Received: 24 October 2023 | Revised: 25 March 2024 | Accepted: 27 March 2024

DOI: 10.1111/fme.12706

REVIEW

Fisheries Management and Ecology WILEY

Tracking aquatic animals for fisheries management in European waters

Aytaç Özgül[1] | Kim Birnie-Gauvin[2] | David Abecasis[3] | Josep Alós[4] | Kim Aarestrup[2] | Jan Reubens[5] | Jon Bolland[6] | Altan Lök[1] | Jena E. Edwards[7] | Polona Pengal[8] | Marie Prchalová[9] | Milan Říha[9] | Renanel Pickholtz[10] | Knut Wiik Vollset[11] | Pedro Afonso[12] | Jan Grimsrud Davidsen[13] | Robert Arlinghaus[14] | Vahdet Ünal[1] | Robert J. Lennox[11]

[1]Faculty of Fisheries, Ege University, Izmir, Turkey

[2]Section for Freshwater Fisheries and Ecology, National Institute of Aquatic Resources, Technical University of Denmark, Silkeborg, Denmark

[3]Center of Marine Sciences, Universidade do Algarve (CCMAR), Faro, Portugal

[4]Instituto Mediterráneo de Estudios Avanzados, IMEDEA (CSIC-UIB), Esporles, Spain

[5]Flanders Marine Institute (VLIZ), Ostend, Belgium

[6]Hull International Fisheries Institute, University of Hull, Hull, UK

[7]NIOZ Royal Netherlands Institute for Sea Research, Department of Coastal Systems, Den Burg, The Netherlands

[8]Institute for Ichthyological and Ecological Research–Revivo, Šmartno pri Slovenj Gradcu, Slovenia

[9]Institute of Hydrobiology, Biology Centre, Czech Academy of Sciences, České Budějovice, Czech Republic

[10]School of Zoology, Tel Aviv University, Tel Aviv, Israel

[11]NORCE Norwegian Research Centre, Bergen, Norway

[12]Okeanos—Institute of Marine Sciences, University of the Azores, Horta, Portugal

[13]NTNU University Museum, Trondheim, Norway

[14]Albrecht Daniel Thaer Institute, Faculty of Life Sciences, Humboldt-Universität zu Berlin, Berlin, Germany

Correspondence
Aytaç Özgül, Faculty of Fisheries, Ege University, Izmir 35100, Turkey.
Email: aytac.ozgul@ege.edu.tr

Funding information
European Cooperation in Science and Technology, Grant/Award Number: CA18102

Abstract

Acoustic telemetry (AT) has emerged as a valuable tool for monitoring aquatic animals in both European inland and marine waters over the past two decades. The European Tracking Network (ETN) initiative has played a pivotal role in promoting collaboration among AT researchers in Europe and has led to a significant increase in the number of tagged and observed aquatic animals in transboundary European waters. While AT benefits decision-making and delivers essential data to management bodies, its potential for management decision-making mechanisms has yet to be fully harnessed. We reviewed existing research, studies, and organisational initiatives related to aquatic animal tracking and their utility in fisheries management in European waters. We found that AT has already contributed to many aspects of fisheries management, such as improved understanding of stock dynamics, identification of critical habitats, assessment of migration routes, and evaluation of the effectiveness of conservation measures. However, broader utilisation of tracking technologies is needed. By leveraging the full potential of AT, managers can make more informed decisions to protect, restore, and sustainably manage European waters and creatures that live therein.

KEYWORDS
acoustic telemetry, Europe, fisheries management, marine connectivity, marine spatial planning, migration

1 | INTRODUCTION

Aquatic ecosystems around the globe are threatened by many anthropogenic impacts, such as habitat degradation, pollution, warming, and overfishing, which includes bycatch of non-target species, some of which are threatened (Díaz et al., 2019; McCauley et al., 2015). Management strategies need to be identified that can reconcile conservation goals with maintaining or increasing fisheries yields for a growing human population (Gaines et al., 2010; Jupiter et al., 2017). Monitoring the status of resources and generating data for modelling population trajectories informs decision-making about regulating the exploitation of aquatic resources, including space, water (e.g. for energy production and carbon storage), or living resources in lakes, rivers, and oceans (Costa-Pereira et al., 2022; Hussey et al., 2015; Lennox et al., 2019; Vivian et al., 2017).

