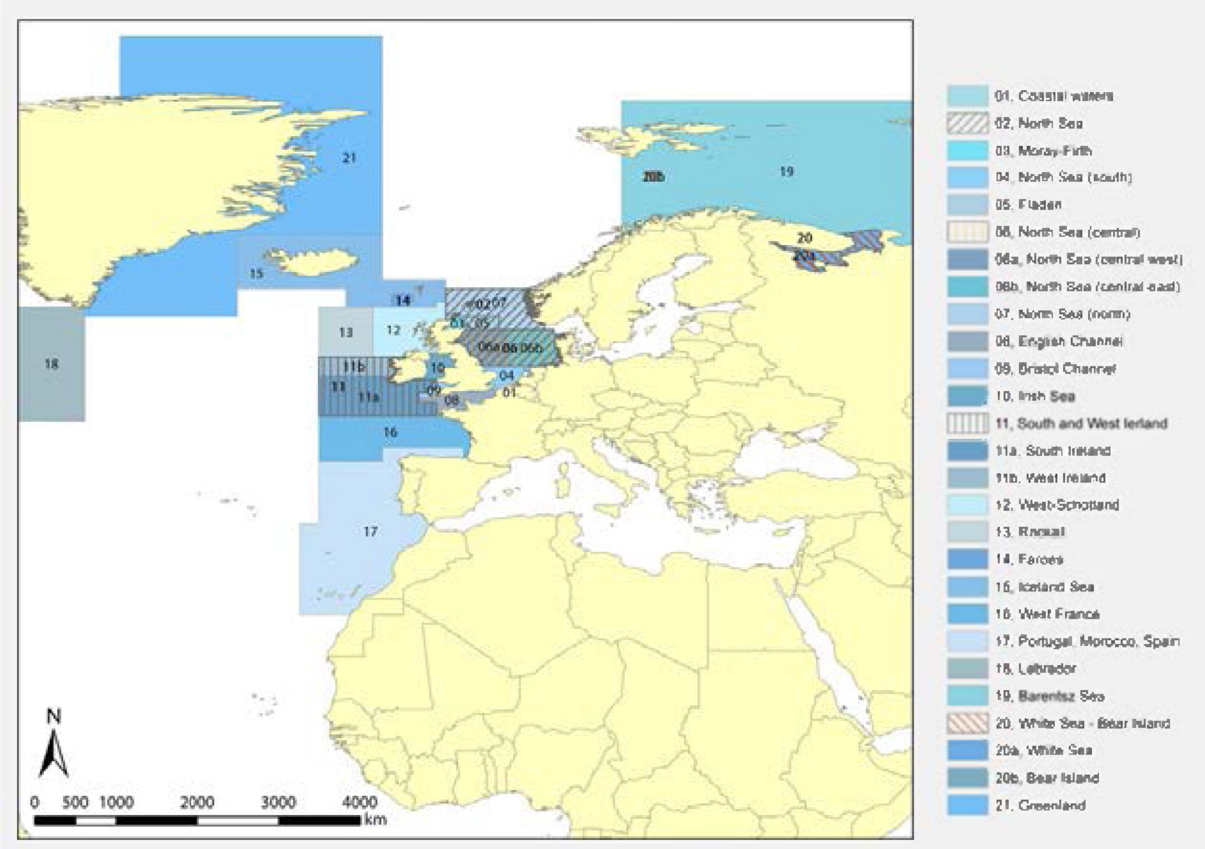

Figure 6.1.: Boundaries and names of fishing areas where the Belgian fleet was active between 1929 and 2010, as referred to in historical data sources. *Source: 'Marine Regions' www.marineregions.org (VLIZ).*

Fisheries and fishing gear 1929-2010

In Belgium the transition from sail to motor engines was near to completion by 1929 and after WWII the commercial fleet consisted mainly of motor engine-powered vessels. The last steamer disappeared in 1964 (Lescrauwaet et al. 2012). As was the case for the steamers, the motor engine-powered vessels used the otter trawl to catch fish. Before 1950, the otter trawl was the main fishing gear, together with drift nets (for pelagic fisheries). After 1960, the otter trawl was mainly used for roundfish (e.g. whiting and cod) fisheries and for shrimp (*Crangon crangon*). The pelagic trawl for herring and sprat was used from 1950 onwards and remained important until 1965 in terms of effort (SD) and landings (Gilis 1962). After 1960, the (re)introduction of the beam trawl (*boomkorvisserij*) – the most efficient gear for catching targeted flatfish – and the subsequent technological improvements to increase catch efficiency of the beam trawl required an increasing average engine power (Polet et al. 1998). The installment of the beam trawl was subsidized by the Belgian government and supported by royal decree 1/03/1958 (Lescrauwaet et al. 2012). In 1985 otter trawling targeting herring and sprat, shrimp, and other species represented respectively 1%, 11% and 21% of effort in SD while beam trawl targeting sole and plaice represented 62%. The remaining 5% effort was realized by twin trawling (‘*spanvisserij*’) for cod. With the increasing cost of diesel, recent interest has been given to the otter trawl (10% of SD) compared to the shrimp beam trawl (14% of SD) the flatfish beam trawl (68% of SD) and passive gear (1% of SD) in 2010. Passive forms of fishing that are gaining importance are angling (handlines) for cod and sea bass, trammel- and gillnetting.

6.3 MATERIALS AND METHODOLOGY

Data and information sources

ICES Fishstat database

The 'ICES Official Catch Statistics' electronically available from the ICES webpages, describes reported landings by country, species (or higher taxonomic grouping), ICES reporting area and year. The electronic database is publicly available for redistribution and used as the EU official report on fisheries 'catch' to the Food and Agriculture Organization of the United Nations (FAO). The version 2012 - with updated time-series up to 2010 - is used as a baseline in the present study and throughout referred to as 'ICES Fishstat'.

HiFiDatabase: Historical fisheries database (landings and value of landings)

Based on fragmented and disperse data sources, including previously uncovered original reporting cards, time-series for Belgian sea fisheries were standardized, quality controlled and integrated from 1929 onwards. The detailed procedures for quality control and integration of data are explained in Lescrauwaet et al. (2010b). The resulting historical fisheries database (HiFiDatabase) contains data by species (41), by port of landing in Belgium (4) and in 'foreign ports,' and by fishing area of origin (31) (Lescrauwaet et al. 2010a). Landings in the HiFiDatabase are reported as 'dead weight' and hence were converted to live weight to compare to the ICES Fishstat. Compared to the ICES Fishstat, the HiFiDatabase offers advantages in temporal coverage (data from 1929 onwards), temporal scale (monthly values), weight class (e.g., 5 to 7 weight classes for sole) and taxonomic resolution (less grouping). It also provides more detailed information at the spatial scale as it contains a reporting unit for the western central North Sea (IVb-1) and the eastern central North Sea (IVb-2), and it is the only source of historical information on landings originating from the 'coastal waters', Fladen, and Morray-Firth.

ICES baseline data do not contain statistics with spatial reference to the Belgian EEZ or to the BNS. Only from 1996 onwards, data are available for research purposes at a spatial scale that is of relevance to the BNS. An additional challenge with the data by ICES rectangles is the position of these rectangles by which the data are aggregated. Although one of the 3 relevant reporting rectangles (31F2) has a significant proportion of its area within the BNS, unknown but likely significant landings from the areas of 2 other rectangles (31F3, 32F2) should be taken into account (Figure 6.9.). The HiFiDatabase however contains data reported for the 'coastal waters' from 1929-2010. These unique historical data were used in the present estimates of total removals at the scale of the BNS. For the purpose of quality control, the reported landings for the 'coastal waters' (1929-2010) were compared to the fragmented historical source documents that report at ICES statistical rectangle. The data for the combined rectangles 31F2 and 31F3 provide a fair match (<10% difference) with the historical time-series for the 'coastal waters'. Considering the spatial scale of the BNS, this time-series is therefore considered to provide an acceptable representation of the landings originating from the BNS. Inconsistencies between the ICES Fishstat (version 2008) and HiFiDatabase – in particular for the years between 1929 and 1960 – were previously reported by Lescrauwaet et al. (2010b). The ICES Fishstat version 2008 was amended by ICES in 2012. The values included in the amended version Fishstat 2012 are closer to the values in the HiFiDatabase, compared to the Fishstat 2008 version. The Fishstat 2012 also contains updates of the landings up to 2010. The differences between the HiFiDatabase and the Fishstat 2012 (our baseline for this study) are considered as unreported removals and are included in the present reconstruction.

Historical literature and literature databases

Literature databases were searched for historical publications and references related to unreported catch (Web of Science, JSTOR, Google Scholar, IMIS). Flanders Marine Institute (VLIZ) manages the Integrated Marine Information System IMIS for Belgium, which provided crucial relevant historical information to complete the estimates (Table

6.1. and list of references). Much of this information is contained in previously unpublished manuscripts that were disclosed in IMIS to this purpose, or in publications in native languages (Dutch, French) that are not picked up by global scientific literature databases focusing on English-speaking literature. These references contain information that is potentially relevant for similar exercises in other fishing nations around the North Sea. Relevant historical legislation with an impact on sea fisheries management (fleet, effort, gear, etc.) was obtained from the historical timeline on sea fisheries application. All taxonomic references were obtained from the World Register of Marine Species WoRMS.

Adding components

The separate components were quantified or estimated and added to the baseline to reconstruct total removals (as opposed to reported landings) for Belgian sea fisheries. To structure this stepwise process, the categorizations as defined in Zeller et al. (2010) were used in the approach:
(1) 'adjustments' to the baseline ICES Fishstat, based on HiFiDatabase and considered as 'unreported' landings
(2) other unreported landings from the commercial fleet
(3) discards: mainly 'boat-based' discards resulting from fishers' behavior (e.g. the so-called high-grading)
(4) recreational removals and artisanal/subsistence fisheries, not included in the reported landings

Discard is the dumping of the un-wanted portion of the catch whereas by-catch is the part of the catch that is captured incidentally to the target species and as such may have some economic value. With regards to (3), the proposed 'discard ban' (COM(2007) 136) has revived the debate related to the need to take into account survival rates of certain species of discarded fish and invertebrates in order to achieve more accurate discard mortality estimates as part of stock assessments. The results of survival rate studies were shown to be highly dependent of the experimental design, the environmental conditions (season, fishing area, temperature, depth, etc.) and fishing conditions (gear, duration of tow or soaking time, weight of the catch, etc.) (Depestele et al. 2008). While acknowledging the potential survival rates of discarded fish and invertebrates, a precautionary approach is taken in the present reconstruction.

The baseline adjustments, unreported landings and recreational removals were added to the baseline data. Information on discards and discard rates was generally applied as a percentage rate to the reported plus the unreported catches of specific species, by type of fisheries. Any assumptions adopted in the present estimates on discarding are science-based. Estimates on recreational fisheries are founded on expert judgment from people that have >30 years experience in the field. Where insufficient information is available for the estimation of a missing component, this is indicated and identified as a challenge for future research. This stepwise and bottom-up approach is conducted for the most important fisheries in Belgium between 1929 and 2010: the otter and beam trawl *Crangon* shrimp fisheries, the pelagic trawl fisheries for herring and sprat, the otter trawl *Nephrops* fisheries, the otter trawl fisheries for cod and other roundfish, the beam trawl flatfish fisheries (sole and plaice), and recreational sea angling (section 6.4. f). Other fisheries or fishing gear such as dredges, seine nets, trammel nets etc., were not taken into account in the reconstruction because of their limited contribution to total landings and fishing effort. Mortality that was not taken into account includes underwater discards such as tow path mortality or escape mortality caused by the gear, changing or decreasing mesh size and other technological developments affecting bycatch of the gear. Ghost fishing caused by lost or abandoned trawl nets was considered negligible or zero (Depestele et al. 2012).

Approach and assumptions by type of fisheries

Estimates, variables and bibliographic sources used in the present reconstruction of total removals are summarized by type of fisheries (Table 6.1.). In a first step, the different components (reported landings, unreported catch, discards) are added for each fishery. Although they are intermediate results of the present analysis, they provide a unique level of detail, and therefore are included in the first subsections a) to g) of the 'Results and Discussion'. These intermediate steps are necessary for understanding the overall results of the reconstruction for the Belgian fisheries in all ICES areas (subsection h) and for the Belgian fisheries in the BNS (subsection i) in Results and Discussion).

6.4 Results and Discussion

a) Shrimp fisheries (Crangon crangon):

Commercial shrimp fisheries (reported and unreported landings, and discards)

The Belgian fisheries for brown shrimp are mainly conducted by small (<221 kW) vessels that operate within the Belgian territorial sea and to a lesser extent in northern France and Dutch waters. In 1929 approximately 250 vessels participated in the shrimp fisheries, in 1950 these were 187 (otter trawlers, single net) whereas today less than 30 vessels (beam trawler, double beam, 22 mm mesh size) are full-time active in the shrimp fisheries. Part of these 30 vessels operate from foreign (Dutch) ports under Belgian flag since at least 1990 (Churchill 1990, Hoefnagel 1998) and hence report their landings in foreign (Dutch) ports as part of the Belgian statistics. Over the entire period, shrimp fisheries represented on average 10% of SD of the total fishing effort of the Belgian fleet (Annual reports 'Landings and value of landings', Flemish government Fisheries Agency). The estimation of discards in both the commercial and recreational *Crangon* fisheries are based on Leloup and Gilis (1965) for the period 1929-1970, and on Polet (2004) for later years. Both report comparable discard rates and fractions of undersize *Crangon* in commercial landings (46% and 47%, see Table 6.1.).

Recreational Crangon landings

In Belgium it is not mandatory for vessels less than 10m length over all (LOA) to report catches. Recreational shrimp fisheries operate in the Belgian coastal waters, from smaller vessels (<8m) using towed gear. Although they are locally regarded as 'semi-commercial' shrimp fisheries given their relative importance if compared to commercial *Crangon* landings, they are not part of the official fishing fleet and not included in formal reporting and data collecting systems. There is no limit to the catch of *Crangon* for the recreational fleet, but the prohibition is on commercializing the catch. The vessels can only operate within the 3nm zone and make use of only one towed net per vessel (max. 3m wide for beam trawl and 4.5m for otter trawl). Regular surveys on ships' safety regulations conducted by government officers along the ports and mooring sites in Belgium, show that approximately 60 recreational vessels are involved and operate from the 4 ports.

A conservative estimate of their catches is based on an effort of 120 SD per vessel and catches of 20kg per fishing trip, although catches of up to 100kg per fishing trip may be achieved (E. Hiele, Shipping Control Service, federal government, pers. comm.). The proportion of the recreational catch versus the commercial catch over the last 5 years was used to back-calculate recreational catches, assumed to exist at least from 1975. Other removals that were taken into account are the recreational-artisanal shrimp fisheries that operate from the beach (on foot and on horseback). We used detailed figures reported during WWII, when these artisanal fisheries were widespread practices for subsistence purposes by coastal residents, as a maximum estimate for this component. This conservative estimate indicates that the landings of this component of the recreational fleet amount to at least 8% of that of the commercial fleet. Since similar gear is used as in the commercial fleet, the same parameters were applied to estimate discards in this recreational segment.

Adding components: Crangon fisheries

Overall, 2,000 t of unreported *Crangon* landings were positively corrected for in the baseline by the local dataset (HiFiData) particularly before 1960 where underreporting existed for brown shrimp. Reported landings of shrimp by the commercial fleet average 1,350 t per year, with a maximum of 4,282 t in 1956. Nearly the same weight (i.e., 1,290 t per year) of undersized shrimp is discarded, while on average more than twice the weight of undersized fish is discarded (i.e. plaice, sole, dab, whiting). Overall, for each kg of reported shrimp landed there is at least 3.3 kg of fish and shrimp discarded. Taking into account the high discards of North Sea crab (*Cancer pagurus*) reported by Leloup and Gilis (1965), particularly towards the west of the fishing areas, these discards would amount to 5,070 t per year. This component is not taken into account in the overall reconstruction of total removals. The recreational and artisanal landings and discards of *Crangon* were added based on the estimators described above, and included in the reconstruction of total removals by the *Crangon* fisheries (Figure 6.2.).

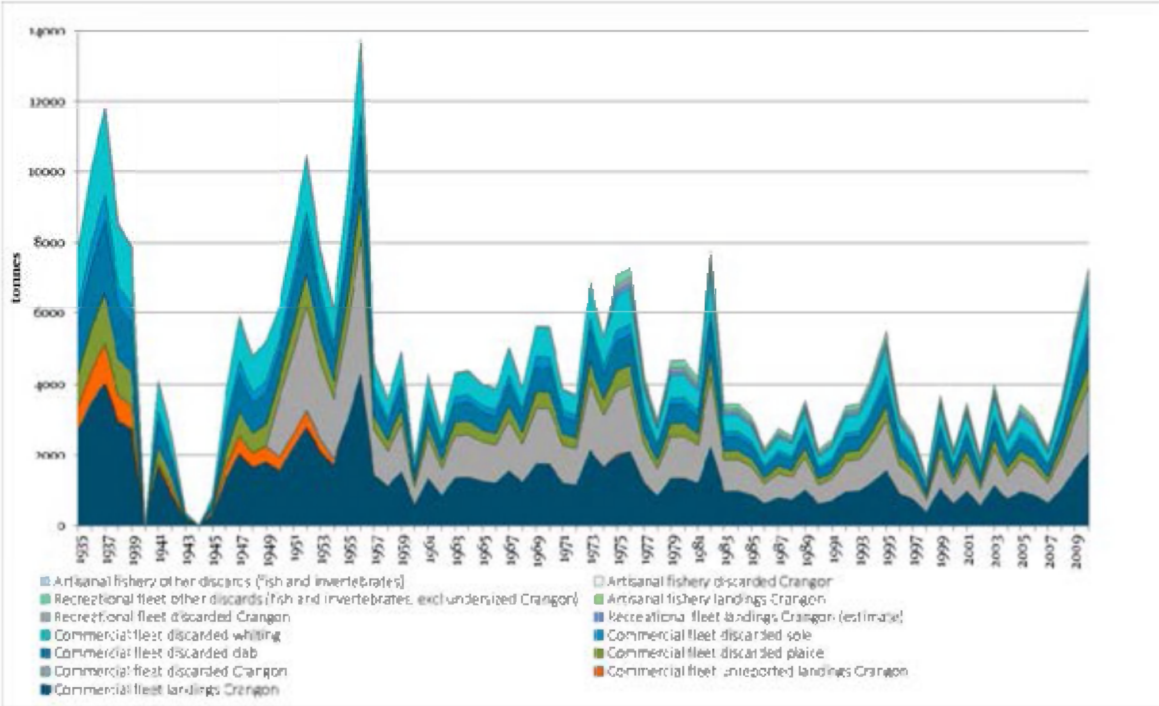

Figure 6.2.: Reconstruction of total removals in the *Crangon* fisheries: unreported landings, legal-sized and undersized *Crangon* landings and discards from the commercial, recreational and artisanal segments.

b) Herring and sprat fisheries

Commercial herring and sprat fisheries (landings and discards)

Before and during the WWII, Belgian herring fisheries mainly used drift nets and otter trawl nets. During WWII, when fishing was only allowed during daytime and within the territorial sea, unprecedented catches of herring and CPUE values were reported from Belgian coastal waters (Lescrauwaet, unpublished data). The herring fishery remained important after WWII in terms of landings in particular between 1950 and 1965. After 1965, ≤1% of the overall fishing effort expressed as SD is assigned to the pelagic (herring and sprat) trawl (Anon. 1965, Tessens and Velghe 2010, 2011). Although from 1950 onwards the pelagic trawl was gradually introduced (Gilis 1962), both the

bottom otter trawl and the pelagic trawl was used until 1965. Gilis (1961) reported and compared both gear in terms of effort, landings, LPUE and bycatch, reporting that pelagic trawl landings contained 91.8% of the targeted herring, compared to 65.3% in the otter trawl (data 1958). Gilis (1961) reported details on the bycatch by species (supporting material, Table I), however without making reference to discards in this or any of his other thorough studies on Belgian pelagic herring trawl fisheries throughout the 1940s-1960s.
There are few historical references with regards to discards in pelagic (herring) fisheries that can be used for extrapolation in the North Sea (Garthe et al. 1996). Morizur et al. (1996) refer to the Celtic Sea (winter) herring fishery as very selective with 99.5% of the total catch by weight consisting of the target species. Discards reported by Morizur et al. (1996) amounted to 4.7% (mainly herring) by weight of the total catch (Table 6.1.). Reasons for discarding were mostly due to market requirements leading to rejection of undersized and poor quality fish.

In the present study, a conservative discard rate of 4.5% was applied for the commercial herring and the sprat fisheries (Figure 6.3.) corresponding to the lower estimates in the available literature (see above). Overall, the HifiDatabase positively corrected landings of herring with approximately 10 t between 1929 and 1960 as underreported compared to the ICES baseline. For sprat, differences between the two databases were only due to rounding. Artisanal/subsistence catches from open boats in the territorial sea were carefully documented during WWII (Lescrauwaet, unpublished data). Based on these records, an average of 120t of herring and 60t of sprat was added for the period 1929-1960 as a maximum for annual artisanal/subsistence catches. We assumed no artisanal/subsistence fishing for herring occurred after 1960, and no discards were taken into account in this artisanal/subsistence component. There are no records or indications of the existence of a recreational fisheries targeting herring or sprat in this period.

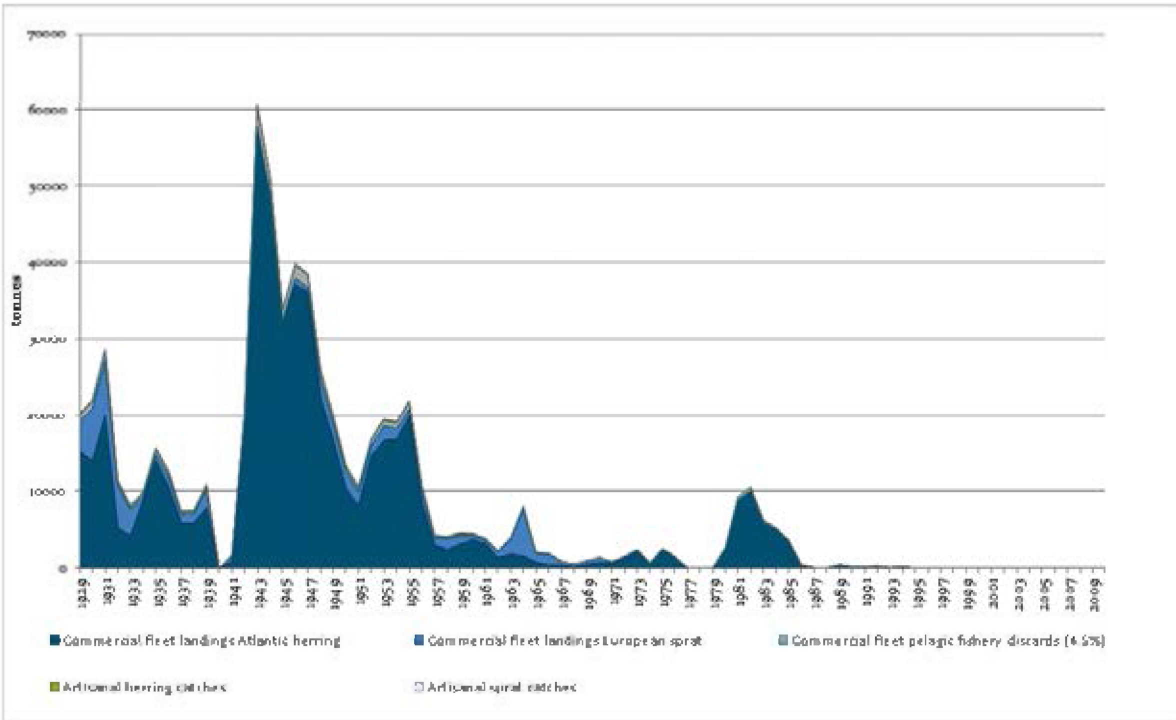

Figure 6.3.: Reconstruction of total removals in the pelagic fisheries: commercial reported landings and discarded fish in commercial landings (4.5%). Maximum estimates for artisanal catch of herring and sprat are included for 1950-1960.

The effects of changing or decreasing mesh size and other technological developments affecting bycatch of the gear, on-board discarding and underwater discard mortality, were not taken into account in the current estimates. Rahikainen et al. (2004) estimated that underwater discards or escape mortality caused by the gear for the age 0 and age 1 components is potentially similar or up to twice the amount of what is landed. However Gilis (1962) reported that these age classes made up a minor component of the herring fisheries in Belgium with age 3, 4 and 5 making up 97% of the catch. This may be due to the fact that Belgian herring fisheries targeted adult autumn-spawners (the 'disappeared' *Sandettie* herring) in the vicinity of the spawning areas. There are no indications of unreported removals due to ghost fishing or predation by birds or mammals.

Table 6.1.: Overview of discard rates, survival rates, variables used in the calculation or as reference material for the present reconstruction, with an indication of source, by type of fisheries.

FISHERY	VARIABLE	VALUE	COMMENT	SOURCE
Brown shrimp (Crangon crangon) fisheries				
Commercial *Crangon* fisheries, Belgium	Undersized Crangon	46%	Undersized *Crangon* fraction in *Crangon* total catch (1949-1964)	Leloup&Gilis (1965)
Commercial *Crangon* fisheries, Belgium	Undersized Crangon	47%	Undersized *Crangon* fraction in *Crangon* total catch. Discards composed of whiting, plaice, dab, and bib	Polet (2004)
Commercial *Crangon* fisheries, Germany	Discard rate	40-50%		Avia et al. (2011)
Recreational *Crangon* fisheries, Belgium	Annual catch	144t	120 SD*60 vessels*20kg, since 1975	This study
Artisanal *Crangon* fisheries, Belgium	Annual catch	9t	Based on data reported during WWII	This study
Crangon fisheries, Portugal	Discard survival rate	4%		Gamito&Cabral, (2003)
Crangon fisheries, Solway Firth (Scotland)	Bird predation	0.5-4.5%	Predation on *Crangon* discards	Lancaster and Frid (2001)
Herring and sprat, pelagic fisheries				
Herring fisheries, Belgium	Bycatch	35% 9%	By catch of non-target in otter trawl Bycatch of non-target in pelagic trawl	Gilis (1961)
Dutch commercial pelagic trawl fisheries	Discard rate	3,6%	38kg pelagic fish (mackerel, herring and saithe) discarded per 1,000kg marketable herring	Corten (1991)
Celtic sea winter herring fisheries	Discard rate	4.7%	Discards are mainly undersized target species	Morizur et al. (1996)
Danish pelagic trawl fisheries	Discard rate	5%	Herring as target species (if mackerel is targeted, discard rate is 20%)	Kirkegaard (1991)
Belgian pelagic trawl fisheries herring& sprat	Discard rate	4.5%		This study
Artisanal & subsistence fisheries, Belgium	Annual catch	120t herring 60t sprat	1950-1960	This study
Gadoid and other roundfish fisheries				
North Sea demersal (gadoid) fisheries	Annual discards	15,000t 10,000t	Cod Plaice	Garthe et al. (1996)

French gadoid trawlers, Celtic Sea (1997)	Discard rate	26%	Gadoid trawlers discard mainly target species: whiting& haddock (together 47%) and grey gurnard (13%). Data 1997.	Rochet et al. (2002)
Trawlers, Skagerrak and North Sea areas	Cod discard rate	14% 34% 47%	Cod in the demersal trawl >100mm mesh Cod in the demersal trawl 70-99mm, Cod in beam trawl >80mm	Horwood et al. (2006) *after STECF(2005)*
Icelandic and foreign fleet in Icelandic waters	Discard rate	1-14% 1-28%	Cod discard rates in Icelandic cod fisheries Haddock discard rate (based on all gear combined).	Forrest et al. (2001)
Flatfish fisheries (sole and plaice)				
Flatfish beam trawl, southern North Sea	Discard rate	71-95%		Catchpole et al. (2005)
German flatfish and other beam trawlers, North Sea and the NE Atlantic	Discard rate	56-72%	Discards mostly composed of dab, whiting, plaice, grey gurnard and undersized brown shrimp (Ulleweit et al., 2009).	Borges et al. (2005); EU (2008); Ulleweit et al.(2009)
UK beam trawl fleet, North Sea	Discard rate	50%	Average discard rate. Discard: mainly undersized dab& plaice, species with low market value (e.g. whiting& dab)	MRAG (2007)
Beam trawls(flatfish), English Channel, Irish Sea, Celtic Sea	Discard rate	42-67%	Discard: mainly dogfish, whiting, gurnards, common cuttlefish, plaice and dab, and undersized haddock	Borges et al. (2005); Enever et al. (2007)
French benthic trawlers, Celtic Sea (1997)	Discard rate	24%	60% of discard consist of 4 bycatch species: red gurnard, horse mackerel, boar fish and grey gurnard.	Rochet et al. (2002)
Beam trawl fisheries, Belgium 2008	Discard rate	25%		Vandendriessche et al. (2008)
Beam trawl fisheries, North Sea	Discard survival rate	0%	Higher survival rates reported for skates (42%) and rays (55%), while sole (4%) and lemon sole (7%) discard survival rates remain below 10%.	van Helmond&van Overzee, 2008 ; Lindeboom&De Groot, (1998)
Recreational flatfish fisheries Belgium	% of commercial catch	9%	Estimate for Based on 280 vessels*120SD*fishing days*20kg per fishing trip	This study
Nephrops fisheries				
French *Nephrops* trawlers, Celtic Sea	Discard rate	55%	discards % of biomass whiting (41%), target *Nephrops* (20%). Data 1997.	Rochet et al. (2002)
English&Welsh *Nephrops* trawlers, North Sea	Discard rate	36%	Discards: dab, whiting, plaice, legal-sized and undersized *Nephrop*s, gurnards, cod, long rough dab, haddock, lemon sole, Dover sole. Discards mainly due to <MLS	Enever et al. (2009)
Nephrops trawlers, Firth of Clyde (W-Scotland)	Discard rate	70%	Discard, mostly demersal fish, in particular young whiting<MLS. Typical mesh size= 80mm	Stratoudakis et al. (2001)
Sea angling Sea angling BNS	Annual catch	50t	2,000 anglers* 5seadays* 5kg catch, since 1970	This study

Note: discard rates are weight-based (biomass).

c) Gadoid and other roundfish

Commercial gadoid and other roundfish trawl fisheries (landings and discards)

The otter trawl was the main fishing gear before and during the 1950s. It was replaced by the beam trawl in the *Crangon* fisheries by the end of the 1950s and in the flatfish fisheries by 1965 in Belgium (Lescrauwaet et al. 2012).

Although currently Belgium has no directed fishery for cod or gadoids, specific *métiers* such as the pair-trawlers (‘*spanvisserij*’) fishing for cod were important in the past. They operated in Icelandic waters until 1975, a few vessels until 1995 (Lescrauwaet unpublished data). An important part of the landings originated from the southern North Sea and in the central North Sea: first in the western part of the central North Sea from 1960 to 1975, afterwards in the eastern part. Icelandic waters were also the main fishing grounds for otter trawl fisheries targeting ling (*Molva molva*), redfish (*Sebastes sp.*), monkfish (*Lophius piscatorius*), haddock (*Melanogrammus aeglefinus*), saithe (*Pollachius virens*) and to a lesser extent whiting (Lescrauwaet et al. 2010a). Today the otter trawl has recovered some importance due to its lower fuel consumption compared to the beam trawl (Tessens and Velghe, 2008, 2009, 2010).

Historical references on the selectivity and impact of the otter trawl and data on discards in roundfish fisheries are limited. One of the variables that influence discarding in otter trawls is the mesh size of the trawl net. Horwood et al. (2006), e.g., reported a discard rate of cod in the Skagerrak and North Sea areas of 14% in the demersal trawl with mesh size >100mm, 34% in the demersal trawl 70-99mm, and 47% in the beam trawl over 80mm (after STECF, 2005b). The International Convention for the regulation of the meshes of fishing nets and the size limits of fish minimum sizes of fish nets and fish (London, 05/04/1946, entry into force 05/04/1953) set a minimum mesh size limit of 75mm with 110mm for arctic and Icelandic waters because cod tended to be larger there. The Convention regulations entered into force in 1951 in Belgium. Demersal fisheries for gadoids are carried out by all North Sea coastal nations with various gear and different sources provide estimates of discarded weight (Van Beek 1990, Anon. 1995, Garthe et al. 1996, Rochet et al. 2002). However these studies cover different survey designs and gear specifications. Rochet et al. (2002) reported for the French fleet operating in the Celtic Sea a total estimate of 30,000 t of discards in 1997, while landing about 63,000 t. Gadoid and *Nephrops* trawlers caused the majority of these discards with respectively 25% and 55% of the catch weight being discarded. Gadoid trawlers discarded mainly their target species: whiting and haddock (together 47%), and also grey gurnard (13%). Forrest et al. (2001) estimated unreported catches of cod and haddock by the Icelandic and foreign fleet in Icelandic waters over time, on a species by species basis. Based on reported distributions of fishing effort by fishing gear in Icelandic waters, the authors concluded that Icelandic cod catches may have been underestimated by between 1% and 14% at different times, and haddock catches by between 1% and 28% (based on all gear combined). It must also be noted that ‘high-grading’ (discarding fish of lower value in order to fill the hold or quota with fish of the greatest value) of high-valued fish species such as cod and haddock is not only related to the implementation of regulatory measures such as quota. High-grading already existed before the on-set of quota, because of technological constraints, e.g., when catching power exceeded onboard storage or processing facilities (Anderson 1994,Turner 1997).

No studies or survey reports related to discarding proportions in the demersal roundfish fisheries for Belgium or for demersal (roundfish) trawlers fishing Iceland waters were identified in screened databases. To conclude, while acknowledging the significant variability in the estimates of weight and species composition of discard fractions in the demersal whitefish fisheries (otter trawler) depending on the fishing area, season and specific gear, historical sources suggest that discarding in this fishery is not a recent practice related to the CFP and quota restrictions. Instead, in the past 50 years the weight-based proportion of discards in the catch may have decreased due to increasing mesh sizes and improvements in gear selectivity. In the present estimate, the conservative low discard estimate of 25% was applied over the sum of the landings of species targeted in this fishery (cod, ling, haddock, redfish, monkfish, saithe, whiting, see Table 6.1.). While it is recognized that this is a simplistic approach based on assumptions, it is a precautionary approach and can be justified over the less acceptable alternative of interpreting non-reported or missing data components as zero removals (Pauly 1998).

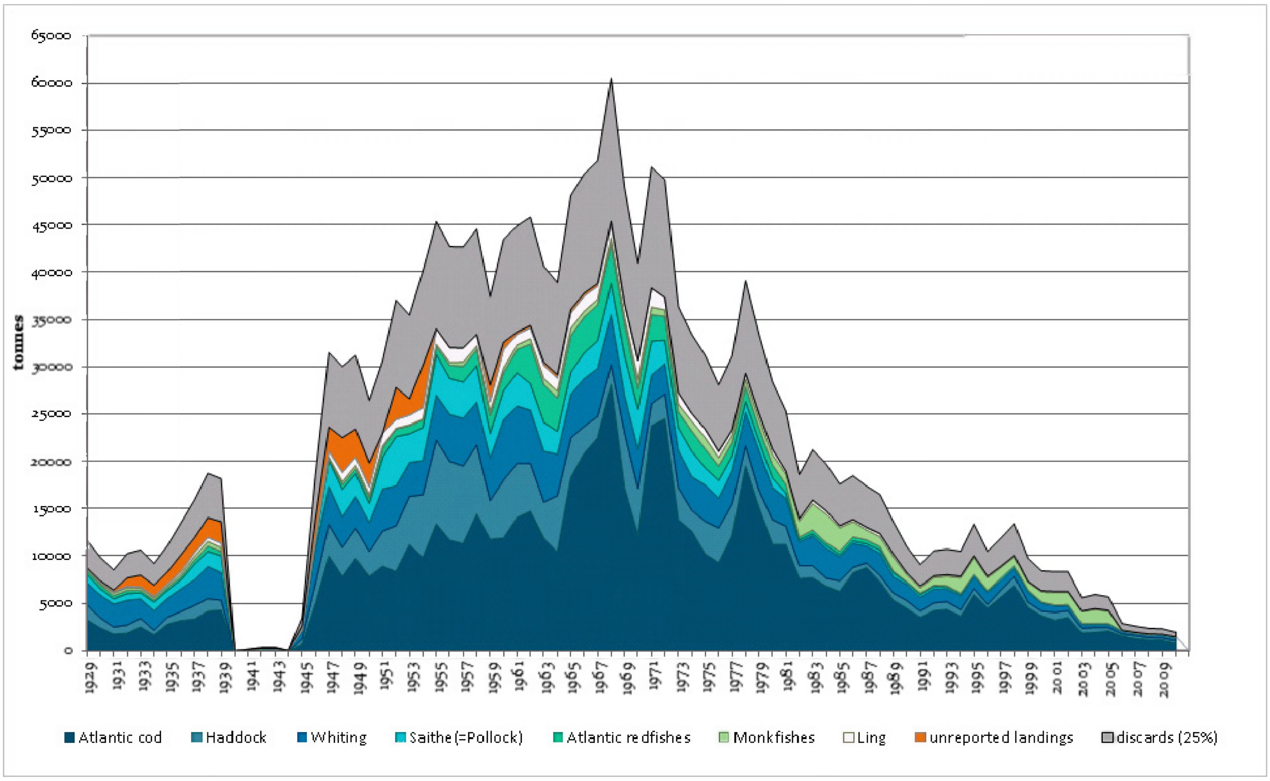

Figure 6.4. Reconstruction of total removals in the demersal gadoid and roundfish fisheries: reported and unreported landings and discarded fish by the Belgian commercial fleet.

Annual landings of the 7 taxa included (cod, haddock, whiting, saithe, redfishes, monkfishes, ling) from the commercial fleet averaged approximately 10,000t before WWII and 30,000 t between 1950 and mid 1970s. After 1975, a decline in landings set in, which is to a large extent explained by the 'cod wars' by which the foreign fleet was gradually excluded from Icelandic waters (Lescrauwaet, unpublished data). Currently less than 2000 t of fish are landed for these 7 taxa together. Overall the HifiDatabase positively corrected landings with approximately 41,600 t of unreported landings, 88% of these unreported commercial landings are before 1955. A flat discard rate of 25% was applied (Figure 6.4.) corresponding to the lower estimates in available literature (see above).
The effects of changing or decreasing mesh size and other technological developments affecting bycatch of the gear, on-board discarding and underwater discard mortality, were not taken into account in the estimates. Discard survival rates of 0% were taken into account for the species targeted in this estimate (ICES Discard Survival Table 2012). Reported landings from these species in artisanal/subsistence catches from open boats in the territorial sea during WWII were negligible, except for whiting: 11 to 13 t per year in the period 1941-1943 (Lescrauwaet, unpublished data).

d) Flatfish beam trawl fisheries (sole and plaice)

Commercial flatfish beam trawl fisheries (landings and discards)

Before 1960, the Belgian fleet of steamer and motor engine powered vessels used the otter trawl as fishing gear in the 'fresh fish' fisheries for targeted sole and plaice (Gilis 1954). By 1965, the beam trawl had become widely introduced. In 1985, beam trawling accounted for 62% of SD and by 2006, this segment of the fishing effort had further increased to 79% of total SD. In 2010, beam trawl represented 68% of the SD (Anon. 1965, Tessens and

Velghe 2010). Landings of plaice and sole from the commercial fleet averaged approximately 5000t before WWII, 10,000 t per year between 1950 and mid 1980s, and after 1995. Between 1985 and 1995 increased landings of plaice raised the annual landings of this fishery to an average of 17,700 t. Overall, HiFiData corrected the baseline with 3750 t of unreported plaice and 2100 t of unreported sole, mainly before 1955.

No quantitative information is available to estimate historical discards and survival rates for this fishery by the Belgian fleet but different values are reported in the literature concerning current levels of discarding. Catchpole et al. (2005) recorded estimates of 71-95% discarding in flatfish beam trawl fisheries in the southern North Sea, while estimates of 56-72% discarding were observed in German flatfish and other beam trawlers in the North Sea and the NE Atlantic (Borges et al. 2005, EU 2008, Ulleweit et al. 2009). These discards are mostly composed of dab, whiting, plaice, grey gurnard and undersized shrimp (*Crangon crangon*) (Ulleweit et al. 2009). The UK North Sea beam trawl fleet targeting primarily sole, plaice and dab discard 50% of catch on average. This consists of mainly undersized dab and plaice, and species with a low market value or no market, such as whiting and dab (MRAG 2007). Beam trawls in the English Channel, Irish Sea, Celtic Sea and the western approaches targeting flatfish such as sole and plaice discard 42%-67% of total catches. The dominant species discarded are dogfish, whiting, gurnards, common cuttlefish, plaice and dab, as well as undersized haddock (Borges et al. 2005, Enever et al. 2007).

Vandendriessche et al. (2008) estimated the current levels of discarding and discard rates in the Belgian beam trawling. In this study, 30% of a total of 109 sampled hauls was located in fishing areas in the southern and central North Sea, where approximately 30% of the reported landings of sole were caught that year. The authors found that on average 25% of the catch weight in this fishery is discarded. The conclusions are specific for the Belgian beam trawlers and reflect the current as opposed to the historical situation. It must be noted however that the current core of the spatial distribution of the Belgian beam trawling fleet has moved away from the North Sea and towards the western waters (Irish and Celtic Sea, Bristol Channel, English Channel). Whereas in the mid 1950s nearly all of the sole (97%) was caught in the North Sea, this proportion decreased to 40% in the 1980s and even to 30% after 2000, in favour of the western waters. This may help explain why current discard rates reported for the Belgian flatfish beam trawling fleet (Vandendriessche et al. 2008) are lower than those reported for the Dutch, German and UK fleet operating mainly in the North Sea (see above), but similar to the discard rate value of 24% reported by Rochet et al. (2002) for the French benthic trawlers in the Celtic Sea. Vandendriessche et al. (2008) reported the composition of the discarded weight as follows: 2% of sole, 13% of plaice, 7% of dab, 10% of bib, 4% of cod, 3% of anglerfish, 13% of gurnards, 7% of rays, 22% of sharks. These proportional values 'by-species' were accounted for in the present reconstruction. For the reconstruction of the historical discards, a time variant discard rate was applied. The time-variant discard-rate takes into account the proportion of landings originating from the North Sea (50% discard rate as the lower value in reported North Sea flatfish beam trawl discard rates) and the proportion of landings originating from the western waters (25% discard rate, as reported by Vandendriessche et al. 2008).

