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The non-indigenous freshwater fishes of Flanders (Belgium): review, status and trends over the last decade

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Fourteen non-indigenous fish species have been successfully introduced to the wild within the territory of Flanders; nine are considered naturalized. Most of the introductions occurred prior to 1950, with six species introduced since then. This paper reviews the available, hitherto scattered, information (including 'grey literature') on these 14 non-indigenous fish species introductions, and evaluates a decade of data from fisheries surveys to assess the recent development of these non-indigenous populations. Gibel carp *Carassius gibelio* and topmouth gudgeon *Pseudorasbora parva* are the most widespread of the non-indigenous species in Flemish waters, and both continue to expand their ranges. A reduction in range has been observed in brown bullhead *Ameiurus nebulosus* only. A case is presented for not including European catfish *Silurus glanis*, sunbleak *Leucaspius delineatus* and European bullhead *Cottus gobio* on the list of non-indigenous freshwater fishes in Flanders. Also discussed are non-indigenous fish species that are likely to colonize Flanders inland waters in the near future.

Key words: alien fishes; fish stock assessment; gibel carp; introductions; topmouth gudgeon.

INTRODUCTION

The introduction and spread of non-indigenous species are major global concerns because of the potential for adverse ecological and socio-economic impacts (Gurevitch & Padilla, 2004). Amongst vertebrates, freshwater fishes are among the most commonly introduced species (Jeschke & Strayer, 2005), with translocations occurring since the early Roman times and increasing in intensity since the 19th century (Jeschke & Strayer, 2005). At least 76 freshwater fish species from other continents have been introduced to European waters, with at least 50 species having established self-sustaining populations in one or more European countries (Lehtonen, 2002). The Database of Invasive Aquatic Species (DIAS; FAO, 2007) describes 20 introductions of non-indigenous fishes into Belgium, whereas Louette *et al.* (2001) found evidence in the literature

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of 47 considered, attempted or successful introductions of fishes in Belgium since 1800; of these, 23 were partially successful (*i.e.* recorded in public waters after introduction or known to be reproducing). The aim of the present paper is to provide the first comprehensive review of non-indigenous fish species introductions to Flanders, evaluate the development of the successful introductions and discuss their present status.

MATERIALS AND METHODS

BIBLIOGRAPHIC RECORDS AND NON-INDIGENOUS SPECIES CLASSIFICATION

To reconstruct the introduction history of non-indigenous fishes in Flanders, historical and recent data were acquired from various published and 'grey' literature sources (*e.g.* reports, books and manuscripts). The classification of species as 'native' and 'non-indigenous' was based on these historical and archaeological records, with species considered to be native if they occurred in Flanders 6000 years before present (Copp *et al.*, 2005*a*). Because of uncertainty regarding the native status of certain species, three fishes were not included in the non-indigenous fish fauna list: European catfish *Silurus glanis* L., sunbleak *Leucaspius delineatus* (Heckel) and European bullhead *Cottus gobio* L. The two former species have been categorized as non-indigenous by Welcomme (1988) and Louette *et al.* (2001); however, Van Neer & Ervynck (1993) discovered archaeological remains of European catfish in Flanders that date from the Neolithic to the 12th century. This suggests that European catfish was native to Flanders, was extirpated locally by some agent (human or natural), and the current wild (and probably reproducing) population (Simoens *et al.*, 2002) is effectively a re-introduced species (escapees or re-introduced illegally). There are no archaeological records of sunbleak in Flanders (Van Neer & Ervynck, 1993), but its bones were probably overlooked at archaeological sites (W. Van Neer, pers. comm.) due to its relatively late identification as a separate species (*i.e.* in 1843). Sunbleak is native to the neighbouring regions and countries of Wallonia (Philippart & Vranken, 1983), France (Keith & Allardi, 1998) and The Netherlands (van Emmerik, 2003), and therefore should be classed as native to Flanders (Vandelannoote *et al.*, 1998). Whereas, the exclusion of European bullhead from the list is due to a lack of clarity regarding the species' taxonomic (and thus non-native) status (Volckaert *et al.*, 2002; Freyhof *et al.*, 2005).