Biotelemetry is one technology that can provide valuable information to researchers and managers to track individuals for days, months, or years within a coverage area (Crossin et al., 2017). Biotelemetry is increasingly used to investigate diverse questions regarding the biology and ecology of fish, sharks, reptiles, invertebrates, and marine mammals (Florko et al., 2021; Hussey et al., 2015; Matley et al., 2022; McIntyre, 2014), but is underused to inform fisheries management (Crossin et al., 2017). Quantifying and describing animal movements and space use at various scales appears key to understanding the fundamental ecology of any aquatic organism, but is also essential for effective fisheries policy and conservation action (Cooke et al., 2016, 2022; Crossin et al., 2017). Acoustic telemetry is one of the most common types of biotelemetry to obtain these data (Lennox et al., 2023).

Acoustic telemetry is a widely used aquatic tracking method, in which signals transmitted from implanted or externally attached acoustic transmitters are detected and logged by nearby acoustic receivers. Continued advances and miniaturisation of transmitters have allowed researchers to quantify previously unobserved processes that are important for population dynamics, reproductive performance, and fitness for a wide range of taxa (Arnold & Dewar, 2001; Crossin et al., 2017; Lennox et al., 2023; Lucas & Baras, 2000). Introduced to European waters in the 1970s, telemetry is now widely used throughout Europe and neighbouring countries to monitor aquatic living resources and support research efforts to deliver essential data and insights to local, regional, national, and international management bodies (Abecasis et al., 2018; Alós et al., 2022; Young et al., 1972).

Fisheries management is an integrated process that includes determination of objectives, often in consultation with stakeholders or following legal mandates, information gathering, analysis, planning, consultation, decision-making, and allocation of resources, alongside the formulation, implementation, and enforcement of regulations and other rules that govern fisheries activities to ensure continued productivity of resources and accomplishment of other objectives (FAO, 1997). Any deficiency or weakness in one of these mutually reinforcing steps (e.g. information gathering) can adversely affect success of fisheries management. The European Union's Common Fisheries Policy (CFP) is the legal framework for management of marine European water. In inland waters, national and regional policies apply, but issues of fisheries management are generic. The CFP seeks to protect fish stocks and contribute to economically viable and competitive fisheries and aquaculture industries. In inland fisheries, and also some coastal sites, objectives of recreational fisheries are also important (Arlinghaus et al., 2019) as a broader conservation objective that are often derived from fisheries and nature conservation policies. In marine waters, with a focus on commercial fisheries, the European Union (EU) acts against the objective of meeting maximum sustainable yield (MSY) as part of the 2013 reform of the CFP. Against this objective and in light of historical overfishing, contemporary fisheries management in marine waters aims to regulate fishing mortality on a given stock to ideally produce MSY (O'Farrell & Botsford, 2006; Punt et al., 2014). Objectives for inland waters can differ from MSY-based objectives, especially if recreational fisheries are predominant and whose optimal experience is typically achieved at fishing mortality levels below MSY (Johnston et al., 2015). Besides a focus on fisheries, conservation objectives are also common in marine and fresh waters, sometimes conflicting and creating trade-offs with fisheries goals (Cowx et al., 2010).

To inform fisheries management, individual-level data provided by biotelemetry are useful information sources that can help to estimate difficult-to-estimate variables, such as population-level catchability, natural mortality, bycatch, catch-and-release mortality, or critical spawning habitats (Alós et al., 2022; Benaka et al., 2014; Donaldson et al., 2011; Lees et al., 2021). In most fisheries, the key spatial parameter is the stock unit, defined as all fish in an area that are part of the same reproductive process, with no immigration or emigration to or from the stock. In marine systems, data clearly delineating stock boundaries are often unavailable, and stock divisions are commonly assigned based on management convenience rather than relying on ecological data (Smedbol & Stephenson, 2001;

Stephenson, 1999). Such knowledge gaps, and challenges that impede effective fisheries management, can be partly overcome by using telemetry to quantify movement, migration timing, habitat use, and interactions among species and fishing gear. Thus, acoustic telemetry can be a relevant tool for scientists and managers to generate knowledge needed for decision-making. The present review builds on Crossin et al. (2017) to shed light on the key role of acoustic telemetry in research and management of European aquatic ecosystems. We non-exhaustively reviewed existing research, studies, and organisational initiatives related to aquatic animal tracking and discussed their utility in fisheries management in European waters.