Unreported flatfish catch by 'recreational' or semi-commercial fisheries

As reported for the *Crangon* fisheries (section a), recreational flatfish fisheries exist in Belgium, which operate from smaller vessels that are not part of the official or commercial fishing fleet. Although flatfish are targeted today, it is acceptable to believe that other species may have been targeted over the last decades depending on their relative abundance on economic value. These fisheries have existed for at least 30 years (E. Hiele, pers. comm.) and for the current estimate it was assumed that they started in the 1970s. Regular surveys conducted by government officers along the ports and mooring sites in Belgium confirm that approximately 280 small vessels are involved in this recreational activity and operate from the 4 ports.

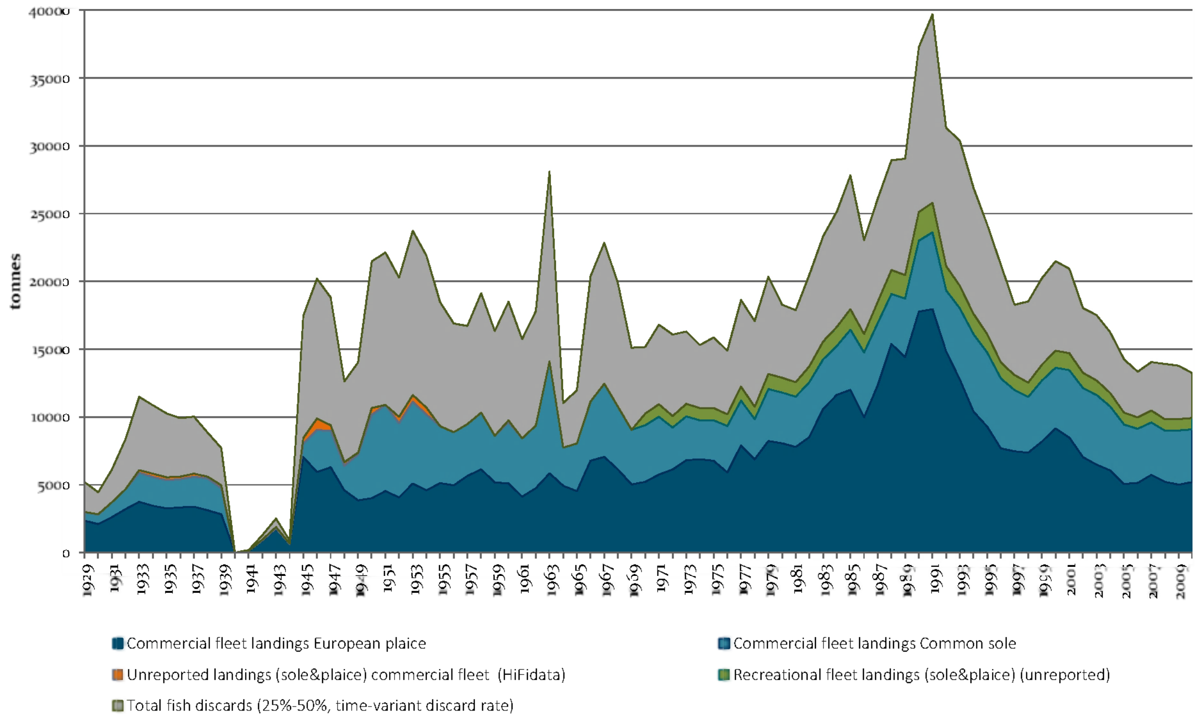

Figure 6.5.: Reconstruction of total removals in the beam trawl flatfish fisheries (sole and plaice): reported and corrected (baseline) commercial landings (green), and estimates of recreational fisheries (orange) and discards (grey).

A conservative estimate was derived based on an average effort of 120 fishing days per vessel, 280 vessels and average catches of 20kg per fishing trip. The parameters applied to estimate discards by the commercial fleet were applied to estimate discards in the recreational segment. Reported landings in artisanal/subsistence catches during WWII were negligible for sole (less than 0.5t per annum) and amounted to 2-19t of plaice between 1941-1943 (Lescrauwaet, unpublished data). Ghost fishing caused by lost or abandoned trawl nets was considered negligible or zero (Depestele et al. 2012).

Effects of changing or decreasing mesh size and other technological developments affecting bycatch of the gear (e.g., the short-lived introduction of the Vigneron-Dahl system, tickler chains, sumwing etc.), underwater discard mortality (e.g., Chopin 1995), and predation and infection mortality (Broadhurst et al. 2006) were not taken into account in the estimates. According to these sources, such mortalities can be substantial, and should be considered for comprehensive stock assessments for all gear-types and fisheries. Discarding practices for plaice and sole were found to be mainly driven by Minimum Landing Size (MLS) regulations (Vandendriessche et al. 2008), which are established by law Nr. 56/12/1950 (see full text of this royal decree and modified by royal decree Nr. 425/02/1964). An important part of the cod discards in these fisheries are not explained by MLS but by high-grading (Vandendriessche et al. 2008). Reported discard survival rates in beam trawl fishing gear can strongly vary according to experimental design, fishing techniques and environmental parameters (Van Beek et al. 1990, Berghahn et al. 1992, Lindeboom and De Groot 1998, Lapithovsky 2004, Rodriguez-Cabello et al. 2005, Enever et al. 2009). In the current exercise, the precautionary approach leads to assume a survival rate at or near of zero for cod, whiting, pouting, dab, plaice and gurnards. Higher survival rates are reported for skates (42%) and rays (55%)

(Enever et al. 2009), while sole (4%) (Lindeboom and De Groot 1998) and lemon sole (7%) discard survival rates remain below 10%.

e) Nephrops fishery

Commercial Nephrops fisheries (landings and discards)

Today, Norway lobster (*Nephrops norvegicus*) in the North Sea is commonly caught using a twinrig trawler, which is composed of two nets towed by one vessel along the seabed. Between the two nets a heavy weight keeps the net at the bottom, while otter boards are used to keep the mouth of the net open while trawling. The twinrig trawl is lighter than the beam trawl and is towed at lower speed (4 knots), which results in lower fuel costs and less bottom disturbance (van Helmond and van Overzee 2008). The Minimum Landing Size (MLS) of Norway lobster in the North Sea (ICES area IV) is 25 mm of carapace length.

Differences between the ICES Fishstat baseline and the local HiFiDatabase amounted to 2300t and mainly before WWII. Landings of Belgian fisheries for Norway lobster peaked in 1959 with 970 t, and averaged 450 t per year (st. dev. = 192 t) over the period 1950-2010 (Figure 6.6). Historically, the Belgian *Nephrops* landings mainly originated from Botney Gut – Silver Pitt (ICES area IVb,c). Currently (i.e., 2010), landings have dropped to a historical low of 133 t. Efforts are now underway to reactivate this fishery in the context of diversification in the fishery coupled with regeneration of coastal economies.

Trawls targeting *Nephrops* are typically smaller meshed (80–90 mm) than trawls used to target whitefish which results in higher proportions of discards (Catchpole et al. 2005). Enever et al. (2009) reported discard rates of 36% in English and Welsh *Nephrops* trawl fisheries in the North Sea. Discards were mostly dab, whiting, plaice, legal-sized and undersized *Nephrops*, gurnards, cod, long rough dab, haddock, lemon sole and Dover sole, the majority of which were discarded due to being undersized. *Nephrops* trawlers off the Firth of Clyde (West of Scotland) discard 70% of total catch, mostly consisting of undersize demersal fish, in particular young whiting (Stratoudakis et al. 2001). No dedicated studies on discards and survival rates exist for Belgian *Nephrops* fisheries. However, Belgian vessels participated in Dutch-led studies exploring lower fuel and less discards in this fishery (Steenbergen et al. 2012). Hence, the estimates of discards in the present study are based on the Dutch *Nephrops* fishery, which uses similar gear, engine power and fishing grounds. Discard estimates (weight-based) in *Nephrops* fisheries in the North Sea range between 76.5% and 84.2% (Belgian vessel and gear) (Steenbergen et al. 2012). According to van Helmond and van Overzee (2008), discards were composed of 30% *Nephrops* (90% of which were legal-sized), 27% dab, 18% whiting, 15% plaice, 2% cod and 8% other fish. These weight proportions were applied to the reported *Nephrops* landings.

There are no written reports or other communications on the existence of a recreational fishery for this species. This can be explained by the distance of the traditional fishing grounds.

Most fish species discarded will not survive the catching and sorting process (van Beek et al. 1990). For the *Nephrops* fishery in particular, the survival of captured species (including *Nephrops*) are thought to be close to 0% (Evans et al. 1994). Ridgway et al. (2006) indicated that survival rate of *Nephrops* fifteen days after capture is less than 30% for long trawls (5 hours). Specific survival experiments with *Nephrops* in the Belgian or Dutch twinrig fishery have not been carried out so far (van Helmond and van Overzee 2008) and therefore no corrections are conducted for survival of discarded *Nephrops* in the current estimates.

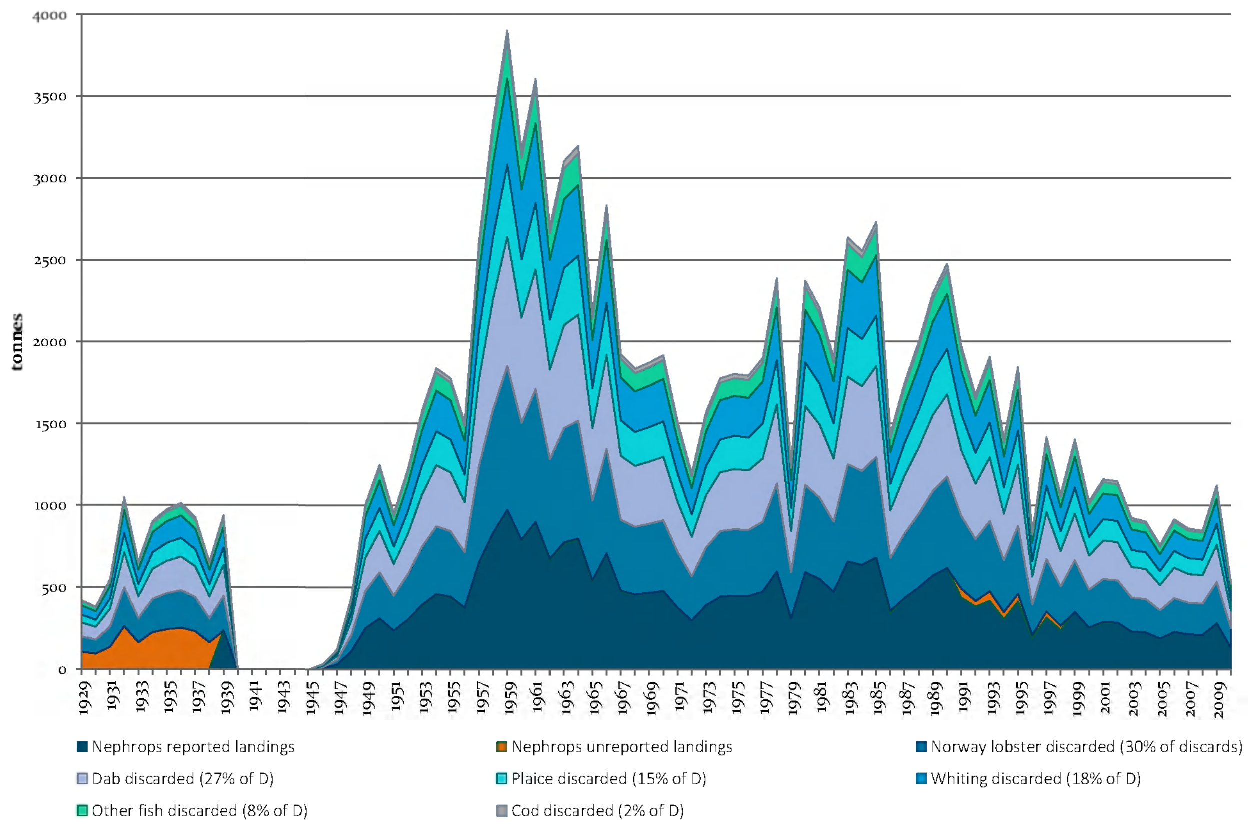

Figure 6.6.: Reported landings of *Nephrops norvegicus* by Belgian fisheries (dark blue), discards of *Nephrops* (light blue) and other species, 1929-2010.

f) Sea angling: cod *(Gadus morhua),* European sea bass *(Dicentrarchus labrax),* and other species

Recreational fisheries include all forms of fishing that do not pursue commercial objectives. Little information exists on recreational fisheries in most North Sea countries (Zeller et al. 2011). Recreational fisheries in Belgium include recreational *Crangon* fishing (section a), fishing from the coastline (angling from the beach, shrimp fishing on feet or on horseback, and the setting of passive nets along the low watermark) and sea angling. Except for the use of fixed (passive) nets from the beaches, recreational fisheries are not subject to licensing. Sea anglers are not allowed to fish at night and are allowed a daily maximum of 20kg per angler, of which cod is not allowed to exceed 15kg. The magnitude of recreational angling on the Belgian part of the North Sea (BNS) has so far only been addressed in a pilot study which estimated recreational angling for cod on the BNS at 100-200t per annum (ILVO-Fisheries 2007). The pilot study was based on the outcomes of angling contests organized by the Associations of Anglers (VVHV), which counts approximately 2000 members as active sea anglers in 2006. In the present estimate, a low of 50t per annum was applied (2000 anglers, 5 days at sea, 5kg catch), assuming this form of sea angling existed at least since 1970. These estimates are in the same order of magnitude as those for the Dutch recreational sea angling for cod and eel (Zimmerman et al. 2007, Van der Hammen and de Graaf 2012). Systematic sea bird counts by the Institute for Nature and Forest Research (INBO) recording the presence of sea anglers, have shown a clear overlap between the position of anglers and shipwrecks (E. Stienen *in* Goffin et al. 2007).

g) Unaccounted removals

A number of other gears which are not accounted for in the present estimates have been used in Belgian fisheries, however with much lower intensity and spatial coverage than those presented in a) to f) in this section. These include seine nets, bottom dredges (1980's), trammel nets and other passive gear used in commercial fisheries but not covered here, and angling and netting from land (jetties, piers). The use of trammel nets in commercial fisheries is rather recent (since 2000) and discards are limited. Depestele et al. (2012) studied the impact of trammel nets on different components of the marine ecosystem of the BNS (sea birds, benthos, fish stocks, and marine mammals). Sea bird and marine mammal by-catch was investigated through strandings data, questionnaires and independent observers, and in cooperation with fishers. The results indicate there is a potential danger for diving seabirds and harbour porpoises (*Phocoena phocoena*). Haelters and Kerckhof (2005) found that a significant part of the dead strandings on Belgian beaches was caused by drowning in trammel nets, in particular in the first quarter of the year when nets are set for sole and plaice. The coastal municipalities issue licenses for passive beach nets and in 2006 approximately 250 licenses were issued in 4 municipalities (Goffin et al. 2007). Regulations prohibit the use of trammel (multi-layered gillnets) as well as the use of gillnets below low watermark, sets maximum lengths and total number of nets, and enforces the minimum landing sizes of species (royal decree KB 1989-08-14, KB 2001-12-21 and ministerial decision 2006-12-21). In the Scheldt estuary, other fisheries, e.g., targeting eel were important in the past. However, no landing or catch statistics are available upon which to reconstruct total removals. The dynamics of the Scheldt fleet was reconstructed for the period 1930-2010 (Lescrauwaet et al. 2012); this information can be used as a basis for catch reconstruction in a next step.

h) Reconstructing total removals by the Belgian sea fisheries 1929-2010s

Total removals by Belgian fisheries from 1929-2010 were reconstructed by including the unreported or misreported landings of the commercial fleet, the unreported (here: estimated) landings by the recreational and artisanal fisheries and by estimating discards for 6 of the most important fisheries based on the estimators described above. The reported landings for these 6 fisheries together represent approximately 80% of all reported landings over 1929-2010. Publicly reported landings over the period 1929-2010 amounted to 3.7 million t, with a peak of 81,000t in 1947 (ICES Fishstat) and gradually decreasing to 22,000t in 2010 (Figure 6.7). However, total reconstructed removals were estimated at 5.2 million t or 42% higher compared to the 3.7 million t publicly reported over this period. Table 6.2. gives an overview of the amounts (t) and proportions (%) of the unreported landings and of the estimated discards for each of the 6 reviewed fisheries considered in this reconstruction. Overall, unreported landings were estimated to represent 3.5% (0.2 million t) and discards 26% (1.3 million t) of these total reconstructed removals.

Unreported landings

Overall, the unreported landings amounted to 0.2 million t with a median annual value of approximately 1300t and a maximum of 9300t in 1948. The unreported landings were particularly important between 1935 and 1955 and mostly due to under- or misreporting in the baseline. The unreported landings of sole and plaice in commercial and recreational fisheries (55,100t) and the unreported landings of the commercial fisheries for gadoid and roundfish in bottom trawlers (41,600t) made up the major part of these unreported landings between 1929-2010 with respectively 30% and 23%. Most of the unreported landings of *Crangon* by the commercial fleet (8100t) are explained by underreporting before 1955; the recreational shrimp fisheries contributed to unreported landings with an estimated 3800t and these fisheries were assumed to have started in 1975. Together they represent 11,900t or 6.5% of the unreported landings overall. Underreporting for the commercial pelagic fisheries was negligible (10t herring). 120t of herring and 60t of sprat - estimated from artisanal/subsistence fishing between 1929 and 1960 - explain for 3% of the total unreported landings.

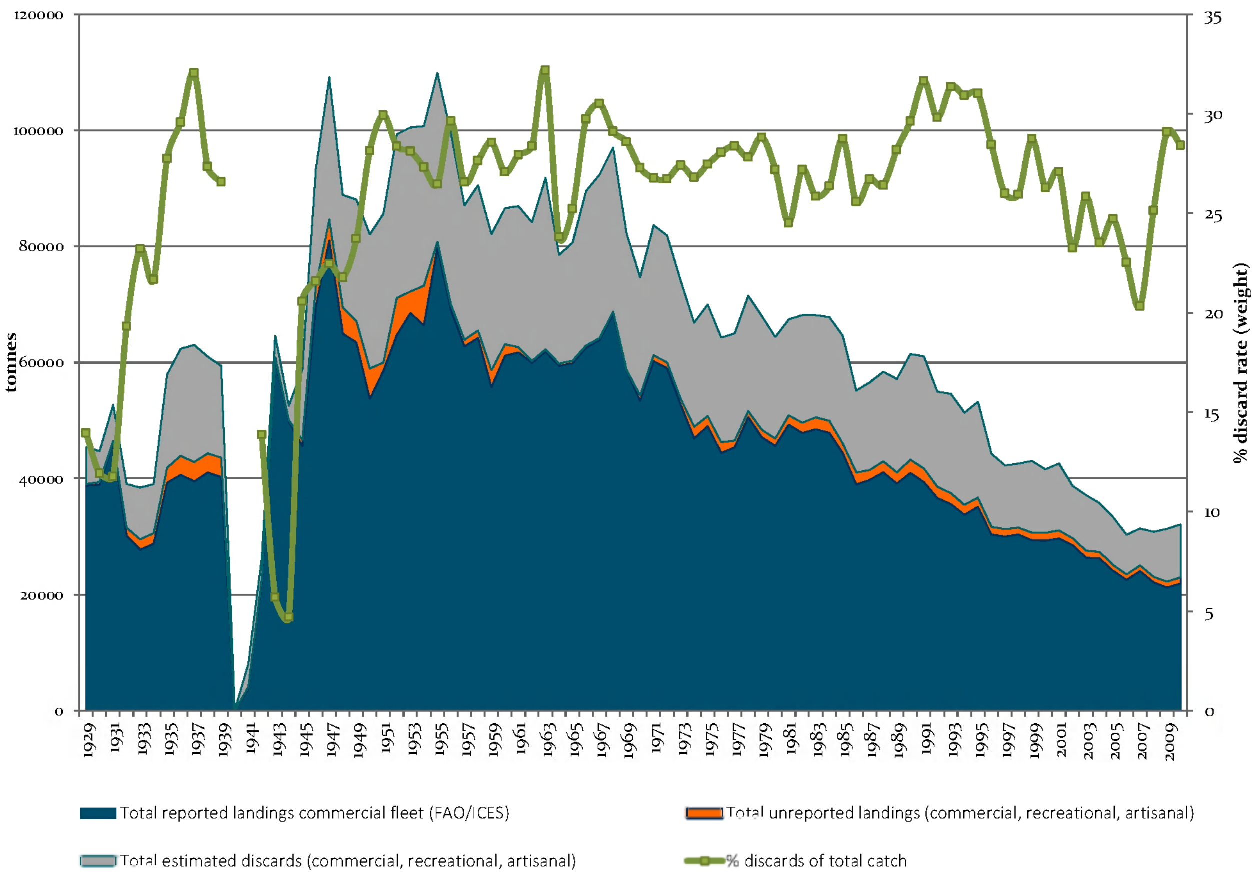

Figure 6.7.: Total reported landings of the commercial fleet (ICES baseline 2012), unreported landings (unreported commercial landings, landings from recreational, artisanal fisheries) and discards in t (t, left-hand axis), by the Belgian sea fisheries 1929-2010. The right-hand axis shows the annual discards as a percentage of the reconstructed total removals. See text for details.

For the 7 taxa included in the present reconstruction of landings and discards from the Belgian commercial fleet targeting gadoid and roundfish (section 6.4.c), the underreporting before 1968 explains nearly all of the unreported landings in this fishery, while 23% of overall unreported landings refers to this fishery (Table 6.2.). Reported landings for this fishery from 1950 to 1975 averaged 30,000t per year. After 1975 the decline in the landings is to a large extent explained by the 'cod wars' which gradually excluded the foreign fleet from Icelandic waters. Currently less than 2000t of fish are landed for these 7 taxa together.

Landings of plaice and sole from the commercial fleet averaged approximately 5,000t per year before WWII and 10,000t per annum between 1950 and mid 1980s. Between 1985 and 1990, the annual landings of sole and plaice in this fishery increased and peaked to nearly 23,600t in 1991. The recreational fisheries for sole and plaice, which were assumed to have started in 1970, explain the largest portion of total unreported landings. Underreporting of sole and plaice landings occurred before 1960 and amounted to 5,800t.

There are no recreational *Nephrops* fisheries and the 2315t of unreported *Nephrops* landings correspond to underreported *Nephrops* from the commercial fleet mainly before WWII. Sea angling was not included in public reporting and the estimated recreational landings of 50t per year from 1970 to 2010 amount to 1% of all unreported landings. The unreported landings and the estimated discards by recreational and artisanal fisheries are mainly from the BNS and are discussed in further detail (section i).

Table 6.2.: Overview of the amounts (t or 1,000kg) and proportions (%) of the reported and unreported landings and of the estimated discards for 6 fisheries in the Belgian sea fisheries 1929-2010

	Reported landings (x1000kg)	% of total reported landings	Unreported landings (x1000kg)	% of total unreported landings	Discards	% of total discards
Crangon fisheries	106,053	2.9	11,900	6.5	254,281	18.6
Pelagic fisheries (herring&sprat)	619,924	16.7	5,580	3.0	27,897	2.0
Nephrops	28,085	0.8	2,315	1.3	91,199	6.7
Flatfish beam and otter trawl (plaice and sole)	827,198	22.3	55,069	29.9	528,918	38.8
Gadoid (otter trawlers)	1,342,631	36.3	41,600	22.6	461,410	33.8
Sea angling	-	-	2,050	1.1	-	-
Other species	777,846	21.0	65,358	35.5	-	-
Total all reported landings Belgian sea fisheries	3,701,737 (70.5%)	100	183,873 (3.5%)	100	***1,363,705***	100

Discards

Discards were estimated for each of the 6 fisheries covered in the present reconstruction (Figure 6.8). The major components of the discards since 1929 were the discards in flatfish fisheries (528,900t or 39% of the total discards) and the discards in gadoid and roundfish fisheries (461,400t or 34% of the total discards). The discards in the *Crangon* fisheries (254,300t or 19% of the total discards for the 6 fisheries) and *Nephrops* fisheries (91,200t or 7% of total discards) consisted mainly of their target species: respectively 39% of all discards in *Crangon* fisheries and 30% of all discards in *Nephrops* fishery are target species. Plaice, dab and whiting make up significant proportions of the discards in the directed fisheries for *Crangon, Nephrops* and flatfish (sole and plaice).

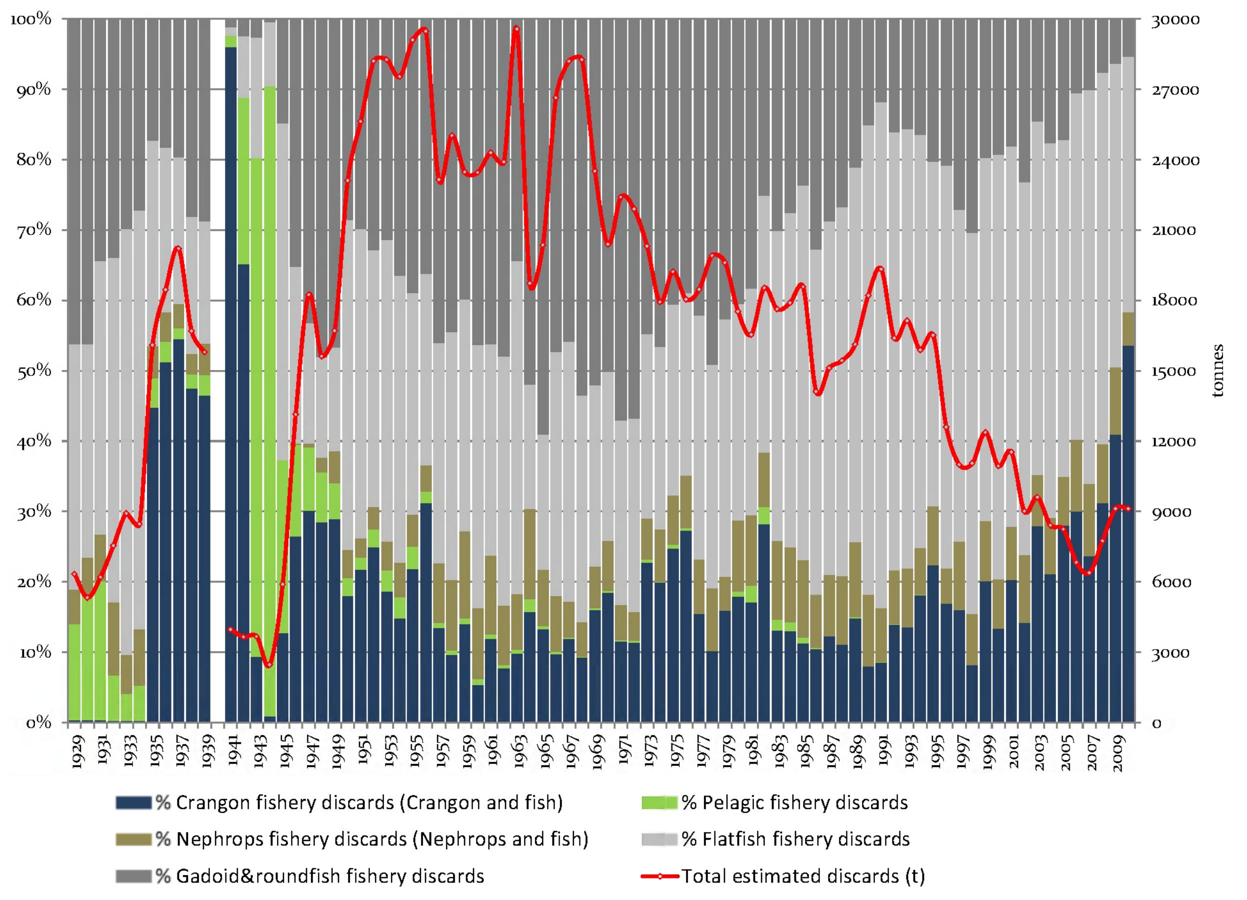

Figure 6.8.: Total estimated discards (t, right-hand axis) by the Belgian sea fisheries 1929-2010 and percentages of the discards for the 6 fisheries covered in the present reconstruction. For sea angling, no discards were considered. See text for details.

The proportion of discards from the total catch was estimated to reach a historical high of 32% in 1963 (29,500t), and a median value of 16,600t per annum. After the peak in 1963, total estimated discards gradually declined to less than 15,000t. In the early 1990s however, the discarded proportion of the total reconstructed removals was estimated to peak again around 31% (19,000t), before decreasing to 6,500t in 2007. Before 1935, no data are available for the shrimp fisheries and therefore both the discards (t) and the discarded proportion of *Crangon* fisheries in the total discards were underestimated. Between 1935 and WWII the *Crangon* fisheries constituted 45-55% of all discards (15,000-18,000t). During WWII, pelagic fisheries were the main fisheries practiced and therefore explain nearly all discards. From 1955 until 1980 the gadoid and roundfish fisheries explain the largest proportion of discards with a maximum estimate of 15,100t and up to 60% of the overall annual estimated discards. From 1980 to 2000, the beam trawl fisheries explain most of the discarded weight with up to 72% of the estimated discards in 1991. The recent increases in landings from the *Crangon* fisheries also explain the proportional increase of discards (%) since 2009 in the present estimates (Figure 6.3.). Reported landings of shrimp by the commercial fleet average 1350t per annum, with a maximum of 4282t in 1956. Nearly the same weight (i.e., 1290t per annum) of undersized shrimp is discarded, while on average more than twice the weight of undersized fish is discarded in this fishery (including plaice 6%, sole 3%, dab 10%, whiting 12%). The discard estimates in the *Nephrops* fisheries peaked in 1959 (2,900t) when highest landings were achieved (970t).

i) Reconstructing total removals from the Belgian part of the North Sea by the Belgian sea fisheries 1929-2010s
The Belgian coast is 67 km long and located in the province of West-Flanders (region of Flanders, Belgium). The Belgian part of the North Sea (Figure 6.9.) is 3,457 km² (0.5% of the North Sea area). The unique historical data reported for the 'coastal waters' from 1929-2010 (HiFiDatabase) were used in the present estimates of total removals at the scale of the Belgian North Sea (BNS). Since formal reporting started, roughly one fifth of all landings of the Belgian sea fisheries originated from the BNS, while these waters contributed nearly 60% of all landed pelagic species and 55% of all landed 'molluscs and crustaceans' (Lescrauwaet et al. 2010). Fisheries in this area has generated 1000kg/ha compared to the fishing area of the Bristol Channel (southwest UK) which is 2 times larger and generated 77kg/ha over similar time frame of exploitation. The BNS has been a continuous source of food for the local population, of economic turnover and profit, direct and indirect employment and an area for recreational fishing.

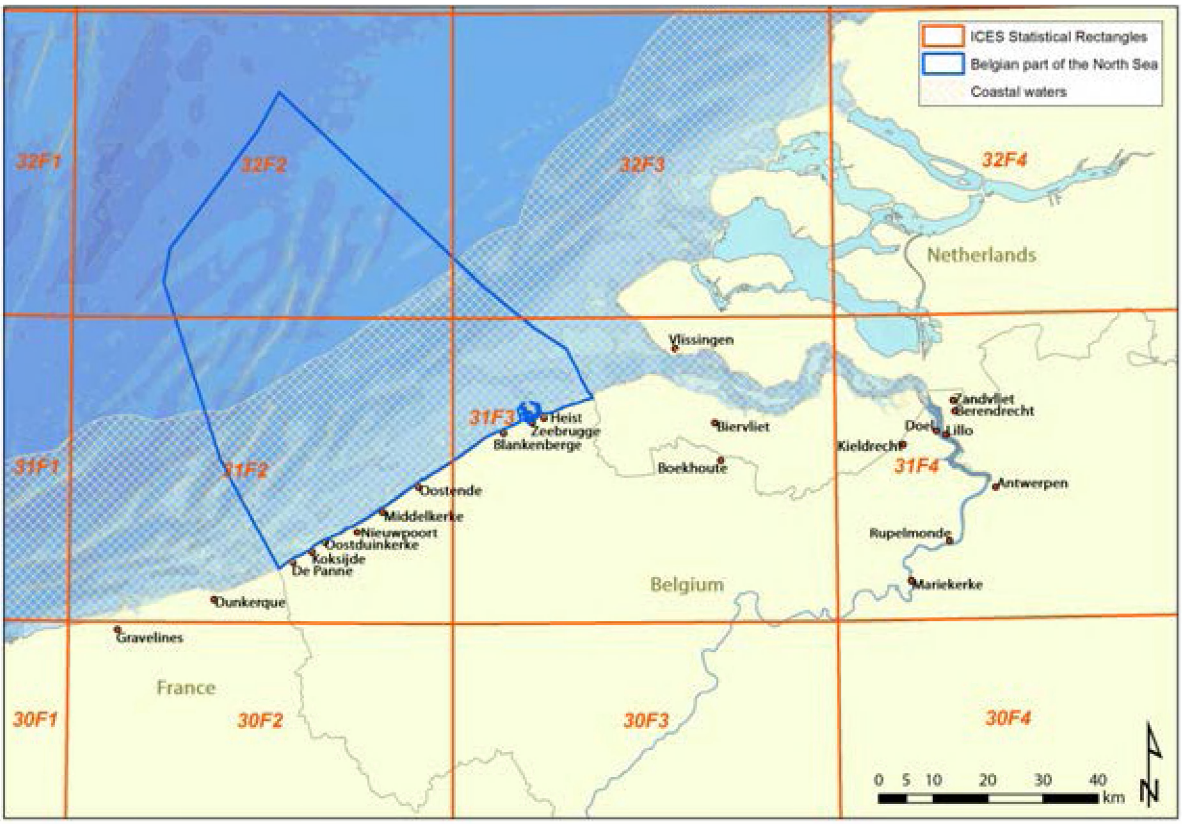

Figure 6.9.: Map of Belgium coastline and the Belgian part of the North Sea BNS (blue line), demarcation of the fishing area or reporting unit 'Coastal waters' (white shaded area), current and historical fishing ports and overlapping areas with ICES rectangles. ICES rectangle shape file layer created by the Danish Institute for Fisheries Research (DIFRES).

The reported landings from the BNS from 1929-2010 (Figure 6.10.) follow a similar pattern as that for the fisheries as a whole (Lescrauwaet et al. 2010a). A first period (1929-1940) characterized by pelagic and shrimp fisheries, is followed by a peak in landings of pelagic species during and after WWII (1942-1964). Cod is the dominant species in the reported landings from 1965-1980. After the mid 1980s the composition of the reported landings is less dominated by a single species. Herring and sprat (49%), brown shrimp (12%), cod (9%), plaice (6%), whiting (4%) and sole (3%) represent an important proportion over the entire period. Reported landings from the BNS over the entire period, amount to 841,700t (dead weight). The median of annual reported landings over the entire period is 8,100t with a peak value of 60,500t in 1943 and a minimum of 1900t in 2007 (Figure 6.10.).

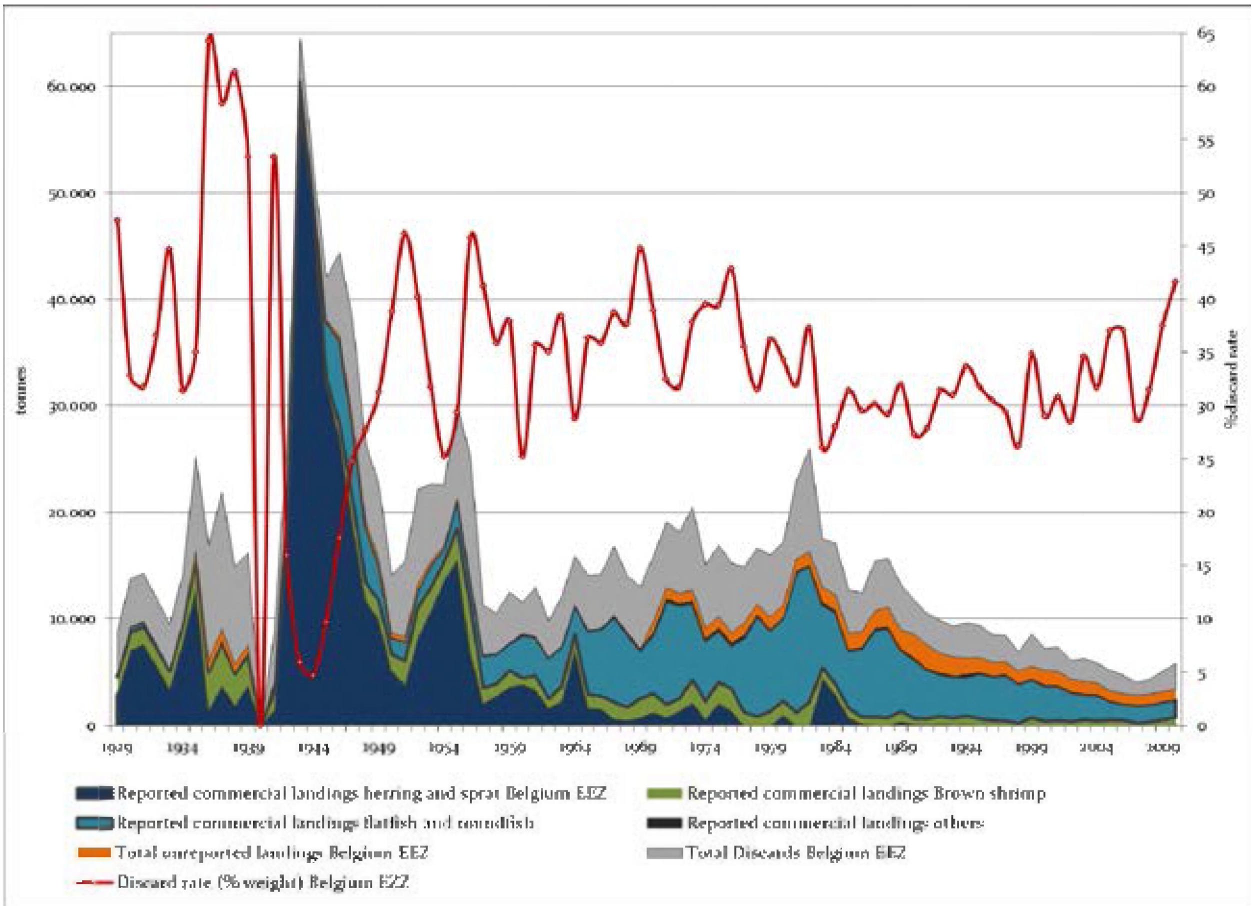

Figure 6.10.: Total reported landings of the commercial fleet (ICES baseline 2012), unreported landings (unreported commercial landings, recreational and artisanal fisheries) and discards (t, left-hand axis), by the Belgian sea fisheries 1929-2010 from the BNS. The right-hand axis shows the annual discards as a percentage of the reconstructed total removals. See text for details.

Together with the publicly reported landings, the unreported landings and estimated discards reconstruct the total removals in the BNS. Following the approach applied in 6.4.a)-g), the unreported removals for the BNS from 1929-2010 amount to 59,600t and the total discards in this period are estimated at 407,300t (Table 6.3.). The reconstructed total removals for the BNS were therefore estimated at 1.3 million t or 55% higher than the 0.8million t publicly reported over this period. Because of the presence of recreational (hence unreported) fisheries in coastal water, and the fact that the *Crangon* fisheries are by nature coastal fisheries, these two components contribute with an important proportion to the total unreported removals from the BNS. In particular since the late 1980s this proportion is estimated to range between 15-20% of the total removals by Belgian fisheries from the BNS.

Table 6.3.: Overview of the amounts (t) and proportions (%) of the reported and unreported landings and of the estimated discards for 6 fisheries in the Belgian sea fisheries from the BNS, 1929-2010.

	% of total reported	% of total unreported	% of total discarded
Commercial fleet pelagic (herring&sprat)	48	-	4
Shrimp fisheries *Crangon crangon*	13	14	69
Beam (flatfish) and otter trawl (non-shrimp)	39	-	27
Recreational trawling (fish)	-	86	-
Total BNS(=100%) rounded numbers (in 1000t)	***842 (100%)***	***60 (100%)***	***407 (100%)***

<0,01 is not listed or indicated by '-'

The estimates of annual discarded weight on the BNS range between 4,600t and 12,800t. In terms of percentages, annual discards fluctuated between 5% and 64% of total removals from the BNS. The lower percentage coincides with the period when pelagic fisheries provided the main source of fish from the BNS (1940-1948) whereas the higher percentages coincide with the periods when brown shrimp make up an important proportion of the landings (1935-1939). It is estimated that shrimp fisheries (commercial and recreational) represents 69% of all discards on the BNS in the entire period, whereas trawling for roundfish and flatfish is estimated to represent 27% and pelagic fisheries 4%. Based on the literature sources consulted (see 6.4.a), it is expected that both historically and in recent times, whiting, plaice, dab, sharks and shrimp were the most discarded species on the BNS. To quantify the non-perceived economic value due to UU, the total hypothetical value of the unreported and discarded fish and shrimp from the BNS was calculated based on HiFiData economic information by species and by year. Expressed as prices 2010 (corrected for inflation) and based on the average price EUR/kg of the commercial landings, the calculations show that the total value of the unreported and discarded weight is approximately 90% of the value of commercial landings considering the entire period 1947-2010. This calculation may represent an overestimation since discards are mostly undersized and therefore of lower commercial value.

It is important to note however that the Dutch and French fleets also obtain substantial amount of landings from the BNS, which currently may exceed 4 times the landings achieved by the Belgian commercial and recreational fisheries covered in this section. Depestele et al. (2012) estimated the discards from different métiers from the Belgian, Dutch and French commercial fleets on the BNS, by using landings and discard sampling data and raising the outcome at the fleet level (2006-2008). Their results indicated that total discards on the BNS from all commercial fleets and métiers together may reach values around 8000t of fish and shrimp per year and up to 25,000t -30,000t per year if benthic invertebrates are included. This estimate of discarded fish on the BNS is in the order of magnitude of reported annual landings by the total Belgian commercial sea fisheries (18,000-22,000t). Beam trawl discards - in particular from the Dutch flatfish beam trawlers- were found to be the highest source of discarding throughout the year, while discards from the sole-targeting gill net fishery were found to be significantly lower. Discards from shrimp beam trawlers are highest in the second half of the year and located closer to the shoreline, corresponding with temporal and spatial patterns of this fishery.