Also excluded from consideration was black bullhead *Ameiurus melas* (Rafinesque), which some literature (Wheeler, 1978; Welcomme, 1988) suggested was introduced to Belgium along with its North American congener ictalurid, brown bullhead *Ameiurus nebulosus* (Lesueur). No published confirmations of black bullhead in Flemish open waters exist. This contrasts with other European countries, *e.g.* Great Britain (Wheeler, 1978) and Spain (Elvira & Almodóvar, 2001), where black bullhead is the only established North American ictalurid. Therefore, recent reports of black bullhead in Flanders are most likely mis-identifications of brown bullhead (Vandelannoote *et al.*, 1998).

RECENT FISH STOCK ASSESSMENTS

Data on the occurrence and distribution of non-indigenous fishes in Flanders were extracted from a collective fish stock assessment database [Research Institute for Nature and Forest (INBO), University of Antwerp, University of Leuven], which was established from fisheries surveys undertaken between 1990 and 2006 at > 2100 locations (streams, canals and public standing waters) throughout Flanders [Fig. 1(a)]. To quantify the trends in frequency of occurrence (presence or absence) and abundance, data from fish surveys undertaken by the INBO at 487 sites [Fig. 1(b)], which were sampled once between 1996 and 2000 and again between 2001 and 2005, but with