2 | THE EUROPEAN CONTEXT

Acoustic telemetry is widely used in European lakes, rivers, fjords, and coastal areas of Atlantic and Arctic Oceans (Figure 1). Fewer studies have been in Mediterranean and central European rivers and lakes, although these areas contain some of the largest European ecosystems, such as the Danube and Rhine, and some of the most prominent lakes, such as Lake Balaton and Lake Constance (Abecasis et al., 2018). Most species studied are commercially or recreationally important fishes, such as Atlantic salmon (*Salmo salar*), brown trout (*Salmo trutta*), Atlantic cod (*Gadus morhua*), European eel (*Anguilla anguilla*), northern pike (*Esox lucius*), and white seabream (*Diplodus sargus*). Focusing work on species of relevance to fisheries is a common feature of tracking research (Matley et al., 2022). Relative to fish, other taxa such as mammals, crustaceans, and cephalopods are currently less represented in European tracking studies (Abecasis et al., 2018; Cabanellas-Reboredo et al., 2012; Giacalone et al., 2019). Moreover, many existing studies have been designed for a particular species or a specific challenge, with tracking infrastructure deployed for short periods without capacity for long-term observation. Most existing studies are therefore temporary and limited in geographic and population scope (Table 1).

Acoustic telemetry can provide European fisheries management with key population parameters, such as survival and emigration, but is thought to be underutilised, as is the potential for investigating species interactions (e.g. fish vs marine mammals), fisheries interactions (e.g. the overlapping area of exploitation and harvest), and marine protected area (MPA) functionality (e.g. is the targeted fish species' home range actually covered by the MPA; Alós et al., 2022; Lees et al., 2021; Matley et al., 2022). This represents a potential loss in knowledge that is fisheries-independent (unlike many traditional sampling methods) and also potentially cheaper because the cost of launching marine surveys with research vessels is expensive and