6.5 CONCLUSIONS

In the present exercise to reconstruct total removals by the Belgian commercial, recreational and artisanal sea fisheries for the period 1929-2010, total removals were estimated at 5.2 million t, which is 42% higher than the 3.7 million t publicly reported over this period. Unreported landings and discards were estimated to represent respectively 3.5% (0.2 million t) and 26% (1.3 million t) of these total reconstructed removals. After the peak in 1963 (29,500t) and the period of increased discard rates (31%) in the early 1990s, total estimated discards gradually decreased to 6500t in 2007.

The reconstructed total removals on the BNS (Figure 6.10.) were estimated at 1.3 million t or 55% higher than the 0.8million t publicly reported over this period. In terms of percentages, discards on the BNS represent on average of 34% over the entire period. The estimates of annual discarded weight by Belgian commercial, recreational and artisanal fisheries on the BNS range from 4600t to 12,800t. These numbers do not take into account the non-commercial benthic invertebrate species, or the landings and discarding by foreign vessels (mainly Dutch and French) from the BNS.

Historical landings data availability and reliability

The present analysis shows that after 1960 the numerical data in the baseline (ICES 2012) and the national database are comparable. Overall, approximately 80,000t were positively corrected for the period 1929-1949 and 19,000t in the 1950s. It was assumed that the national database was more accurate for this period because it is based on the original paper documents, because footnotes were taken into account and thorough quality control was effectuated based on a secondary source for local datasets (Lescrauwaet et al. 2010a). Whereas the baseline does not allow distinguishing the landings from the BNS within the broader fishing area IVc, the national database allows for an analysis at a scale comparable with the boundaries of the BNS and offers opportunities for advanced research on seasonal and annual trends in historical landings, effort, and economy of the fisheries.

Gaps in data and information on discarding

This first reconstruction of total removals by Belgian sea fisheries from 1929-2010, is largely based on historical landing statistics by type of fisheries. Although this approach is widely applied and accepted in current studies on discard estimates, expanding and refining the approach by taking into account criteria related to fleet characteristics and fishing effort and to environmental conditions (local features of fishing areas, seasonality) should improve reliability of the outcomes (Depestele et al. 2011). Time-variant discard rate estimates are needed by fishing area and discard survival rates need more focused research by fishing métier and varying environmental conditions. The historical references and data to expand this approach however are not available at present. In general, there is insufficient information regarding historical discarding in Belgian sea fisheries to allow for a validation of the discarding rates that were applied for the earlier years. Insights in the historical impact of quota and market forces on ship-board discard behaviour are also needed to improve the estimates. The effects of the presence of observers in discard surveys must be excluded to obtain reliable estimates of discard rates, and in general caution is required when applying or extrapolating discard rates obtained from particular survey conditions. However, the estimates presented here are based on a conservative approach and lowest ranges of reported discards rates.

The estimates of landings and discards of the recreational fleet targeting brown shrimp and fish are based on assumptions and cover at least 4 decades. The estimates indicate that recreational fisheries need to be taken into account when looking at historical, current and cumulative impact of fisheries on the BNS. The catches and efforts of the recreational fleet targeting brown shrimp and flatfishes and their impact on the coastal ecosystem will be the subject of systematic surveying in the context of the national data-gathering program for the CFP and the monitoring in compliance of targeted GES. ICES and member countries need to establish regular surveys (every 4–6 years) of total recreational removal, by species, area and gear category. The Data Collection Regulations of the Common Fisheries Policy CFP require European Member States to collect data on technical, biological and economic aspects of their national fisheries and their impact on the marine ecosystem, and to collect data and report on discards. As a consequence of the 'discard-ban', formal reporting on commercial landings will be extended with commercial discards and removals from non-commercial fishing. This information must be spatially explicit and will improve stock assessments by including unaccounted removals.
Research was initiated by Depestele et al. (2012) to unravel current impacts of the main deployed fishing gears on the ecosystems of the BNS (WAKO II project). This research also takes into account the effects of fishing on species such as the harbour porpoise (*Phocoena phocoena*) which is listed on the EU habitat directive annexes (92/43/EEG) and directive 812/2004, protected by the royal decrees KB 1980-09-22 and KB 2001-12-21 and targeted by ASCOBANS. In these legally binding commitments, Belgium has agreed to monitor incidental catches of small cetaceans in both recreational and commercial sea fisheries, and to take action to reduce bycatch and protect their environment.
Also, underwater mortality such as towpath mortality and escape mortality and their effects on total mortality of commercial and non-commercial species require further studies. Finally, though anecdotal, information gathered from local ecological knowledge studies on socio-economic data on employment, income, fish consumption etc. can provide important references to support the reconstruction of missing time-series or validate the assumptions used in the historical reconstructions.

Historical reconstruction of total removals in support of integrated marine policies

The importance of the small-scale fleet is a broad policy objective and the social and cultural role of small-scale fisheries is explicitly stated in the EC Green paper on the Reform of the CFP. Policy options to support small-scale fisheries include special treatment under the European Maritime and Fisheries Fund EMFF, the exemption from particular management requirements and safeguards in a context of rights-based management systems with e.g. transferable quota. The 12nm limit that is reserved for coastal fisheries is also extended for another 10 years. It is therefore important to further quantify recreational and non-commercial fishing activities within the BNS, and their position and importance in comparison to commercial coastal fisheries. The results presented here suggest that:

- Since the 2000s, approximately 50% of all Belgian removals from the BNS are unreported landings and discards (IUU). This does not include benthic invertebrates.
- The unreported landings and discards are increasingly taken by non-commercial, small-scale (<12m) vessels that are not subject to reporting and not taken into consideration in planning, monitoring and enforcement
- The proportional importance of recreational fisheries has increased substantially in the last 4 decades, and currently may represent near to 20% of all removals by the Belgian fisheries in the BNS

- The total fish discarded by the Belgian fisheries on the BNS may range between 30-40% of all Belgian landings from the BNS. Based on estimates of fish discarded by the foreign fleet on the BNS (Depestele et al. 2012), our hypothesis is that since the 1990s, all fish and shrimp discarded by both the Belgian and the foreign fishing operations on the BNS together approximates 50% of the total reported landings (t) of Belgian commercial sea fisheries (all fisheries, all species, all fishing areas).

From an environmental perspective, this is cause for concern as it represents a waste of valuable resources of food, energy and biological diversity, and generates a non-quantified impact on the food web, seabed and ecosystem services in the coastal environment. From an ecosystem perspective this information - as well as the information on the activities of the foreign fleet on the BNS - must be included in particular to obtain reliable data in compliance of the e.g. the GES targets set forward in the MSFD (2008/56/EG), to improve stock assessments and achieving targets of maximum sustainable yield MSY in the CFP, and to achieve favourable conservation status FCS for the species and habitats protected in marine and coastal Natura 2000 sites. While not explicitly mentioned in its final statement, the UN 2002 declaration intended to also cover unregulated and unreported catches by recreational fisheries from 2004 onwards. The daily allowable catches in recreational fisheries must also be connected to EU quota regulations and recovery plans for cod and plaice. However, in terms of social, economic and cultural considerations, the unreported removals and discards represent wasted or lost opportunities for local jobs and security for the formal fishing industry, for secure food, and for leisure and tourism for the wider population. These non-perceived or non-quantified socio-economic benefits and externalized environmental costs need to be taken into account in future strategies and planning for more sustainable fisheries. Although this study refers to the particular situation of the Belgian fisheries, similar trends may exist in neighbouring countries around the North Sea. Finally, taking into account total removals is one aspect in moving towards an ecosystem-based approach and planning for future socio-economic viability of fisheries. A more integrated view takes into account aspects of energy and fuel consumption to steam towards distant grounds, employment, food safety and quality. In Belgium, the Fisheries Authority (department of Agriculture and Fisheries, Flemish government) together with the producers' organisation, the Fisheries Research Institute ILVO and an environmental NGO have taken first steps towards a more sustainable future for fisheries through a Strategy for Sustainable Fisheries, which is carried forward by its Task Force.

In spite of the remaining gaps and uncertainties, the current estimates provide a first overview of historical trends and current estimates of the IUU by Belgian fisheries, and in particular by the Belgian fleet on the BNS. As such they can support the wider debate about how to move to more sustainable fisheries, what the role of small-scale fisheries are, how to achieve the agreed policy targets in Belgian marine waters and in particular in the marine areas protected under the EU Habitat and Bird directives.

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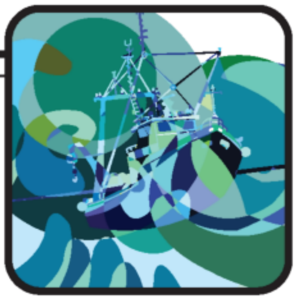

CHAPTER 7: Flooded by herring: Downs herring fisheries in the southern North Sea during World War II

CHAPTER 7: FLOODED BY HERRING: DOWNS HERRING FISHERIES IN THE SOUTHERN NORTH SEA DURING WORLD WAR II

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ICES Journal of Marine Science.

Abstract

During the Second World War (1939-1945) herring fishing effort in the North Sea was greatly reduced. The traditional autumn herring fisheries by Belgian fishers on the Flemish banks around the spawning areas in the southern North Sea however, continued during WWII. Data presented here show a 10-fold increase in the Belgian 'autumn spawning herring' catches and a 5-fold increase in landings per unit of effort of Downs herring during WWII. It is argued that these increased catches are explained by a combination of factors including the sustained effect of a major increase in catch power, the effects of strong pre-WWII year classes and the effects of decreased fishing mortality during the 6-years cessation in fishing on the herring feeding grounds in the central North Sea and in the English Channel. The data and information presented here represent a period in which a gap exists in time-series of herring catches from the North Sea and in the stock assessment time series which currently go back to 1947. The results are also discussed in the context of the recovery of the autumn-spawning Downs herring. The recovery of stock components and the spatial diversity in the spawning areas of the herring stock in the North Sea is a crucial aspect of fisheries management that aims to enhance stock resilience to changes in environmental conditions and direct effects of anthropogenic activities.

Key words:

Downs herring, autumn-spawners, North Sea, Second World War,

7.1 INTRODUCTION

In the 20th century, the Belgian 'spent herring' fisheries were seasonal and took place on the Flemish banks in the southern North Sea between November and March, with peaks in January (Gilson 1931-1939, Gilis 1942-1962). With the large-scale introduction of engine-powered vessels between the First World War (WWI 1914-1918) and WWII, Belgian herring fisheries switched from using driftnets to otter trawls as the main fishing gear (Lescrauwaet et al. 2012). In the years before WWII, Belgian fishers landed approximately 40,000 tonnes (t) of fish and other seafood per year, a quarter of which consisted of herring. Herring was fished mainly in the coastal waters of the Belgian part of the North Sea and across the border in French waters (spent herring), while smaller quantities were also caught in the southern North Sea and Fladen (East of Scotland) (Lescrauwaet et al. 2010a).

In Belgium, WWII started on May 10, 1940 and ended on October 1, 1944. At the outbreak of WWII, the Belgian fleet consisted of 460 motor trawlers – 201 had engines less than 80 PK (Dutch Horse Power) – and 14 steam trawlers. Most of the fleet fled to the UK or was set to service military purposes and no fishing took place from the end of 1939 (Lescrauwaet et al. 2012). In 1941 a limited part of the fleet was allowed to fish under close surveillance by the occupying forces (De Mulder 1984). In practice the 'coastal waters' was the only fishing area to which access for fishing was granted after 1940 and before 1945. This area is not distinguished separately as one of the ICES reporting/fishing areas and landings from coastal waters are reported to ICES as part of 'Southern North Sea' (ICES area IVc). Local historical sources mention how unprecedented catches of 'spent herring' in Belgium during WWII provided protein that saved the Belgian population from starvation and how processing and distribution systems in Belgium were not able to cope with these unexpected catches in 1942-1943 (Henau 1983, Balthazar et al. 1984). Unusually high herring catches were also reported for the ports of Dunkerque and Gravelines in the north of France where, in spite of WWII restrictions on fishing effort, Gravelines increased landings of herring by 1028% in 1942 compared to 1938 just before WWII (Oddone 1987). Few sources however contain detailed quantitative information on landings, CPUE of the fisheries, or age structure of herring catches during WWII.

The North Sea herring (*Clupea harengus* Linnaeus 1758) is a demersal spawner and most herring spawn for the first time at the age of three or four years. Herring stocks in the North Sea are generally described in terms of four spawning components: the Shetland/Orkney, the Buchan, the Dogger or Banks, and the Downs herring, each with different growth rates, migration routes, and recruitment patterns (Bjerkan 1917, Cushing and Bridger 1966, Harden Jones 1968). These spawning components migrate to their separate spawning areas to spawn at different times (Maucorps 1969, Heath et al. 1997, Corten 2001): the Orkney-Shetland herring spawn off the Shetlands (August-September), the Buchan off the eastern Scottish coasts and the Dogger or Bank herring off the English Coasts in the central North Sea (September-October), while the Downs herring spawns in the English Channel and the southern bight of the North Sea (November-January) (Figure 7.1.). After hatching, the larvae of different components drift in a counter clock movement towards nursery areas in the central North Sea (Burd 1962, Maucorps 1969).

The spawning components also face different fishing pressures in their respective spawning or resting (post-spawning) areas. In each annual cycle, adult Downs herring recovered on the Flemish banks after spawning in autumn and before returning to the northern feeding grounds in spring where large drift net fisheries take place on mixed schools of the different stock components. The traditional driftnet fisheries in Belgium (pre-20th century), later replaced by trawl fisheries (after WWI), were based on the knowledge of the location and timing of these concentrations of spent herring. The commercial herring trawl fisheries were conducted with the otter trawl, and fishing trips were one day of length as fishers would return to the nearby ports the same day to land their fresh catches. The fisheries would start off each year to the west of the Belgian coastline or even just across the border in the territorial sea of France and move eastwards along the coast as the season progressed, targeting the eastbound schools of spent herring (Gilson 1939).

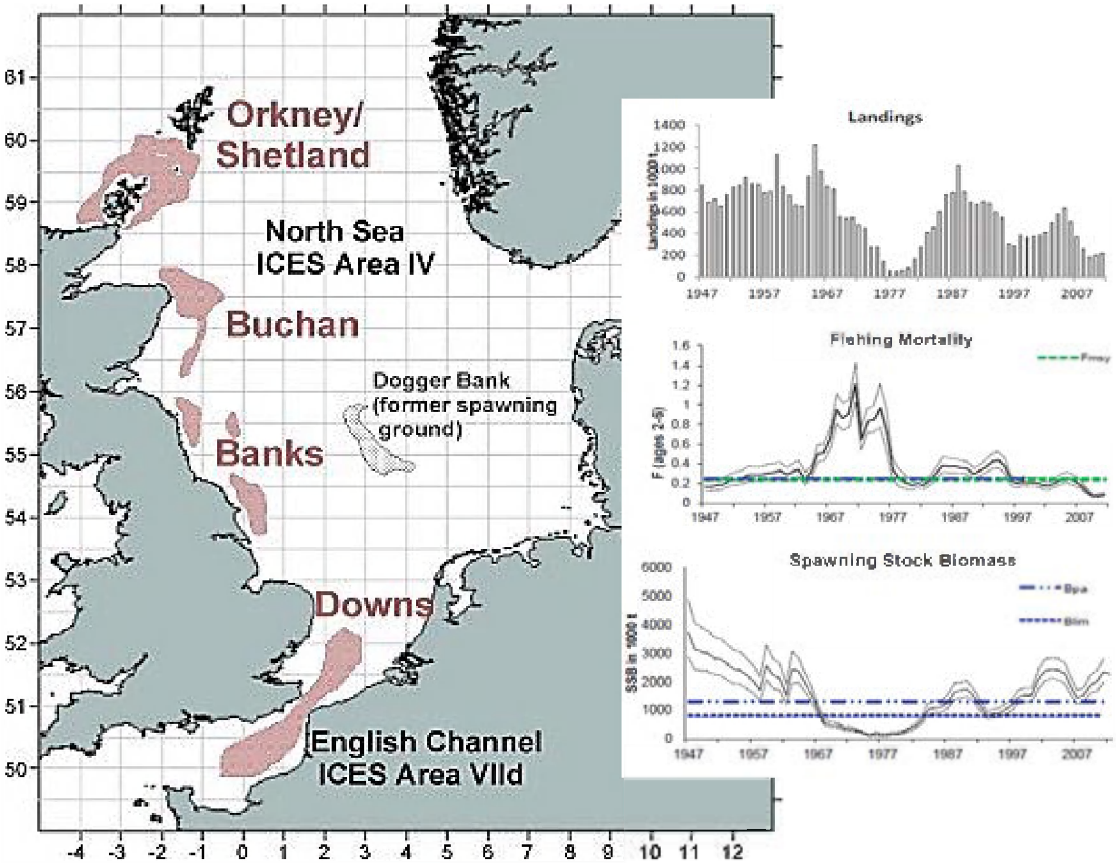


Figure 7.1.: North Sea herring: Generalised major spawning grounds (after Dickey-Collas 2010). The inset shows the time-series of the Landings (top), Fishing Mortality (middle) and Spawning Stock Biomass SSB (bottom) of herring in subarea IV and Divisions IIIa and VIId (North Sea autumn spawners) source: ICES HAWG 2012.

Before WWII, reported annual landings of herring fisheries fluctuated around 300,000-500,000 t (ICES landing statistics Fishstat). This compares to the minimum acceptable spawning stock biomass B_{lim} that was set at 800,000 t at the end of the 20^{th} century (Dickey-Collas et al. 2010, ICES Advice 2012). During WWII, the larger fishing nations in Northwest Europe were forced to drastically reduce their fishing effort in the North Sea because of the war hazards (Baerends 1947, Gilis 1947) and because many fishing vessels were required to serve in the naval forces. The large-scale (drift net) fishery for Atlantic herring on adult feeding grounds was one of the affected commercial fisheries in the North Sea.

In the current paper we present unpublished data collected during WWII on the landings of Atlantic (Downs) herring in the coastal waters of Belgium and the North of France. The wide-scale effort to reconstruct and integrate historical fisheries data (HiFiDatabase) in Belgium uncovered previously neglected paper copies of official statistical tables for the WWII period (Lescrauwaet et al. 2010a) and a description of material and methods for the reconstruction of time-series is included in Lescrauwaet et al. (2010b). These data collected during the WWII period of restricted fishing were previously unknown in national and international reporting. The data refer to the commercial fishing fleet’s activities in coastal waters and provide detailed accounts of landings by species, by month, by fishing area and by port of landing during a period for which limited or no information exists in neighbouring countries in the North Sea. Data on the small-scale fisheries (*strandvisserij*, or beach-based fisheries) for herring from small open boats with passive gear are also included in the reconstruction. The data presented here refer to a period in which a gap exists in time-series of herring catches and herring stock assessments from the North Sea. We explore potential causes for the sudden increases in catches of the Downs herring in its spawning areas by analysing data on catches, landings per unit of effort LPUE, and age structure of the catches from the commercial Belgian herring fishery.

7.2 MATERIALS AND METHODS

The data presented here are obtained from different sets of data sources. The first data were obtained from official national landing statistics and were used to reconstruct the total landings of herring (t) and the effort by the herring fisheries (number of vessels, days at sea, engine power HP), as well as to calculate the LPUE. In Belgium, a centralised statistical data collection system on sea fisheries was in place by 1929, which collected monthly value and composition of landings by species in the 4 fishing ports in Belgium (Lescrauwaet et al. 2010a). Belgian autumn spent herring fisheries were located each season in the same restricted area of high concentrations of herring which congregated after spawning, and within a restricted season of 3 months time. A second source of data was the scientific reports and unpublished manuscripts of Gilson (1931-1939) and Gilis (1942-1962) which contain detailed annual accounts of the seasonal 'spent herring surveys' (November-March). The time-series covers 31 years of systematic monitoring of the commercial fleet activities and the biological conditions of the herring concentrations in the 'Sandettie area' during each winter from 1930 to 1960. The Sandettie area makes reference to the sandbank of the same name. It extends 15 nm from the shoreline, stretching from the northern French coasts along the Channel towards the Belgian-Dutch border, and it corresponds to the broader spawning area of the Downs herring component. Between 1930 and 1952, these surveys were conducted from the second half of December - when most of the herring had spawned - to the end of the spent herring season (March). From 1953 onwards, the surveys were extended to cover November-March. All original survey reports were inventoried and described in the Integrated Marine Information System IMIS of the Flanders Marine Institute VLIZ, and made available in full text (pdf). The list of herring-related publications by Charles Gilis and by Gustave Gilson are disclosed on the IMIS webpages.

Finally, for the reconstruction of the time-series of Belgian herring landings for the 18^{th} -20^{th} century, a thorough literature study was conducted and the City archives of Oostende, Brugge and Antwerpen and the State Archives in Brugge and Brussels, were consulted. Since fish landings in the 18^{th} and 19^{th} century were often reported in ancient units of weight or in economic values, the reported commercial value of landings were standardized and reconverted to units of weight based on equations of value per kg obtained from literature references for that period (Cloquet 1842, De Zuttere 1909). The sources for this reconstruction are available from the supporting material Table II. For the sake of completeness, it should be noted that accidentally, minor proportions of sprat may have been caught within the herring schools, and erroneously reported as herring. However, sprat and herring were reported separately at least since 1929.

To provide a proxy of the herring concentrations and to allow for comparison between consecutive seasons, the landings of spent herring were divided by the number of fishing days and total developed horsepower HP and expressed as commercial landings per unit of effort (LPUE in kg/day*HP). To explore whether increases in LPUE were due to the presence of strong year classes incorporating into the spawning population from age 3 onwards, we reconstructed the age structure of spent herring landings in post-spawning areas off the Belgian coast from 1930 to 1960 based on the data reported by Gilis (1942-1962).
Mean length of herring specimens calculated per 1000 sampled herring for the period 1930-1939 and for the second period 1941-1950, is included in the result section.

To explore the effect of the reduced fishing effort on the adult herring feeding grounds during WWII and its possible causal relation with increased catches in Belgium, catch ratios were calculated from the age structure. The catch ratios measure the rate of decrease of a catch of one age-class over two successive years, for all fully recruited ages. From the catch ratio, mean total mortality Z (Z = Fishing mortality F+ Natural mortality M) was calculated for the grouped ages 3-9 years (a=3-9). Natural mortality M was assumed to remain stable, and changes in Z to be a reflection of changes in fishing mortality F.

7.3 RESULTS

Fishing effort and spent herring catches during WWII

The data collected from the statistical tables show that the 10,878 t of landings obtained from coastal waters in 1939 consisted mainly of sprat (*Sprattus sprattus*) and brown shrimp (*Crangon crangon*). No data are available for 1940 which confirms sources stating that no fishing could take place that year (De Mulder 1984). In 1941 the total landings of 3,867 t consisted mainly of brown shrimp but important herring catches were landed in December (Figure 7.2.). The year 1942 benchmarked the first of four consecutive years 1942-1945 with unprecedented herring catches: respectively 18,470t (or 80% of the total landings), 58,080t (93%), 49,002t (97%) and 31,958 t (74% herring). The monthly landings available for this period are represented in Figure 7.2. No monthly landing statistics were available for 1945.

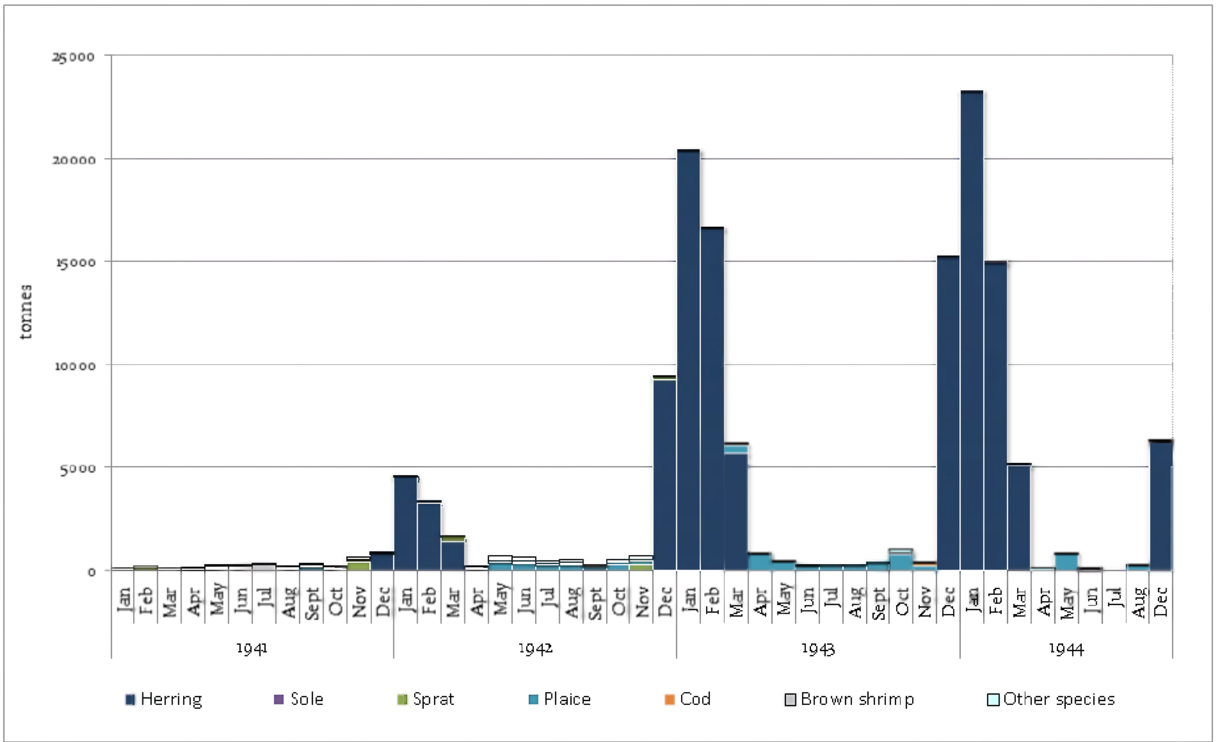
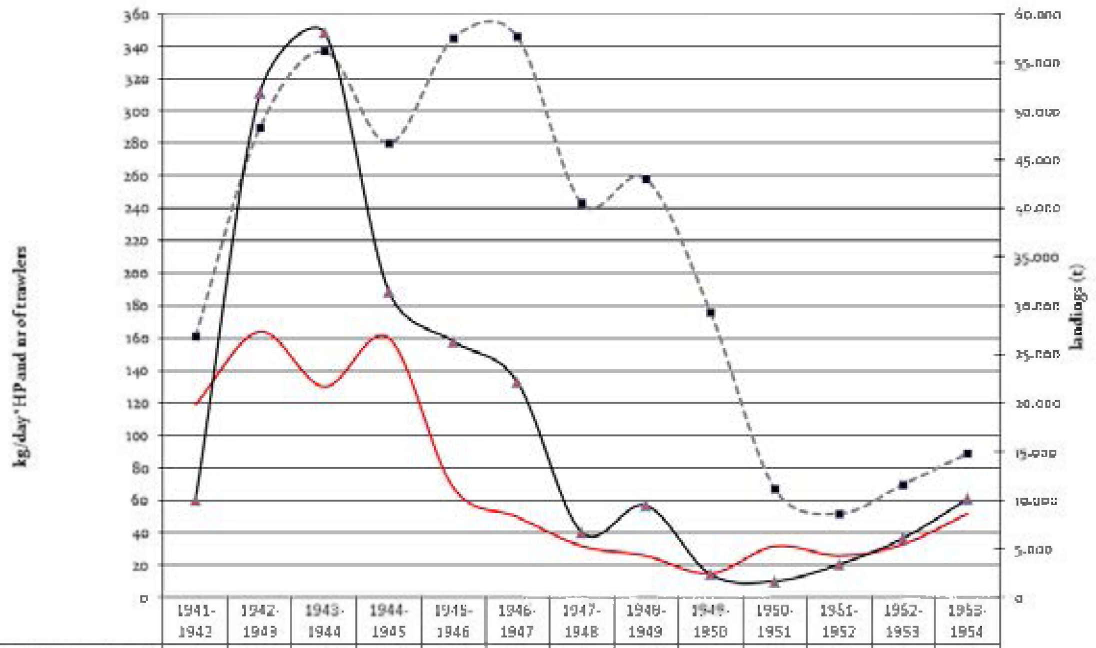


Figure 7.2: Monthly distribution of fish species landings from the (restricted) fishing activities in Belgian coastal waters during the WWII by Belgian fishermen, 1941-1944 (no monthly data for September-November in 1944).

Expressed as 'spent herring seasons' (November-March), the catches were rearranged and compared to Gilis (1947a) who reported aggregated landings of spent herring per 'herring season' (supporting material Table I).

Although commercial catch per unit of effort (CPUE) is widely used as an index of abundance, the factors that may potentially bias this index are well documented (Hilborn and Walters 1992). The present study – in particular the years of the WWII - covers a delimitated and well-defined area and period during which fishing gear and bycatch rates are expected to have remained relatively stable. In the years after the WWII, the average engine power, technological developments (e.g. fish finder) and other factors that positively affect catchability, took a further increase. After 1950, the more selective pelagic trawl was increasingly used for herring and sprat fisheries (Gilis 1962).

The landings of spent herring from the Sandettie area increased from 10,031 t in the season 1941-1942 to 58,120 t in 1943-1944 (Figure 7.3.). The number of trawlers fishing during daytime in the Sandettie area increased from 161 to 337 in the same period. After the season 1944-1945 both the landings and the LPUE declined quickly, although the number of trawlers dedicated to the seasonal spent herring fisheries remained high (346) until 1946-1947, i.e. two seasons after the LPUE had declined by >60% from 160 kg/day*HP to 50kg/day*HP. The average LPUE for the 4 herring seasons during WWII (1941-1945) was 143 kg/day*HP compared to an average of 26 kg/day*HP for the 4 herring seasons 1949-1953.



	1941-1942	1942-1943	1943-1944	1944-1945	1945-1946	1946-1947	1947-1948	1948-1949	1949-1950	1950-1951	1951-1952	1952-1953	1953-1954
kg spent herring/day*HP	119	164	130	160	68	50	32	26	15	32	26	33	52
nr of trawlers	161	290	337	280	345	346	243	258	176	67	52	70	89
landings (t)	10.031	51.895	58.120	31.446	26.359	22.172	6.738	9.572	2.426	1.706	3.475	6.130	10.173

spent herring season

Figure 7.3: Landings (kg) per unit of effort (day*HP) of spent herring fisheries for the seasons 1941-1942 to 1953-1954.

Biological parameters of the spent herring catches during WWII

Large year classes can dramatically change the dynamics of a herring population, as was shown for the year classes 1998 and 2000 (Dickey-Collas et al. 2010). Year-class strength in the North sea autumn spawning herring stock may be determined by larval survival, and some of the hypotheses suggested by Payne et al. (2009) explore the effects of local changes in temperature, salinity, water column stability, turbulence, primary production and zooplankton community, on the survival rate of herring larvae (Fassler et al. 2011).

The data represented in the age structure graph (Figure 7.4.) show that year class 1936 and 1938 are strong year classes present throughout the period under study that can be traced through the cohorts e.g. as the age 3 and age 5 groups in 1941 in Figure 7.4. (for numbers see supporting Table III), before they combine in age classes 10+ in 1947. The age structure in Figure 7.4. shows that the increased LPUE during WWII can at least in part be explained by an increased proportion of older and larger specimens of spent herring. In fact, during WWII the age classes 6 and older represented approximately 80% (1944) of the catch composition whereas after WWII, these groups would represent around 40% of the observed frequencies and in 1959 - in the absence of any of the war year classes - they composed less than 5% of the catch.

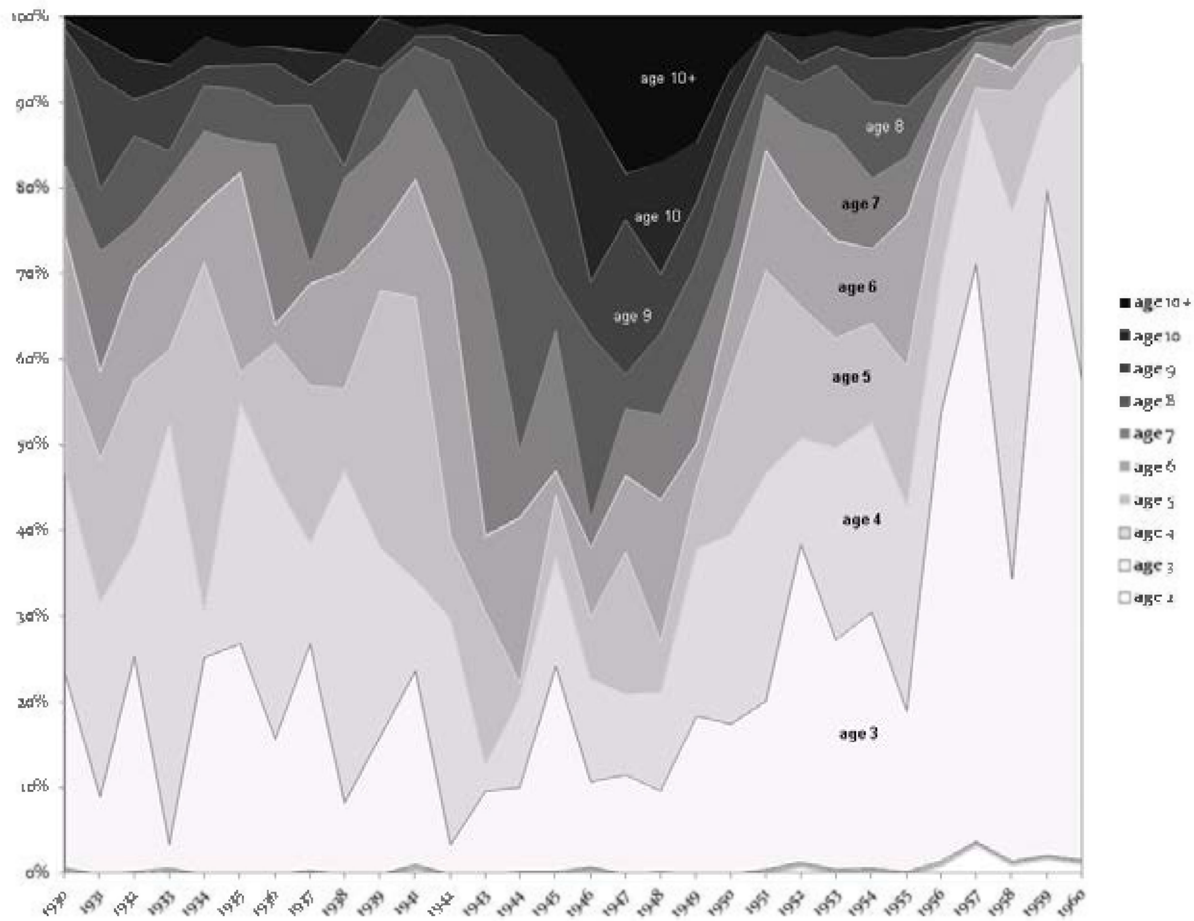


Figure 7.4.: Reconstruction of the age structure of sampled spent (Downs) herring catches from 1930-1960, by the Belgian sea fisheries in post-spawning areas off the Belgian and northern French coasts. Based on data reported by Gilis (1942-1962).

Interestingly, the effect of strong year classes also seems to have determined this ratio between age groups 6 and older, and those younger than 6, e.g. in 1931, 1953 and 1955. The effect of the latter however coincides with a modest increase in LPUE if compared to the increase in LPUE during WWII. Based on the frequency distribution of age classes in the sampled catch, Gilis (1962) reported another 14 stronger year classes in the period 1930-1960.

Based on 31 years of sustained morphological studies of catch samples, Gilis (1962) observed a significant increase in the average length by sampled age classes of spent herring catches from the commercial fleet over the three decades, in particular in the third decade from 1951-1960. This increase in length and size at age (in mm) by decade evidences an increase in size at age in the last decade (Table 7.1.; annual data in supporting material Table IV). Gilis (1962) also reported increases in the size at age for herring for the last decade 1951-1960, based on the observed length and growth rings of scales. Mean length per 1000 sampled herring increased from 245,5mm before WWII (1930-1939) to 257,6mm during the period 1941-1950 (supporting material Table IV). In spite of the reported increase in size at age of individual herring in the period 1951-1960, the mean length of the sample in that period decreased to 255,1mm. The latter is explained by the decrease in the proportion of older herring compared to the decade 1941-1950.

Table 7.1.: Mean length (mm) by sampled age classes, and growth in mm between consecutive years of age (between brackets) for three consecutive decades 1930-1960. Source: Gilis 1962.

Decade	Age 3 years	4 years	5 years	6 years	7 years	8 years
1930-1939	219	235 (+16)	248 (+13)	257 (+9)	262 (+5)	266 (+4)
1941-1950	230	247 (+17)	256 (+9)	263 (+7)	267 (+4)	271 (+4)
1951-1960	239	259 (+20)	272 (+13)	278 (+6)	284 (+6)	286 (+2)
1930-1960	**229**	**247 (+18)**	**259 (+12)**	**266 (+7)**	**271 (+5)**	**274 (+3)**

Total Mortality

To look at the effect of the reduced fishing effort on the adult herring feeding grounds during WWII and its possible causal relation with increased catches in Belgium, catch ratios were calculated from the age structure (Figure 7.5.).

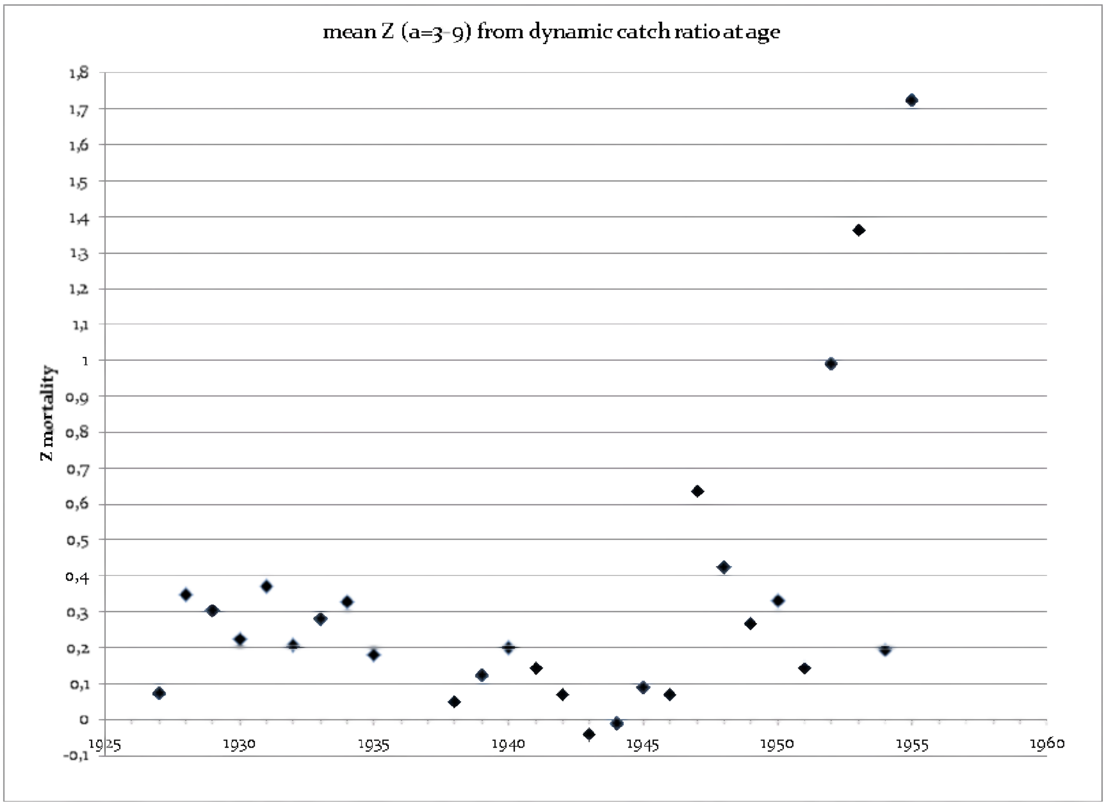


Figure 7.5: Mean mortality Z of spent Downs herring for grouped ages 3-9 years, calculated from dynamic catch ratio at age. Based on data reported by Gilis (1942-1962).

Although patterns are not clearly identified, comparison of mean mortality Z over time in Figure 7.5. suggests a decrease in total mortality Z for the cohorts reaching age 3 up to age 9 during WWII. Between 1940 and 1943 lower Z values can be observed. The lower Z values start in 1941 (which may reflect the reduced fishing pressure on year class 3) and continues to decrease up to 1943 (when year-classes 3 up to 6 are incorporated in the pooled age group 3-9). The trends in Z in the WWII period may be explained by the cumulative effect of decreasing fishing pressure on an increasing number of age classes. After the 1950s, when the industrial herring fisheries started at a larger scale, the Z values show a steep increase (Figure 7.5.)

7.4 DISCUSSION

Various authors studied the effects of WWII on fish stocks and their recovery during and after WWII. The relation between the reduced fishing effort and the increase in mean sizes and catch rates of haddock as compared to pre-war times was explicited by Baerends (1947). Similar conclusions were drawn for the demersal fisheries off the UK and Dutch coasts and the Danish seine-net fishery, indicating an increase in stock density of three times the pre-war level (Baerends 1947). The effects of WWI and WWII on increases in catch per unit of effort of North Sea plaice (*Pleuronectes platessa*) were illustrated by Rijnsdorp and Milner (1996). Graham (1949) and Wimpenny (1953) examined the effects of WWII on plaice populations in the Southern North Sea. Beare et al. (2010) looked at the effects of WWII on gadoid species in the Buchan area (East coast of Scotland) and reported an increase in catch per unit effort CPUE of haddock (*Melanogrammus aeglefinus*) from 11 to 59 kg h^{-1} of fishing between 1939 and 1945, while the CPUE of cod (*Gadus morhua*) increased nearly ten times from 4 kg h^{-1} in 1939 to 36 kg h^{-1} in 1945. Based on an analysis of age structure, Beare et al. (2010) concluded that - if supported by good recruitment - wild fish stocks may respond rapidly and positively to reductions in harvesting rates.
Poulsen (2008) reconstructed herring landings from the North Sea for the Dutch, English, Scottish and Danish fleets between 1600-1860. According to the author, It was not until the introduction of the motor engine after WWI and the increasingly efficient catch technology (purse seine and pelagic trawls) that fishing significantly impacted the reproduction potential of the herring stocks in the North Sea, with catches reaching levels of up to 1,000,000 t per year from a total estimated SSB of 1,500,000 t (Poulsen 2008). The Dutch and UK fleet maintained relatively high catch levels of herring during the first part of WWI (approximately 150,000t in 1915 and 1916) and joint Dutch and UK annual herring catches amounted up to 300,000 t in e.g. 1929 and 1937 (ICES Fishstat) while in contrast, catches dropped to near zero during WWII.