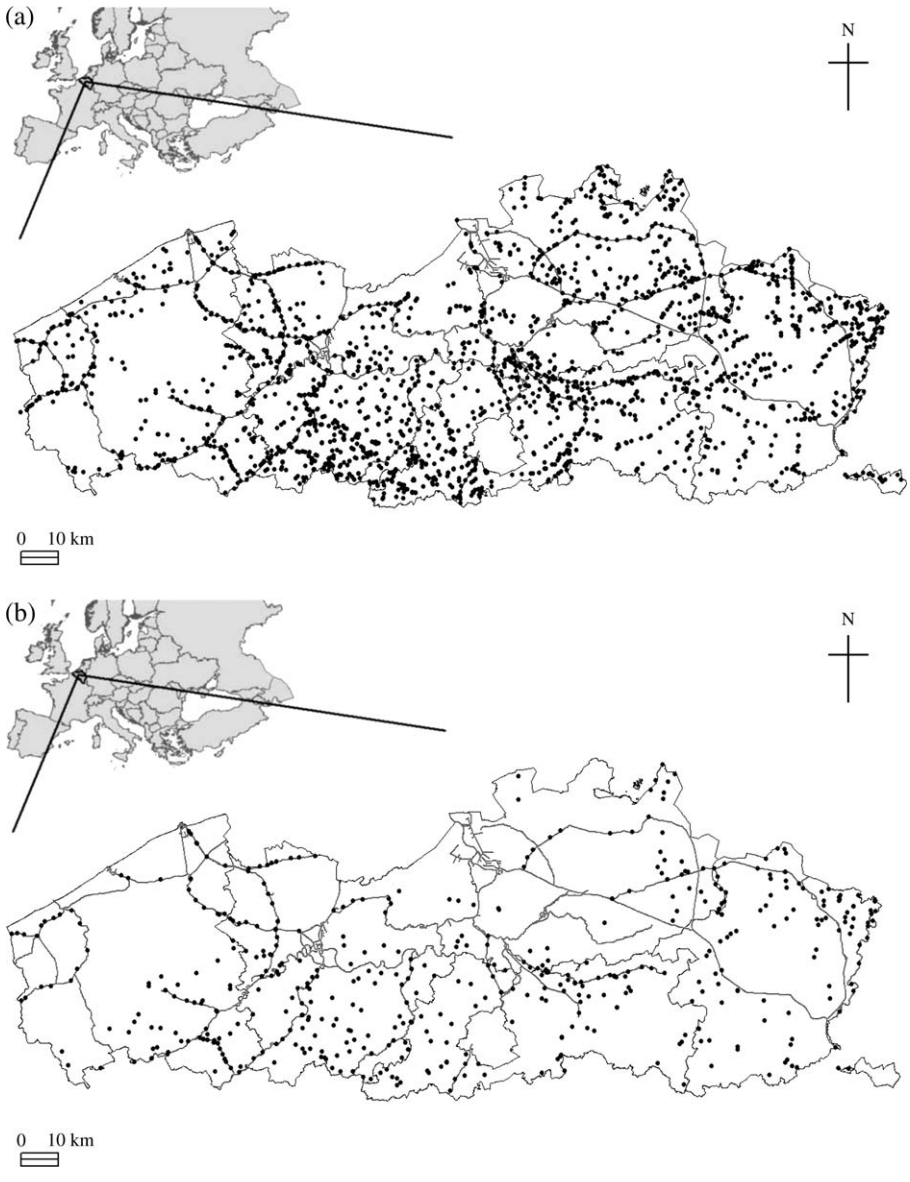

FIG. 1. Map of Flanders with indication of the main rivers and (a) >2100 sampling locations where fish stock assessments were undertaken between 1990 and 2006 by the Research Institute for Nature and Forest (INBO), University of Antwerp and University of Leuven and (b) the locations of 487 site-specific fish surveys, which were carried out by INBO twice between 1996 and 2005, once between 1996 and 2000, and again in the period 2001–2005.

a minimum of 3 years in between were used. At each site, fish sampling was generally carried out in the same season, and often in the same month, using similar methods (*i.e.* electrofishing, fyke nets or a combination of both methods) and fishing effort. Electrofishing was undertaken using a pulsed-DC generator unit. At each site, catch per unit effort (CPUE) estimates were made for a stretch of *c*. 100 m from a single depletion by

two persons moving in an upstream direction, each with a hand-held anode and attached nets. Fyke nets were placed overnight and each fyke string consisted of two fyke nets, each 5 m long with a first hoop of 0·9 m diameter, connected to each other by a 12 m wing. Fish CPUE abundance was the number of fish per 100 m river stretch for electrofishing and the number of fish per 24 h exposure for the pair of fyke nets.

STATISTICAL ANALYSES

A two-step approach was used to evaluate trends in the species. First, changes in the frequency of occurrence (presence or absence) of a species over time were examined using logistic regression, which is applicable when presence or absence data follow a binomial distribution (McCullagh & Nelder, 1983). The model fits the expected frequency of occurrence in a given year, as follows: $\text{Logit}(\pi) = \log\pi\ (1 - \pi)^{-1} = \alpha + \beta\ (Y - 2000)$, where Y = year. The value 2000 was subtracted from Y to give a specific meaning to the intercept α; it can be easily demonstrated that the frequency of occurrence in 2000 depends solely on α as follows: $\pi(2000) = e^{(\alpha)}\ [1 + e^{(\alpha)}]^{-1}$. Positive values imply an increase and negative values a decrease in prevalence. The adequacy of the above logistic model was evaluated by residual analysis.

Secondly, at sites where a species was present on both sampling occasions, changes in abundance (N), which were based only on electrofishing data, were analysed. To account for data derived from the same locations, a linear mixed model approach, using log-transformation to normalize the data, was used with a random intercept (Pinheiro & Bates, 2000): $\log_{10}(N) = \alpha + \beta\ (Y - 2000)$. This model was validated using residual analysis, with 95% CL calculated for the trend (slope) parameter β. The precision depends heavily on the prevalence of the species resulting in large interval bars for species with low prevalence. All analyses were conducted in S-plus version 6.2 (Insightful, 2003).