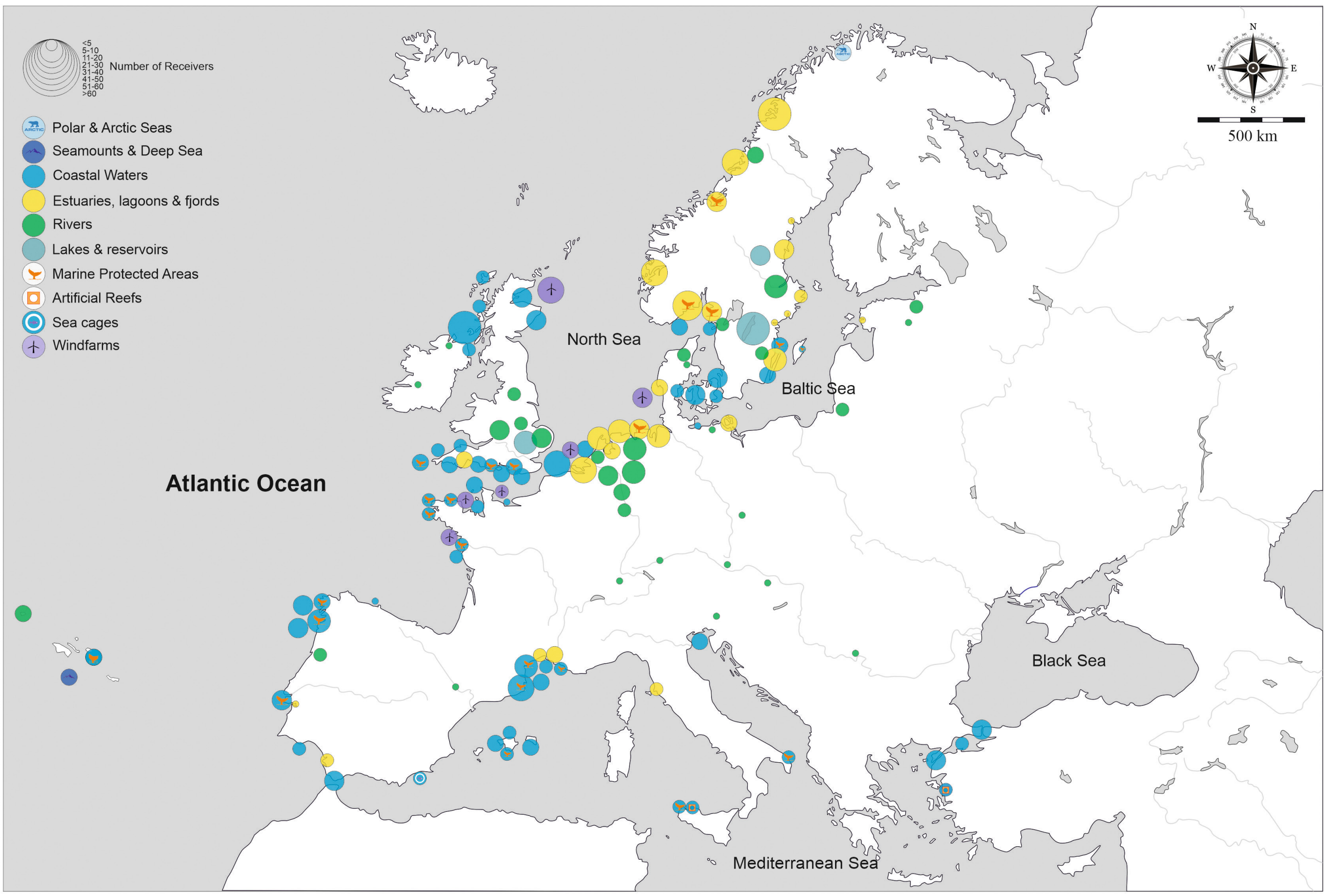

FIGURE 1 Locations of acoustic telemetry studies in European waters. Circle size indicates the number of receivers, and colours indicate area of use (data are from the European Tracking Network, https://www.lifewatch.be/etn).

TABLE 1 Applications of acoustic telemetry in European waters: Species, highlights, challenges and recommendations.

Realm	Species	Highlights	Challenges	Recommendations	References
Polar & Arctic seas	• *Melanogrammus aeglefinus* • *Salmo trutta* • *Salvelinus alpinus*	• Global warming • Sea ice melting • Interaction between species	• Losses of acoustic performance • Highly research costs • Rougly environmental conditions	• Raising awareness • Review of management & conservation policies	• Halvorsen (2019) • Davidsen et al. (2020) • Davidsen et al. (2021)
Sea mounts & deep sea	• *Pagellus bogaraveo* • *Pagrus pagrus* • *Pseudocaranx dentex*	• Conservation & management of the deep sea ecosystem • Management of deep-sea fishery and regularization of fisheries restrictions	• Difficulties of working with deep-water species • Technological and logistical challenges	• Improving equipment design & methodology • Specialized tagging/surger techniques • Development of custom-built acoustic equipment	• Afonso, Fontes, Guedes, et al. (2009); Afonso, Fontes, Holland, & Santos (2009) • Afonso et al. (2012) • Afonso et al. (2014)
Coastal waters	• *Anguilla anguilla* • *Dicentrarchus labrax* • *Gadus morhua* • *Loligo vulgaris* • *Merluccius merluccius*	• Increase of water temperature & thermocline • Urban development • Overfishing • Anthropogenic impact • Conservation & spatial management • Impact of invasive species	• Loss of acoustic equipments due to overfishing • Highly cost of long-term & large-scale studies • Legal processes and licensing • Lack of collaboration between cross-border countries • Compatibility between research equipment	• Revising the European Union recovery plan • Re-organize fishery regulations and bans • Long-term data collection from coastal waters • Managing stakeholders in the coastal waters	• Righton et al. (2007) • Cabanellas-Reboredo et al. (2012) • De Pontual et al. (2013) • Neat et al. (2014) • Bultel et al. (2014) • Verhelst et al. (2022) • De Pontual et al. (2023)
Estuaries, lagoons & fjords	• *Anguilla anguilla* • *Clupea harengus* • *Esox lucius* • *Gadus morhua* • *Platichthys flesus* • *Salmo trutta* • *Sarpa salpa* • *Scophthalmus maximus*	• Determination of migration & survival of key species • Stock management • Species-specific conservation and management • Identifying and conserving spawning areas	• Performance loss of acoustic equipment • Natural or human-induced underwater noise • Habitat loss due to land reclamation • Variable water level and environmental conditions	• Development of conservation & management strategy • Frequent checking & cleaning of acoustic receivers • Increasing the performance of acoustic equipment	• Aarestrup et al. (2010) • Abecasis et al. (2012) • Eggers et al. (2015) • Eldøy et al. (2019) • Kristensen et al. (2021) • Baden et al. (2022) • Dhellemmes et al. (2023)
Rivers	• *Alosa fallax* • *Anguilla anguilla* • *Barbus barbus* • *Lampetra fluviatilis* • *Leuciscus leuciscus* • *Petromyzon marinus* • *Platichthys flesus* • *Salmo trutta* • *Silurus glanis*	• Determination of migration & survival of key species • Fish passage • Species-specific conservation and management • Fisheries regulations • Habitat selection & management	• Natural or human-induced underwater noise • Fragmentation & pollution • Difficulty working in shallow water (<30 cm) • Decreased acoustic performance due to high water flow rate and turbulence • Vandalism	• Miniaturization of tags • Fixed stations for long term studies • Improving detection and noise filtering technology • Collaboration between cross-border countries • Labeling & citizen science	• Aarestrup et al. (2010) • Le Pichon et al. (2014) • Aarestrup et al. (2015) • Stein et al. (2016) • Tummers et al. (2016) • Silva et al. (2017) • Gutmann Roberts et al. (2019) • Barry et al. (2020) • Flávio et al. (2020) • Davies et al. (2021) • Lenhardt et al. (2021) • Davies et al. (2022)