To put the WWII herring landings by the Belgian fleet in a wider historical context, the authors reconstructed the time-series for Flemish herring landings from the North Sea from 1767-2010. The time-series (Figure 7.6.) shows that Flemish herring production fluctuated around 1,000-2,000 t in the 18th and 19th century. The data also suggest that – similar to the findings of Poulsen (2008) - the introduction of engine powered vessels equipped with otter trawls from WWI onwards, may partly explain the unprecedented herring catches during WWII, for Flemish herring fisheries.

A strong increase in catching capacity in the Belgian fleet took place in the inter-war period. Figure 7.6. shows important increases in spent herring catches of up to 18,000 t in the years following WWI with the implementation of new technologies based on engine power. In 1925 about half of the fleet (excluding the smaller open boats) used motor or steam engines as propulsion and by 1929 nearly the entire fleet was motorized (steam or engine) (Lescrauwaet et al. 2012). The otter trawl gradually replaced the traditional drift nets as fishing gear in the first half of the 20^{th} century. Throughout WWII only the otter trawl was used and after 1950 the -more selective- pelagic trawl was the main fishing gear for catching herring.

The North Sea herring stock has shown large fluctuations in spawning stock biomass SSB since its collapse from more than 5 million t in the late 1940s to a low of 50,000 t in the 1970s (ICES HAWG 2012), see also inset Figure 7.1.). In June 1977 a ban was set on directed herring fisheries in the North Sea, which was however not fully respected in the Channel area where smaller quantities of spawning herring were still caught (Dickey-Collas et al. 2010). The ban was lifted in June 1983 and the SSB had partially recovered to 1.8 million t in 2004 (Dickey-Collas et al. 2010). A recent stock assessment (ICES 2012) estimated the North Sea herring SSB is now at >2million t and total biomass is >4 million t.

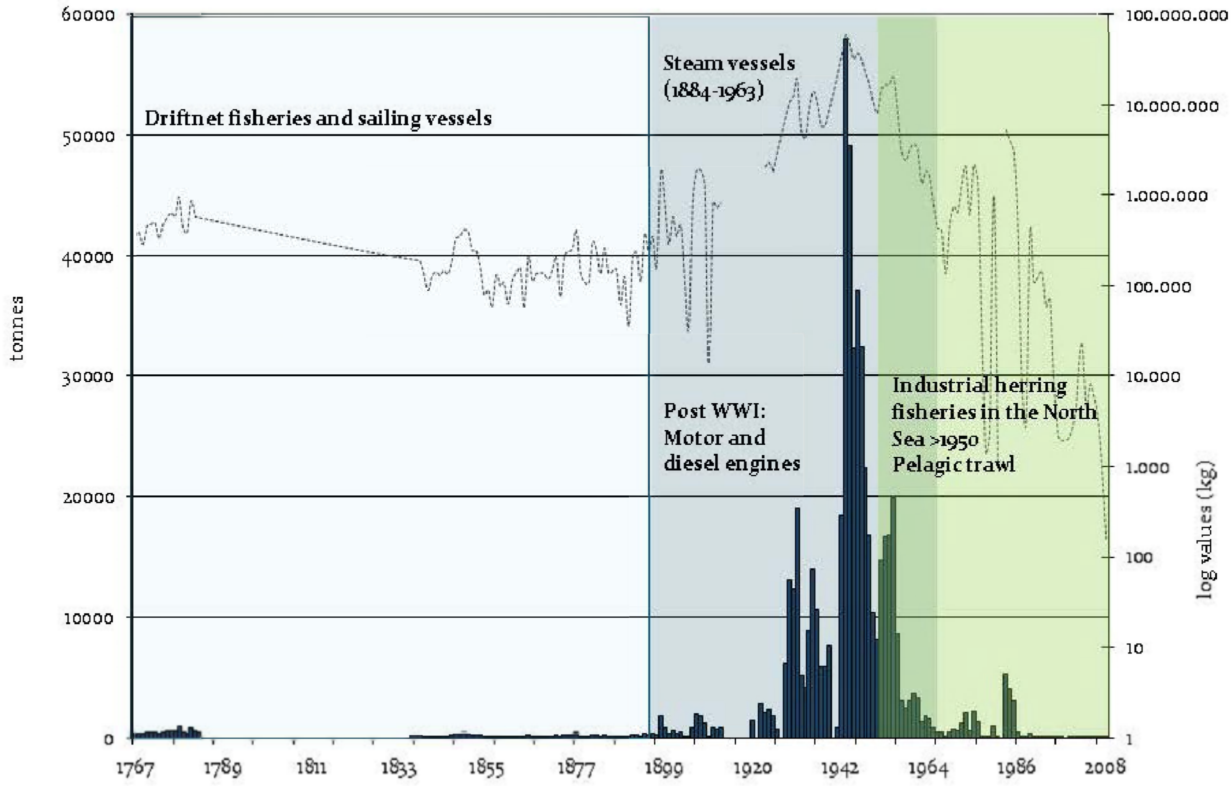


Figure 7.6.: Reconstruction of landings (x1000kg, bar chart left-hand axis) of the Flemish herring fisheries in the 18th-20th century. The 18th and 19th century estimates are based on literature sources while 20th century data are provided by the HiFiDatabase. Blanks before the 20th century indicate absence of data (both for reported nominal landings or estimates). The time-series is expressed as log values on the right-hand axis (dotted lines) to improve reading and comparison for landings below 10,000t.

However, as Schmidt et al. (2009) indicated, a recovery in the total SSB does not necessarily indicate full recovery of the individual components of a stock and of the number and distribution of their spawning sites (Saville and Bailey 1980). Payne (2010) demonstrated that although the total North Sea herring SBB recovered relatively quickly after the 1970s collapse, the component diversity of the stock was not fully re-established before the mid-2000s. The patterns of collapse and recovery have been different for the distinct spawning components: based on mainly qualitative information it has been suggested that the Downs component collapsed as early as the 1950s and its recovery is only of recent years (Cushing 1992, Payne 2010). Currently, upon ICES stock management advice, the Downs herring IVc-VIId TAC is set at 11% of the total North Sea TAC to conserve the spawning aggregation of Downs herring, at least until the uncertainty about the contribution of the Downs herring to the total herring catch in the North Sea is reduced.

The results presented here show that the Belgian fisheries benefited a 10-fold increase in catches and 5-fold increase in LPUE of Downs herring during WWII. It is argued that these increased catches are explained by a combination of factors including the a) sustained effect of a major increase in catch power thanks to improved technologies that were implemented after WWI, and b) the effects of strong pre-WWII year classes (e.g. 1936 and 1938) which joined the adult Downs herring during WWII on the post-spawning resting areas that were targeted by the Belgian fisheries. This was associated with a period with an apparent almost zero mortality Z. It must be noted that, because of the 6-years cessation in fishing efforts on the herring feeding grounds in the central North Sea, an increased number of individuals aged 3-4 and older, would arguably also be able to join the spawning areas as war progressed. These age classes were subject to a decreased fishing mortality in the drift net and pelagic trawl fishery on the adult feeding grounds in the central North Sea and during their migration to the spawning grounds in the Southern North Sea. Although it is difficult to quantify their proportional importance, it is argued that both factors positively affected the proportion of older age classes as well as the observed increase in LPUE and overall landings in Belgian commercial herring fisheries. In spite of the existence of other strong year classes previous to, and after WWII, these could not be related to increased landings or LPUE on the post-spawning areas of the Downs herring.

The data presented here suggest the presence of increased abundance of spent herring during the cessation of fishing activities and before large-scale herring fisheries in the North Sea resumed again after 1945. Belgian fishermen that fished the coastal waters during the WWII were to witness the most productive herring seasons documented in Belgium since the 18th century. In spite of the severe damage that the fishing fleet suffered during the WWII, the Belgian fisheries benefited economically from this unintended 6-year temporary closure to fisheries in the North Sea and this success triggered a period of rapid expansion and investments in the Belgian fleet in the years to follow.

Acknowledgements

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Supporting material

Table I: landings during the 'spent herring seasons' based on monthly landings (HiFiDatabase Figure 7.2.) and compared to the aggregated landings per 'spent herring' season in Gilis 1946, 1947

Season	*Landings (x1000kg) (HiFiDatabase)*	Landings (x1000kg) (Gilis 1946, 1947)
1941-1942	9,982	10,007
1942-1943	51,929	51,895
1943-1944	58,445	58,119
1944-1945	No monthly data for 1945	31,847

Table II: Average annual landings of herring (kg) over periods (column 1) in the 19th and 20th century, and data source.

Period	*Average Annual Belgian landings of Atlantic herring (kg)*	Source
1767-1783	512,684	Cloquet 1842
1836-1905	221,645	Cloquet 1842, Dezuttere 1909
1906-1928	1,709,200	ICES, Dezuttere 1909
1929-1940	9,718,716	VLIZ, HiFiData
1941-1950	27,782,058	VLIZ, HiFiData
1951-1960	9,718,163	VLIZ, HiFiData
1961-1970	1,106,165	VLIZ, HiFiData
1971-1980	918,602	VLIZ, HiFiData
1981-1990	1,477,163	VLIZ, HiFiData
1991-2000	46,263	VLIZ, HiFiData
2000-2009	6,418	VLIZ, HiFiData; Flanders Fisheries Service

Table III: Distribution (number per 1000 sampled herring) of age class, 1930-1960. Source: Gilis 1962.

Distribution of age class per 1000 sampled herring										
year	**age 2**	**age 3**	**age 4**	**age 5**	**age 6**	**age 7**	**age 8**	**age 9**	**age 10**	**age 10+**
1930	5	228	236	126	150	82	125	34	11	3
1931		88	229	167	102	140	71	132	45	26
1932	1	252	133	191	120	61	102	43	48	49
1933	5	29	491	87	126	72	32	76	26	56
1934		251	55	407	68	84	53	25	34	23
1935		268	282	36	232	36	60	30	21	35
1936		157	301	162	20	210	45	50	21	34
1937	3	265	118	184	118	23	186	23	40	40
1938		82	389	95	137	108	14	125	7	43
1939		160	220	300	70	100	80	10	60	
1940	No data reported									
1941	9	227	107	329	138	106	49	13	9	13
1942		33	264	97	303	136	114	31	14	8
1943		95	32	178	88	311	142	112	21	21
1944	2	98	106	16	193	77	307	117	64	20
1945	1	241	128	72	27	165	57	188	74	47
1946	7	99	121	73	81	34	212	63	200	110
1947		115	94	167	88	79	40	180	55	182
1948	2	94	116	59	165	98	95	70	132	169
1949		184	195	75	46	124	88	72	70	146
1950		174	222	187	84	65	103	60	43	62
1951	4	197	266	237	140	65	32	39	4	16
1952	12	372	124	153	120	95	46	24	30	24
1953	4	268	225	128	114	122	82	23	18	16
1954	6	298	222	116	87	82	90	51	24	24
1955	2	203	259	176	190	73	65	63	36	14
1956	13	524	164	111	69	35	20	28	21	15
1957	37	674	183	23	39	14	5	9	9	7
1958	14	328	430	141	25	28	21	5	4	4
1959	21	776	103	70	16	6	3	4	1	
1960	15	561	372	33	15	3				1

Table IV: Average length in mm at age 3-8 for the period 1930-1960, and average length in mm of 1000 sampled herring (Source: Gilis 1962).

	Age (years)							**Average Length in mm/1000 herring**
Seasons	**3**	**4**	**5**	**6**	**7**	**8**	***Year Classes***	
1930	215	229	249	254	262	263	*1927-1922*	241
1931	220	233	241	257	260	267	*1928-1923*	251
1932	211	226	237	245	256	260	*1929-1924*	238
1933	222	234	243	251	257	264	*1930-1925*	245
1934	217	233	247	255	258	261	*1931-1926*	242
1935	217	236	250	257	262	265	*1932-1927*	243
1936	219	238	249	259	262	266	*1933-1928*	247
1937	223	242	256	259	265	268	*1934-1929*	250
1938	223	237	253	263	265	275	*1935-1930*	252
1939	224	237	250	266	269	270	*1936-1931*	246
1930-1939	**219**	**235**	**248**	**257**	**262**	**266**		**245,5**
1941	235	248	254	261	266	268	*1938-1933*	248
1942	226	249	258	259	266	269	*1939-1934*	254
1943	234	249	257	267	264	270	*1940-1935*	258
1944	228	239	255	256	264	264	*1941-1936*	252
1945	229	248	260	266	264	273	*1942-1937*	254
1946	228	246	257	265	273		*1943-1938*	263
1947	231	248	256	265	270	273	*1944-1939*	260
1948	233	249	255	264	267	273	*1945-1940*	264
1949	223	246	254	266	268	272	*1946-1941*	256
1950	236	245	257	264	269	274	*1947-1942*	254
1941-1950	**230**	**247**	**256**	**263**	**267**	**271**		**257,6**
1951	235	251	260	265	270	276	*1948-1943*	254
1952	239	255	268	271	276	279	*1949-1944*	258
1953	240	261	270	277	280	283	*1950-1945*	270
1954	242	261	276	281	286	286	*1951-1946*	265
1955	246	262	275	283	288	290	*1952-1947*	271
1956	238	260	272	283	289	295	*1953-1948*	251
1957	239	258	276	283	289	283	*1954-1949*	244
1958	242	260	274	284	290	299	*1955-1950*	257
1959	233	261	274	283	288	286	*1956-1951*	234
1960	239	258	272	277	283		*1957-1952*	248
1951-1960	**239**	**259**	**272**	**278**	**284**	**286**		**255,1**

ADDITIONAL NOTES TO SUBCHAPTER 7

Belgium flooded by herring: local historical sources on the miraculous catches of fish in Belgian waters during the Second World War (1940-1945)

Much has been written in local Belgian historical sources about the so-called 'miraculous' catch of sea food during the Second World War (WWII, 1940-1945) by the Belgian fleet. During our search effort for historical fisheries statistics we uncovered official statistical tables that give account of monthly landings by species and by fishing area for the WWII period. Although a well-coordinated and centralised statistical national and international (to ICES) reporting on sea fisheries was in place in Belgium by 1929 (Lescrauwaet et al. 2010) quantitative datasets on the total fishery production collected locally during the WWII period of restricted fishing are scarce and the data presented here were previously unknown in national and international reporting. These data cover particular interest because for most countries around the North Sea (UK, NL) no detailed quantitative data are available for this period (Baerends 1947), because current stock assessments on North Sea herring go back to 1947, and therefore information on the period before this reference year are very useful for herring biologists. The information on landings, LPUE and age structure is analysed in the publication included in chapter 7. A number of local historical sources were consulted that are of relevance for the Belgian context, and are not included in the article, since they are more of a local relevance. These references are included in the present short introduction note.

Fisheries in Belgium at the outbreak of the WWII

The WWII started in Belgium on May 10, 1940 and ended on October 1, 1944. Until the outbreak of the First World War (WWI, 1914-1918), annual landings from the Belgian fleet originated mainly from the 'North Sea' and fluctuated between 10,000 and 15,000 t (Lescrauwaet et al., unpublished data HiFiDatabase). After the WWI, landings from the North Sea quickly increased again to pre-war levels (12,000-15,000 t). From 1928 onwards the importance of the nearby fishing areas (North Sea south) gradually declined and Iceland and the 'western waters' (West-Scotland, South-and West-Ireland, the Bristol Channel) gained importance (see Chapter 4). The diversification of fishing grounds is especially evident from these statistics between 1934 and 1939, at the outbreak of the WWII (1940). The Belgian fleet counted 460 motor trawlers - 201 had engines less than 80 PK or Dutch Horse Power- and 14 steam trawlers (Lescrauwaet et al. 2012). At that time, approximately 40,000 t were landed annually mainly in Oostende which was the most important fishing port and fish auction of the 4 operational fishing ports at the Belgian coast.

An overview of historical references to (semi) quantitative data on landings during the Second World War

A first category of screened sources consists of local newspapers and magazines that published about aspects of daily life (Oostende newspaper, Visserijblad, Dagblad van Noord-Brabant en Zeeland) or specifically on the commercialisation of fish products (Vischhandel) before, during and after the WWII. Although these sources tend to be fragmentary and selective in reporting quantitative data on fisheries or fish landings, most of them make reference to the particularly high catches of herring. The 'Vischhandel' (1942, 1943) published quantitative data based on the official government statistics, on each of the herring fisheries seasons that Flemish fishermen achieved during the WWII from the northern French coastal ports and from the Belgian ports. Interestingly the July 1943 publication (Vischhandel Nr. 7, 1943) which reports on the 'record' herring landings from the previous season (winter 1942-1943) also raises the question as to why there is no (other) fish in the fishing areas.

Recent publications interested in pricing mechanisms of food items during wartimes mentioned that the processing and distribution systems in Belgium were not able to cope with the unexpectedly high landings of herring in 1942-1943 (Henau 1983, Gobyn 1984, Balthazar et al. 1984) and that the sudden increases caused herring prices on the black market to drop even below those on the formal market (Beke 1984). Other recent authors give account of unusually high herring catches in Belgium and the North of France (Jansoone 2010, De Mulder 1984, Henau 1983) but few contain quantitative data on landings. Similar accounts are available for the ports of Duinkerke and Grevelingen in the north of France. In spite of restrictions on fishing effort during wartimes, Grevelingen increased landings of herring by 1028% in 1942 compared to 1938 (Odonne 1987). However, for the WWII period no data were published so far that give account of all species landings, by species, by month, by fishing area and by port of landing, as according to the reporting format applied before and after the WWII.

The quantitative data of fishing productivity during the WWII

According to De Mulder (1983) no fishing took place in Belgium from the end of 1939 until in the course of 1941 a limited part of the fleet was allowed to fish, under close surveillance by the occupying forces. In practice the 'coastal waters' was the only fishing area to which access for fishing was granted after 1940 and before 1945. This area is not part of the geographical ICES reporting/fishing areas. The data collected from the national statistical tables (uncovered in the present exercise) show that in 1939 the total landings of 10,878 t from coastal waters consisted mainly of sprat (Sprattus sprattus) and brown shrimp (Crangon crangon). Overall, during the war period for which monthly landings are available (1941-1944), 82% of the landings consisted of herring, 7% of plaice (Pleuronectes platessa), 2% of sprat and 2% of brown shrimp. In terms of economic benefits, the spent herring catches during WWII (1942-1945) represented an annual average income of 4.9 million euro direct sale value, compared to 0.2 million euro before WWII (1936-1939). The increase by four, in the average price of herring from 0.03 euro/kg to 0.13 euro/kg – mostly effect of the war economy- explains part of this 24-fold increase in overall value of landings. Inflation indexes to calculate and compare prices in current values, are not available for the WWII period.

Compared to North Sea fishing nations with large herring fisheries, the Belgian herring fisheries were not significant. The Dutch and UK fleet maintained relatively high catch levels of herring during the first part of WWI (approximately 150,000t in 1915 and 1916) and joint Dutch and UK annual herring catches amounted up to 300,000 t in e.g. 1929 and 1937 (ICES Fishstat) while in contrast, their catches dropped to near zero during WWII, at times when Belgian landings of spent herring from the coastal waters experienced a 5-fold increase.

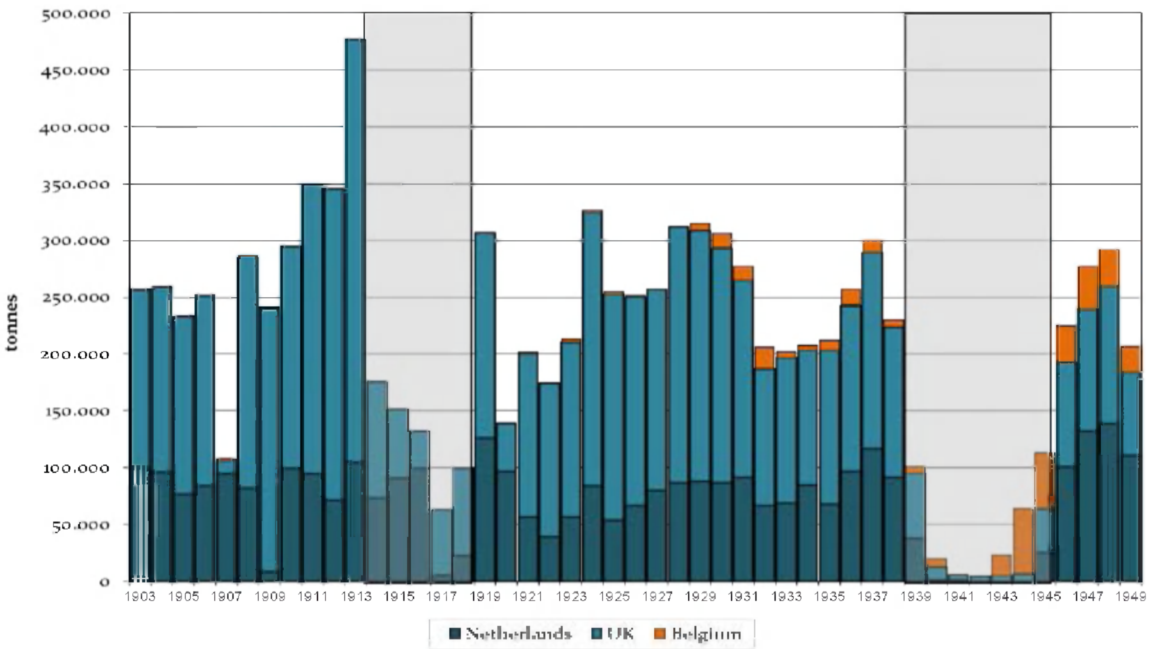
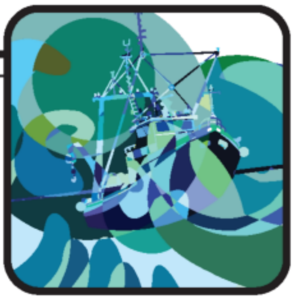


Figure 7.6.: A comparison of landings of herring from the UK, Netherlands and Belgium. Before, during and after WWI and WWII (grey bars).

The scientific reports of Gilis (1946, 1947) contain detailed accounts of the seasonal (Nov-March) landings and indices of catch per effort for the 'spent herring' fisheries. There is a good correspondence between the few locally published numerical data (Vischhandel) and the scientific reports (Gilis 1946, 1947) related to the herring catches.

The smaller vessels that stayed in Belgian ports to fish the Belgian coastal waters during the WWII were to witness what would turn out to be the most productive herring seasons documented in our country since the 15th century. In spite of the severe damage that the coastal fishing fleet suffered during the WWII, this success triggered an expansion from 217 vessels at the end of 1941 to 323 at the beginning of 1944 (Poppe 1977) and the onset of the large expansion and technological increase in the Belgian fleet in the years to follow.



CHAPTER 8: 'In Cod we trust': trends in gadoid fisheries in Iceland 1929-1996

CHAPTER 8. 'IN COD WE TRUST': TRENDS IN COD AND GADOID FISHERIES IN ICELAND 1929-1996

Publication submitted:
Lescrauwaet, A.-K., Vincx, M., Vanaverbeke, J. and Mees, J.
In Cod we trust: Trends in Cod and gadoid Fisheries in Iceland 1929-1996. submitted manuscript currently under review, Canadian Journal of Fisheries and Aquatic Sciences.

ABSTRACT

Iceland's fishing resources have played a major role in the economy of fishing nations around the North Sea in the 20th century and before. While the decline in total landings from Icelandic waters started after Iceland expanded its EEZ in 1958, the fishing effort of the Belgian fleet continued to increase until a peak was reached in 1963. Historical data on Belgian commercial fisheries landings and fishing effort include information on vessel class and fishing rectangle. The results document the Belgian gadoid fisheries in Icelandic waters from 1929-1995 and argue that the decline in the Iceland cod stock was visible at different levels before the foreign fleets were excluded from Icelands' expanded EEZ in 1975; the decrease in the proportional importance of cod in the overall landings, the 75% decrease in the LPUE (1946-1983), the decline in the proportion of 'large' fishes, and finally the decline or shift in the definition of a 'large' specimen.

Keywords: LPUE; Historical reference; Iceland; Belgium; Atlantic cod; large fish

8.1 Introduction

Iceland and its historical importance as fishing ground

The rich waters around Iceland have sustained Icelandic and foreign nations' fisheries for gadoids (e.g. haddock, cod, saithe, hake, and ling) for many centuries (Palmadottir 1989, Jones 2000, Valtysson 2001). The Icelandic cod is one of the most important economic species in Icelandic waters and is distributed along depth gradients of 50-200m. Spawning takes place in late winter mainly off the southwestern coast, although smaller spawning components were observed in other areas (ICES Advice 2012b). At the end of World War II (1939-1945), the English, Scottish, French and German fishers returned to the rich Iceland fishing areas.

In 1950 Iceland extended the boundary of its territorial waters from 3 nautical miles (nm) to 4 nm from the coastline in the northern territories and prohibited all trawling, *Danish seine* (including Icelandic) and foreign herring fisheries within this Exclusive Economic Zone EEZ. In 1952 the 4 nm was extended to the entire area of Iceland (Valtysson 2001). There was no objection to this regulation on behalf of the foreign fleet until in 1958 the EEZ was extended from 4 nm to 12 nm because this second extension restricted their access to the major fishing grounds. The British-Icelandic conflict arising from this new regulation lasted until 1961 and is known as the first modern 'cod war' (Valtysson 2001). In 1972 -in part fuelled by the concern over the state of the main fish stocks- the boundaries of the EEZ were extended, again, to 50 nm and finally to 200 nm in 1975 (the last modern cod war). The British fleet left the Icelandic waters in 1976, followed by the West German fleet in 1977. However, Belgian, Faroese and Norwegian boats were allowed to continue fishing in the EEZ (ICES Fishstat). Similar to the cod stocks in the northwest Atlantic which showed first signs of overfishing in the late 1950s and collapsed in the 1970s (Kenneth et al. 2005), the spawning stock biomass SSB of Icelandic cod reached a historic low in the 1970s (Figure 8.1., ICES Advice 2012b).

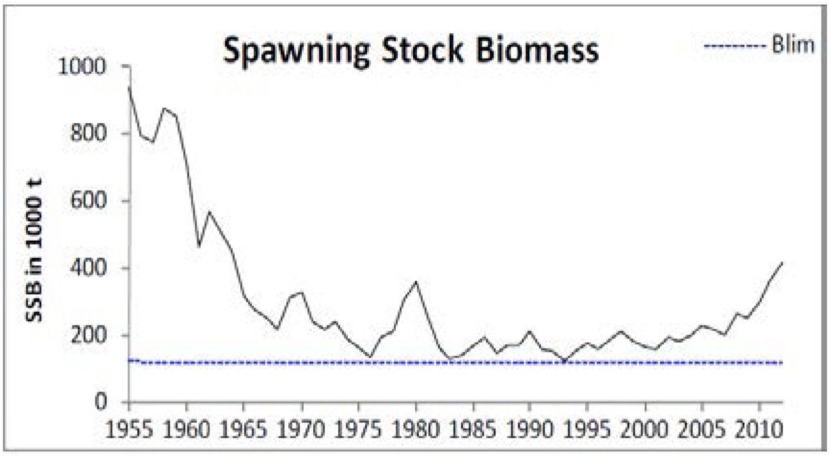


Figure 8.1.: Cod in Division Va (Icelandic cod). Spawning Stock Biomass SSB (weights in thousand tonnes).

In spite of the great economic importance of cod and other gadoid species for Iceland and the foreign commercial fleets fishing in Icelandic waters in the first half of the 20th century, little information is available on the composition of cod and other gadoid landings, on the fishing effort, vessel type and spatial dynamics of the fleet. Estimates of biomass, recruitment, landings and fishing mortality of Icelandic cod are available from 1955 onwards (for other gadoids from the 1970s), but earlier information is scarce or unavailable. The SSB of Icelandic cod is now increasing and at its highest value since decades, while fishing mortality is currently at a historical low and believed to be below safe limits (F_{lim}). Historical information on commercial fishing activities can provide valuable information to reconstruct the evolution for the earlier decades and serve as a reference for other species' restoration and management plans.

DATA AND INFORMATION ON ICELAND (COD) FISHERIES DURING THE 20TH CENTURY

In spite of its historic and economic importance, the data on Icelandic fishing in the early 20th century is scarce. The Iceland Marine Research Institute (MRI) collected scientific survey data on cod and other species, on a continuous basis since 1928. In 1995 a major effort was initiated to recover this historical data and make it available digitally. British survey vessels conducted research in Icelandic waters in the 1950s and 1960s (Goodwin et al. 2001). The Danish public record office holds ca. 20 logbooks from scientific surveys from 1906 to 1920 with information on location and catches of species such as cod and halibut (ICES 2008).
Historical landings of commercial fishing from the Icelandic waters are available from 1903-1949 in the ICES *Bulletins Statistiques*, although incomplete (not all species not all ports/countries) and from 1950 available in a digital format (ICES Fishstat). Data on the Icelandic fisheries (effort, catch, landings, and catch by fleet, season, month and port) are available from the MRI in printed format from 1957 although reporting format is inconsistent and prior to the WWII there is no detailed data on fishing activity by the Icelandic fleet (ICES 2008).
Engelhard (2005) inventoried a set of archived maps from the series 'British Sea Fisheries Statistical charts' which also refer to catch and effort in Icelandic waters by the English fleet and by statistical squares. This series of maps gives unique fine-scale information on geographical distribution of the foreign fishers in Icelandic waters during the first years of the 20th century (ICES 2008).

From ICES stock assessments, landings and fishing mortality, total and spawning stock biomass and recruitment are available for the Icelandic cod stock from 1955 onwards, for other species (e.g. haddock, saithe) time series go back as far as 1979 (ICES Advice 2012b). The importance of historical information in current management issues has been evidenced by, e.g., the documented large-scale migration of cod originating from West and East Greenland stocks into Icelandic waters (Harden Jones 1968, Schopka 1993) affecting the stock abundance at Iceland. In the past, low weights-at-age of cod have been related to a low biomass of capelin linked to hydrographical changes in Icelandic waters, and historical time-series of landings of haddock supported the hypothesis of the positive effect of increased water temperatures on the stock biomass of haddock in Icelandic waters (ICES 2012b).
After Iceland extended its EEZ to 50 nm (1972) and later to 200 nm (1975), respectively 19 and 12 Belgian vessels were permitted to continue fishing under the condition of a phase-out. In 1995, the last Belgian trawler stopped fishing in Iceland. An effort was conducted to recover historical fisheries data from the Belgian fisheries (HiFiData) including detailed statistics collected from its fleet operating in Icelandic waters between 1929 and 1995 (Lescrauwaet et al. 2010a). The data presented here add detailed spatio-temporal information on trends in fisheries by the foreign fleet, for a period for which limited information is available.

8.2. METHODS AND MATERIALS

Data on fishing effort and landings by Belgian commercial fisheries in Icelandic waters (fishing area Va) were recorded between 1946 and 1983, while general data on landings are available from 1929 (incomplete data from 1905). The data related to fishing effort include, per year, per month, per type of fisheries and per vessel class: the number of vessels, the number of fishing trips, number of days at sea, number of days fishing, landings (tonnes, t), value of landings (Belgian francs BEF), hours at sea, hours spent fishing, HP (Horsepower or *paardenkracht PK*) *hours at sea, HP*hours fishing and since 1972 also Gross tonnage (GT)*hours at sea and GT*hours fishing. From 1956 until 1983 the monthly reported data on landings and LPUE are spatially explicit by rectangles (Figure 8.2.). These rectangles are spatial aggregations of the ICES statistical rectangles that are currently in use. The reporting formats cover 19 rectangles numbered 1201-1219, although data were only reported for rectangles 1201-1204, 1206, 1210-2014 and 2016-1219 (no data for numbers 1205, 1207-1209 and 1215). Additionally these monthly data were reported by vessel class and by rectangle between 1961 and 1963. Fishing effort (PK * hours fishing or PKHF) after the 1970s was mainly concentrated in rectangles 1212, 1216, 1214 and 1211 in the southern and western part of the island (Figure 8.2.). Before the 1970s also 1202 to the north and 1204 to the east were important rectangles. Based on these historical data for Belgium, estimates of LPUE by rectangle were calculated and monthly composition of the landings was obtained.

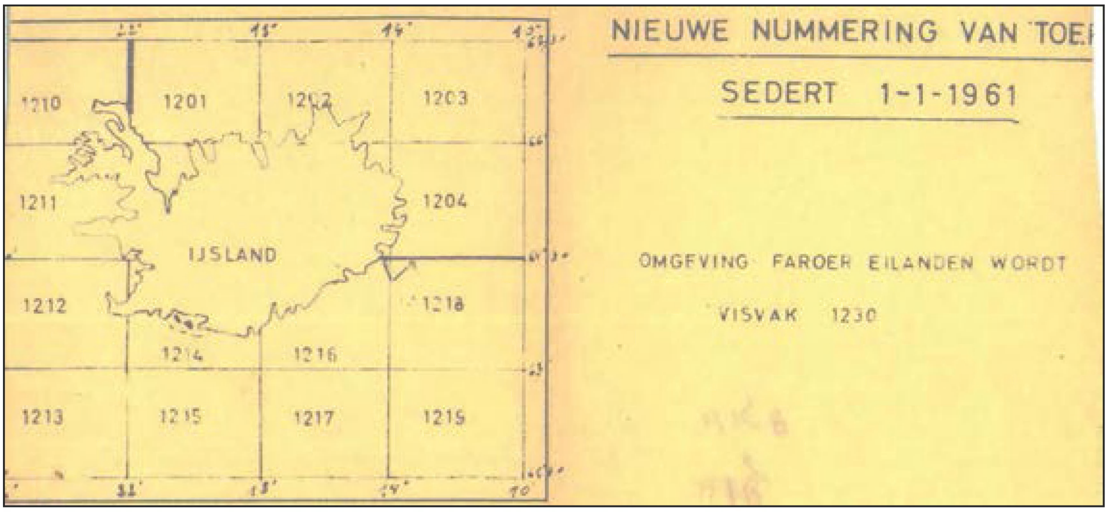


Figure 8.2.: Fishing area Iceland (Va) and its rectangles 1201-1219. To the right of the map, says: *'New numbering operational as from 1/1/1961'* and *'Area of Faroer Islands becomes rectangle number 1230'*. Map recovered from the archives of the Fisheries Service- Flemish Government.

For the most important commercial species between 1929 and 1981 (cod, haddock, hake, brill, plaice), monthly landings were also reported by size class (small, medium, large) or size categories (1 to 5). The data on size classes are available from 1929-1933 on an annual basis and from 1947 to 1981 on a monthly basis. The boundaries of classes are species-specific, and these boundaries change as time progresses (Table 8.1.). Metadata on these class boundaries are scarce, but available for a number of anchor points 1909, 1947 and 1972 (Table 8.1.). For cod, size class boundaries are based on weight (kg): whereas 'large' specimens were classified as such if >8kg in 1909, a cod in 1947 would be classified as 'large' if weighing >5kg, and in 1972 this boundary was lowered to >4kg, with an additional class for 'largest' cod >7kg. Similarly, 'medium' sized and 'small' cod have had decreasing class boundaries. In terms of length classes, a cod was classified as 'large' if >95cm in 1909, and if >84cm in 1954.

Table 8.1.: Weight class boundaries for cod landings based on weight (kg); anchor points 1909, 1949-1959 and 1970. Based on metadata collected from different data sources by VLIZ

Year	Weight Class											
Cod 1909	Large									large		
	Medium						medium					
	Small					Small						
Cod 1947	Large						large					
	Medium				medium							
	Small			small								
Cod 1972	Size 1								largest			
	Size 2					Large						
	Size 3			medium								
	Size 4		small									
	Size 5	smallest										
weight class (kg)		0-<1kg	1- <2	2- <3	3- <4	4- <5	5- <6	6- <7	7- <8	8- <9	9-<10	+10kg

Similarly decreasing class boundaries were described for haddock (*Melanogrammus aeglefinus*). In 1947, 'large' specimens were >2kg, medium between 0.75- <2kg and small under 0.75kg. In 1970 'largest' is >1kg, large is 0.4-1kg, medium 0.25 to <0.4 kg and small <0.25kg. The data for cod and haddock were included in the present analysis because of their importance in the Iceland landings. The data for the other species are available for further analysis. The data were digitized, quality controlled, standardized and integrated. For more information regarding the QC and integration the authors refer to previous work (Lescrauwaet et al. 2010b).

Data were reported by vessel class between 1959-1983, with vessel classes 4-7 reported for Iceland fisheries. Vessel class 4 comprised medium-sized trawlers with motor engine power between 240 and 349 Dutch Horse power HP. Vessel classes 5 and 6 are large-sized trawlers with engine power between 350-499 HP and >500HP respectively. Vessel class 7, which disappeared from the Iceland fisheries reporting after 1963, refers to steam-engine powered vessels >439 and up to 800 indicative HP. The classes 4-7 are respectively referred to as 'medium' (4), 'large' (5), 'large >500HP' (6) and 'steam' (7) trawlers. The HP were not converted to kilowatt (kW) because it is uncertain whether the reported HP refer to Dutch horsepower (736 Watt) or - though unlikely – the English HP (745,7 Watt).

To test whether the LPUE was mainly determined by factors other than changes in the fish stocks, the monthly data for vessel class and for fishing rectangles were compared over the period 1962 and 1963, when all vessel classes contributed to effort and landings. A univariate PERMANOVA test Type III using a 2-factor model design (factors: 'fishing rectangle' (re), and 'vessel class' (ty) with Euclidean distance to calculate resemblance, was conducted on the untreated data, in PERMANOVA+ for PRIMER. The main factor test was followed by an a posteriori pair-wise comparison for 'rectangles' for each 'vessel class' with a Monte Carlo (MC) permutation of the data.

8.3. Results

Trends in landings of (cod) fisheries in Iceland waters, Belgium sea fisheries (1929-today)

Fisheries data collected from 1929 until today illustrate the sharp increase of the total landings by Belgian vessels after World War II (Lescrauwaet et al. 2010a). This sharp increase was to a large extent explained by the fisheries in Iceland which increased steeply after WWII to reach a maximum of 23,260 t in 1955 (Figure 8.3.).

The Iceland Sea has provided approximately 502,800 t of reported landings of fish products (dead weight) for the Belgian fisheries industry (Figure 8.3.) and was third in importance as fishing area for the Belgian fisheries throughout the 20th century. The Iceland Sea has been predominantly a provider of gadoids. Cod (*Gadus morhua*, 29%) and saithe (*Pollachius virens,* 17%) were important species throughout this period. The landings of cod decreased after the last peak in landings in 1963. While haddock (*Melanogrammus aeglefinus*, 16%) was important until 1963, redfish (*Sebastes* sp., 15%) became an important component of the landings from 1964 onwards. Together these 4 species sum 77% of all landings from this area over the entire reported period. Pelagic species (mainly herring in the early 1980's) and shellfish are minor components of the landings. The Iceland waters were also fished for Norway lobster (*Nephrops norvegicus*) by Belgian vessels.

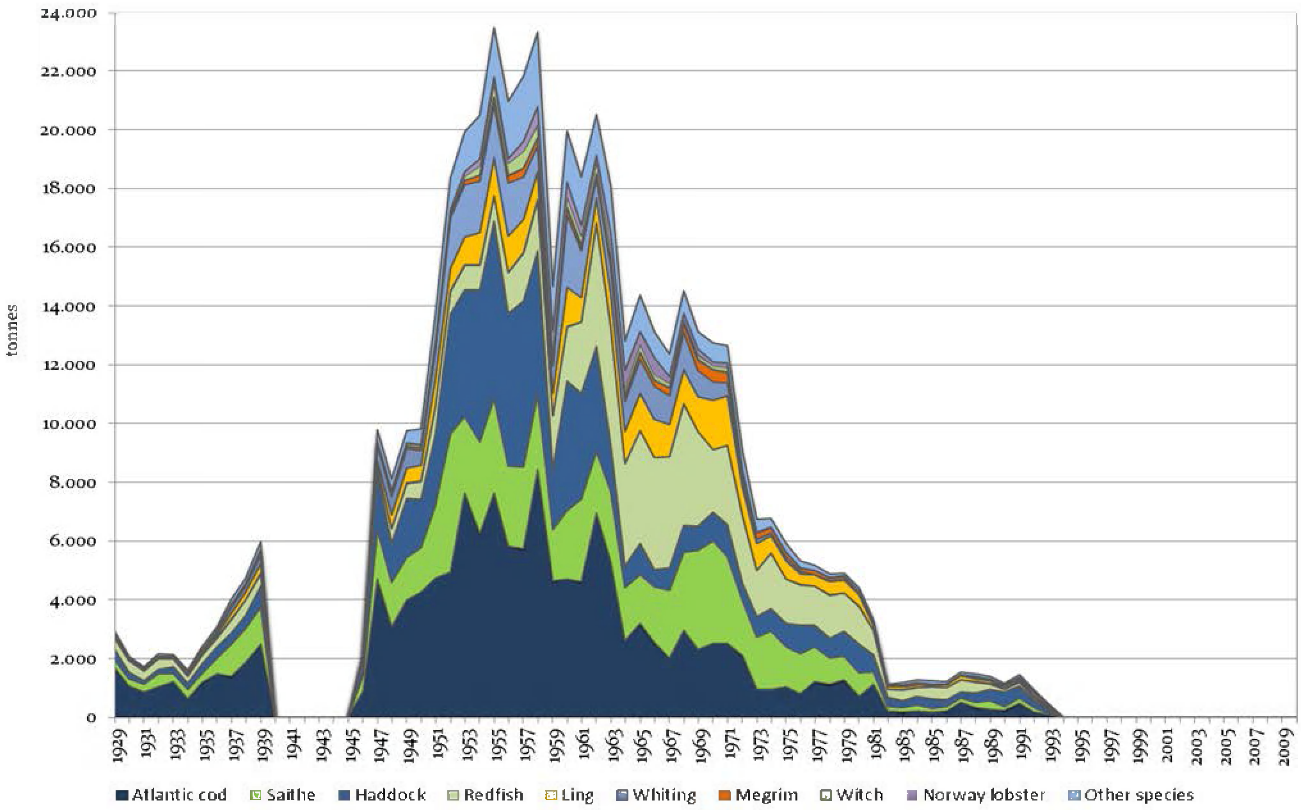


Figure 8.3.: Landings (t) by Belgian sea fisheries from Icelandic waters in 1929-2010; landings by species for the 9 most important species, remaining species were aggregated as 'other species' for visualization purposes.