RESULTS

Most non-indigenous species (six species) were introduced between 1950 and 2000, with three prior to 1800 and four between 1851 and 1900 (Table I). The majority of introduced species in Flanders originate from North America and Asia (five species from each), with three from Eastern Europe and one from Africa. Fisheries surveys over the last decade provide evidence of 14 non-indigenous freshwater fish species (Table I), which represents *c*. 35% of the current number of freshwater fishes in Flanders. Nine species have become established: gibel carp *Carassius gibelio* (Bloch), topmouth gudgeon *Pseudorasbora parva* (Temminck & Schlegel), common carp *Cyprinus carpio* L., pumpkinseed *Lepomis gibbosus* (L.), European pikeperch *Sander lucioperca* (L.), brown bullhead, eastern mudminnow *Umbra pygmaea* (DeKay), fathead minnow *Pimephales promelas* (Rafinesque) and asp *Aspius aspius* (L.). Four species do not reproduce in Flanders: rainbow trout *Oncorhynchus mykiss* (Walbaum), Nile tilapia *Oreochromis niloticus* (L.), silver carp *Hypophthalmichthys molitrix* (Valenciennes) and grass carp *Ctenopharyngodon idella* (Valenciennes). One species, goldfish *Carassius auratus* (L.), is known to reproduce in private (garden) ponds only, and its abundance and occurrence in open waters are so low that self-sustaining populations probably do not exist in the wild.

At the river basin scale, the distribution of non-indigenous fish species in Flanders can be grouped into the following categories: wide, intermediate and single basin occurrence (Table II). Gibel carp, common carp, topmouth gudgeon

TABLE I. Species and common names of the 14 non-indigenous freshwater fishes occurring in Flanders, with their continent of origin (AS, Asia; EE, Eastern Europe; AFR, Africa; NA, North America), suspected pathways (AQ, aquaculture; OR, ornamental; AN, angling or bait fish; BC, biological control; UN, unintentional), date (year or period; c., century) of introduction and current status (Copp *et al.*, 2005*a*; A, acclimatized; N, naturalized; A*, acclimatized only in restricted areas at cooling water discharges of power plants)

Species name	Common name	Origin	Date	Pathway	Status
Ameiurus nebulosus	Brown bullhead	NA	1871	AQ, OR	N
Aspius aspius	Asp	EE	1984	AN	N
Carassius auratus	Goldfish	AS	17th c.	OR	A
Carassius gibelio	Gibel carp	AS or EE	17th c.	UN	N
Ctenopharyngodon idella	Grass carp	AS	1967	BC	A
Cyprinus carpio	Common carp	EE	13th c.	AQ	N
Hypophthalmichthys molitrix	Silver carp	AS	1975	BC	A
Lepomis gibbosus	Pumpkinseed	NA	1885	OR	N
Oncorhynchus mykiss	Rainbow trout	NA	1884	AQ, AN	A
Oreochromis niloticus	Nile tilapia	AFR	1990	AQ	A*
Pimephales promelas	Fathead minnow	NA	1984	AN	N
Pseudorasbora parva	Topmouth gudgeon	AS	1992	UN, AN	N
Sander lucioperca	European pikeperch	EE	1890	AN	N
Umbra pygmaea	Eastern mudminnow	NA	1920	OR, AQ	N

and European pikeperch occurred in all river basins, with pumpkinseed occurring in all but one basin, but being most abundant in the eastern part of Flanders (basins of Demer, Nete and Meuse), where they have become locally invasive. The intermediately distributed species were brown bullhead, goldfish, rainbow trout, fathead minnow, eastern mudminnow and grass carp, which were observed in two to five river basins. Of these, brown bullhead and eastern mudminnow were largely confined to, and become locally invasive in, the eastern part of Flanders. In the three river basins where fathead minnow occurred, the species was detected in low abundance in nine watercourses (one to 24 specimens) and in high abundance (>100 specimens) in one pond, which was located in a nature reserve. Both the wild and the ornamental form ('rosy red') were found. In the final group, asp, silver carp and Nile tilapia were observed in one river basin only and were very rare (Table II).

At the scale of site-specific fish surveys ($n = 487$ sites), gibel carp was also the most widespread non-indigenous species, occurring at 25·2% of the sites, followed in decreasing order by: topmouth gudgeon (17·9%), common carp (15·6%), pumpkinseed (12·2%), European pikeperch (8·6%), brown bullhead (4·4%) and eastern mudminnow (3·9%). The remaining seven non-native species were observed in <1% of the surveys, exhibiting a rather limited distribution. The frequency of occurrence of six non-indigenous species increased between sampling periods (Fig. 2). For most species, large residuals were found prior to 2000 (when samples per year were not representative for the total region), but between 2001 and 2005, the residuals around the logistic model were small (indicating a good model fit). The observed increase was significant