TABLE 1 (Continued)

Realm	Species	Highlights	Challenges	Recommendations	References
Lakes & reservoirs	• *Anguilla Anguilla* • *Cyprinus carpio* • *Esox lucius* • *Perca fluviatilis* • *Rutilus rutilus* • *Salmo trutta* • *Sander lucioperca* • *Silurus glanis* • *Tinca tinca*	• Anthropogenic impact • Eutrophication & acidification • Management of recreational fisheries • Habitat management & stock assessment • Invasive species	• Decreased acoustic performance due to macrophytes • Natural or human-induced underwater noise • Vandalism	• Reservoirs management strategies • Fixed stations for long term studies • Frequent checking & cleaning of acoustic receivers • Labeling & citizen science	• Baktoft et al. (2013) • Jacobsen et al. (2014) • Trancart et al. (2018) • Trancart et al. (2020) • Monk et al. (2020) • Monk et al. (2021) • Říha, Gjelland, et al. (2021) • Říha, Rabaneda-Bueno, et al. (2021)
MPA	• *Diplodus sargus* • *Epinephelus marginatus* • *Homarus gammarus* • *Labrus bergylta* • *Palinurus elephas* • *Raja brachyura* • *Raja microocellata* • *Raja undulata* • *Sepia officinalis* • *Serranus atricauda* • *Solea senegalensis* • *Sparisoma cretense* • *Xyrichtys novacula*	• Spatial management & conservation • MPA efficiency & productivity • Species-specific conservation & management • Impact of invasive species • Habitat management & stock assessment • Habitat preference & side fidelity in the MPA • Identifying and conserving spawning areas	• Compatibility between research equipment • Lack of collaboration between cross-border countries • Vandalism • Illegal fishery	• Using acoustic telemetry data in MPA creation and management • Fixed stations for long term studies • Improving network between MPAs	• Moland et al. (2011) • Alós et al. (2012) • La Mesa et al. (2012) • Abecasis et al. (2013) • Morel et al. (2013) • Abecasis et al. (2014) • Koeck et al. (2014) • Abecasis et al. (2015) • Afonso et al. (2016) • Aspillaga et al. (2016) • Belo et al. (2016) • Giacalone et al. (2019) • Villegas-Ríos et al. (2020) • Leeb et al. (2021)
Artificial reefs	• *Diplodus sargus* • *Gadus morhua* • *Sciaena umbra* • *Scorpaena porcus* • *Scorpaena scrofa*	• Habitat selection & residency • Fisheries management • Fish stock enhancement • Conservation & spillover • Site fidelity and habitat use	• Losses of acoustic performance • Difficulties in tracking cryptic animals • Illegal fisheries	• Fishery regulations and bans • Improvement of AR design & location • Fine-scale acoustic tracking systems • Using powerful tags	• Lino et al. (2009) • D'Anna et al. (2011) • Abecasis et al. (2013) • Koeck et al. (2013) • Reubens et al. (2013) • Özgül et al. (2015) • Özgül et al. (2019)
Sea cages, offshore structures	• *Dicentrarchus labrax* • *Gadus morhua* • *Salmo salar* • *Sparus aurata*	• Fish welfare • Fish behaviour • Escapement • Interaction wild fish & sea cage • Fishery management • Planning the feeding and culture regime	• Decreased acoustic performance due to noise from cultured fish • Need for high resolution data • Decline in post surgery due to stress and disease	• Improving equipment design & methodology • Specialized surgery techniques • Transmitters with different sensors • Fine-scale acoustic tracking systems	• Uglem et al. (2010) • Arechavala-Lopez et al. (2012) • Muñoz et al. (2020) • Svendsen et al. (2021) • Alfonso et al. (2022)

(Continues)

TABLE 1 (Continued)