Trends in fishing effort and LPUE in Icelandic waters for Belgian fisheries (1946 - 1983)

Data on the landings and the effort of commercial otter trawl fisheries (fishery type I) by vessel class of Belgium in Icelandic waters were available from 1946 to 1983 and reported by rectangle from 1959. The fishing effort (PK*hours fishing, PKHF) and landings per unit of effort LPUE (kg per PKHF) were reconstructed for the period 1946 to 1983 for trawl fisheries (all vessel classes aggregated) (Figure 8.4.). Fishing effort ranged between 5 and 45 million PKHF, with a peak in the early 1960s at a time when total landings from the Icelandic waters were already in decline (see also Figure 8.3.). It must be noted however that fishing effort may have reached up to 130 million PKFH per year in the first half of the 1950s (Chapter 4, Figure 4.5. Lower panel).

The total fishing effort increased from approximately 11 million PKHF in the period 1947-1950; from 1956 it further increased from 30 million to a maximum of 45 million PKHF in 1963. The latter is entirely explained by the increase in the fishing effort of large (>500HP) trawlers. At that time, the Belgian fleet conducted 820 fishing trips/year to Iceland summing a total of 16,000 days at sea of which 8,500 fishing. Total fishing effort then gradually decreased from 45 to 5 million PKFH. In particular the decrease after 1971 corresponds to the 'phase-out' for Belgian vessels allowed fishing within Iceland's EEZ.

LPUE values decreased from 0.95 kg per PKHF in 1946 to 0.24kg per PKHF in 1983. A few temporary peaks in landings of cod, haddock and redfish (1965 and 1968) combined with a sudden decline in effort (PKHF) in these years, explain the temporary increase in LPUE in the late 1960s (Figure 8.4.). The overall decrease in LPUE between 1953 and 1963 is explained by the decrease in obtained landings, since overall effort is still on the rise in that period.

The reconstruction suggests that LPUE - a measure used to indicate relative efficiency of fisheries and often used as a proxy for relative abundance of fish and the state of fish stocks - has decreased by 75% over a period of 4 decades (1946-1983). The polynomial trend regression (4 orders – 'Poly LPUE', Fig. 8.4.) underlines the overall declining trend in LPUE.

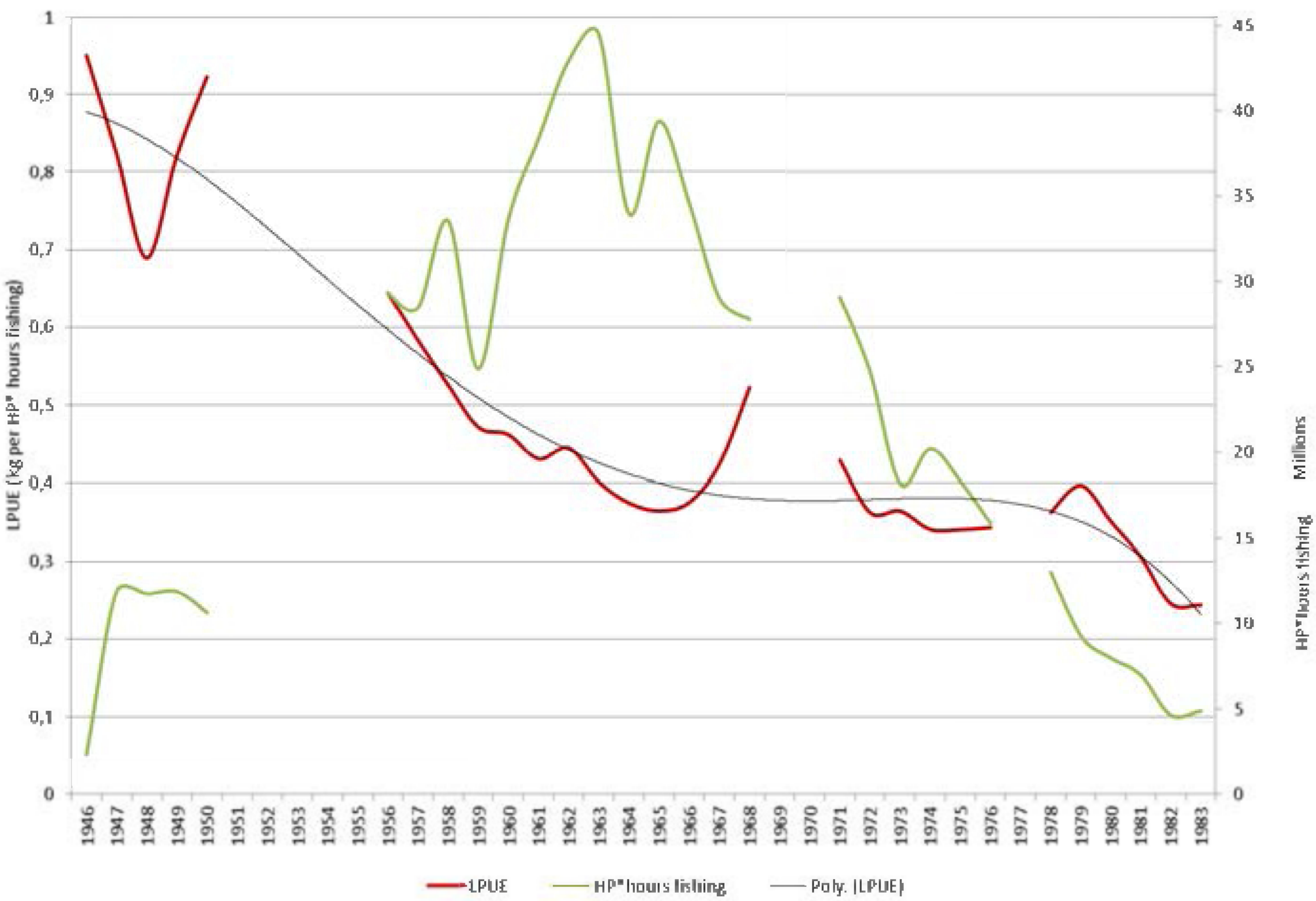


Figure 8.4.: Reconstructed effort (PK*hours fishing, PKHF) and cod landings per unit of effort LPUE (kg per PKHF) and the polynomial regression LPUE (Poly LPUE) from 1946 to 1983 aggregated for all rectangles 1201-1219 and all trawler classes, Belgian fisheries in Iceland.

However, the index of LPUE must be considered with care if interpreted as a measure of relative abundance of fish stocks, and a number of conditions must be met: the index must be used in the context of a particular fishery, fishing area, vessel class and fishing gear. Fishing potential must always be used to a maximum, catchability is to remain constant or increasing as a consequence of increasing technological improvements, the proportion of the catch reported as landings should be constant and market prices should not be the main drivers for decisions leading to decreases in the total reporting. Also, it is important to take into account technological improvements that affect fishing efficiency over time. To test whether these assumptions were met in the LPUE dataset, a separate analysis was conducted for vessel class, fishing rectangle, and species composition.

VESSEL CLASS

Over time, vessel classes with a lower LPUE could have become proportionally more important, therefore explaining the observed changes in LPUE. We therefore statistically compared LPUE values between vessel classes. The monthly data by vessel class (available for 1960-1967) were compared over the period 1962 and 1963, when all vessel classes contributed to effort and landings. PERMANOVA test showed that LPUE of medium-sized and steam-trawlers are similar (p>0.05) and have a significantly higher LPUE than those of the large trawlers (class 5 and 6).

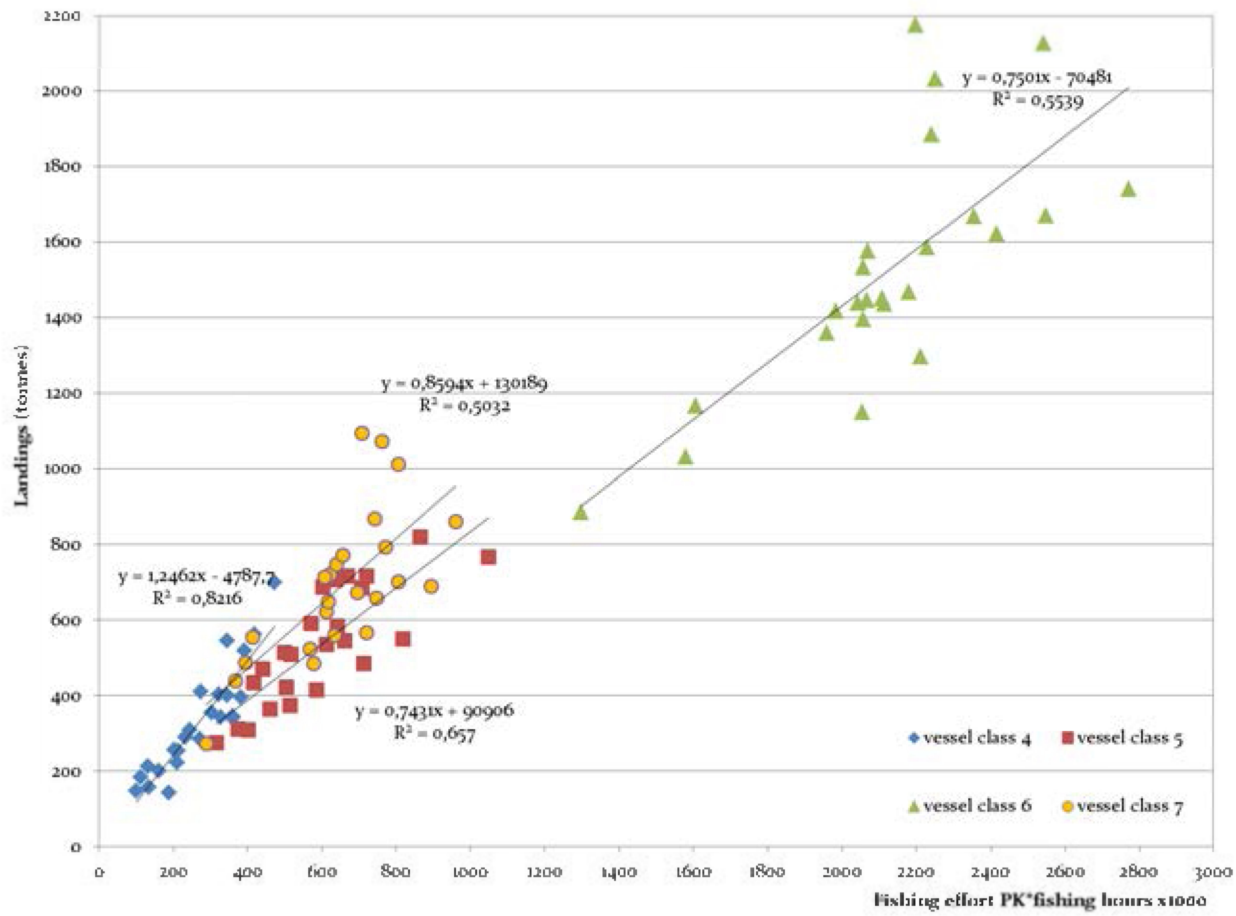


Figure 8.5.: Reconstructed effort (PK*hours fishing, PKHF, x-axis) and landings (kg, y-axis) for 1962-1963, by vessel class , aggregated for all rectangles 1201-1219, Belgian fisheries in Iceland.

Steam-trawlers represent on average 15% of all fishing effort in 1960-1963 however, this class stopped participating after the peak in effort in 1963. Medium- and particularly the large trawlers (class 5) also gradually phase-out from 30% to less than 10%. Large (>500HP) trawlers are the dominant class throughout the period 1960-1983. However, even a simulation of a transition from a 100% fishing effort by vessel class with the highest LPUE to a 100% fishing effort by a vessel class with lowest LPUE could not explain the observed decline in LPUE.

As a conclusion, the data do not seem to support the hypothesis that observed changes in LPUE were due to change in proportional importance of vessel classes.

Although there is no data on vessel class for the period 1946-1960 in Iceland fisheries, the detailed reconstruction of the Belgian fleet dynamics (Lescrauwaet et al. 2012) showed that the maximum in steam-powered vessels occurred in the 1920s. Between 1947 and 1950 less than 20 steam-powered vessels remained, and between 1950 and 1960 this number decreased to around 5-6 steam trawlers. The data on average GT however show that it were particularly the larger steam-trawlers that remained operational, and it were the smaller steam-trawlers that were taken out of the fleet.

FISHING RECTANGLES

Monthly data on fishing effort (PKHF) by fishing rectangle is available from 1956-1983. Fishing effort was also reported by vessel class and by rectangle between 1961 and 1963. After the 1970s, fishing effort was mainly concentrated in rectangles 1212, 1216, 1214 and 1211 in the southern and western part of the island (Figure 8.2.). Before the 1970s also 1202 to the north and 1204 to the east were important rectangles. Interestingly the rectangles 1213-1215-1217-1219 that are located at further distance from the southern coastline of Iceland have not been of particular importance throughout the time-series, also not after the EEZ of 50nm (1972) and 200nm (1975) were declared by Iceland. This suggests that the movements of the Belgian fleet were not significantly affected by the new Icelandic EEZ regulations, in terms of access of foreign vessels to Icelandic fishing areas.

The overall results of the PERMANOVA test confirm that the observed differences in LPUE between fishing rectangles are co-determined by 'vessel class'. The main factor test was followed by an a posteriori pair-wise comparison for 'rectangles' for each 'vessel class' with a Monte Carlo (MC) permutation. The results of this analysis suggest that significant differences may exist in LPUE between fishing rectangles, for the medium-sized and steam-trawlers. However, for the medium-sized and large (>500HP) trawlers there are no significant differences in LPUE between fishing rectangles. The large trawlers (>500HP) represent the dominant vessel class in terms of number, in fishing effort and in landings - Therefore, the analysis does not support the hypothesis that a change in fishing rectangles explains for the decline observed in LPUE observed (Figure 8.4.). The data by rectangle presented here provide valuable information to compare fishing activities and LPUE between rectangles. However, the data can not distinguish for the effects of environmental factors (e.g. depth, currents, temperature, sediment type).that may occur within rectangles and influence LPUE, as a consequence of spatial shifts in the core area of fishing activities of the fleet within rectangles.

FISHING GEAR, SPECIES COMPOSITION

The minimum allowed mesh size for groundfish and midwater trawls in Iceland was increased from 110 mm in 1954, to 120 mm in 1963, 135 mm in 1976 and finally to 155 mm in 1977, the largest minimum mesh size in the North Atlantic (Gilis 1957, Halliday and Pinhorn 1996). Trawling with 135 mm is however still allowed in some areas in the south, mainly for redfish (ICES 2012). The increase in mesh size - under unchanged conditions in the population structure – is expected to increase or at least not to decrease the average size/weight of specimens in catch.

Although selectivity data are not available for the period, area and gear under study, it must be noted that Belgian fisheries in Iceland have targeted cod, whereas the other species were regarded as bycatch. This is sustained by the significantly higher market value of cod compared to the other species landed (HiFiDatabase, VLIZ 2009). Changes in the species composition of the landings may indicate a change in fishing gear, fishing technique, targeted species or environmental changes.

From the monthly data on landings by species, there is a clear shift with increased catches of redfish during the mid 1960s, while the landings of cod and haddock decreased. Whereas the pattern in landings of redfish followed that of cod in e.g. 1961-1962 (high in summer with peaks in June-August, and low in winter), the landings in 1966-1967 in contrast show clear peaks in redfish catches in March-April and September-October while the much decreased landings of cod remain highest in June-August. This suggests that a targeted and seasonal fishery for redfish occurred from the second half of the sixties. Although it remains unclear whether this shift is due to changes in seasonal patterns in abundance of cod in Iceland, or whether other (environmental) variables influenced this shift, it probably did not correspond to a market-driven fishing strategy as fishermen received on average 3 times higher value for Iceland cod than for Iceland redfish in the Belgian market in the 1960s (HiFiDatabase, VLIZ 2009).

TRENDS IN PROPORTION OF LARGE SPECIMENS IN LANDINGS OF COD AND HADDOCK IN ICELAND WATERS (1947-1971)

Data on landings by weight classes for cod and haddock from Belgian commercial fisheries in Icelandic waters were collected for 1929-1933, 1947-1971 and 1972-1981. Different boundaries were applied to the categories 'small', 'medium' and 'large' over these 3 periods. After 1972, a system of 5 size classes was implemented for cod. The 'downsizing' of the class boundaries (Fig. 8.6. and text boxes, Table 8.1.) is an example of what Pauly (1995) identified as 'shifting baselines'. Although the weight classes are too broad to detect trends over shorter periods, the breaks generated in the time-series when class boundaries change (i.e. 1947 and 1972) allow drawing some conclusions related to the second period 1947-1971, and in particular related to the 'large' class. Firstly, what was considered a 'medium' weight cod (5kg-8kg) before 1947 was classified as 'large' (>5kg) after 1947. Although in 1947 approximately 83% of the cod landings were classified as 'large', we could presume that at the beginning of this period 1947-1971 approximately 30% of the this large cod was actually >8kg. Over the second period, the proportion of cod classified as 'large' (>5kg) decreased from 85% in 1947 to 35% in 1971. However, from the class boundaries in 1972, we may conclude that by 1971 hardly any cod was >7kg. The observed trends for the period 1929-1981 (Fig. 8.6.) are based on commercial catches and confirm the SSB estimations based on scientific surveys available from 1955 (Fig. 8.1.)..

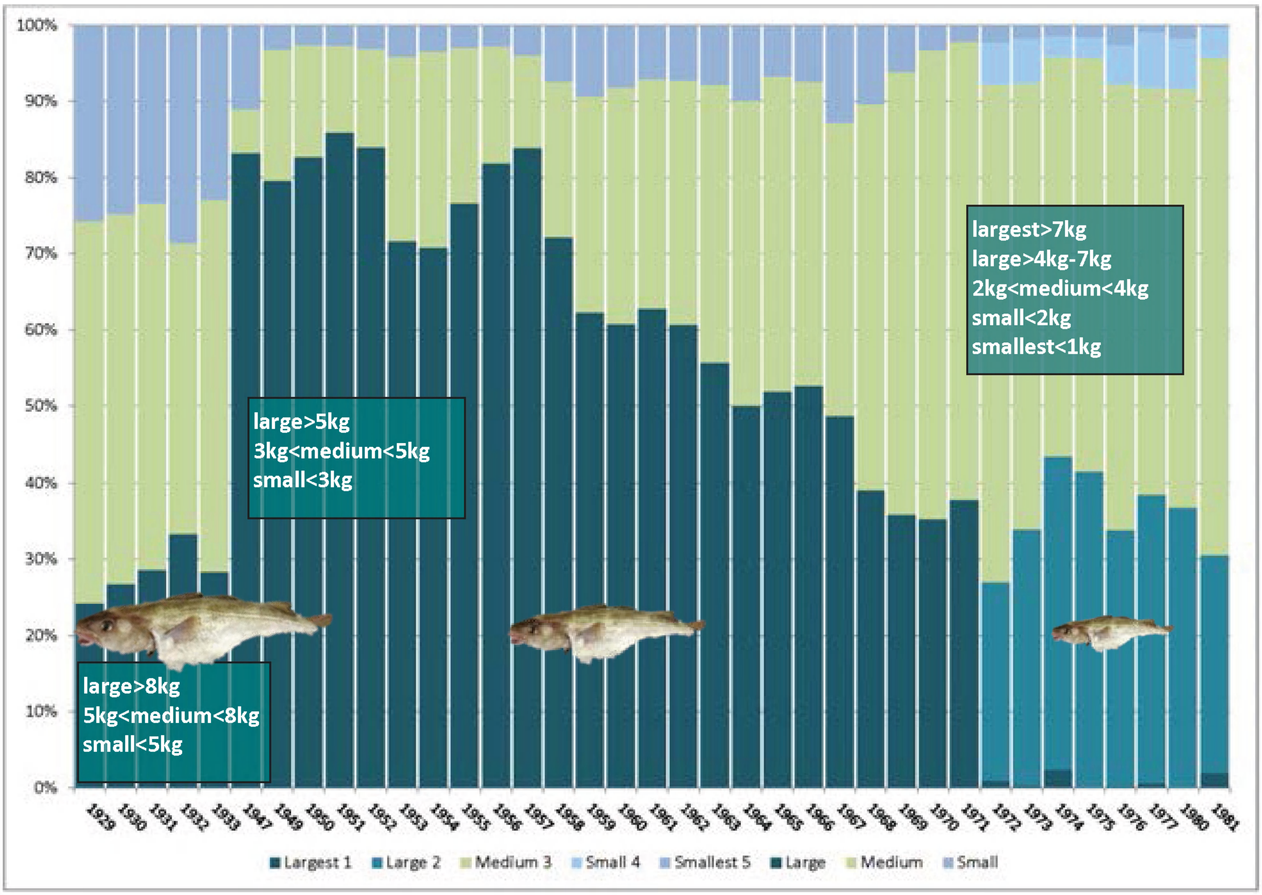


Figure 8.6.: Proportion of cod landings by different weight classes, Belgian commercial fisheries, Iceland 1929-1981.The changes in weight class boundaries over time are documented in the text boxes in the figure.

The data in Figure 8.7. show the monthly/seasonal fluctuations for cod (a) and for haddock (b) for the period 1947-1971. Monthly data also exist for the first and third period, but were not included in Figure 8.7. The decrease in the proportion of larger specimens was gradual for cod, and set in particularly after 1957. The proportion of large haddock (>2kg) decreased from 53% to 13%, with a temporary increase in 1958-1961.

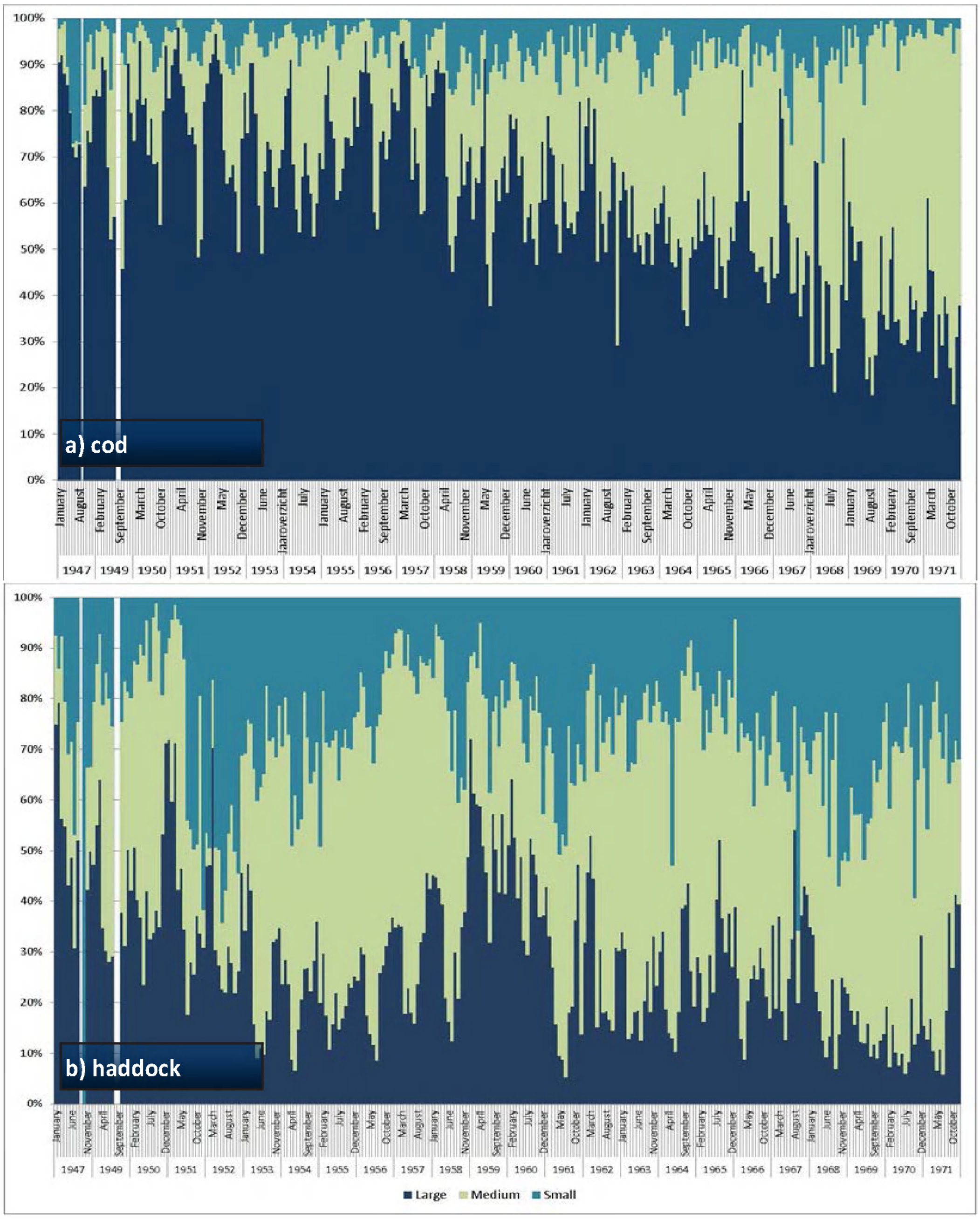


Figure 8.7.: Proportion of cod (a) and haddock (b) landings by different weight classes, Belgian commercial fisheries, Iceland 1947-1971.

8.4. Discussion and Conclusions

Cod, and Iceland's fishing resources, have played a major economic role for Belgium and other fishing nations around the North Sea in the 20th century (Palmadottir 1989, Jones 2000, Robinson 2000, Valtysson 2001) . The fisheries in Icelandic waters represented approximately 40% all landings by the Belgian commercial fisheries in the late 1950s, and over the entire reporting period 77% of these landings were composed of only 4 species (cod, haddock, saithe and redfish). While the total landings from Icelandic waters clearly started to decline from 1958, the fishing effort continued to increase until a peak of 45 million PKHF was reached in 1963. It must be noted however that effort-data were not available for the first half of the 1950s when effort in Icelandic waters was probably at a historic high. The reconstructed time series of LPUE in Icelandic waters by Belgian commercial otter trawlers refers to a homogeneous situation in terms of fisheries type (demersal, bottom trawling), fishing gear (otter trawl) and main target species (cod, gadoids). The data suggest that a decline of 75% occurred in LPUE between 1946 (0.95 kg/PKHF) and 1983 (0.24kg/PKHF). The reconstructed LPUE time-series confirms the decline in the biomass of fish stocks, in particular in cod, as demonstrated by the ICES stock assessments that are currently available from 1955 onwards. Moreover, the data on weight classes presented here (Figure 8.7.), suggest that a decline in the proportion of 'large' fish in the stocks of cod and haddock, may have started as early as 1947. The data on 'large cod' indicate that 'double erosion' took place in the targeted Icelandic cod stocks by which not only the biomass declined but also the proportion of larger fishes declined simultaneously. Superimposed on these processes, we also document the shift in the definition of 'large' fish, which took place over the 50 years observed in this time-series.

Our findings coincide with those of recent authors who have taken a broader historical view on changes in commercial fish stocks. Thurstan et al. (2010) found a 94% reduction in LPUP over 118 years of UK industrial bottom trawl fisheries in the North Sea, Cardinale et al. (2009b) reported an 86% decline in biomass of turbot (*Psetta maxima*) in the Kattegat-Skagerrak based on standardized research surveys extending back to 1925. Similar conclusions were drawn for the large predatory fishes in the North Atlantic, evidencing a decline by 90% since 1900 (Christensen et al. 2003) and for predatory fish worldwide since the onset of industrial fisheries (Myers and Worm 2003). In exploited fish stocks, larger fish generally suffer higher fishing mortality, affecting the size distribution of the stock. Systematically extracting the larger specimens in a population of fishes affects reproductive and growth parameters, and has shifted maturation towards younger and smaller animals (Rijnsdorp and Milner 1996, Rijnsdorp et al. 2003, Mollet et al. 2007, Garcia et al. 2012). The importance of large fishes in the ecosystem is acknowledged in current EU policies (2008/56/EU). There is evidence that a change in the size distribution of fish communities in the North Sea has taken place (OSPAR 2008) and the OSPAR Ecological Quality Objective for the restoration and conservation of the size-structure of the fish community of the North Sea sets as target that the proportion (by weight) of fish greater than 40 cm in length should be greater than 0.3, based on the ICES International Bottom Trawl Survey series (OSPAR 2008). The undesirable effects of selective fishing on the equilibrium in the trophic web and wider ecosystem have also been questioned by García et al. (2012).

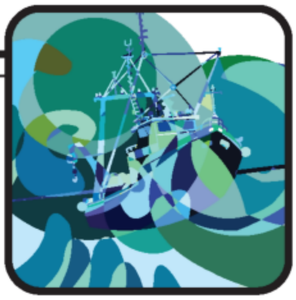
There are different factors that may potentially have affected this proportional decline in large cod, and ultimately in biomass, in Iceland. Begg and Marteinsdottir (2003) investigated the effects of fishing on the composition of the cod SBB in Icelandic waters and found that SBB and relative fishing mortality were spatially unevenly distributed. They concluded that changes in stock structure and demographic characteristics caused by changes in spatially explicit exploitation patterns can significantly affect stock productivity through differential loss of reproductive potential. Petursdottir et al. (2006) found that populations of Icelandic cod from adjacent spawning areas within the main spawning area at the southwest coast, can be discriminated based on otolith growth and shape. They suggested the existence of different populations in the coastal and offshore areas, underlining the importance of special protection for the large and fast growing cod spawning in the coastal area, given their significance to the overall productivity of the stock. Historical data on commercial fisheries with a high temporal and spatial resolution are scarce. The data by rectangle presented here provide valuable information to compare fishing activities and LPUE between rectangles. However, the data can not elucidate whether cod and other gadoids were caught in deeper or shallower parts, in particular for rectangles which cover a wide depth gradient and both inshore and offshore habitats within the main spawning areas (e.g. 1212, 1214). Possibly, different populations may have been exploited over time; targeting first the larger and faster growing cod in the coastal area and later, after these became less abundant or after access to coastal areas became increasingly restricted, targeting other populations.

It has been well documented that cod in Icelandic waters form a unit stock marked by very little emigration, but migrations of cod also take place from the West and East Greenland stocks into Icelandic waters (Harden-Jones 1968, Schopka 1993). The large-scale immigrations which occur in particular years, may affect the stock abundance at Iceland and in the past have resulted in the overestimating of the Iceland stock size. While catch-at-age for Icelandic cod peaks at ages 4 or 5, in years with large-scale immigrations from the Greenland stock the catch-at-age peaks again at 7-9 years (Schopka 1993). Between 1941 and 1990, Schopka found some strong year classes emigrated from Greenland, in particular the 1945-year class which appeared in large quantities from 1953 onwards on the spawning grounds off the southwestern coast of Iceland. Schopka (1993) related the origin of this strong year-class to drifting mechanisms of larvae/eggs from Iceland, hence demonstrating the strong linkage between the larval drift and immigration mechanisms, and hence the linkage between Greenland and Iceland stocks in different stages of the life cycle. It is believed that these migrations occurred more frequently before the 1970s (Schopka 1993) and that this migration decreased due to the poorer state of the stock at (West) Greenland after 1970. In spite of the fact that the data presented here do not show evidence of an increased proportion of large(r) cod specimens in 1953, and following years, it may well have been that these 'Greenland immigrants' consistently strengthened the weight class of the large cod (>5kg) before 1970, and large (>8kg) before 1947.

As a cold-water fish which thrives in temperatures of 4°-7°C, cod has been used as an indicator species for climate change in different studies (Cushing 1976, Jones et al. 1999, Drinkwater 2009). During the warming which occurred in the Icelandic and Greenland waters in the 1920s and 1930s, changes in fish distributions were observed (Jones et al. 1999) and Sæmundsson (1934) documented a marked episode of massive spawning of cod off the northern and eastern waters in Iceland in addition to the known spawning areas in the southwest. In the late 1960s, water temperature and salinity and air temperature decreased again while drift ice increased. This cooling had an impact on zooplankton community and changed the marine species composition in Icelandic waters from boreal to arctic (Jakobsson 1978). Drinkwater (2009) compared the responses of Atlantic cod in Iceland during two major warm periods in the North Atlantic; a first period from the 1920s to the 1960s, and a second which started in the 1990s. While the author found that abundance in cod stocks from West Greenland, Iceland, and the Northeast Arctic increased and individual growth and recruitment were high during the first warm period, this did not seem to be the case during the second warming. The author attributed these different responses to the effects of intense fishing pressure and possibly the added effects of environmental changes in the ecosystem. In particular, abundance of Icelandic cod has remained low during the second warming, when spawning stock biomass and total biomass were at near-record low values.

Taken together, the historical data from Belgian commercial landings of trawl fisheries in Iceland, correspond with a period for which there is scarce information. The results document the Belgian gadoid fisheries in Icelandic waters and argue that the decline in Iceland cod stock was visible at different levels, even long before the peak in fishing effort of the Belgian fleet -and other foreign nations- was achieved in 1963 (or earlier). This decline is observed in terms of the decrease of the proportional importance of cod in the overall landings, the decrease in the landings per unit of fishing effort, the decline in the proportion of 'large' fishes, and finally the decline or shift in the definition of a 'large' specimen. The evolution of the Icelandic cod fisheries show a certain similarity with the northwest Atlantic cod fishery which suddenly collapsed in 1992, following years of overfishing since the late 1950s, and after a first sign of collapse in the 1970s (Kenneth et al. 2005). After trusting for centuries in the infinite reproductive capacity of the Icelandic cod stocks, the long-standing traditional fisheries in distant waters by the Belgian fleet and other foreign nations gradually came to an ending due to overfishing and changes in environmental conditions, and ended abruptly after the last political turmoil, dictated by a once mighty fish.

ACKNOWLEDGEMENTS
The authors thank all who contributed to the HiFiData project by digitizing data, archiving historical documents or with the development of web applications (S. Behiels, H. Debergh, N. De Hauwere, D. Depooter , J. Haspeslagh, L. Lyssens, B. Vanhoorne, and many students who helped digitizing data). The present paper is partially produced in the context of the ICES Working Group on the History of Fish and Fisheries WGHIST and its formal terms of reference.



CHAPTER 9: General Discussion and Conclusions.

CHAPTER 9. GENERAL DISCUSSION AND CONCLUSIONS

9.1. THE SHIFTING PERCEPTION ON THE STATUS OF MARINE ECOSYSTEMS

Human activity has been impacting marine ecosystems for millennia, and the concept of 'pristine' ecosystems is merely a theoretical one (Myers and Worm 2003). Fishing is considered to be a human activity with major impact in the marine environment, both on regional and global scales (Salomon 2009), and it is the activity that is most often seen as the cause of overexploitation and depletion of marine biological resources (Myers and Worm 2003). Concern about overexploitation of fish stocks is certainly not a recent phenomenon (Mann 1777, Du Bus and Van Beneden 1866, Olsen 1883, Garstang 1900) and measures to regulate fishing intensity and mitigate fishing impact on the exploited stocks were established as early as 1289 in the Southern North Sea (Roberts 2007).

There is a wealth of recent studies illustrating how our perception of pristine conditions in the seas and oceans has shifted over generations. In reference to fisheries management, depleted fisheries have often been evaluated by using the state of the fish and fisheries at the start of the data collection as a baseline, rather than the fish stocks in untouched state or under conditions of low impact or subsistence fisheries (Pauly 1995, Saenz-Arroyo et al. 2005, McClenachan et al. 2012). In fact, the concept of the 'shifting baseline syndrome' was developed by Pauly (1995) in reference to fisheries management, who signposted the risks associated with this shifting perception and the challenge this represents for the sustainable management of marine ecosystems. A shifting baseline (also known as sliding baseline) is defined as a change to how a system is measured, usually against previous reference points (baselines), which themselves may represent significant changes from an even earlier state of the system.

Fuelled by current policies in support of a sustainable management of the marine environment, evidence is being built about (pre) historical reference conditions and early baselines (Pinnegar and Engelhard 2008, section 1.1.). This evidence has increased the awareness on the limitations associated with the current scientific methods in determining appropriate reference conditions against which current targets for conservation and management are set, in particular for fisheries. It is acknowledged that environmental reference conditions and targets must strive to integrate all available and relevant data and information for improved assessments, including incorporating historical data into conservation and management frameworks (Pinnegar and Engelhard 2008, McClenachan et al. 2012). Historical data can contribute in explaining underlying cause-effect relations in changes in the ecosystems, but they can also potentially reveal information and knowledge from past conditions (Jackson et al. 2001) and help defining reference conditions and achievable targets for environmental management today. In other words, historical data can counter the 'shifting baseline syndrome'.

The present thesis focuses on quantitative data to extend the timeframe of current analyses on fisheries (landings, fleet dynamics, spatial dynamics, indexes of productivity of the fleet and impact of fishing), and on historical time-series to expand our knowledge on historical references for the Belgian sea fisheries.

The conclusions presented here, are structured according to the topics addressed in the different chapters of this thesis:

- General conclusions in relation to data sources to reconstruct historical time-series for Belgian Sea Fisheries

- 'Shifting Baselines' applied to the Belgian Sea fisheries: an overview of trends observed in the reconstructed time-series:
    - Landings, species, fishing areas

  - Fleet dynamics
  - Landings per unit of effort and landings per unit of power
  - Changes in targeted fish stocks

- Potential use of the HiFiDatabase in other fields of application

- Next steps in data management and analysis of data

9.2. DATA ON COMMERCIAL SEA FISHERIES IN BELGIUM

9.2.1. THE POLITICS BEHIND THE STATISTICS

A number of authors have published reviews of available data and information sources for the Belgian sea fisheries: Cloquet (1842), De Zuttere (1909), Vilain (1962), Omey (1982), Poppe (1977), Hovart (1985). Although these reviews are instrumental to obtain an overview of potential (data) sources on the history of sea fisheries in Belgium, the sources remained fragmented and disperse. This was particularly the case for historical quantitative datasets describing fisheries dynamics. Information sources consulted in the context of the present thesis were documented in the Integrated Marine Information System IMIS (VLIZ) and - where possible - disclosed full-text and open access to the public. Sources in archives and literature databases were specifically screened for:

i. **numerical data**
ii. **metadata** needed for a correct interpretation thereof (e.g. minimum legal mesh sizes of nets, landing sizes of species, ancient reporting units),
iii. elements that triggered the **onset of systematic and centralized data collecting systems** in Belgium (e.g. international cooperation, subsidies, etc...), and
iv. **marking events and legislation** that provide context for understanding observed trends and sudden changes in time-series.

A few generalised conclusions are drawn specifically in relation with the driving forces behind the data collection on sea fisheries both in Belgium and in the other fishing nations bordering the North Sea. Because data sources are incomplete and the search was not exhaustive, the conclusions related to data sources must be considered as indicative.

Different drivers interact to shape data collection systems on fisheries throughout history
The search in the literature, archives and databases has illustrated how different driving factors have interacted to facilitate – in some cases hamper – the data collection on sea fisheries in Flanders/Belgium since the 15th Century (Figure 9.1. and text box). Depending on the period in history these driving factors were economic power, regional politics and national security (e.g. during warfare), the fisheries policies and the administration enforcing the policy requirements, the fisheries sector itself (economic interests e.g. to obtain subsidies), the research community, environmental policy targets, or a combination of two or more of these drivers.
It is not the purpose of the present thesis to conduct an exhaustive study of the literature. Nevertheless, the most important events were documented in an on-line application on the Belgian sea fisheries that can be consulted in chronological order (www.vliz.be/cijfers_beleid/zeevisserij/timeline.php, VLIZ 2010) (Appendix). The timeline provides an overview of the historical events that describe the Belgian sea fisheries since the earliest years and integrates different topics. It is based on the sources identified, inventoried and screened for the purpose of the present thesis. The tool is available to the wider public and is continuously updated.