TABLE II. Occurrence of non-indigenous fishes in river basins of Flanders [$n = 11$; Lower Scheldt (LS), Upper Scheldt (US), Bruges Polders (BP), Demer (Dm), Dender (Dn), Dijle (Di), Ghent Canals (GC), Leie (Le), Meuse (Me), Nete (Ne) and Yser (Ys)] expressed as percentage of sites where a non-indigenous species is present compared to the total number of sample sites per river basin [VR, very rare (≤2·0%); R, rare (2·1–10·0%); C, common (10·1–25·0%); W, widespread (>25%)]

	LS	US	BP	Dm	Dn	Di	GC	Le	Me	Ne	Ys	
S_b	6	8	5	12	5	7	5	6	10	9	5	n
Gibel carp	R	C	W	W	R	C	W	C	C	C	W	11
Common carp	R	R	W	C	R	C	W	R	R	C	W	11
Topmouth gudgeon	R	R	C	W	C	C	C	C	R	R	C	11
European pikeperch	C	VR	R	VR	VR	R	R	R	R	C	C	11
Pumpkinseed	C	VR	VR	W	R	R	VR	R	C	W		10
Brown bullhead	VR			C		VR			R	C		5
Goldfish		VR		VR					VR	VR		4
Rainbow trout		VR		R		R			R			4
Fathead minnow		VR		R						VR		3
Eastern mudminnow				C					C	C		3
Grass carp				VR							VR	2
Silver carp								VR				1
Nile tilapia				VR								1
Asp									VR			1

n, total number of basins where a species is present; S_b, total number of alien species in a basin.

($P < 0{\cdot}05$) for gibel carp, topmouth gudgeon and European pikeperch only. Three species declined in occurrence, with a significant result for brown bullhead only ($P < 0{\cdot}05$). The occurrence of the five remaining species was too low to model. The relative densities (CPUE) for seven species were sufficiently high to permit between-sampling period comparisons (eastern mudminnow, topmouth gudgeon, brown bullhead, gibel carp, common carp, European pikeperch and pumpkinseed), but the only significant differences ($P < 0{\cdot}05$) observed were decreases in common carp and gibel carp (Fig. 3).

DISCUSSION

INTRODUCTION HISTORY AND PRESENT OCCURRENCE OF NON-NATIVE FISHES

Similar to most European countries (Lehtonen, 2002), the majority of introduced species in Flanders originate from North America and Asia (Table I), and many were introduced between 1950 and 2000 (Elvira & Almodóvar, 2001; Gollasch & Nehring, 2006). Compared with the 15 other European countries listed by Copp *et al.* (2005*a*), Flanders has the second lowest number (14) of established non-native fish species but a high proportion of non-native species (35%) relative to the total number of freshwater fish species present in the region. Indeed, Flanders ranks fourth amongst the countries and regions listed in Copp *et al.* (2005*a*), after Italy (48%), France (44%) and Spain (42%), being