Realm	Species	Highlights	Challenges	Recommendations	References
Wind farms	• *Gadus morhua* • *Pleuronectes platessa* • *Solea vulgaris*	• Fisheries management • Fish stock enhancement • Habitat selection & residency • Anthropogenic impact	• Natural or human-induced underwater noise	• Fine-scale acoustic tracking systems • Fishery regulations and bans • Fixed stations for long term studies	• Winter et al. (2010) • Reubens et al. (2013) • Reubens, De Rijcke, et al. (2014); Reubens, Degraer, & Vincx (2014) • Van der Knaap et al. (2022) • Buyse et al. (2022) • Buyse et al. (2023)

limited in spatio-temporal scale (Matley et al., 2022) and because poor management decisions can be costly. Acoustic telemetry can also be developed further by moving beyond nearshore areas into the open sea via larger-scale deployments, at natural gates to fish migration, or into areas of aggregation after migration (Abecasis et al., 2018). Narrow access points between larger marine areas such as the Gibraltar Strait (between the Mediterranean Sea and the Atlantic Ocean), Dardanelles and Bosporus Straits (between the Black Sea and the Mediterranean Sea), Danish Straits (between the Baltic Sea and the Atlantic Ocean), and the Bergen–Shetland corridor between Norway and Scotland (Lennox et al., 2022) are natural gates where acoustic arrays can enable study of local species and movement of animals on a wide scale. The value has already been demonstrated in the Danish Straits, where an array has provided Baltic countries studying European eel (*Anguilla anguilla*) migration in local systems, with additional detections for tagged eels that migrate through the Danish Straits system (Verhelst et al., 2022). However, arrays of this magnitude require investment over a longer timescale and beyond a single-study approach. Many species have the potential to move or migrate through these natural gates, so arrays or infrastructure in place enable many more species to be studied with the same array deployment cost. This calls for a more international collaboration and funding, such as EU funding schemes. Fine-scale telemetry can also inform fish ecology and responses to harvest in smaller freshwater systems, for example lakes (Lennox et al., 2021; Nathan et al., 2022), where fine-scale tracking can elucidate how fish interact with gear through fisheries-induced selection (Monk et al., 2021) and other relevant questions of management.

3 | HOW CAN TELEMETRY BE USED AS A FISHERIES MANAGEMENT TOOL?

3.1 | Exploitation and stock sizes

Telemetry can be used to assess whether fishery quotas are harvested, while providing an in-the-water estimate of the number of fish removed through harvest (Hightower & Harris, 2017; Monk et al., 2021). These critical insights can be derived from properly designed tracking data with arrays that cover large fractions of an ecosystem or even an entire ecosystem, which can support fisheries management by strengthening stock assessments and exploitation studies (Block et al., 2019; Byrne et al., 2017). Acoustic tags are expensive, so smaller numbers of fish are typically tagged than with standard external tags (e.g. T-bar, anchor, and spaghetti tags). This makes acoustic telemetry less optimal for mark–recapture studies, for estimating abundance. However, mark–resight models can be used to supplement or replace traditional mark–recapture methods by estimating stock abundance based on detection rates of tagged animals (Dudgeon et al., 2015; Lees et al., 2021; Sollmann et al., 2013). Such spatial models are, however, still challenging to parameterize and can be improved by accurate reporting of recaptured fish, which can be achieved by additional release of external marks (either acoustic tag or standard tag) and incentives for fishers to report recaptures.

3.2 | Vital rates

Most fisheries are managed based on knowledge of total mortality (*Z*), which is the sum of natural (*M*) and fishing (*F*) mortality. Age-specific mortality of fish is critical to understanding the rate of population growth and resiliency to harvest, which are challenging to calculate. Tracking can provide an estimate of natural mortality based on attrition of tags (Alós et al., 2016; Hightower & Harris, 2017), fish movements and receiver configurations (Villegas-Ríos et al., 2020), or tracking a large number of individuals over long periods (Block et al., 2019). However, movement of fish outside arrays, tag failure, and natural predation that are difficult to detect, and intraspecific variation (e.g. sex and age), can affect estimates of natural mortality based on telemetry. For small species that must be tagged with relatively large transmitters, tag effects can particularly confound natural mortality estimates and short battery life can bias estimates of mortality (Brownscombe et al., 2019). Predation tags can differentiate mechanisms of natural mortality to provide a more synoptic view of vital rates of fish in the wild in support of fisheries management (e.g. Weinz et al., 2020). However, validation of methods is needed to fully support fisheries management.