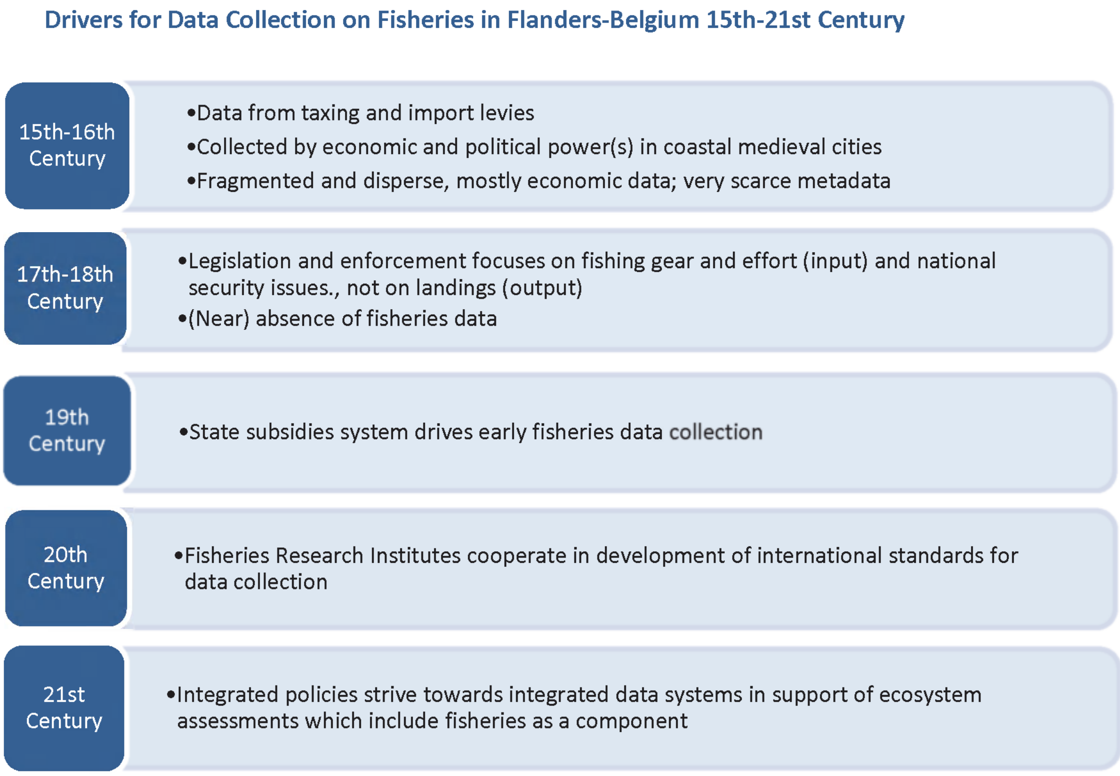


Figure 9.1.: Main drivers for data collection on sea fisheries in Flanders-Belgium 15th-21st Century

THE POLITICS BEHIND THE STATISTICS

In the Late Middle Ages (15^{th} – 16^{th} century) *fishing was basically a free enterprise all over Europe (Hovart 1985). Data on commercial sea fisheries in Flanders were collected by cities and port authorities using local accounting systems that focused on the production of the salted herring and codfish industry for taxing purposes. The gains from taxing were crucial to sustain the established political powers of medieval cities such as e.g. Nieuwpoort, Brugge and Oostende.*

Political turmoil during the 17^{th} and 18^{th} century *affected the Flemish ports and their fisheries in different ways: Flanders' fisheries benefited from the conflicts between England and France. Subsidies or indirect support were implemented to the local fisheries e.g. through tax levies or straight prohibitions on foreign import of herring or cod (Cloquet 1842, De Zuttere 1909, Hovart 1985). The Compagnies of Oostende and of Nieuwpoort were established but did not persist in these unstable conditions. Numerical information is scarce and patchy, fragmentary records were preserved from individual company owners accounts (e.g. Schreurs Grootboek from 1771, facteurboek Serweytens from 1814-1820, Parmentier 2001). Governmental information on fishermen and fisheries was often collected from the perspective of warfare and security and maritime control. Interestingly, in terms of fisheries management a number of technical measures and regulations were established because of the alleged negative effects on the juvenile fish and larvae (Appendix III: overview historical fisheries measures and laws). These were mainly oriented to mesh size and the prohibition of trawling in the coastal waters (e.g. Ordinance 30/04/1752).*

Information is ***particularly scarce for the French (1794-1815) and Dutch periods (1815-1830)*** *and additional efforts were conducted to identify data sources. The 'City of Ghent Newspaper' (1666-1940) contains data on ship movements in the ports of Oostende for these periods. Landings of salted codfish in Oostende were also* *reported in the newspaper of Ghent. These data were inventoried with the aim to reconstruct indices of fishing effort and productivity, however because of the fragmentary nature of the data they could not be integrated in the time-series reconstruction. For cod and herring, partial reconstructions were conducted including the salted cod and herring data from the 19th century (Lescrauwaet et al. 2010a, Lescrauwaet et al. under review).*

To subsidise or not…economic incentives to the fisheries in the 19th Century

In 1815 (Congress of Vienna) the United Kingdom of the Netherlands was established and Flanders was annexed as the 'southern provinces'. Governmental subsidies were tailored to the particular fishing gear, techniques, and corporate structures of the northern Dutch fisheries. With the establishment of the Kingdom of Belgium in 1830 the subsidies were adapted to local characteristics of the Flemish fisheries (see Chapter 2 for details on this period). The system of state subsidies is the driver for early fisheries statistics collected in the 19th century. The period between 1860-1900 is of particular interest because of the interplay between the government and administration, scientists, and the private sector. Interestingly, upon a parliamentary inquiry about the usefulness of subsidies to the fisheries and the issue of overexploitation that was brought under the attention of a vessel owner and skipper, scientists defended the infinity of renewable resources of the sea. It was a period during which liberal views were advocated in economic models, and e.g. in The Netherlands fisheries were set fully free of regulations in 1857 (Du Bus and Van Beneden 1866). The first International Conferences were organised around the North Sea region – e.g. Convention of The Hague in 1882 - and the issue of overexploitation of fish resources and commonly agreed regulations to access resources were on the agenda. To underpin the debate, the first nation-wide detailed surveys and stocktaking were commissioned. Today, this early stocktaking provides an interesting baseline for fisheries as an economic sector in 19th century Belgium.

*In 1902 the **International Council for the Exploration of the Sea (ICES)** was founded. ICES developed a system of subareas and divisions for use in the collection and presentation of fisheries statistics, and the first (preliminary) international fisheries statistics were published in 1903 (Hoek and Kyle 1905). Belgium acceded in 1903. Concern for some fish stocks lead to e.g. the establishment of the international Plaice-committee in 1912. Other species or stocks would follow later (herring, cod, sole). WWI severely hampered this initial process of statistical data collection, but by the onset of WWII the statistical systems were largely in place in most countries bordering the North Sea. After WWII, international territorial policies in the maritime environment were largely driven by interests in fisheries; e.g. the declaration of the 12 nautical miles as territorial sea, the establishment of the 200 nm as Exclusive Economic Zones in 1982 (Finley 2011), and the 'cod wars' in Iceland in 1958, 1972 and 1975 (Valtysson 2006). Access to marine resources is increasingly debated in the context of international agreements and models for international cooperation are set up to develop cross-border single stock management.*

***21st Century Fisheries in the EU policy context: the challenge to move to ecosystem-based approach requires integration of data and data systems.** EU wide efforts to balance economic objectives and fishing efforts against the availability of the resources are further pursued through the establishment of the EU Common Fisheries Policy CFP (1983). The need to regulate access to economically important but declining resources becomes an important drive for data collecting. Whereas fisheries formerly competed with each other over resources between fisheries and metiers (Rijnsdorp et al. 2008), the different fisheries now need to join forces to interact with other sectoral demands to claim their spatial needs (International Conference on MSP, EU DGMARE, 26/03/2012). The UN Conferences on sustainable development (Rio 1992, Johannesburg 2002, Rio+ 2012) and the science-based evidence of overexploitation of most of the commercial fish stocks, support the slow transition to an ecosystem-based management of the marine environment.*

In the pursuit of an ecosystem-based approach in the marine environment, Data Collection Regulations in support of the Common Fisheries Policy CFP (EU Council Regulation 1543/2000 and Commission Regulations 1639/2001, 1581/2004 and 199/2008) require EU MS to collect data on technical, biological and economic aspects of their national fisheries, and their impact on the marine ecosystem. The Commission Regulation

136/2007 requests member states to collect data and report on discards. Besides these measures related to data collection and the scientific stock assessments that need to advise the Council of Fisheries each year on the definition of Total allowable Catch (TAC) and MS quota, there is a large number of technical measures to reduce fishing effort and to implement measures, techniques and initiatives to support the development of sustainable fishing communities throughout Europe.

The reformed EU CFP (2012) is also to be aligned with the objectives as defined in the EU Marine Strategy (2008). The EU proposal for a directive on Marine Spatial Planning (COM 133/ 2013) and the Habitat and Bird directives are mechanisms to support these legal commitments by 2020. By aligning targets across policy frameworks (Fisheries, Environment, Nature Conservation, Sea Use) the transition from single stock management to a more integrated ecosystem management is pursued. The integration of policy objectives is a driver for the development of rich data environments that integrate data on living and non-living components of the marine environment and ecosystem functioning, as well as pressure and impact by human uses.

9.2.2. Reconstructing long-term data series on sea fisheries in Belgium: strengths and limitations

The screening of literature databases, archives and other sources indicated that in Belgium, structurally embedded reporting based on detailed taxonomic and geographical resolution started in 1929 with an acceptable degree of consistency and continuity ever since. During the second half of the 19th century and the beginning of the 20th century, efforts were conducted by government officials to achieve standardized collecting and centralized reporting on fisheries data in Belgium. In spite of these early efforts, all data on catches, landings, fleet and effort collected before 1929 are either spatially incomplete or taxonomically aggregated (Table 9.2).

The 'Historical Fisheries Database' (HiFiDatabase) is a product of this thesis. It is the result of a thorough search, rescue, inventory, standardization and integration of data for Belgium's sea fisheries that were not available before in the public domain or were not available before in the appropriate format for redistribution. It is documented and stored in the Marine Data Archive MDA of VLIZ and freely available for end-users. It contains a collection of time series with standardized species names, reporting units, fishing areas and ports of landing (Lescrauwaet et al. 2010b, Chapter 2 Table 2.6.). It counts 0.7 million data rows and is a 'living' product in the sense that new, relevant, quality-controlled time-series can be added as they are discovered or produced.

The HiFiDatabase is a quite exceptional because it documents the sea fisheries of one country, over one century, and for a wide range of topics. Considering the relative size of the fleet, the short coastline and the limited number of fish auctions and fishing ports, it is fair to say that the present reconstruction of sea fisheries in Flanders/Belgium may depict a relatively complete picture of historical volume, value and composition of landings, fleet dynamics, fishing effort and spatial dynamics for this time period, compared to other countries. It contains unique data with advantages compared to recently developed databases (ICES Official Catch Statistics 1950-2010 (ICES 2011)). However, a number of limitations need to be taken in to account (Table 9.1). The most relevant limitations refer to the coarse scale of spatial reporting units and the patchy and discontinuous data on fishing gear and effort.

For commercially important species such as cod and herring, time-series on landings can be extended with caution towards the early 19th century (Lescrauwaet et al. 2010a, Chapter 3) and even earlier (Lescrauwaet et al. 2013, under review).

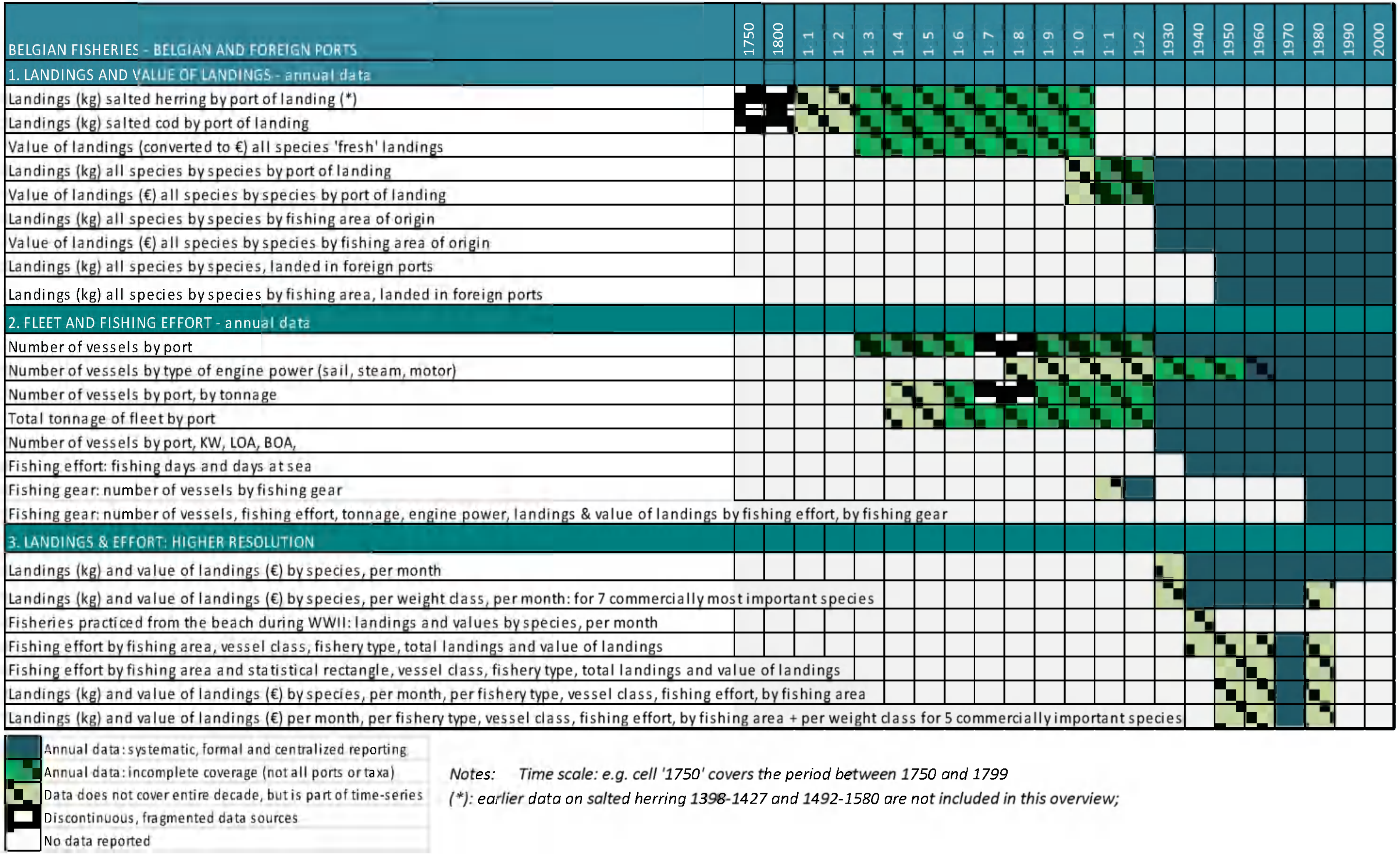
Time-series of landings and value of landings by fishing rectangle, by month, by weight or size class, by fishing effort and fishing métiers (vessel type and gear) provide unique insights at higher spatial, temporal and taxonomic resolution. Unfortunately these data are not continuous throughout the period from 1920 onwards (Chapter 2 and overview Table 9.2).

Table 9.1.: Overview of the main strengths and limitations of the HiFiDatabase

	Strengths	**Limitations**
General	A complete reconstruction of historical volume, value and composition of landings, fleet dynamics, fishing effort and spatial dynamics over (nearly) one century	
Taxonomic coverage	Data available at the level of: - 41 reported species - and 15 aggregated taxa	Taxonomic validation for species that are difficult to identify in the field (e.g. the case of 'rays') can raise doubts
Temporal coverage	1929-1999 (and continued to present)	-
Spatial coverage	-All fishing areas where Belgian fishing fleet has operated between 1900-present, including 4 fishing areas not reported separately by ICES/FAO these are: Fladen (in ICES area IVa), North Sea central-east and North Sea central-west (in area IVb). and 'Coastal waters' (in area IVc). -All fishing ports	-No data were found on Belgian landings in foreign ports before 1950. The data from 1950-1960 however suggest that landings in foreign ports were few. -The proportion of the catch that may have been landed informally or illegally in other sites along the coast is not known
Temporal resolution	Monthly values	-
Spatial resolution (smallest reporting units)	Data available by statistical rectangle: 1946-1983	In general (except for statistical rectangles) spatial units of reporting remain coarse (= ICES fishing areas and subareas)
Thematic coverage	Economic data (value of landings) Fleet and fishing effort data: • Effort data (chapters 5 to 8) • Fleet characteristics (Chapter 5) • Fleet and fishing gear (Chapter 5 to 8) Employment and Education levels	Data on fishing effort and gear at statistical rectangle are often patchy, discontinuous
Other	Data by size or weight class (large, medium, small, -extra large, extra small), for commercially important species	
	More information in Chapter 2, and from Materials& Methods sections in Chapters 3-8	

The screening of archives, databases, libraries and other repositories as described in Chapter 2 has generated an inventory of data sources related to historical fisheries in Flanders-Belgium. The data contained in these sources were copied to electronic formats, quality controlled and integrated according to a priority setting by which the datasets that are feasible to be reconstructed as long-term time-series were tackled first (Chapter 2). Based on the resulting time-series a number of descriptive statistics (Chapters 3 to 5) and analyses (Chapters 6 to 8) were conducted in the context of the present thesis.

Next steps in data rescue and digitization need to focus on more fragmentary sources such as the logbooks of individual vessels. These logbooks contain detailed information for each fishing trip, including environmental data. From the logbooks, a correlation can be drawn between fishing effort, deployment of the fishing gear, spatial coverage, and catches. Logbooks have been used in different studies to reconstruct historical references (Poulsen 2008, O'Donnell et al. 2010). If the logbook is assumed to be a reliable report, and provided one or more particular vessels can be followed over time, the logbooks may potentially offer anchor points that document the change in technology over time, or provide information on the time of introduction of specific technologies that improved the efficiency of fishing and the catchability of target species. This is of particular use as a reference or to set a baseline for the datasets which are discontinuous over time, or for which gaps in spatial coverage were identified.



1

Notes: Time scale: e.g. cell '1750' covers the period between 1750 and 1799

(*): earlier data on salted herring 1398-1427 and 1492-1580 are not included in this overview;

Table 9.2. Overview and chronology of data and time-series on fisheries

9.3. RECONSTRUCTED TIME-SERIES: SHIFTING BASELINES IN BELGIAN SEA FISHERIES

9.3.1. RESCUE AND MANAGEMENT OF HISTORICAL DATA IN SUPPORT OF AN ECOSYSTEM-BASED ASSESSMENT

Many countries have invested great efforts to systematically collect scientific data and statistics. This is also the case for Belgium. Initially, most of the raw data was recorded on paper, at the best summarized for storage and reporting purposes and kept in punch cards or other 20th century technologies that are not available anymore. In some cases the data were analysed and published in summarized form to be transferred to new, digital carriers while the raw or underlying data were discarded. A few decades ago, computing capacities were still limited and even until recently raw data were encoded and stored on paper, limiting their redistribution and accessibility. Many of these potentially valuable datasets and sampling designs are now archived in libraries and institutions where they are at risk of being lost for science. As libraries and institutions occasionally clean up their holdings, this may lead to loss of archived data (Zeller et al. 2005). Today, computing technology and infrastructure is not the limiting factor. Data are electronically encoded in standardized and exchangeable formats so they can theoretically be shared and exchanged all over the world. Web based search engines increase efficiency and speed of harvesting and exchanging of data and information. Spatial Data Infrastructures allow sharing spatial data from web-based clients worldwide. Although important progress is made in this direction, further improvements can still be achieved in sharing and accessing data and information:

- **Establishing institutional Data policies and Data management procedures**

Universities and research institutes, private companies, government services are paying increasing attention to aspects of data management and ethics, responsibility in managing and sharing data that are collected with taxpayers' money. Academic institutions as well as other scientific research institutes are developing data policies, including regulations for the recording and storing of data associated to graduate and pre-graduate research.

- **Developing a Vision for the future**

Data that may seem of limited relevance today may be of crucial importance in the future. It is important to invest in data sharing infrastructures and capacity building to safeguard data, information and knowledge for future use and to pass it on to the next-generation of data infrastructures (Matthews 1993).

- **Society's perception on data ownership**

Despite marine research and monitoring being largely paid by tax money, environmental and fisheries related data are often perceived to be owned by the public institutions and academic and research institutes that generate them (Russ and Zeller 2003). This issue of perceived ownership of data (Matthews 1993) has been a continued cause for hampering access to and use of data, in many cases even the definite loss of valuable datasets. One of the most important responses to the latter is the global Open Access Movement (www.openarchives.org/).

In the present thesis, a case is made for the importance of the rescue and integration of historical fisheries data, demonstrating the need for historical fisheries data and its potentialities for the analysis of and assessment of historical marine reference conditions in the 20th century. In the process, an important number of trainees, internships and students participated were trained in the basic aspects of data management and the principles of Open Access.

9.3.2. LANDINGS, VALUE OF LANDINGS, MAIN SPECIES, MAIN FISHING AREAS

The concept of shifting baselines can be applied in different environments. In the reconstruction of time-series on commercial fisheries, the trends in landed volumes are often most conspicuous. The reconstructed time series indicate that landings reported by the Belgian sea fisheries both in foreign and in Belgian ports over the period 1929-2008 amounted to 3.3 million t, of which 90% was landed in Belgian ports. After a maximum of 80,000 t in 1947 (rounded figures), annual landings declined steadily to only 26% of this peak by 2008 (Lescrauwaet et al. 2010a). Currently (2010), landings are below those achieved in 1929.
The most important species over the observed period in terms of landings were cod (17% of all landings) and herring (16%), closely followed by plaice (14%), sole (8%), whiting (6%) and rays (6%) (Table 3.1.and Figure 3.8.). In terms of economic value and based on values corrected for inflation, sole (31%) and cod (15%) were the most valuable, closely followed by plaice (11%), brown shrimp (5%), rays (5%) and turbot (3%). Near to 73% of all landings originated from 5 of the 31 fishing areas (Table 3.3. and Figure 3.9.). Twenty percent of all landings originated from the 'coastal waters', while these waters contributed nearly 60% of all landed pelagic species and 55% of all landed 'molluscs and crustaceans' (Chapters 3 and 6.1). The North Sea (south) and the Iceland Sea are next in importance with 17% and 16% of all landings respectively. The eastern and western part of the central North Sea, contributed each with approximately 10% of the total landings (Lescrauwaet et al. 2010a).

Interestingly, three groups of targeted species have explained on average 75% of all landings between 1929 and 1990 (red line, Figure 9.3.) These are:

a) the pelagic fisheries for herring and to a lesser extent sprat,
b) the roundfish fisheries targeting mainly cod but including also other species (haddock, saithe, whiting, ling, redfish, monkfish)
c) the flatfish fisheries targeting plaice and sole.

Before and during WWII the bulk of the landings consisted of herring (and sprat): this component explains 52% of all landings before 1946 and up to 100% of all landings during WWII. On average, herring and sprat represent 66% of the landings of the 3 major components before 1946. After WWII, the large-scale herring fisheries in the central North Sea quickly resumed and after 1950 these fisheries take an industrial dimension (Chapter 7). Mortality in the North Sea herring stocks increased significantly, affecting also the Downs herring, which was targeted by the Belgian fishers on the post-spawning sites on the Flemish banks, before and during WWII (Chapter 7).

After WWII and until the mid 1980s, 47% of all landings consist of the group of gadoid and other roundfishes, mostly from Icelandic waters. Towards the second half of the 1960s, when the Belgian fisheries in Icelandic waters was at its peak in terms of fishing effort, this group of species represented up to 80% of the 3 main components (Figure 9.3.). In the wider context of the Belgian fisheries, the landings of cod and other roundfish represented 66% of all landings in 1968.
Between 1980 and 2000, the proportional importance of the 'gadoid' component and the 'flatfish' component within the sum of these 3 large components, were reverted: sole and plaice increased from approximately 30% to 70% while the relative importance of the 'gadoid' component – except for the smaller peak at the end of the 1990s - decreased from 70% to 30% (Figure 9.3.).

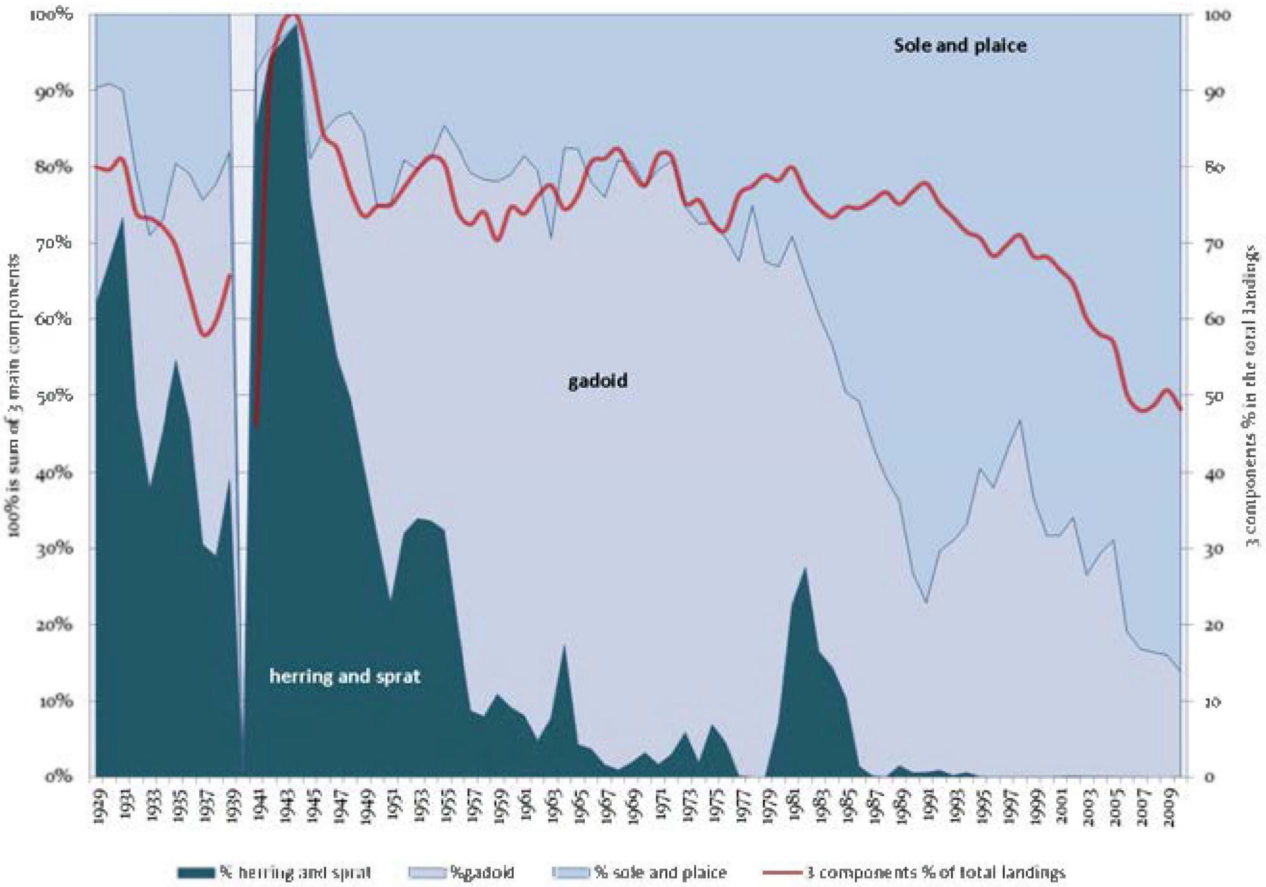


Figure 9.2.: Landings of the 3 main components (herring and sprat, gadoid and other roundfish, sole and plaice). The sum of these 3 main components as a percentage of the total landings, is indicated in the red line. The relative proportions of each of these 3 components are indicated as areas (%).

After 2000, plaice and sole make up 70%-85% of the main components. However, from 2000 onwards the importance of these 3 major components in the total landings decreased from 70% to less than 50%. This decrease suggests that the proportional composition of landings (weight-based became more diverse after 2000 (Figure 9.2, red line). Important landings of anglerfish (*Lophius piscatorius*), cuttlefish (*Sepia officinalis*) and scallops (*Pecten maximus*) are also reported in recent years (Tessens and Velghe 2012).
The reconstructed time-series suggest that the Belgian fisheries have followed a development of 3 successive exploitation phases in which 3 major target species or target species groups were exploited until events or processes triggered a transition to a new phase. This pattern of successive exploitation was also described by Pauly et al. (2005) for the fisheries worldwide. For Belgium we can distinguish – simplification permitted – a 'herring' period between 1929 and 1950, a 'cod' period between 1950 and 1980 and a period marked by plaice/sole between 1980 and 2000 (and after). This successive exploitation of targeted species was also associated with exploited fishing grounds, successively the Coastal waters for herring, the Icelandic Sea for cod, the North Sea south and the North Sea central (east and west) for sole/plaice, later also joined by the 'western waters' (English Channel, Bristol Channel, Irish Sea) for the flatfish fisheries (Figure 9.3.).

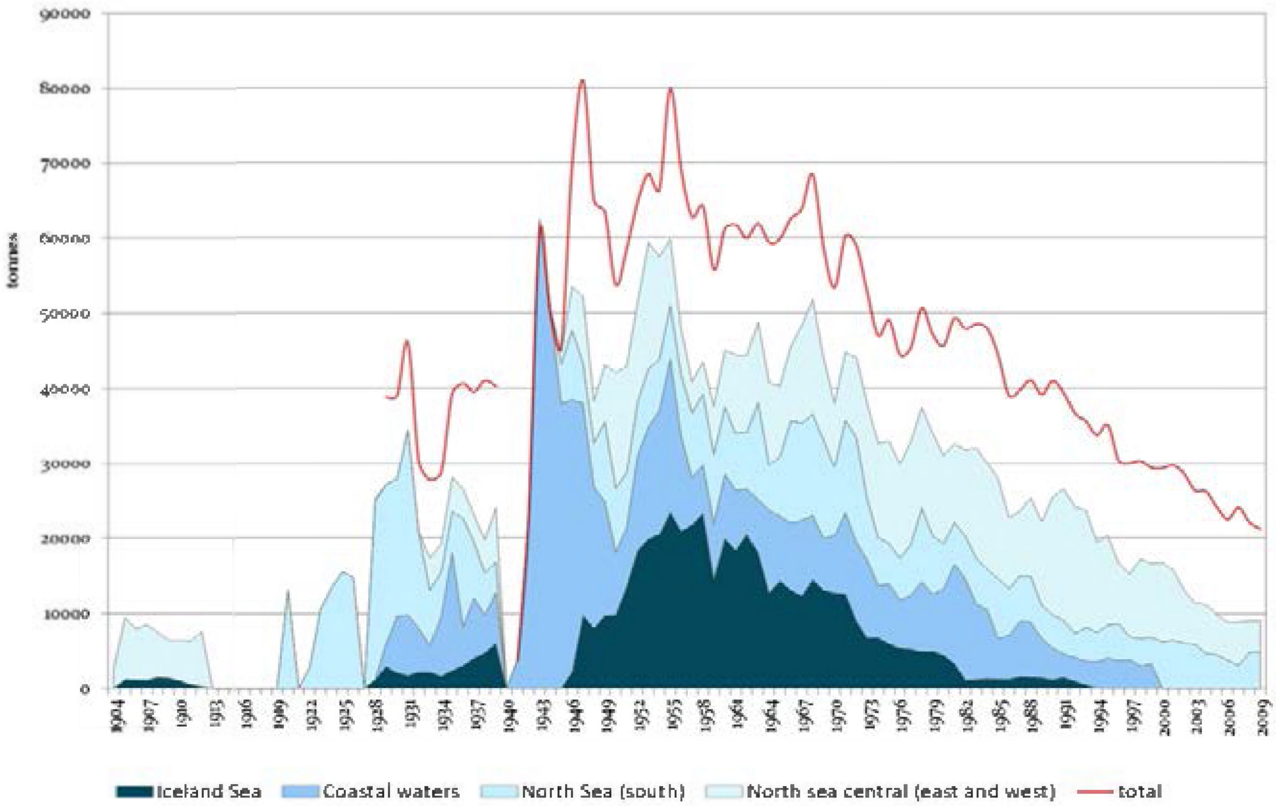


Figure 9.3.: Landings in the 4 main fishing areas of historical importance and associated to the landings of the 3 main components as represented in Figure 9.2. (herring and sprat, gadoid and other roundfish, sole and plaice). The total landings are indicated as a reference (red line).

9.3.3. Fleet dynamics and vessel characteristics

Although the volume of landings shows a decline of -74% since 1947, this decline cannot be interpreted as an indicator of change in the biomass of targeted fish stocks. To understand and interpret the trends in landings and changes in target species (groups) as described above, it is crucial to look at trends and changes in the fishing fleet and the fishing sector inserted in a wider socio-economic and political context. Most time-series on the fleet dynamics start after the 1980s, at times when major changes in fleet characteristics had already taken place. In the present thesis work, a reconstruction was made of the fleet size (from 1830), tonnage (from 1842) and engine power (kW from 1912) of the Belgian sea fisheries fleet. The time-series show a 85% decrease in fleet size and a 5% decrease in overall engine power (kW). This decrease was compensated by a 10-fold increase in average tonnage (GT) per vessel and a 6-fold increase in average engine power (kW) per vessel, from an average of 100kW after WWII to approximately 600kW in the mid- 2000s (Figure 9.4. and Chapter 5 for details on fleet dynamics).

During the WWII, the Belgian fisheries benefited a 10-fold increase in catches and 5-fold increase in LPUE of Downs herring. These increased catches can be explained by the combined effects of a major increase in catch power thanks to improved technologies that were implemented after WWI (motor engine, fish detecting devices), and by the effects of strong pre-WWII year classes (e.g. 1936 and 1938) which joined the adult Downs herring during WWII on the post-spawning resting areas that were targeted by the Belgian fisheries

(Lescrauwaet et al. under review, Chapter 7). This was associated with an apparent almost zero mortality Z in the North Sea herring stocks, because of the 6-years cessation in fishing efforts on the herring feeding grounds in the central North Sea. In spite of the severe damage that the fishing fleet suffered during the WWII, the Belgian (coastal) fisheries benefited economically from this unintended 6-year temporary closure to fisheries in the North Sea that triggered a period of rapid expansion and investments in the Belgian fleet in the years to follow.

After the cessation of the fishing activities during WWII, the sector was severely hit by an economic crisis in 1948. According to local fisheries experts, the North Sea showed marks of depletion of its fish stocks again by 1950 (Poppe 1977, Omey 1982). In only 10 years time after WWII, the fleet size decreased from approximately 550 to 450 vessels (Lescrauwaet et al. 2012). This decrease in fleet size is reflected in the decrease in total GT and total kW of the fleet (Figure 9.4) and by the sudden drop in landings between 1948 and 1950 (Figure 9.3.).

Between 1955 and 1970, major structural changes took place in the Belgian sea fisheries fleet (Figure 9.4.). These changes were driven first by the larger otter trawling vessels that shifted their fishing activities to the Icelandic waters to ensure profitability and in the early 1960s by the governmental subsidies for the purchase of new steel-hulled medium-sized motor trawlers and the introduction of the beam-trawl (Poppe 1977, Lescrauwaet et al. 2012). From 1955 to 1970 the total kW of the fleet increased while the total GT remained stable, which is explained by the increase in average kW per vessel as a consequence of the events described above (Figure 9.4.). This led to less but more powerful vessels: between 1960 and 1975 the fleet size declined from 430 to approximately 250 vessels (-42%). The decline in fleet size was exacerbated when Iceland demarcated its territorial waters from 12 nm to 50 nm in 1972 and when the presence of Belgian fishermen within the declared 200 nm EEZ of Icelandic waters became subject to a 'phase-out' in 1975 (Chapter 8 and Lescrauwaet et al. under review).

Although the peak in fishing effort by the Belgian fleet in Icelandic waters was situated in 1963, various of the indicators were already in decline by then: the total landings, the relative importance of target-species cod in the total landings from Icelandic waters, the LPUE, and the proportion of larger cod in the total landings (Lescrauwaet et al. ms under review, Chapter 8). As a consequence of the loss of the Icelandic waters towards 1980, Belgian vessels shifted their activities again towards the central part of the North Sea (Omey 1982) and - to a lesser extent - towards the English Channel, Bristol Channel, South and West Ireland and the Irish Sea.

Before 1974, the Belgian fisheries fleet remained largely free of restrictive measurements except for aspects related to minimum mesh sizes and minimum landing sizes MLS of the fish, as e.g. established by royal decree of 30 December 1950 (http://www.vliz.be/imis/oma/imis.php?refid=204569). In 1975 the 'total allowable catches' or TAC were introduced for the first time by the North East Atlantic Fishery Commission NEAFC, and this system was later followed-up by the EU Common Fisheries Policy. Two years later, on 22 September 1977, the 12nm was established as a zone for coastal fisheries where beam-trawling was prohibited for vessels with engine power above 221kW (http://www.vliz.be/imis/imis.php?module=ref&refid=207089). Although in spirit this law was issued to favour the 'protection of marine biological resources', an EEC subsidy scheme implemented from 1980 onwards stimulated the construction of new '*Eurocutters*' or vessels with engines <221kW and LOA < 23.99m to be able to exploit the 12nm zone. This is reflected in a temporary stabilization of the fleet size (number of vessels) at least until the 1990s. This period also coincided with an increase in the overall kW of the fleet and in the average kW of a vessel (Figure 9.4.).

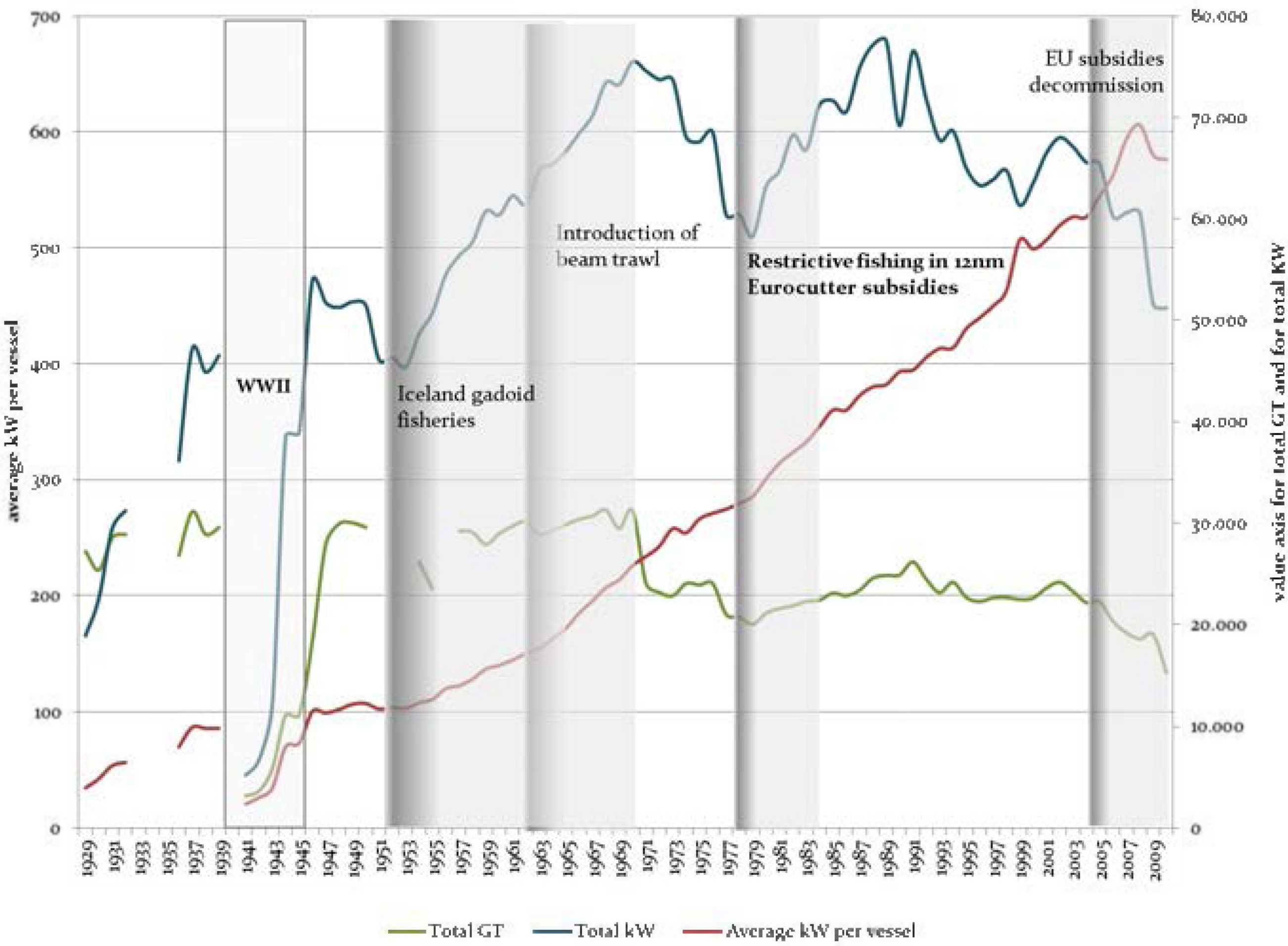


Figure 9.4.: Landings of the 3 main components (herring and sprat, gadoid and other roundfish, sole and plaice) as a percentage of total landings (red line). The relative proportions of each of these 3 components are indicated as areas (%).

As was the case for the Dutch fleet (Rijnsdorp et al. 2008), this management restriction generated a bifurcation in the Belgian fleet between the Small Fleet Segment SFS and the Large Fleet segment LFS which persists until today. For the case of the Belgian LFS, the continued increase in average engine power is related to a gradual introduction of *technological creep*, e.g. the size of the gear, the towing speed, the number of tickler chains rigged in the net-mouth of the beam-trawl, and which required more engine power (Polet et al. 1998, Rijnsdorp et al. 2008).

The structural changes as a consequence of technological developments in the 1960s, the loss of access to the Icelandic waters as fishing grounds, the energy crisis and the increasing fuel costs in the early 1970s (and later), have contributed in different degrees to these changes in the fleet and spatial dynamics of fisheries (Chapter 4 and Chapter 5, Lescrauwaet et al. 2012). From 2000 onwards specific programmes of the EU CFP were established, oriented to the decommissioning of ships with the aim to reduce fleet capacity although this did not directly led to a decrease in average kW per vessel. In Belgium, the royal decree of 29 June 1984 already foresees decommissioning for vessels of at least 12m LOA and which had spent at least 100 days fishing the previous year. The increasing trend in average engine power (kW) in a declining fleet size was legally capped by measures establishing a maximum of 1,200 kW per vessel. Finally, the decline in total engine power (kW) in recent years is both due to the decline in the fleet size and the gradual replacement of larger vessels by smaller ones (Figure 9.4.). In 2012, the Belgian commercial sea fishing fleet counted 86 ships, with a total engine capacity of 49,135 kW and gross tonnage of 15,326 GT (Roegiers et al. 2013).

These shifts in the overall fleet and fleet dynamics are generally not perceived at the level of individual fishers or vessel crews and difficult to perceive unless visualized over longer periods. To interpret the trends correctly, information from a political, socio-economic and/or cultural context proves indispensable. In an analysis of external factors affecting the Dutch bottom trawling fleet from 1945- 2005, Rijnsdorp et al. (2008) found a direct correlation between changes in the fleet and periods during which species availability – expressed as biomass per unit of engine power - was well above average. Rijnsdorp and co-workers (op.cit.) also found that changes in engine power of the fleet showed a significant positive correlation with the net economic results with a time lag of 1 year, and a periodicity with a period of 6.6 year in the change in engine power. Although different mechanisms explain the change in engine power of the Belgian fleet, the data suggest that the fleet responded very quickly to external factors (see Chapter 7).

9.3.4. LANDINGS PER UNIT OF EFFORT LPUE

At the level of the Belgian fleet, the total number of days spent at sea has decreased from approximately 91,800 days in 1938 to 15,100 days in 2010 (-84%: Figure 9.5 second panel from below). Trends in productivity can be expressed in terms of fishing effort: landings per day at sea or per fishing day, landings per fishing hour FH, or per kW*FH. The total landings decreased with total fleet size (number of vessels), with total fishing effort (days at sea and days fishing) and with kW*FH. Interestingly, the average price of landings (all species, all areas, all fisheries aggregated) is negatively correlated with the decreasing fishing effort and decrease in overall landings. This suggests that the Belgian sea fisheries compensated for the losses by targeting species that achieve better prices in the market (Figure 9.6. second panel from above; Figure 9.9).