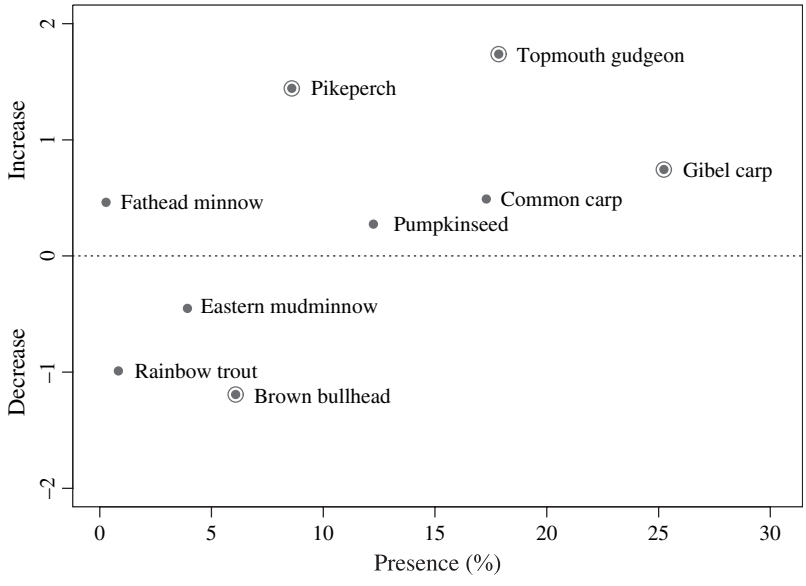

FIG. 2. Logistic regression analysis of the frequency of occurrence (absence or presence) of the non-indigenous fish species on 487 sample sites in Flanders between 1996 and 2005 [x-axis = $\pi(2000)$; y-axis = slope β]. Positive values imply an increase and negative values a decrease in frequency of occurrence. Points with a significant slope ($P < 0{\cdot}05$) are encircled.

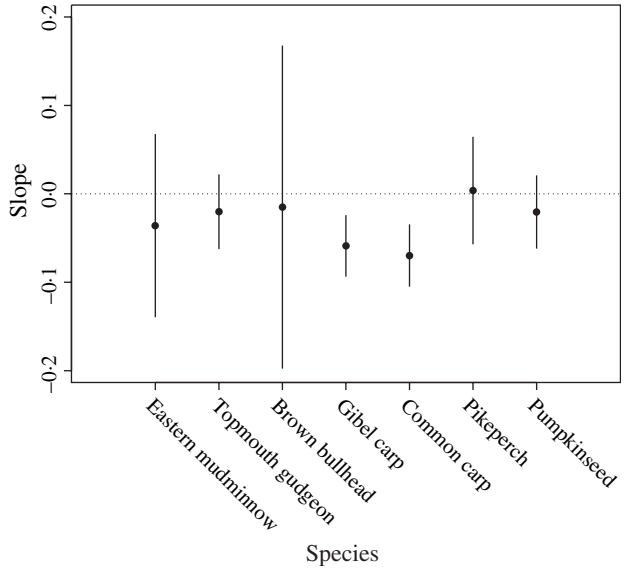

FIG. 3. Estimated trend, with 95% CL, for the catch per unit effort (number of specimens per 100 m stretch of stream) of the non-indigenous fish species in Flanders between 1996 and 2005. Positive values imply an increase and negative values a decrease in abundance. The trend is significant ($P < 0{\cdot}05$) when CL do not include the zero line.

comparable to other West and Central European countries, *e.g.* England and Wales (34%; Copp *et al.*, 2005*a*) and the Netherlands (33%; van Emmerik, 2003). Typically, countries from southern Europe and the Mediterranean area harbour a higher ratio of introduced fishes than countries from West and Central Europe. The reason these countries are more susceptible to invasion by non-indigenous fishes remains unclear, but one hypothesis is that the Mediterranean-type climate is similar to that in south-eastern North America, a major donor region of non-indigenous fish species (Vila-Gispert *et al.*, 2005).

The low absolute number of non-native fishes in Flanders could be explained by its limited geographic area (13 500 km^2) and the current reduced diversity or biotic integrity of aquatic habitats due to human impacts. The number of indigenous fishes is equally limited, however, due to these reasons as well as the region's post-glacial history of species recolonization. As a result, the proportion of non-native fish species established in Flanders is relatively high, and may be associated with the relatively high degree of disturbance to its inland waters.

NATURALIZED SPECIES

Common carp was probably the first fish species subjected to wide-scale introductions (Balon, 1995, 2004), having been translocated from the Danube by the Romans for aquaculture and subsequently distributed throughout Europe as part of the medieval monastic fish pond tradition. The oldest remains of common carp found in Flanders date back to the 13th–14th century (Van Neer & Ervynck, 1993). The species is now widespread throughout Flanders, but seldom occurs at high densities and its numbers are generally decreasing, perhaps due to insufficiently warm water temperatures (van Emmerik, 2003). Common carp were stocked into public waters for angling until the late 1980s, artificially maintaining high population densities, and such introductions remain common practice in private angling ponds from where escapee fish may still contribute to existing populations.