3.3 | Critical habitat

Highly mobile species may move through or reside in multiple jurisdictions during their lifetimes, by using discrete regions for different biological needs for feeding, maturation, and spawning. For such species, connections between seasonally visited habitats can be difficult to recognise. Broad home ranges and associations of individuals with multiple distinct habitats can complicate conservation and management by expanding spatial scales over which threats are encountered and subsequent protective measures must be established (Bangley et al., 2020). Acoustic telemetry studies often rely on prior knowledge of species' spatial distributions to guide placement of acoustic receivers and tagged fish, so prior studies are valuable for identifying and quantifying the significance of critical habitats, such as spawning grounds, especially in nearshore or freshwater environments (Janssen et al., 2006; Le Pichon et al., 2014; Walters et al., 2009), connectivity among areas (Olsen et al., 2023). Simultaneous monitoring of multiple tagged individuals also allows new aggregation sites to be identified in obscure or unexpected locations within a given study area that can indicate trends in local residency and site fidelity (Edwards et al., 2022; Ramsden et al., 2017; Reubens et al., 2013). Although data collection is typically limited to existing acoustic arrays, combining data for individuals detected across multiple networks can significantly expand the spatial scale of monitoring, by encompassing home ranges that span international or ocean basins (Iverson et al., 2019; Reubens, Verhelst, Van der Knaap, Wydooghe, et al., 2019). Furthermore, in contrast to traditional methods that provide a series of temporal snapshots in habitat use (e.g. habitat surveys using divers, Marsden et al., 2005; passive acoustics, Walters et al., 2009; and remotely operated vehicles, Janssen et al., 2006), acoustic telemetry can be used to monitor behavioural cycles over seasons or years (Nakayama et al., 2018). This can highlight the value of essential fish habitats over lifetimes of individuals and populations to reveal connections among distant habitats and potential migration corridors (Daley et al., 2015; Eldøy et al., 2019; Espinoza et al., 2021; Olsen et al., 2023).

3.4 | Stock boundaries and metapopulation structure

Delineation of population structure, or stocks, is a crucial aspect of successful fisheries management, though such information is often limited (Begg et al., 1999; Begg & Waldman, 1999). Fish movements are important determinants of population structure because they act as a mechanism through which populations mix and interact. Despite not being used systematically in fisheries management to identify stock structure, acoustic telemetry can be used to identify areas used by different populations and, if such areas overlap, to quantify connectivity among populations (Olsen et al., 2023) and thus identify boundaries among populations. Network analysis of acoustic telemetry data at a large scale may provide data that support or refute more commonly used genetic analyses, to offer new insights for improving management and conservation (Lédée et al., 2021; Lukyanova et al., 2024). Tagging Atlantic cod (*Gadus morhua*) with data storage tags (DSTs) enabled delineation of the boundary between two North Sea stocks, in direct support of fisheries management (Righton et al., 2007). Boundaries of many highly migratory species, including sharks such as spiny dogfish *Squalus acanthias*, *porbeagle Lamna nasus*, and basking shark *Cetorhinus maximus*, are still not well resolved within Europe, so tracking could help to differentiate between one panmictic population or multiple discrete stocks with unique vulnerabilities to local stressors (Cameron et al., 2018; Johnston et al., 2019; Lennox et al., 2022). In addition, telemetry can be used to identify population mixing and inform decisions about grouping populations together for management (Lukyanova et al., 2024). This approach can potentially save time and effort by considering large-scale dynamics of interconnected populations, rather than treating each population in isolation (Eggers, 2013; Källo et al., 2022).

3.5 | Interactions among invasive species and local fisheries

Controlling invasive species is a critical priority in fisheries management. Acoustic telemetry can be used to track movement and behaviour of native and invasive species to predict potential invasion hotspots and identify areas at high risk of invasion. One of the major pathways for invasions in Europe is the Suez Canal, which connects the Red Sea and the Mediterranean Sea and leads to introductions of algae, invertebrates, and fishes, commonly referred to as Lessepsian migration (Kourantidou et al., 2021). More than 400 Lessepsian multicellular organisms have been introduced into the Eastern Mediterranean (Galil et al., 2021), including 93 fish species, at an alarming rate of 2.5 species per year (Golani, 2021). The lionfish *Pterois* sp. and pufferfish *Lagocephalus* sp. are among the notable invasive species that pose significant threats to the economy and ecology of coastal habitats (Ünal et al., 2015, 2018). Invasive crayfishes are also a major economic and conservation concern in European rivers (Lipták et al., 2023; Weiperth et al., 2020). Pink salmon (*Oncorhynchus gorbuscha*) are invasive in Norway, Scotland, and Finland, and telemetry can be used as part of a strategy to optimise removal of these species to benefit valuable Atlantic salmon fisheries in coastal rivers (Sandlund et al., 2019). Invasive crayfish species, Atlantic blue crab *Callinectes sapidus*, and the round goby *Neogobius melanostomus* are causing significant ecological disruptions in Europe (Clavero et al., 2022; Kornis et al., 2012; Lipták et al., 2023; Mancinelli et al., 2017). Implementing telemetry studies can enhance understanding and management of these invasions (e.g., Bergman et al., 2022; Carr et al., 2004; Florko et al., 2021).