Trends in productivity can also be expressed in terms of fishing effort per vessel. Changes at this level are generally perceived by individual fishers and crews, over decades (Saenz-Arroyo et al. 2005). Fishing crews spent on average 88% of the days at sea as effectual fishing days, with a minimum of 79% in 1963-64 when the distant Iceland fisheries were at their peak effort. A vessel spent on average 171 days per year at sea. During WWII, when fishing was only allowed during daytime breaks and in coastal waters, a day spent at sea was actually spent fishing. Expressed as landings (kg) per vessel per day at sea or per day fishing, the average amount has doubled from approximately 400kg in 1938 to 1,000kg in 2010 (Figure 5.7., Chapter 5). At least 4 successive events or periods are observed. The first event (1939-1945) is marked by WWII and the increased landings of herring in coastal waters. The exceptionally high landings per unit of effort are partly explained by the cessation of large-scale herring fisheries in the North Sea during WWII combined with the effects of two strong year classes (Chapter 7). The second period is situated in 1951-1955 and coincides with the steep increase in landings from Icelandic waters. Thirdly, an increase in landings is observed between 1960 and 1967, which largely coincides with the state subsidies to introduce the beam trawl firstly in shrimp vessels (1959-1960) and later for flatfish fisheries. A final conspicuous increase concerns the period of increased levels of landings per vessel per day between 1977 and 1986. The trend in landings (t) per vessel (Figure 9.5., central panel) largely confirms this, and shows an additional period of sustained increases in the early 2000s.

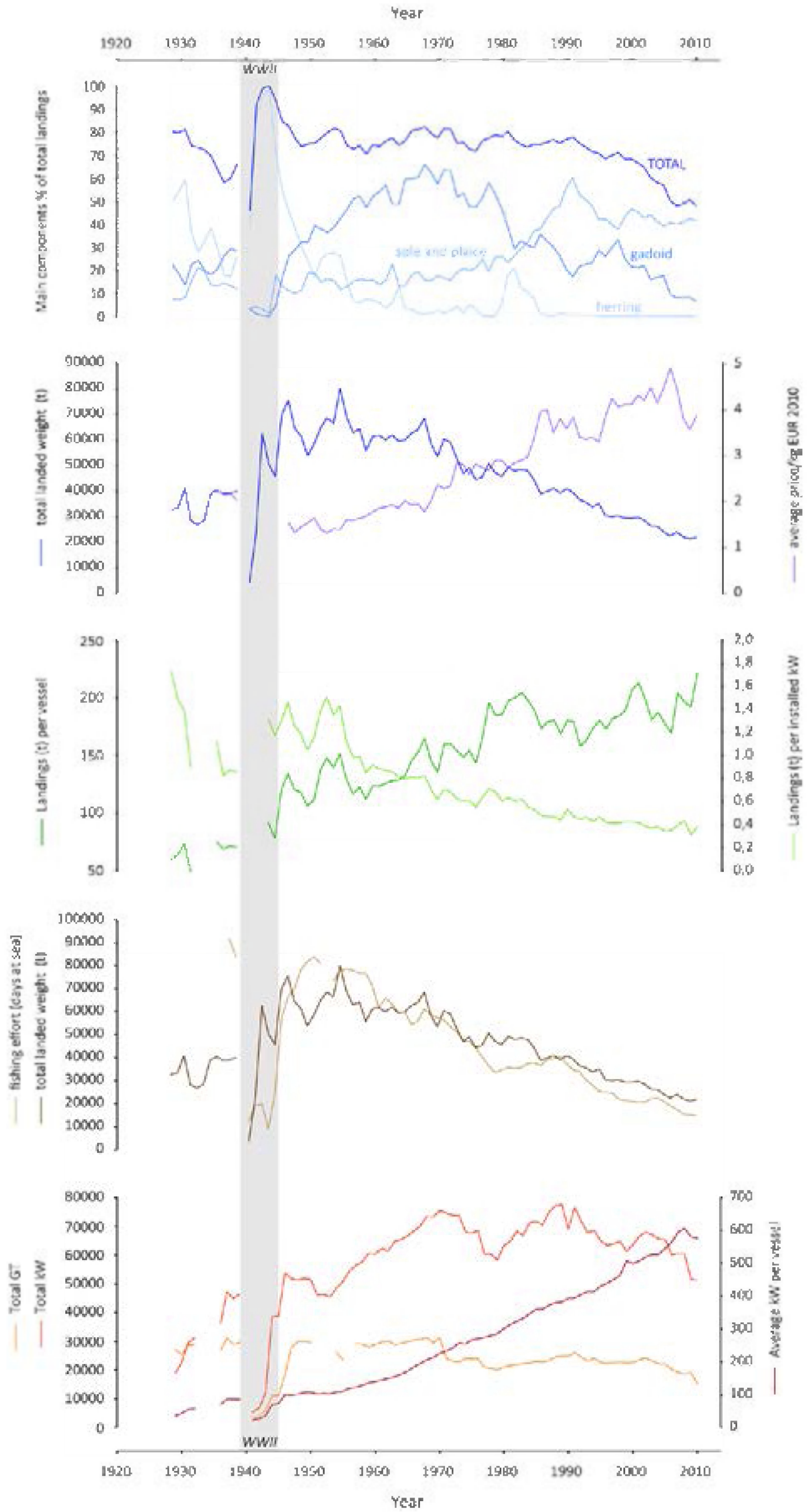


Figure 9.5.: Overview of the main trends in Belgian sea fisheries 1920-2010: fleet dynamics (GT, kW, average kW per vessel, see lower panel), fishing effort (days at sea) versus overall landings (t) (second panel from below), landings per vessel and per installed unit of engine power (kW) (central panel), average price (Euro/kg) expressed as values 2010 corrected for inflation, second panel from above), proportion of landings (%) for the 3 main components of target species.
(drawing T. Verleye)

9.3.5. Landings per unit of power LPUP

The annual landings per operational unit of the fleet (vessel) increased from 119 t per year in 1946 to 220 t per year in 2010 (Figure 9.5. central panel). However, if expressed as LPUP to account for the average increase (x6) of engine power per vessel, the landings have decreased by 74% from an average 1,3 t /installed kW in 1944-1947 to 0,38 t /installed kW in 2009-2010 (Figure 9.5. central panel).

When normalized for installed unit of engine power (kW), only the first peaks in increased landings per vessel referring to WWII and the Iceland fisheries are visible, suggesting that the peaks in landings per vessel are explained as the effect of increasingly powerful vessels (see Chapter 5 on Fleet dynamics, Fig. 7.5. central panel). Again, from the vessel or crews' perspective, the landings per vessel will be perceived as real changes and shifts, whereas the changes in LPUP may go unnoticed except for the vessel owner who invested in additional engine power or received state subsidies to do so.

The historical reconstruction presented here does not take into account other relevant enabling technologies that significantly enhanced fishing power, and that are commonly referred to as 'technological creep'. Marchal et al. (2003) estimated an annual increase in catchability as a consequence of 'technological creep' of up to 10% in North Sea surveys, while Rijnsdorp et al. (1996) reported an annual increase of 1.8-2.6% in beam trawl fisheries for sole and plaice in the North Sea.

Although the LPUP are illustrative of the changes in the productivity of fisheries, they can not be interpreted as a proxy of change in biomass of commercial fish stocks, because the Belgian fisheries have targeted different species and fishing areas over time (Figure 9.3. and 7.4.). Trend analysis to study change in fish stocks must be conducted at the level of different métiers or fisheries, taking into account issues such as specificity and selectivity of gear, environmental conditions in the targeted fishing area, seasonality of fishing and behavior of target species.

9.3.6. Impact of fisheries and change in fish stocks

In Chapter 6 of the present thesis, a closer look is taken at the impact of sea fisheries. In a first part, a quantitative approach is taken to reconstruct total removals by Belgian sea fisheries by including the unreported and misreported landings of commercial and recreational fishing, as well as an estimation of discards. This reconstruction covers 6 fisheries with historical or current importance for Belgium (Lescrauwaet et al. 2013). Total reconstructed removals were estimated at 5.2 million t or 42% higher than the 3.7 million t publicly reported over this period. Unreported landings and discards were estimated to represent respectively 3.5% (0.2 million t) and 26% (1.3 million t) of these total reconstructed removals.

Chapter 7 brings an analysis of the exceptional situation of sea fisheries in Belgium during WWII (1939-1945) when unusually high landings of herring (*Clupea harengus*) were achieved under restricted fishing conditions. The data presented in the context of this thesis show a 10-fold increase in the Belgian 'autumn spawning herring' catches and a 5-fold increase in landings per unit of effort of Downs herring during WWII. It is argued that these increased catches are explained by a combination of factors including the sustained effect of a major increase in catch power, the effects of strong pre-WWII year classes and the effects of decreased fishing mortality during the 6-years cessation in fishing on the herring feeding grounds in the central North Sea and in the English Channel (Lescrauwaet et al. revised manuscript under review).
A third subchapter focuses on the otter trawl fishery in Icelandic waters targeting cod. This fishery was of great economic importance in Belgium but decreased with the 'cod wars' (1958 and 1972) coming finally to a complete end in 1996. While the decline in total landings from Icelandic waters started after Iceland expanded its EEZ in 1958, the fishing effort of the Belgian fleet continued to increase until a peak was reached in 1963. The reconstructed time-series on Belgian commercial fisheries landings and fishing effort include information

on vessel type and fishing rectangle. The results show that the decline in the Iceland cod stock was visible at different levels; the decrease in the proportional importance of cod in the overall landings, the 75% decrease in the LPUE (1946-1983), the decline in the proportion of 'large' fishes, and finally the decline or shift in the definition of a 'large' specimen. The three cases analysed in Chapter 6 document substantial changes in LPUE for specific fisheries, or in targeted stock biomass.

9.3.7. Belgian part of the North Sea

As a result of this thesis, unique data are presented on the trends in volume and composition of landings for the Belgian part of the North Sea (BNS). Since the Middle Ages, Flemish fisheries have targeted a variety of fishing grounds, many of which were distant fishing areas (Faroer, Iceland, White Sea, Labrador, etc., Chapter 2-4). Still, in spite of its limited extension, the BNS has been historically the most important fishing area for Belgian fisheries, representing over 20% of the total Belgian landings (Lescrauwaet et al. 2010a). The waters of the BNS are considered as the most important fishing area in terms of source of food for local population, but also as the most stable provider of food (Chapter 4). The BNS and in particular the ecosystem of shallow underwater sandbanks is also important as (post)spawning and nursery area (Leloup and Gilis 1961, Gilis 1961, Leloup and Gilis 1965, Rabaut et al. 2007). The data also suggest that since the 2000s, approximately 50% of all Belgian removals from the BNS are unreported landings and discards (IUU) and total fish discarded by the Belgian fisheries on the BNS may range between 30-40% of all Belgian landings from the BNS. These numbers do not take into account the non-commercial benthic species and the catches by the French and Dutch fleets that also have a long-standing tradition of fishing in the BNS (Depestele et al. 2011).

Commercial catch per unit of effort (CPUE) - and its variant LPUE - is widely used as an index of abundance of fish, although the factors that may potentially bias this index are well documented and the index may be less suitable for pelagic species that display schooling behaviour (Hilborn and Walters 1992). The index needs to be used for specific métiers and particular fishing areas, in order to be interpreted as a relative index of abundance. This analysis is conducted for the demersal fisheries in the BNS, targeting mainly flatfish. Similar as for the overall Belgian sea fisheries, the time-series for LPUE of the demersal (flatfish) fisheries shows a period of higher LPUE just after WWII, with a decrease of 50% in the decade after WWII, suggesting a decrease in biomass of targeted species (Figure 9.6., Lescrauwaet et al. in prep.).

From the beginning of the 1960s until 1967, in the period coinciding with the transition from the otter trawl to the more efficient beam trawl and an increase in fishing effort, the LPUE remain around 0.35 kg/HP*Fishing Hour with a slight increase to 0.4 kg/HP*FH in 1967. During the 1970s the fishing effort increases, however the LPUE remains at lower levels (0.15-0.25 kg/HP*FH). As a reference, the analysis conducted for the Belgian fisheries in Iceland, indicated that LPUE values decreased from 0.95 kg/HP*FH in 1946 to 0.24kg/HP*FH in 1983.

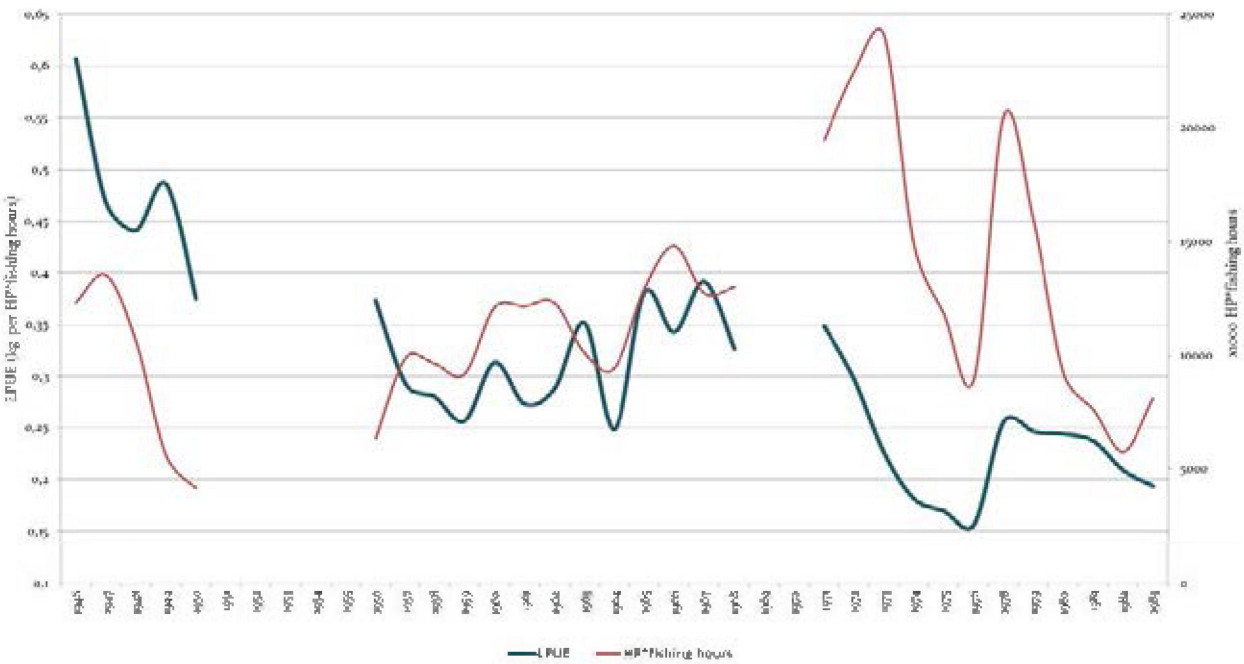


Figure 9.6.: Landings per unit of effort (kg/kW*fishing hour), left-hand axis and total fishing effort (kW*fishing hours) by the demersal trawl fisheries on the Belgian part of the North Sea, 1946-1983.

9.4. Historical time series and policy relevance in support of policy objectives and targets

9.4.1. Historical time-series in support of fisheries policies

Awareness on the shifts in perception of the status of stocks or the health of marine ecosystems has influenced current marine ecological research and its methods and assumptions (McClenachan et al. 2012).Historical baselines are extremely valuable as reference conditions for marine ecosystems, to assess their status and set goals for sustainable management. This is particularly true for fish populations and commercial fish stocks that have long been exploited and the baselines for rebuilding depleted fish stocks typically refer to strongly exploited situations (Pitcher 2001). There is now on-going research to reconstruct and study reference conditions or historical baselines that date from before the onset of industrial or large-scale intensive fishing practices (Pauly 1995, Rijnsdorp et al. 1996, Roberts 2007, Pinnegar and Engelhard 2008, Cardinale et al. 2009). Evidence is available about the shift in the 'centre of gravity' of the main commercial fish stocks over the last 80-90 decades (Pinnegar et al. 2010, Kerby et al. 2013). Although some of these shifts may be (partly) due to climate change, it is not possible to exclude fisheries and modifications in habitat and trophic structure as a factor influencing these shifts. New fisheries have developed for a number of warmer-water species including seabass, red mullet, anchovy and squid (Pinnegar et al. 2010).

Landings from commercial fisheries were used in a number of applications and models and can be accepted as a proxy for fishing mortality (Daan et al. 1994, Walker and Heessen 1996, Zeller and Pauly 2007, Eero et al. 2008). Landing statistics served as a basis for analyses conducted in the present thesis focusing e.g. on estimating the historical losses of valuable resources through the IUU in Belgian fisheries (Chapter 6) or exploring the potential yield of fish stocks under different, lower intensities of exploitation (e.g. Downs herring, Lescrauwaet et al. revised manuscript under review, Chapter 7). Of particular interest are the datasets in which landings are reported in conjunction with fishing effort for particular segments of the fleet, fisheries type, high temporal and spatial resolution, as was the case of Iceland (cod) fisheries. In the two latter cases, the reconstructed data contributed with new knowledge for a period in which a gap exists in the current time-series for the stock assessments (Downs herring and Iceland cod) or information on spatial components of fish stocks that were 'lost' (Downs herring).

The historical time-series for the Belgian sea fisheries can further contribute to local fisheries management and the fisheries policy targets through:

- Reconstruction of historical LPUE to support recovery or management plans for fisheries practiced in the past (e.g. *Nephrops* fisheries).
- Analysis of deployed gear and fishing effort in the past
- Documenting and estimating technological adaptations of the fleet and fishing techniques through time
- (Re)utilization of 'forgotten' fishing gear and fishing techniques
- Seasonality in historical occurrence, distribution and abundance of target species
- Proportional importance of landings by weight classes and reconstruction of historical weight classes of target species
- Descriptive historical statistics of 'Coastal fisheries' in Belgian waters and their relative importance in the past
- Estimates of historical and current unreported and recreational fisheries on the BNS and in other fishing areas, as an unaccounted component in EU quota and stock management. In particular the catches of plaice and sole on the BNS.
- Literature references and metadata for current fisheries research e.g.
    - Qualitative reference conditions for species for which no formal assessments are available such as brill and turbot).
    - Historical references on discard rates for current or future management measures

Efforts to expand assessments further back in time by analyzing historical biological material such as otoliths and bones, have yielded crucial insights in patterns of fishing and exploitation of fish stocks (Barrett et al. 2011, Orton et al. 2011).

Fishing with improved technologies

An important aspect in reconstructing historical fishing effort and catch rates is the adaptation of new technologies to improve efficiency of fishing ('technological creep'). There is evidence that the efficiency of fishing vessels has increased through technological creep (see Marchal et al. 2007 for a review). Fishing effort is estimated by combining available physical measurements of fishing capacity (fixed production inputs) and fishing activity (variable production inputs). Fishing capacity is generally measured as a physical attribute of the operating vessel (engine power, gross tonnage), but is also dependent on other factors, including gear technology and on-board equipment, which are often ignored (Marchal et al. 2007). The introduction of new gear and technology includes new inventions such as acoustic fish-finding equipment, electronic navigation tools, but also refers to smaller and gradual improvements to the gear e.g. different netting materials and changes in the design of the nets or trawling devices. Although the latter may go unnoticed in the reporting on fishing capacity, they may cause a significant increase in fishing capacity over time. Fishing activity is typically estimated by the duration of fishing trips, therefore not taking into account important factors that define fishing pressure such as the number and the sizes of gear deployed, or the effective time used for fishing (Marchal et al. 2007). Marchal et al. (2003) estimated an annual increase in catchability of up to 10% as a consequence of 'technological creep', in North Sea surveys, while Rijnsdorp et al. (1996) reported an annual increase of 1.8-2.6% in beam trawl fisheries for sole and plaice in the North Sea. For the case of the Belgian

fleet, an important example of technological creep is the introduction of tickler chains rigged in the net-mouth (Polet et al. 1998).
Studies to evaluate time variations in fishing efficiency while taking into account the processes of technological creep in the analysis of CPUE, are often restricted by data availability. Historical data on fishing capacity of the commercial fleet are typically collected from vessels' logbooks. Although this includes information on engine power, vessel length, and/or gross tonnage, historical sources may contain other descriptors of fishing effort that are often overlooked (gear type, duration of tow, length of net used per day, crew size). Adjusting the estimates of changes in fishing effort by taking into account technological improvements and changes in the deployment of gear - based on these historical descriptors – can help improve the assessments of change in fishing capacity, in CPUE estimates and therefore improve (stock) assessments.

9.4.2. HISTORICAL TIME-SERIES IN SUPPORT OF ENVIRONMENTAL POLICIES

Current needs for a sustainable management of our coasts and seas have to deal with a number of uncertainties and knowledge gaps. To judge properly these uncertainties, long-term series and historical data are crucial. By rescuing and integrating time-series for policy-relevant datasets, research outcomes can inform about the condition of the North Sea in the past and relate these changing conditions with long-term changes in fishery, in fish assemblages and other ecosystem components (benthic species, pelagic species). Long-term or historical time-series allow the development of instruments in support of policies for the sustainable development and management of the North Sea and enhance our knowledge and understanding of changes in the diversity, distribution and abundance of fish and targeted benthic species (in fishery), the changes in fishing effort and their socio-economic and environmental implications.

From an ecosystem perspective, historical information is valuable in the context of the GES targets as set forward for the descriptors on fish stocks and biodiversity in the MSFD (2008/56/EG). The MSFD is the cornerstone of marine environmental policy within the EU Integrated Maritime Policy, and aims to establish and ecosystem-based approach in management of the EU marine waters. It also aims to strengthen the environmental targets and objectives as set forward in other EU policies for coasts and seas (MSP and ICM, Habitat directive, WFD, CFP), support the objectives of the CFP (managing fish stocks at levels above maximum sustainable yield MSY), and to achieve a favourable conservation status FCS for the species and habitats protected in marine and coastal Natura 2000 sites.

In spite of the remaining gaps and uncertainties, historical time-series, and in particular the data for the BNS, can support the wider debate about the role of small-scale fisheries, about how to move to more sustainable fisheries, how to achieve the agreed policy targets in Belgian marine waters and in particular in the marine areas protected under the EU Habitat and Bird directives.

The contribution of historical time-series has also proven valuable for environmental policies, specifically by means of:

- Information on the shift in distribution of species to different latitudinal and depth ranges in response to changes in environmental parameters (e.g. cod, whiting).
- Historical catches of 'southern' species. Examples are developed in the HiFiDatabase for
    - *Trachinus draco* – Greater weever
    - *Chelidonichthys lucerna* – Tub gurnard
    - *Dicentrarchus labrax* – European sea bass
    - *Sepia officinalis* - cuttlefish
- Predictive studies on the impact of climate change

- (commercial) extinction of fish and other species, and the recovery thereof (e.g. sturgeon) changes in local abundance of non-target species (Greater weever).
- Data on non-endemic species(e.g. *Micropogonias undulatus*)
- Trends in biodiversity indicators

9.4.3. Historical time series in other fields of application

The results of the reconstruction of historical time-series in the present thesis focus on the dynamics of the sea fisheries fleet, trends in volume and composition of landings and parameters related to the output per unit of effort. However, though far from being exhaustive, in this reconstruction effort also other types of data and information were collected and integrated as time-series. These data cover different fields of socio-cultural and societal aspects such as employment in fisheries, age structure of the fishers population, population of fishers by function (skipper, mechanic, sailor,...), number of students in educational institutions for the maritime and fisheries sectors etc. Examples on the historical employment in fisheries are included below, (Figure 9.7 and Figure 9.8.)

Very little work is, e.g., conducted on the socio-economic effects of environmental changes and climate change on the fisheries. In fishing communities where strong traditions persist to use particular fishing gear and target specific - economically interesting - species, these studies are needed. This is of particular importance in communities that depend on species that are directly affected in their distribution and abundance by these environmental changes, e.g. the effect of ocean acidification on molluscs. Historical time-series may offer new perspectives by illustrating or re-discovering forgotten fishing traditions, gear and target species, and their economic potential.

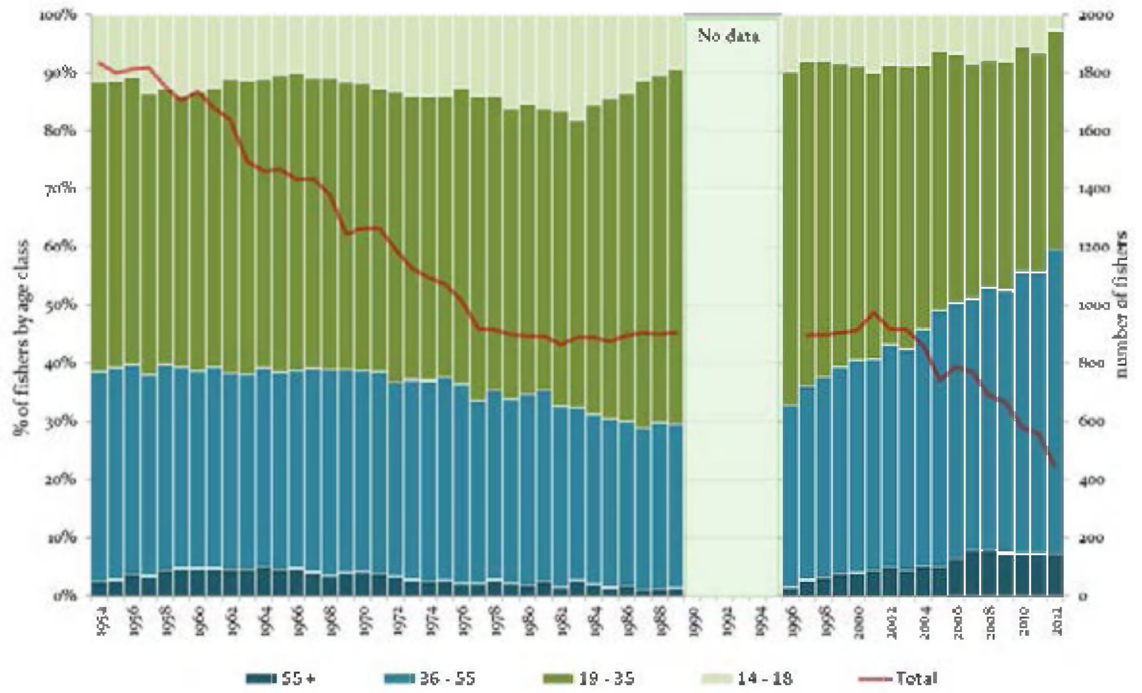


Figure 9.7.: Direct employment in fisheries in Belgium: absolute number of fishers, and proportion by age class, 1954-2012.

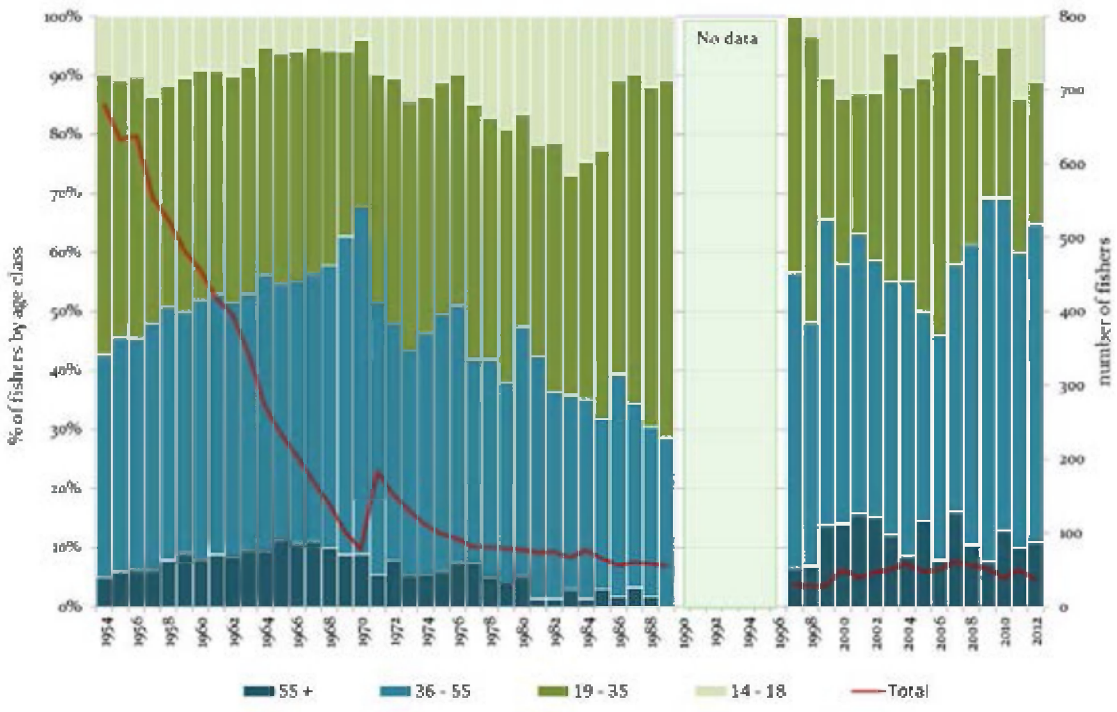


Figure 9.8.: Direct employment in coastal fisheries in Belgium: absolute number of coastal fishers, and proportion by age class, 1954-2012. Note: The sudden increase of coastal fisheries in 1971 is largely due to the change in the definition of 'coastal fisheries'. Whereas this contained the vessel classes I and II (up to 120HP) before 1971, it was modified to contain all vessels smaller than 35GT in 1971 and later expanded to vessels with engine power <221kW and 70GT that conduct fishing trips of 24 hours maximum (recently expanded to 48 hours)

Historical time-series such as landings and catches or fleet parameters can also serve as the basis for the estimation of historical baselines by involving diversity of sources and data (surveys, oral history and interviews, historical population data, fish consumption etc.). In this sense, the results of the reconstruction of time-series of landings were used in a local Belgian project to reconstruct historical ecology of the Belgian part of the North Sea and the Southern North Sea from 1930-1980, through interviews with elder fishermen (Project "Yesterday's Sea"). The HiFiDatabase also served as reference material in the efforts the valorize Local Ecological Knowledge of fishermen on the historical ecology of the Belgian part of the North Sea (LECOFISH project).

Other historical time-series and parameters that were reconstructed for Belgian sea fisheries at the same spatial, temporal and taxonomic resolution as for the landings, are the economic data associated to the commercial landings (total value, price per kg) (Table 9.2.). This data is available for further socio-economic research and applications.

The example included below shows how average price per kg (corrected for inflation) of the commercial fisheries (all species, all fisheries, all fishing areas aggregated) has continuously increased. It illustrates how, in spite of the decrease in landings, Belgian fisheries compensated for the losses by increasingly targeting economically more valuable species.

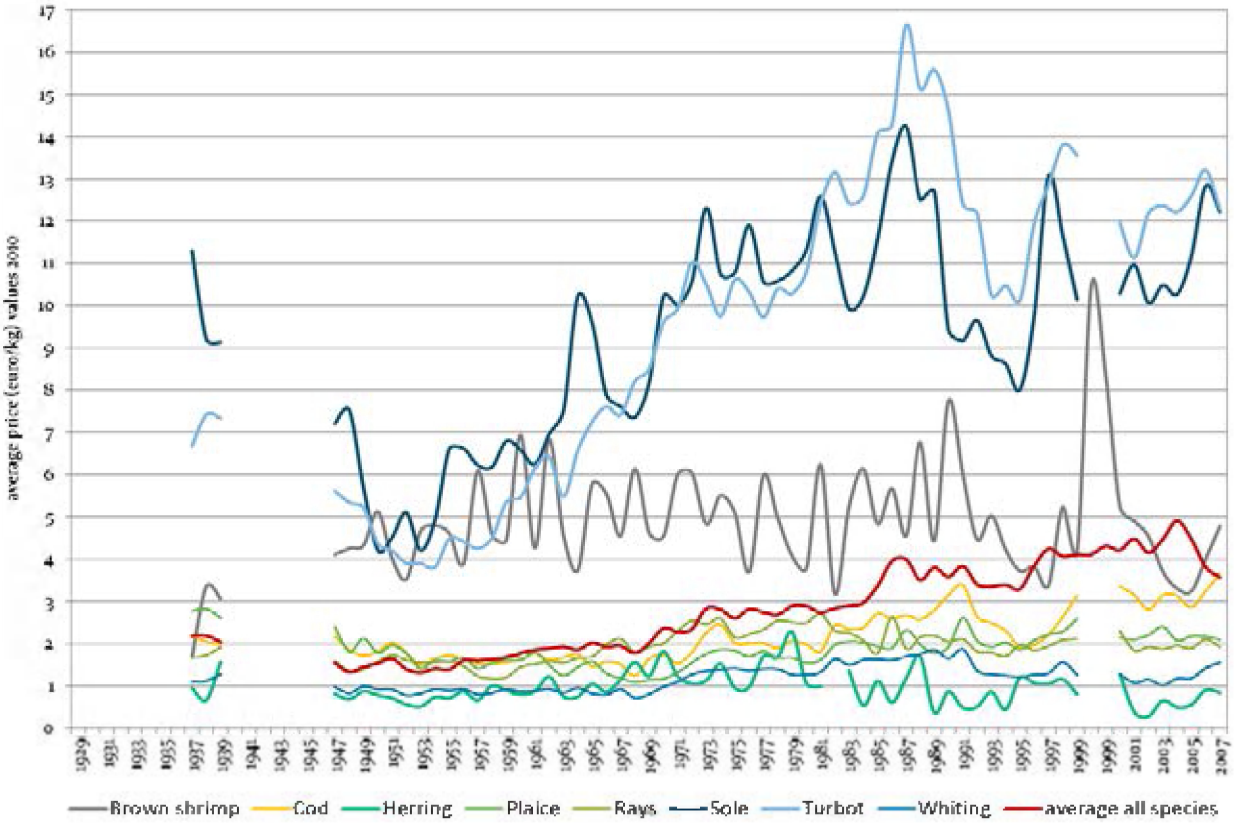


Figure 9.9.: Average price (euro/kg, prices corrected for inflation expressed as values 2010) of total commercial landings, and prices for the most important species in terms of landings or income, Belgian sea fisheries.

9.5. CONCLUSIONS AND OUTLOOK

The purpose of the present thesis is - as a first step - to reconstruct time-series in the Belgian Sea Fisheries based on standardized quantitative parameters in terms of input (fleet, effort) and output (landings, economic value), and explore trends in these parameters trends over one century.

The results of the current efforts to reconstruct these time-series are described in Chapter 2 and 3, and the strengths and weaknesses of the overall database are summarized in Table 9.1. The usefulness of the HiFiDatabase is commented in Chapter 2, and an overview of applications and uses of the HiFiDatabase is included (Appendices).

Next steps and priorities in data integration and analysis include:

- Conduct trend analysis (landings, effort, LPUE) by type of fisheries (métier) and by fishing area of origin at the highest temporal, spatial and taxonomic resolution. Where available, the analysis can be expanded with landings by weight class and improved by taking into account the impact of technological improvements in LPUE estimates..
- Collect evidence and indications to improve the present historical estimates of IUU in Belgian sea fisheries, and improved estimates to complement the current landing statistics (e.g. on sea angling).

- Explore the relevance of collected data, in combination with other time series, for further use in policy making, i.a.:
    - for the description of historical baselines for the Belgian part of the North sea and the wider North Sea area;
    - for inferences related to trophic level of sea fisheries, and for validating or challenging the concept of fishing down the food web (Pauly et al. 1998) in the context of Belgian fisheries.
- Explore with neighbouring countries (The Netherlands, UK, France), the feasibility of reconstructing historical fishing effort and an analysis of flatfish fisheries (sole and plaice) in the otter and beam trawl fisheries in the North Sea: integrating fishing effort, market drivers (including oil prices), policy drivers, and landing statistics (by month, by rectangle, by weight class), and introduction of new technologies;
- Explore with neighbouring countries (The Netherlands, France, UK) the reconstruction of reported and unreported removals (which include discards) in the Belgian coastal waters by the foreign fleet, to obtain an improved assessment of the cumulative impact of fisheries on the BNS.

The reconstructed time-series underline the decline in landings since the start of systematic reporting and quantify the patterns of successive exploitation of target species and fishing areas by the Belgian sea fisheries, changes in species composition and origin of landing, changes in the fleet and vessel characteristics. By integrating the different parameters, general indices were reconstructed that describe the Belgian fisheries in terms of spatial dynamics, sustainability (tkm of catch), diversity of composition (Hill indices of diversity, Chapter 4), fleet dynamics (Chapter 5), LPUE, LPUP.

In a second step, indicators of the impact of fisheries, both on the targeted commercial fish stocks as on other marine resources were reconstructed from some of these long-term data series. By means of specific cases, the concept of 'shifting baselines' was applied in Belgian sea fisheries for important fishing métiers: the spent herring fisheries (1930-1960) and the cod fisheries in Iceland (1947-1996). A historical reconstruction of the IUU for Belgian sea fisheries was conducted for the period 1929-2010 and an estimate of the current unreported fisheries catches on the BNS provided. Again here, the historical time-series demonstrate the profound changes in fishing and in fish stocks, over the last ten decades (Chapter 6, 7 and 8).

The impact of fisheries on the marine biodiversity and on the marine ecosystem functioning is a key concern in marine conservation strategies, especially in areas where fisheries with traditional high-impact are or have been practiced, e.g. shrimp fisheries, *Nephrops* fisheries, beam trawl fisheries. The HiFiDatabase broadens the historical view on fisheries, underlines the decline in landings since reporting started, and serves as a basis for further (fisheries) research, management applications, and policy-making. In particular, the time-series provide unique historical reference conditions of fishing in the Belgian part of the North Sea and a potential baseline for fisheries management in the territorial sea or for the coastal fisheries. The latter is useful in the context of the MSFD and the proposal for Maritime Spatial Planning on the Belgian part of the North Sea.

Particular attention should be drawn to the case of the unreported removals of fish in the BNS. Discarding on the BNS (Chapter 6) represents a substantial waste of resources, is unacceptable from a perspective of environmental impact and sustainable management and is to be considered unethical from a societal viewpoint. The data presented here provide a first assessment of IUU on the BNS and suggest that besides the discards from commercial fishing operations, the recreational fisheries are taking important proportions. Currently, the impacts of the recreational fleet are not taken into account in fisheries or environmental management. In spite of the small vessel size, these impacts nevertheless may be quite substantial due to the employed gear (trawls) and the size of the fleet. Furthermore, from the point of view of ensuring safe

and secure jobs, the recreational fisheries represent unaddressed challenges. Urgently, ways must be explored to include the activities and impacts of the recreational fleet in current fisheries and environmental management schemes for the BNS, while looking at specific measures that can stimulate the development of small-scale low-impact fishing activities on the BNS that are economically viable for professional fishermen.

However, the results of the data aim to reach beyond informing and supporting fishery and environmental research and policies. It is expected that the data, time-series and trends presented in this thesis, may lead to a greater awareness about the profound changes that have taken place in marine ecosystems, and the effects of humans on the marine ecosystems. At the same time, the data aim to elucidate how unregulated activities or activities that are not supported by sound science and following an ecosystem-based approach, are affecting our environment, and opportunities for jobs and income. It is aimed that the results of the thesis work are used in a wider range of educational activities and outreach.

Finally, in the present thesis work, important efforts were dedicated to approach the history of fisheries from different disciplines of work. The results underline the importance of collecting economic data, inventorying historical archives and historical legislation, historical economy and politics, in order to improve the interpretation and analysis of results. In this way, the present thesis work hopes to have contributed to the need for integrated approaches in marine sciences. As advocated by the current integrated policies for the marine environment, both the challenge of the task and the richness of the results rely on a multidisciplinary approach.

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Personal Communications

Mr. Eddy Tessens. Dienst Zeevisserij, Departement Landbouw en Visserij, Vlaamse Overheid.

Mr. Eric Hiele. Dienst Scheepvaartcontrole, FOD Mobiliteit. June 2012

Mr. Jozef Depreeuw, statistical officer at the Fisheries Services and former National Institute for Statistics NIS, between 1953-1975). Interview December 2011.

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APPENDIX I

List of publications Ann-Katrien Lescrauwaet in the context of the present thesis

Peer-reviewed publications

Lescrauwaet, A.-K.; Debergh, H.; Vincx, M.; Mees, J. 2010. Historical marine fisheries data for Belgium: Data sources, data management and data integration related to the reconstruction of historical time-series of marine fisheries landings for Belgium. *Fisheries Centre Working Paper Series*, 2010-08. University of British Columbia: Vancouver. 69 pp., meer

Lescrauwaet, A.-K.; Debergh, H.; Vincx, M.; Mees, J. 2010. Fishing in the past: Historical data on sea fisheries landings in Belgium *Mar. Policy 34(6)*: 1279-1289. dx.doi.org/10.1016/j.marpol.2010.05.006, meer

Lescrauwaet, A.-K.; Fockedey, N.; Debergh, H.; Vincx, M.; Mees, J. 2012. Hundred and eighty years of fleet dynamics in the Belgian sea fisheries *Rev. Fish Biol. Fish. Online first*: 15 pp. hdl.handle.net/10.1007/s11160-012-9287-1, meer

Chapter 6 accepted for publication as:

Lescrauwaet, A.-K., Torreele,' E., Vincx,' M., Polet, H. and Mees, J. accepted. Invisible Catch: A Century of bycatch and unreported removals in Sea Fisheries, Belgium 1929-2010. Fisheries Research. 2013. 10.1016/j.fishres.2013.05.007

Subchapter 7 included as revised manuscript currently under review:

Lescrauwaet, A.-K., De Raedemaecker, F., Vincx, M., and Mees, J. revised manuscript currently under review. Flooded by herring: Downs herring fisheries in the Southern North Sea during World War II. ICES Journal of Marine Science.

Subchapter 8 is included as manuscript currently under review:

Lescrauwaet, A.-K., Vincx,' M., Vanaverbeke, J. and Mees, J. manuscript currently under review. In Cod we trust: Trends in Cod and gadoid Fisheries in Iceland 1929-1996. Canadian Journal of Fisheries and Aquatic Sciences.

Conference Proceedings, Abstracts and Conference presentations

Oral presentation. History of marine Animal Populations. HMAP Conference. November 18-20, 2010. Trinity College, Dublin, Ireland.

ICES SGHIST. Report of the Study Group on the History of Fish and Fisheries. 24-27 October 2011. CEFAS. Lowestoft, UK. ICES CM 2011/SSGSUE:11. 36 p. Contribution to the Report and Oral presentation.

ICES WGHIST. 2012. Report of the Working Group on the History of Fish and Fisheries (WGHIST). 5-7 September 2012, Oostend, Belgium ICES CM 2012/SSGSUE:12. 19 pp. Oral presentation and Organiser of the event, as co-chair of the Working group.