Gibel carp is thought to have been introduced together with common carp (Cakic & Hristic, 1987), but there is no supporting archaeological or historical evidence and the species was probably present in Flanders at least by the 17th century (Louette *et al.*, 2001). Now the most widespread non-indigenous fish in Flanders, gibel carp occurs locally in high densities. The physical similarity of the brown variety of goldfish, gibel carp and native crucian carp *Carassius carassius* (L.) has resulted in these species being commonly mistaken, as reported elsewhere (Wheeler, 2000; Vetemaa *et al.*, 2005), for native crucian carp. This confusion led to many legal stockings of gibel carp, instead of crucian carp, into Flemish public waters until the 1990s, when the Flemish government prohibited the stocking of both species. Stocking with native crucian carp of known origin (from aquaculture facilities of the Flemish government) was reinstated in 2000. Despite the prohibition on gibel stocking, the number of sites inhabited by gibel carp increased significantly between 1996 and 2005 but in significantly decreasing relative densities. This suggests that gibel carp is still in a dispersal and colonization phase, but that established populations are stabilizing within the invaded communities since stocking ceased. Recent research

revealed that >90% of the Flemish gibel carp population is triploid and thus reproduces by gynogenetic means (G. Maes, pers. comm.).

Brown bullhead and pumpkinseed were introduced to Belgium and neighbouring countries in the late 19th century as aquaculture species (Rousseau *et al.*, 1915; Wheeler, 1978). Both species occur more frequently in the north-east of Flanders. Eastern mudminnow, which is also restricted to the north-east, was probably introduced in Flanders around 1920 (Louette *et al.*, 2001) but was only first reported by Poll (1949). The presence of these fishes in north-east Flanders is assumed to be due to the high concentration of pond fish farms in this area, where numerous abandoned peat diggings provided suitable conditions for pond farming. Although the populations of pumpkinseed and eastern mudminnow remain relatively unchanged, there has been a decline in the number of sites in Flanders where bullhead was observed. The recent ban on stocking non-indigenous fishes into public waters is unlikely to affect the occurrences of pumpkinseed, eastern mudminnow or bullhead population, which were never the subject of legal stocking in the last 30 years. So the reasons for the decline in bullhead remain unknown.

European pikeperch is widespread in Flanders and the number of sites inhabited by the species is increasing, although its legal stocking in Flemish public waters ceased in 1995. This species may have benefited from the moderate improvement of the water quality in Flanders during the last decade, either directly or indirectly through an amelioration of the overall fish stocks (*i.e.* greater prey abundance). But, further improvement of water quality, with increased water clarity, may be unfavourable to European pikeperch as this species prefers deep (*i.e.* dark) or turbid waters (Poulet *et al.*, 2005).

Two small-bodied species introduced to Flanders in the last two decades are of particular note, as the introduction pathways were as a consignment contaminant or as 'live bait'. Topmouth gudgeon was accidentally introduced into Europe as a contaminant of Chinese carp consignments (Bănărescu, 1990) and spread rapidly through Europe *via* 'contaminated' fish transports and stocking activities (Copp *et al.*, 2005*a*), reaching Flanders in the early 1990s. The species' wide distribution in Flanders, combined with an ever increasing frequency of occurrence, suggests that topmouth gudgeon is still in its expansion phase. Nevertheless, densities have remained constant over the last decade, occurring frequently in both streams and standing waters, but with the highest densities in (the proximity of) shallow ponds (pers. obs.). Whereas, fathead minnow, which was first observed in Flemish open waters in 1995 (Anseeuw *et al.*, 2005), is much less abundant, with self-sustaining populations probably existing in some river systems (Anseeuw *et al.*, 2005) and a few high density pond populations. Remarkably, despite the many ecological and behavioural characteristics of this species conducive to invasiveness (Copp *et al.*, 2005*b*), fathead minnow has not shown any indications yet of becoming an invasive species in its 10 years of presence in Flanders, this being in clear contrast to topmouth gudgeon in Flanders (Table II) and the neighbouring countries of France (Carpentier *et al.*, 2007), the Netherlands (Pollux & Korosi, 2006) and the U.K. (Pinder *et al.*, 2005).