VLIZ Special publications and Information Sheets

Lescrauwaet, A.-K.; Debergh, H.; De Hauwere, N.; Vanhoorne, B.; Lyssens, L. 2009. Een eeuw zeevisserij in België: Handleiding bij de standaardisering en geografische afbakening van de historische visgronden (1929-1999) in de Belgische zeevisserijstatistieken. *VLIZ Information Sheets*, 249. Vlaams Instituut voor de Zee (VLIZ): Oostende. 14 pp., meer

Lescrauwaet, A.-K.; Debergh, H.; De Hauwere, N.; Vanhoorne, B.; Lyssens, L. 2009. A century of sea fisheries in Belgium: Manual for standardization and geographical delineation of historical fishing grounds in Belgian sea fisheries statistics (1929-1999). *VLIZ Information Sheets*, 248. Flanders Marine Institute (VLIZ): Oostende. 14 pp., meer

Lescrauwaet, A.-K.; Debergh, H.; Behiels, S.; Hernandez, F.; Mees, J. 2008. Belgian sea fisheries statistics: compiling historical data to recover a wider perspective, ***in***: Mees, J. *et al.* (Ed.) 2008. *VLIZ Young Scientists' Day, Brugge, Belgium, 29 February 2008: book of abstracts. VLIZ Special Publication,* 40: pp. 55, meer

Lescrauwaet, A.-K.; Debergh, H.; Scholaert, A.; Mees, J. 2011. Herring - *Clupea harengus*. A Century of Sea Fisheries in Belgium. *VLIZ Information Sheets*, 295. Vlaams Instituut voor de Zee (VLIZ): Oostende. 14 pp., meer

Haspeslagh, J.; **Lescrauwaet, A.-K.** 2011. "Aen alle tegenwoordigen en toekomenden, Salut": markante visserijwetgeving, ***in***: Lescrauwaet, A.-K. *et al.* (Ed.) (2011). *Abstractenboek studiedag "Vissen in het verleden. Een multidisciplinaire kijk op de geschiedenis van de Belgische zeevisserij". VLIZ Special Publication,* 54: pp. 42-47, meer

Lescrauwaet, A.-K.; Debergh, H.; Hernandez, F.; Mees, J. 2009. Belgian sea fisheries: compiling historical fisheries data, *in*: Mees, J. *et al.* (Ed.) (2009). *VLIZ Young Scientists' Day, Brugge, Belgium 6 March 2009: book of abstracts. VLIZ Special Publication,* 41: pp. 53, meer

Lescrauwaet, A.-K.; Fockedey, N.; Scholaert, A.; Debergh, H.; Lyssens, L. 2010. Een eeuw zeevisserij in België: Leeswijzer Belgische vissersvloot. *VLIZ Information Sheets*, 247. Vlaams Instituut voor de Zee (VLIZ): Oostende. 8 pp., meer

Lescrauwaet, A.-K.; Fockedey, N.; Scholaert, A.; Debergh, H.; Lyssens, L. 2010c. A Century of Sea Fisheries in Belgium: Users' guide to the reconstruction of the Belgian fishing fleet history. *VLIZ Information Sheets*, 246. Vlaams Instituut voor de Zee (VLIZ): Oostende. 8 pp., meer

Lescrauwaet, A.-K.; Debergh, H.; Mees, J. 2011. Een eeuw zeevisserijstatistieken: hoe ver reikt ons geheugen?, *in*: Lescrauwaet, A.-K. *et al.* (Ed.) (2011). *Abstractenboek studiedag "Vissen in het verleden. Een multidisciplinaire kijk op de geschiedenis van de Belgische zeevisserij". VLIZ Special Publication,* 54: pp. 90-96, meer

Lescrauwaet, A.-K.; Fockedey, N.; Scholaert, A.; Debergh, H.; Lyssens, L. 2011. Een eeuw zeevisserij in België: Leeswijzer Belgische vissersvloot. Versie december 2011. *VLIZ Information Sheets*, 247. Vlaams Instituut voor de Zee (VLIZ): Oostende. 9 pp., meer

Lescrauwaet, A.-K.; Debergh, H.; Scholaert, A.; Mees, J. 2011. Atlantische kabeljauw - *Gadus morhua*. Een eeuw zeevisserij in België. *VLIZ Information Sheets*, 215. Vlaams Instituut voor de Zee (VLIZ): Oostende. 12 pp., meer

Lescrauwaet, A.-K.; Debergh, H.; Ervynck, A.; Fockedey, N.; Pieters, M.; Seys, J.; Mees, J. (Ed.) (2011). Abstractenboek studiedag "Vissen in het verleden. Een multidisciplinaire kijk op de geschiedenis van de Belgische zeevisserij". *VLIZ Special Publication*, 54. Vlaams Instituut voor de Zee (VLIZ): Oostende. ISBN 978-90-817451-5-4. 112 pp., meer

Roegiers, B.; Platteau, J.; Van Bogaert, T.; Van Gijseghem, D.; Bekaert, K.; De Bruyne, S.; Delbare, D.; Depestele, J.; **Lescrauwaet, A.-K**.; Moreau, K.; Polet, H.; Robbens, J.; Vandamme, S.; Van Hoey, G.; Verschueren, B. (2013). VIRA Visserijrapport 2012 Departement Landbouw en Visserij: Brussel. 98 pp.

Other publications, presentations and public dissemination

Lescrauwaet, A.-K.; Vanhoorne, B.; Scholaert, A.; Lyssens, L.; De Hauwere, N.; Hernandez, F.; Mees, J. (2010). Fishing in the past: Historical data and information on sea fisheries in Belgium [PPT Presentation]. Flanders Marine Institute (VLIZ): Oostende. 23 slides pp., meer

Lescrauwaet, A.-K.; Debergh, H. (2009). Een kilo visserijstatistieken alstublieft *De Grote Rede 25*: 16-22, meer

Lescrauwaet, A.-K.; Debergh, H. (2009). Een kilo visserijstatistieken a.u.b.[PPT Presentatie]. Vlaams Instituut voor de Zee (VLIZ): Oostende. 29 slides pp., meer

Roegiers, B.; Platteau, J.; Van Bogaert, T.; Van Gijseghem, D.; Bekaert, K.; De Bruyne, S.; Delbare, D.; Depestele, J.; **Lescrauwaet, A.-K.;** Moreau, K.; Polet, H.; Robbens, J.; Vandamme, S.; Van Hoey, G.; Verschueren, B. (2013). VIRA Visserijrapport 2012 Departement Landbouw en Visserij: Brussel. 98 pp.

APPENDIX II

Table: official conversion factors to convert dead weight into fresh weight (ICES/FAO reporting). This conversion aims to compensate for losses in biomass of catch (landings) during transport (loss of body mass , water) or during processing (gutting or removing parts of the fish that is not commercialized).

ALFA_3	scientific name	presentation	processed	FACTOR
ANF	Lophiidae	FRESH	COMPLETE	1.18
ANF	Lophiidae	FRESH	NO HEAD	3
BIB	Trisopterus luscus	FRESH	GUTTED	1.18
BLL	Scophthalmus rhombus	FRESH	GUTTED	1.05
BSS	Dicentrarchus labrax	FRESH	GUTTED	1,18
CAA	Anarhichas lupus	FRESH	GUTTED	1.18
CNZ	Crangon spp.	FRESH	COMPLETE	1.25
COD	Gadus morhua	FRESH	GUTTED	1.18
COE	Conger conger	FRESH	COMPLETE	1
CRE	Cancer pangurus	FRESH	COMPLETE	1
CRE	Cancer pangurus	FRESH	COMPLETE	1
CRU	Crustacea	FRESH	COMPLETE	1
CTC	Sepia officinalis	FRESH	COMPLETE	1
DAB	Limanda limanda	FRESH	GUTTED	1.05
DGS	Squalus acanthias	FRESH	COMPLETE	1
DGZ	Squalus spp.	FRESH	COMPLETE	1
DPX	Perciformes	FRESH	GUTTED	1.11
FLE	Plathichthys flesus	FRESH	COMPLETE	1.05
GUG	Eutrigla gurnardus	FRESH	COMPLETE	1
GUR	Chelidonichthys cuculus	FRESH	COMPLETE	1
GUU	Chelidonichthys lucerna	FRESH	COMPLETE	1
HAD	Melanogrammus aeglefinus	FRESH	GUTTED	1.18
HAL	Hippoglossus hippoglossus	FRESH	GUTTED	1.05
HER	Clupea harengus	FRESH	COMPLETE	1
HKE	Merluccius merluccius	FRESH	COMPLETE	1.18
JAX	Trachurus spp.	FRESH	COMPLETE	1
LBE	Homarus gammarus	FRESH	COMPLETE	1
LEM	Microstomus kitt	FRESH	GUTTED	1.05
LEZ	Lepidorhombus spp.	FRESH	GUTTED	1.05
LIN	Molva molva	FRESH	GUTTED	1.18
MAC	Scomber scrombus	FRESH	COMPLETE	1
MOL	Mollusca	FRESH	COMPLETE	1
MOL	Mollusca	FRESH	COMPLETE	1
MUR	Mullus surmuletus	FRESH	COMPLETE	1.04
NEP	Nephrops norvegicus	FRESH (complete)	COMPLETE	3.3
NEP	Nephrops norvegicus	FRESH (part)	COMPLETE	1
OCZ	Octopus spp.	FRESH	COMPLETE	1
PLE	Pleuronectes platessa	FRESH	GUTTED	1.05
POK	Pollachius virens	FRESH	GUTTED	1.18
POL	Pollachius pollachius	FRESH	GUTTED	1.18
PPX	Perciformes	FRESH	GUTTED	1
RED	Sebastes spp.	FRESH	COMPLETE	1
SCE	Pecten maximus	FRESH	COMPLETE	1
SKA	Raja spp.	FRESH	COMPLETE	1.05
SKH	Selachimorpha	FRESH	COMPLETE	1
SOL	Solea solea	FRESH	GUTTED	1.05
SPR	Sprattus sprattus	FRESH	COMPLETE	1
SQC	Loligo spp.	FRESH	COMPLETE	1
TUR	Psetta maxima	FRESH	GUTTED	1.05
USK	Brosme brosme	FRESH	GUTTED	1.18
WHE	Buccinum undatum	FRESH	COMPLETE	1
WHG	Merlangius merlangus	FRESH	GUTTED	1.18

APPENDIX III

List & short description of the use of HiFiDatabase in practical research questions and applications for endusers (2009-2013)

A. Redistributed datasets (8):

1. Institute for Agriculture and Fisheries research ILVO. Study in the Celtic sea (2010, contact: Sofie Derveaux, ILVO)

   Description: project established in response to the open call for tenders, Reference No FISH/2007/03 "*Studies and Pilot projects for carrying out the common fisheries policy, Lot 1: Joint data collection between the fishing sector and the scientific community in Western Waters*" from Directorate-General for Fisheries and Maritime Affairs on 25 July 2007.
   The project involved fisheries scientists and fishing industry partners from Spain, Portugal, France, Ireland, Belgium, Scotland and England in four separate pilot projects:
   - Brown crab (*Cancer pagurus*) fishery
   - Development of a fishery information report for demersal fisheries in the Celtic Sea and western Channel (incl. Belgium, partner ILVO)
   - Study with electronic logbook in the Basque trawling fishery
   - Portuguese artisanal deep-water longline fishery

   The HiFiDatabase contributed data on the landings of Belgian sea fisheries from the Celtic Sea.

2. ADSEI (2010, contact: Cathérine Van Rumst, Attaché Statisticus, Algemene Directie Statistiek en Economische Informatie - Thematische Directie Territorium, FOD Economie, K.M.O., Middenstand en Energie

   Description: time series in national statistics service were available from 1990s. The HiFiDatabase completed time series from 1950 onwards. Links to the HiFiDatabase for the data from 1929 are also available from the National Statistics database
   http://statbel.fgov.be/nl/statistieken/cijfers/economie/landbouw/zeevisserij/
   http://statbel.fgov.be/nl/modules/publications/statistiques/economie/downloads/peche_maritime_series_detaillees_1950-2012_.jsp

3. Stock Assessments of Brill and Turbot (2011, contact: Kelle Moreau, ILVO)

   Description: Turbot, *Psetta maxima*, and brill, *Scophthalmus rhombus*, are examples of valuable commercial species for which the European Commission requests management advice, but for which analytical advice has not yet been provided in the past. Traditional assessment methodologies cannot be applied since biological data (age distributions, sex-ratios, maturity data, etc.) are often fragmented in time or are even lacking altogether, posing a real challenge for the development of new techniques. The HiFiDatabase provided data on landings and value of landings on brill and turbot from 1929 onwards, for the Belgian sea fisheries.
   http://www.ilvo.vlaanderen.be/Portals/53/Documents/MOREAU.pdf

4. EMBC Thesis on Turbot (2011, contact: Noemi Van Bogaert, MARBIOL/ILVO)

   Description: thesis EMBC tarbot:

   Modelling available data for turbot (*Psetta maxima*) in the Irish and Celtic Seas: a first step towards sustainable management?

   The HiFiDatabase provided historical data on the Belgian sea fisheries landings and value of landings for turbot, as background and introduction to its economic importance for the Belgian fisheries.

5. OoLaVis Oostendse Langoustine Visserij, European Fisheries Fund EFF Axis 4 (2012, contact: Dirk Verhaeghe, ILVO)

   Description: OoLaVis is a project endorsed by the Flanders Government, the European Union and the Province of West-Flanders, to promote the "Ostend Nephrops" (*Nephrops norvegicus*) towards the national & international retail and the Belgian consumers. It is a partnership between the fishing industry, the fish auction, science and external experts in the promotional field (VLAM, Keystone, Tradelift,...). It is promoted by ILVO – Institute for Agricultural and Fisheries Research. HiFiDatabase provided detailed historical data on landings and value of landings, by area of origin, by month, from 1929 onwards.

Author: VLIZ (Decleer)

Norway lobster has been for the gourmet, but before World War II (1940-1945) market price was quite higher (11 to 15€/kg, expressed as values 2010) than in the 1990s (6 to 8 €/kg, prices expressed as values 2010). The landings of lobsters before WWII came mainly from the 'North Sea (south)'. After the high period of lobster fishing in Iceland in the 1950s and 1960s, with a peak supply of 974tonnes in 1959, landings decreased to less than half of this by 1999. Lobster was then mainly fished from the 'North Sea (central-east)' and the 'North Sea (central-west)' and mostly landed in the port of Zeebrugge. Previously, Oostende was the major auction for marketing lobster.

6. GIFS INTERREG 2 Seas Programme (2012-2013, contact Timothy Acott, University of Greenwhich-UK)

   Description:Fishing communities along the Channel and southern North Sea are facing challenges and changes at a time of strict regulation and measures to address the 'crisis' in fisheries. GIFS is a project funded by Interreg IVa 2 Seas and aims to understand the socio-economic and cultural importance of inshore fishing to better inform fisheries policy, coastal regeneration strategies and sustainable community development by:

   - Identifying best practice in coastal zone governance and marine fishing
   - Exploring the social and cultural values of fishing places and communities
   - Valuing the economic benefits of inshore fishing
   - Understanding grassroots perspectives on inshore fishing through the 'voice' of communities
   - Creating a 'snapshot' of fishing life at the start of the 21st century

   The HiFiDatabase contributed with time-series on the coastal fisheries of Belgium: volume, value, composition of landings, fleet dynamics, employment.

7. Publication 'Garnalen': In Belgium the brown shrimp Crangon crangon is considered a delicacy: a regional product with a rich history and tradition. But the brown shrimp is also the research subject of many marine scientists: ecologists, fisheries biologists, food technologists, fishing technicians, etymologists, historians and archaeologists. In the commercial publication ‘Garnalen’ – a cookbook annex information book – the maritime journalist Katrien Vervaele takes the public on a tour through today’s and former Belgian shrimp fishing and processing. The marine biologist Nancy Fockedey punctuates the stories and interviews with fascinating historic anecdotes and scientific tidbits.

   The HiFiDatabase contributed historical landings and value of landings of brown shrimp for the purpose of this publication.

8. Catherine Rossillon 2012-2013. (MSc. Biology) doing an additional Master Thesis in Business and Economics at HUBrussels. HiFiDatabase contributed data on landings and value of landings of cod and sole in the North Sea, and recent data were digitised and integrated.
   Economics of cod and sole fisheries by Belgian sea fisheries in the North Sea. Work in Progress

B. Theses and internships, co-promoted or coached by A.K. Lescrauwaet (5).

- Sara Behiels, 2008-2009. Hogeschool Gent. Internship and Bachelor Thesis.
    - **Behiels, S.** (2008). Een studie van de Belgische zeevisserij, toegepast op tong (*Solea solea*) en schol (*Pleuronectes platessa*). BA Thesis. Hogeschool Gent, Departement Biowetenschappen en Landschapsarchitectuur: Gent. 55 pp.

- Elisabeth Van Peteghem, UGent, 2010. Master Thesis.
    - **Van Peteghem, E.** (2009). Belgian sea fisheries landings and their values: shifts in fishing areas during the period 1929-1999. MSc Thesis. Universiteit Gent; MARELAC: Gent. 34 + appendixes pp., details

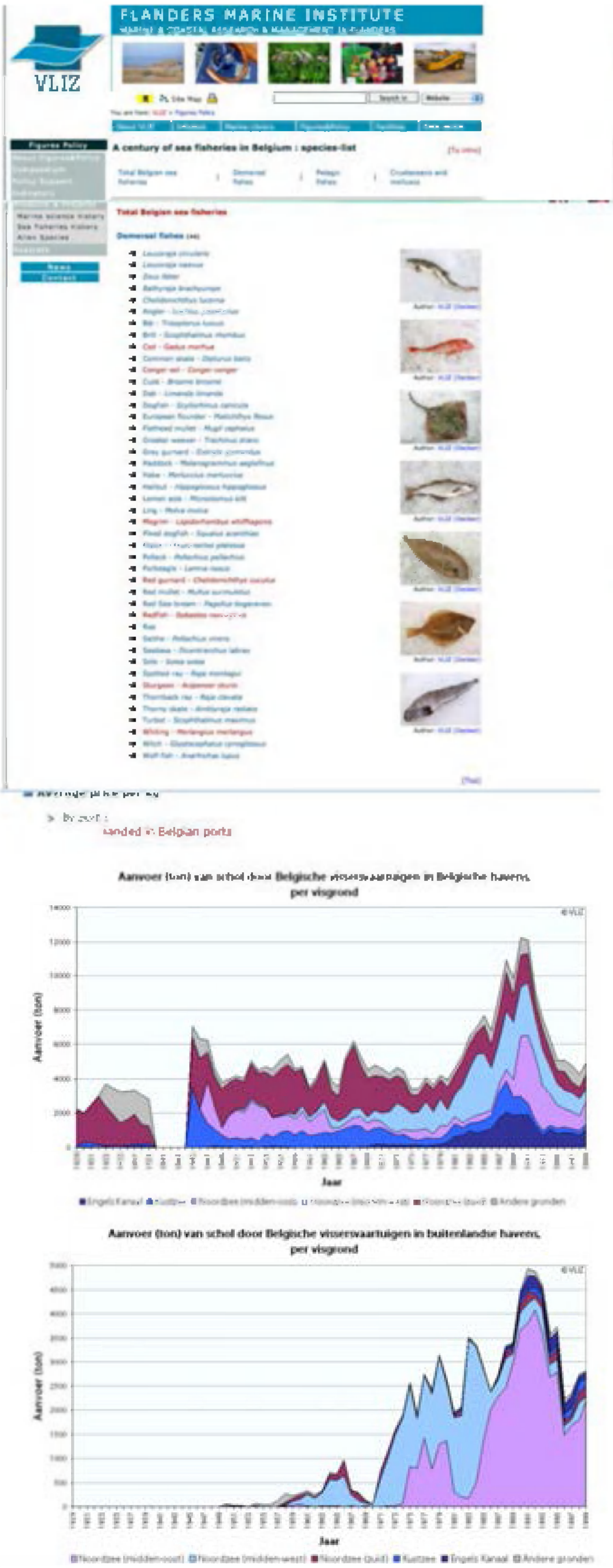
- Ashley Haeck, UGent, 2011. Master Thesis. *Ugent-BSc bio-ingenieur/milieutechnologie (aug 2011)*
    - Haeck, A. (2012). Het digitaliseren, analyseren en beschrijven van de aanvoer en besomming vanuit de kustzee voor de periode 1972-1981: Een eeuw zeevisserij in België - VLIZ. MA Thesis. Universiteit Gent. Faculteit Bio-ingenieurswetenschappen: Gent. 100 pp.(in Dutch)

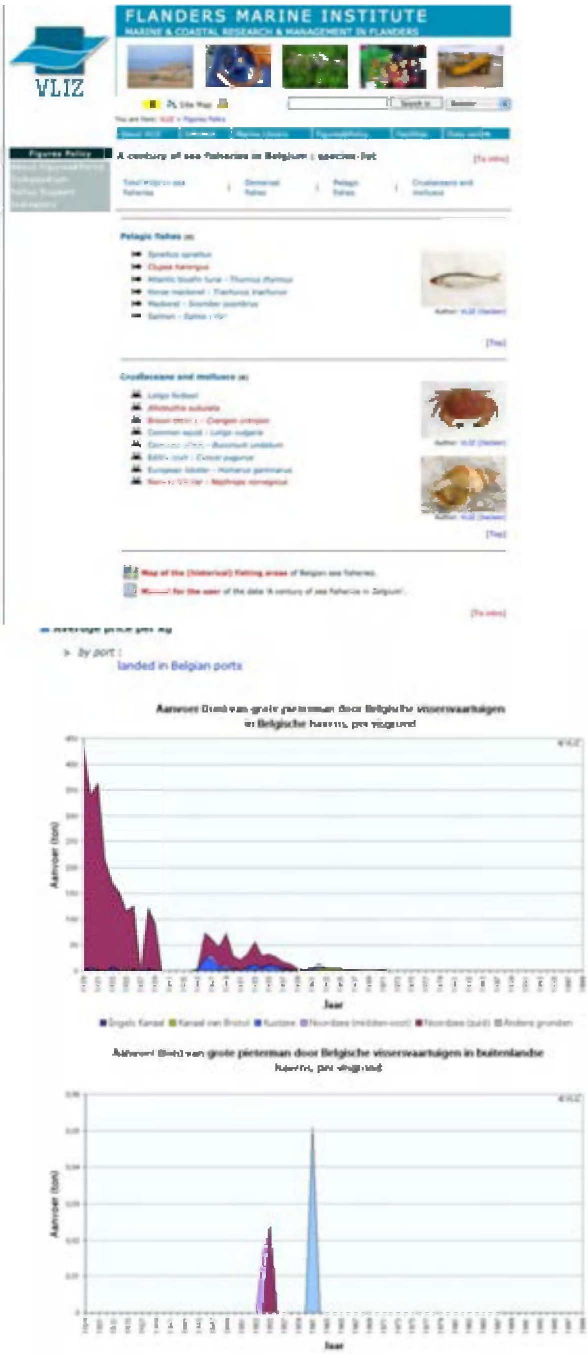
- Gerlien Verhaeghe, 2011. *UCL-MSc Biology. Internship.*
    - Cod, monthly data, by fishing area, 1972.

- Evy Maertens 2013. Hogeschool Gent. Internship. Student Hogent: Campus Melle. Agro- & Biotechnologie: Dierenzorg
    - Historical sea fisheries data across the border: coastal sea fisheries in Zeeland, The Netherlands: landings, value of landings, fishing effort. Work in Progress.

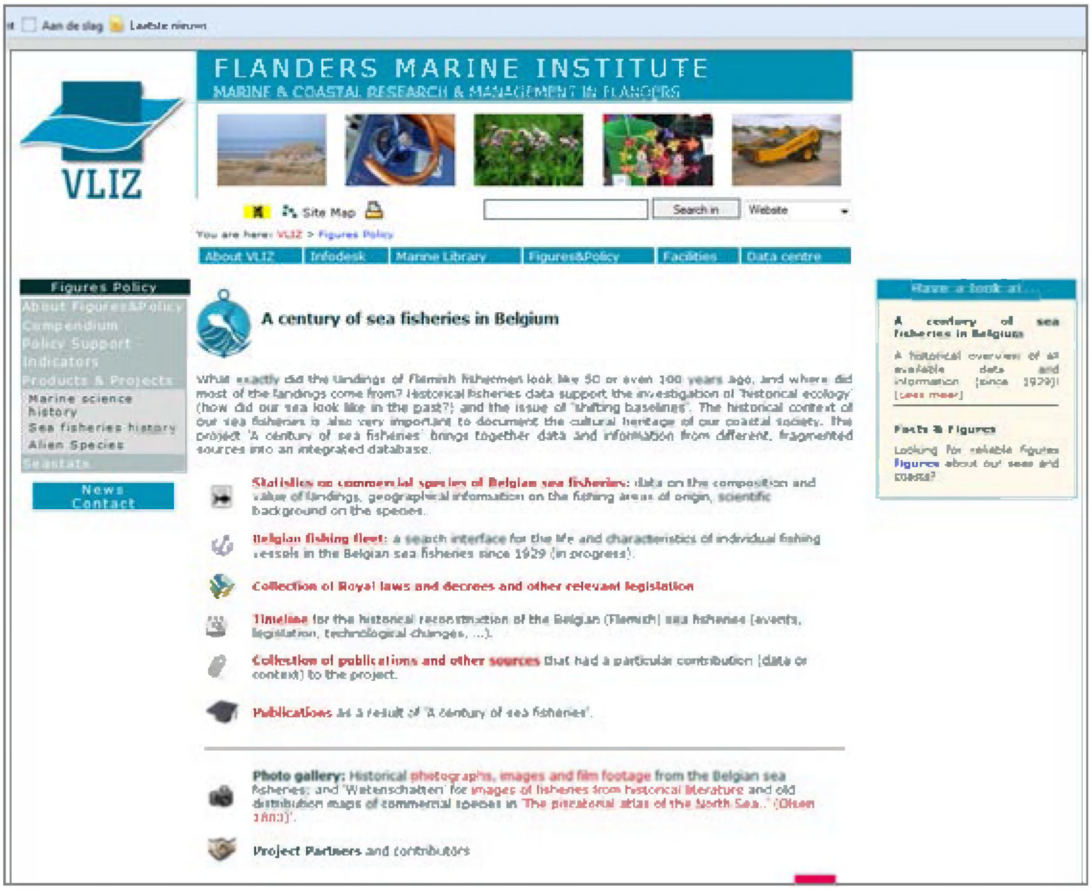
C. Online Applications, Data and Information Products

1) online application to consult value and composition of landings by species and by fishing area (from 1929)





2) Special Collection of peer-reviewed articles, documents, reports, maps, images

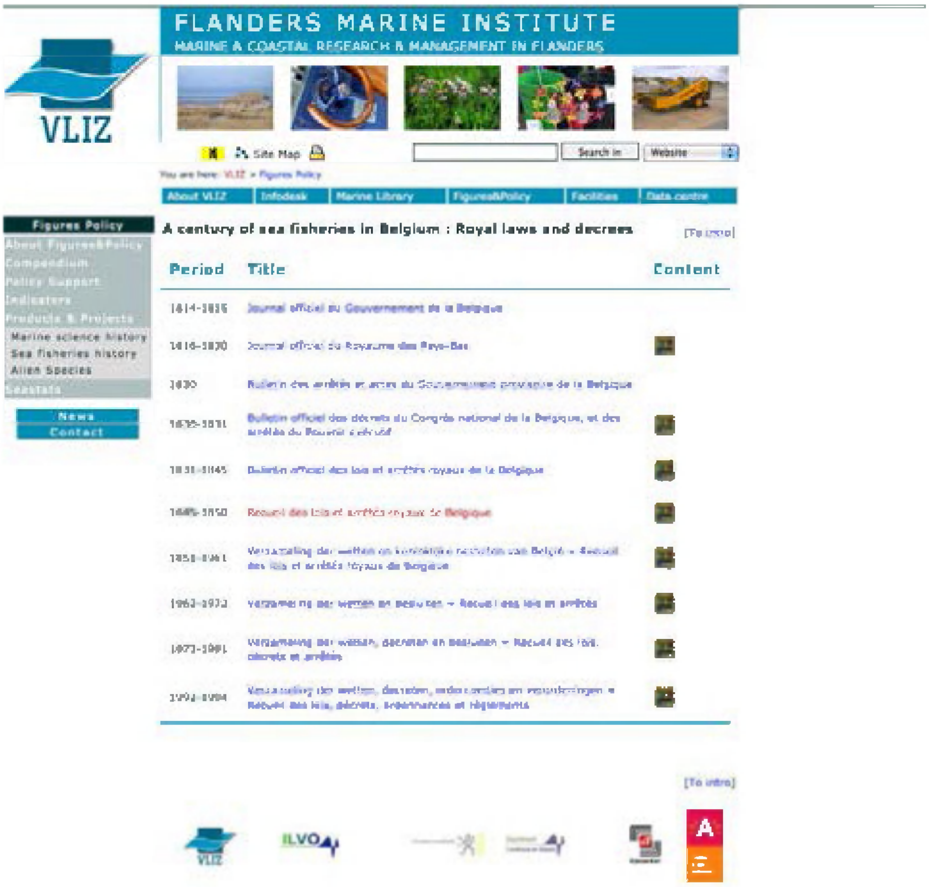


3) Online application 'Timeline sea fisheries: Marking events, Policy and management, Fleet and fishing gear'

Description: A bilingual (Dutch and English) application containing >1000 chronologically ordered events, data, information, laws and other, underpinned by a fully-referenced published sources. First event is situated in 1050 AC. Information sources are searchable by scrolling chronologically through the timeline, or by searching/highlighting for key terms. Most of the data/events are illustrated with fully-referenced historical images and pictures, and source information is digitally available in full-text (pdf) by clicking on the source ('more info').

Figure: Printscreen of the online application 'Time line Belgian Sea Fisheries'
www.vliz.be/cijfers_beleid/zeevisserij/timeline.php (VLIZ, 2010)

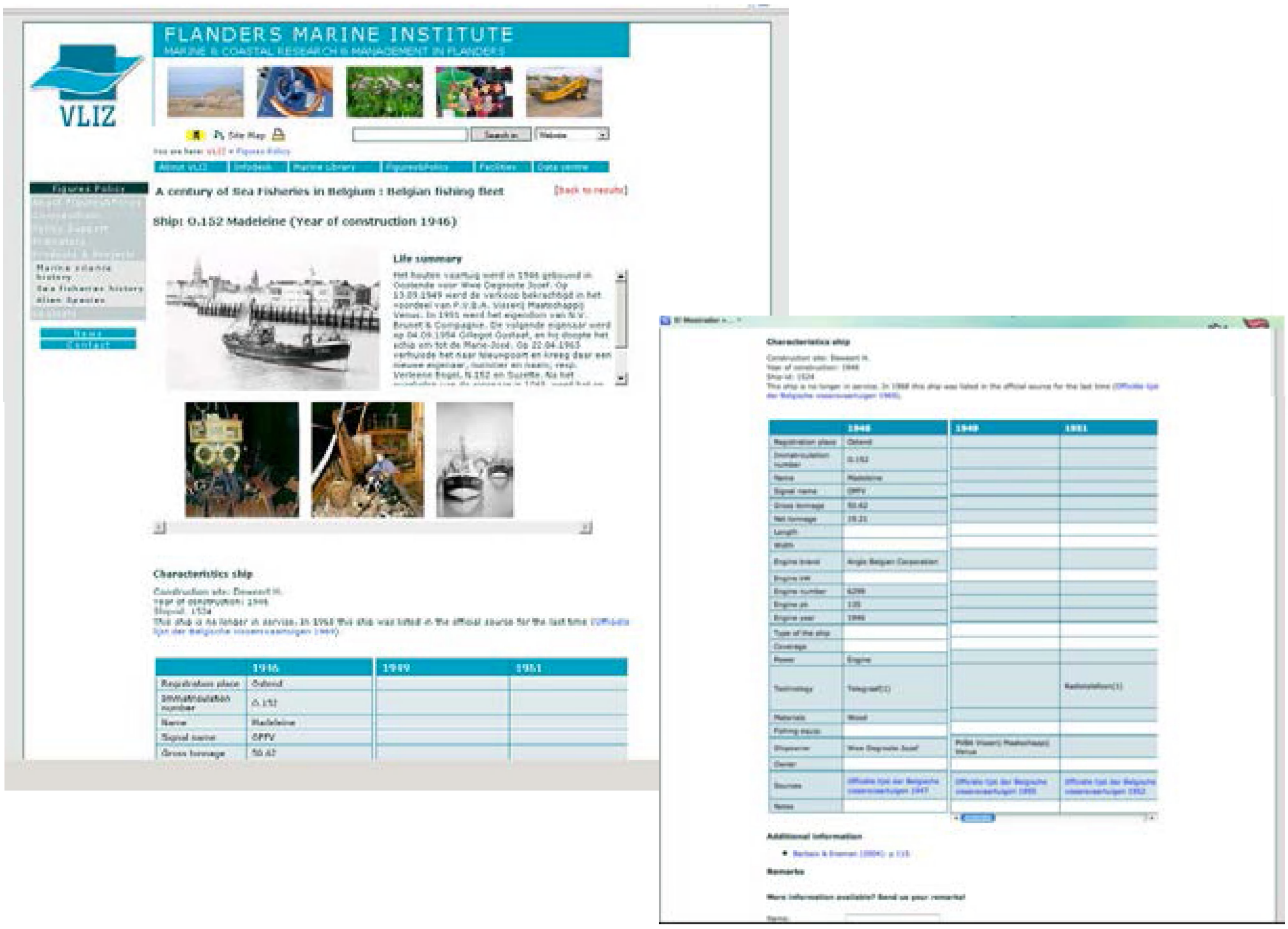
4) Special collection of legal documents on sea fisheries in Flanders/Belgium (laws, royal decrees,..): from 1300-today



5) Online Application 'Belgian sea fisheries fleet'

description: The Belgian fishing fleet has had an interesting evolution: vessels, boats and ships changed owner, immatriculation number, (unique identifying code) or port of registration. Over time ships were converted or equipped with more efficient technology: sailing ships were replaced by steamers and later the entire fleet was gradually motorized.
Because of these rapid changes it is not all that obvious to follow the characteristics or lifetime of a given ship from its construction to the moment the ship is taken out of service. These changes are now searchable **by ship**, for vessels operating from 1929 onwards. For ships registered in the port of Ostend, data is available from the late 19th century onwards. As a result of the search, users will get an overview list of all results (ships) that mention search term or combination of search terms. Each of these returns is characterized by the immatriculation number and name given to the ship at the time of first registration. After clicking on the name of a vessel that you find in this resulting list, the users get a table describing the lifetime of the selected ship.

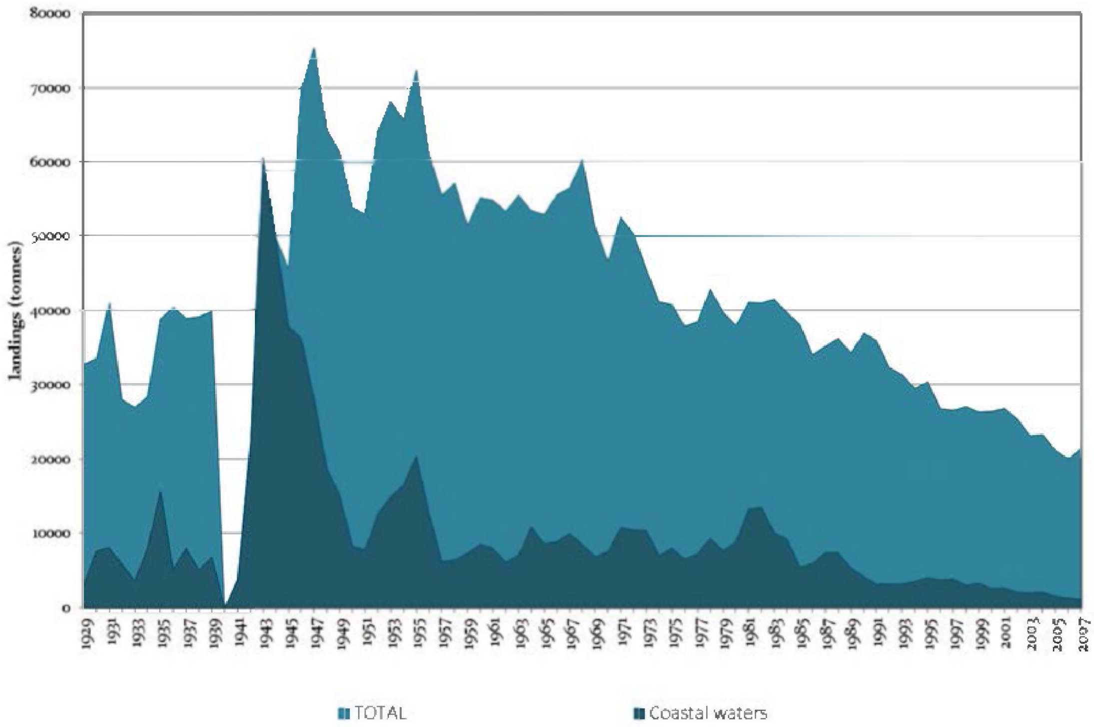
The table describing the lifetime of a selected ship always starts with the year in which the ship was described for the first time and ends with the year in which the ship sank, was taken out of service, or was irreversibly damaged. Only those years in which changes occurred are shown in the resulting table. For these years only the changed features are listed. Light blue bars indicate an unchanged feature. White cells and bars indicate information gaps in the sources. Additional information (identifiable sources) on these missing features or any other reliable additional information about the ship is welcome. You can comment online by using the 'remarks' field on the bottom of each vessel form.

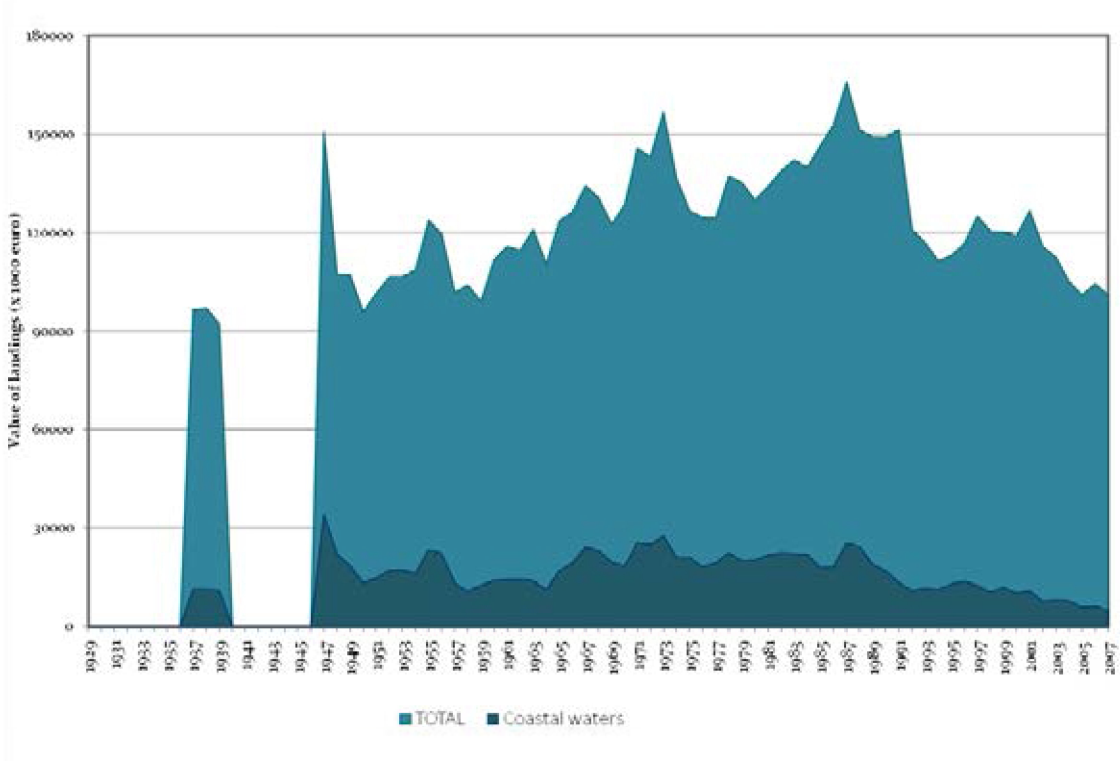


Addendum: Relative importance of fishing area 'Coastal Waters' from the total landings,

a) volume of landings tonnes

b) value of landings, x1000 euro corrected for inflation





BELGIAN SEA FISHERIES: TEN DECADES, SEVEN SEAS, FORTY SPECIES

Human activity has been impacting marine ecosystems for millennia, and fishing is most often seen as the cause of overexploitation and depletion of marine biological resources. There is a wealth of recent studies illustrating how our perception of pristine conditions in the seas and oceans has shifted over generations. This is referred to as 'Shifting Baselines'. Historical data can contribute in explaining underlying cause-effect relations in changes in the ecosystems, potentially reveal information and knowledge from past conditions, and help defining reference conditions and achievable targets for environmental management today. The present thesis focuses on the reconstruction of historical time-series to expand our knowledge on historical references for the Belgian sea fisheries and to extend the timeframe of current analyses on fisheries. In achieving this, it is aiming to counter the concept of 'Shifting Baselines' applied to the Belgian Sea fisheries.

The 'Historical Fisheries Database' (HiFiDatabase) is a product of this thesis. It is the result of a thorough search, rescue, inventory, standardization and integration of data for Belgium's sea fisheries that were not available before in the public domain or were not available before in the appropriate format for redistribution. It is documented and stored in the Marine Data Archive (MDA) of Flanders Marine Institute (VLIZ) and is freely available for end-users. Considering the relative size of the fleet, the short coastline and the limited number of fish auctions and fishing ports in Belgium, the present reconstruction of Belgian sea fisheries depicts a relatively complete picture of historical volume, value and composition of landings, fleet dynamics, fishing effort and spatial dynamics. The project and its methodology offer a blueprint to conduct similar reconstructions in other countries.

The HiFiDatabase broadens the historical view on fisheries and serves as a basis for a range of potential research, management applications, and in support of policy-making. In particular, the time-series provide unique historical reference conditions of fishing in the Belgian part of the North Sea and a potential baseline for fisheries management in territorial waters or for the coastal fisheries. The latter is useful in the context of the EU marine policy frameworks. Finally in the present thesis work, important efforts were dedicated to approach the history of fisheries from different disciplines of work. The results underline the importance of collecting economic data, inventorying historical archives and historical legislation, historical economy and politics, in order to improve the interpretation and analysis of results.

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