One of the few deliberate introductions was asp, which is a favoured sport fish. Originally introduced to the Rhine, the asp's range was expanded and it

has sporadically been reported from the Dutch part of the River Meuse since 1984 (Crombaghs *et al.*, 2000). First reported in the Flemish Meuse in 2002, asp are occasionally captured from the river by recreational anglers (Gaethofs, 2004), including specimens as small as 100–150 mm, which suggests the species is reproducing.

ACCLIMATIZED SPECIES AND EXPECTED NEW SPECIES

Of the non-established species, rainbow trout is the only species that was regularly encountered during surveys. Stocking programmes with rainbow trout in public waters in Flanders ceased during the 1990s, except for an isolated lake (Galgenweel) and a drinking water reservoir (Kluizen). Stocking with this species is still common practice in private ponds and in public waters in southern Belgium (*i.e.* Wallonia) (E. Branquart, pers. comm.), so specimens observed in the present surveys are either escapees from neighbouring ponds or illegally stocked fish. Silver carp and grass carp are only very occasionally found, mostly in man-mediated habitats. Even rarer is the Nile tilapia; its distribution is restricted to warm waters in the proximity of power plants with adjacent aquaculture facilities from where individuals have escaped.

Because countries neighbouring Flanders have been invaded by a variety of rapidly spreading non-native fishes, it is likely that some or all of these species will eventually colonize the inland waters of Flanders and its un-invaded neighbours that share common drainage basins. Freyhof *et al.* (2000) suggested that the white-finned gudgeon *Gobio albipinnatus* Lukasch [now *Romanogobio albipinnatus* (Lukasch)] might already be in Belgium, but this has not been confirmed. Another species, vimba *Vimba vimba* (L.) has been recorded in two brooks in the county of Limburg (the Netherlands), which is contiguous to the Belgian county of Limburg (Crombaghs *et al.*, 1996). Therefore, it is only a matter of time before vimba enters Flemish waters. Similarly, a number of westward-expanding Ponto-Caspian gobies (Copp *et al.*, 2005*a*) are also expected to invade Flemish waters. The round goby *Neogobius melanostomus* (Pallas) has already been recorded in the Netherlands (van Beek, 2006), and both tubenose goby *Proterorhinus marmoratus* (Pallas) and bighead goby *Neogobius kessleri* (Günther) now occur in localized high densities in Germany (Gollasch & Nehring, 2006).

GENERAL CONSIDERATIONS

The impact of the current non-indigenous fish fauna on aquatic ecosystems is difficult to assess, as it is undoubtedly confounded by other human interferences. Water pollution, habitat degradation and fish migration barriers may have had equal, or even greater, adverse impacts on the indigenous fish fauna of Flanders than the introduction of non-indigenous species. Non-indigenous fishes may, therefore, represent both a symptom and a cause of decline in river health and the integrity of native fish communities, by their ability to thrive in degraded habitats and their potential impact. As the possible outcomes of introductions are still very poorly documented, the precautionary approach is most appropriate for dealing with non-native species introductions

and both intentional and accidental releases of non-indigenous species in the wild should be avoided.

Various international agreements (*e.g.* Convention of Biological Diversity, Bern Convention), EU legislation (*e.g.* Water Framework Directive, Council Regulation concerning the use of alien and locally absent species in aquaculture), national initiatives (*e.g.* Belgian Forum on Invasive Species) and regional rulings (*e.g.* Nature Conservation Decree, Resolution of the Flemish Executive on the Introduction of Non-Indigenous Species) should provide a sufficient legislative basis to address the issue of alien species. The conversion of legislative frameworks to regulatory tools, such as non-native species risk assessment (Copp *et al.*, 2005*b*), control measurements and eradication programmes, has not been fully implemented. Currently, increased effort is being made by the Belgium Forum on Invasive Species to prepare a reference list of non-native species, including a protocol for identifying invasive species. One of the major caveats that emerged during the discussions in the expert group was the lack of bibliographic information specifically on the realized impacts of non-native fish species. Research is urgently needed to address these gaps in knowledge, which is crucial to set out a functional policy on non-native species introductions and the protection of aquatic ecosystems integrity.

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