Managing biological invasions calls for an integrated approach based on scientific evidence about the biology of invasive species and social perspectives, because all non-native species are not considered invaders. Unlike native fishes, understanding movements and dynamics of invasive species can be more challenging because basic information about their life history and ecology is often lacking in newly colonised environments (Grubich & Odenkirk, 2014; Simberloff, 2003). Acoustic telemetry, however, has been used to predict and detect invasions, seek and destroy invaders, assess population structure, and evaluate harvest control rules (Lennox et al., 2016). Telemetry has been successfully used to manage invasions, such as in the Laurentian Great Lakes, where invasive sea lamprey (*Petromyzon marinus*) contributed to the collapse of valuable lake trout (*Salvelinus namaycush*) fisheries, and tracking of sea lamprey spawning movements was used to identify environmental drivers of movement and to adjust management strategies for capturing and removing sea lamprey from rivers (Holbrook et al., 2016).

4 | USING ACOUSTIC TELEMETRY TO INFORM MANAGEMENT OF AQUATIC SPECIES IN EUROPEAN WATERS

4.1 | Polar and Arctic seas

Polar and Arctic waters have become one of the most important frontiers in fisheries research because climate-induced melting of ice and increased access to the Arctic have led fisheries to expand into Europe's Arctic (Fauchald et al., 2021). These changes, termed borealisation or Atlantification (Ingvaldsen et al., 2021), will impact marine ecosystems and fisheries in unpredictable ways. Effects vary from being optimistic with increasing productivity to feed the world (Sundby & Nakken, 2008), to problematic with north-ward expansions being truncated by geographic limitations and seasonality (Wiencke & Hop, 2016). Informing fisheries management in rapidly changing environments is crucial to accurately predict how much of Arctic ecosystems will be lost and how fast changes will progress (Harris et al., 2022; Wassmann & Reigstad, 2011). An important question to answer is whether changing ecosystems will impact Arctic keystone species, such as polar cod *Boreogadus saida*, and how newly arrived Atlantic species, such as haddock *Melanogrammus aeglefinus* and Atlantic cod, will interact with native species (Mueter et al., 2020). Future habitat refuge for Arctic species will depend on factors such as microclimatic conditions and habitat heterogeneity, so fine-scale tracking studies will be essential for shedding light on the details of these interactions. For example, limited acoustic telemetry research has already been used to study these topics in the Arctic (Barkley et al., 2018; Edwards et al., 2022; Kessel et al., 2016; Moore et al., 2016). Furthermore, despite a recent surge in studies of movement ecology of Arctic gadoids, major knowledge gaps still exist in the behavioural ecology of these fishes and how they will respond to future climate change as polar and boreal specialists increasingly overlap (Pettitt-Wade et al., 2021).

The Arctic environment is one of the least accessible environments to conduct fisheries research. Arguably, acoustic telemetry is one of the few remaining methods to apply that does not require the presence of humans for most of the study period and can be conducted under winter ice (Hussey et al., 2015; Song et al., 2014; Wartzok et al., 1992). With continuous development of robust acoustic release systems and long-lived batteries, deployment of long-term acoustic receiver arrays in the Arctic might be one of the most insightful methods to study fish ecology and inform fisheries management based on distributions, migration patterns, and natural and fishing mortality of polar species (Hammer et al., 2022; Moore et al., 2016). Although challenged by harsh winter conditions, underwater deployments are now functionally and economically viable and should be pursued to fill gaps affecting the capacity for effective management in the Arctic (Hussey et al., 2017; Kessel et al., 2016).

4.2 | Seamounts and the deep sea

Biotelemetry has seldom been used to support the management of deep-sea fisheries in comparison with freshwater or coastal environments (Alós et al., 2022). Yet, the use of biotelemetry, and specifically acoustic telemetry, holds great promise for addressing the large knowledge gaps which still subsists in relation to the vast majority of fished species and other ecologically important organisms inhabiting seamounts and other deep-sea environments (Morato et al., 2006). This lag results from multiple factors, including the technical difficulties in handling and tracking animals in the remote, cold, and pressurised environments of the deep sea and use of classical approaches for fisheries management that do not consider variation in individual ecology (Edwards et al., 2019). However, recent technical and analytical advances have occurred fuelled by an increased interest in deep-sea species, including pelagic predators that venture into great depths (Braun et al., 2022), and the growing perception that effective, science-based conservation is needed to protect vulnerable deep-sea ecosystems, in particular, seamounts, which are considered oases of life and productivity (Morato et al., 2006).

Acoustic telemetry has been used to elucidate short- and long-term movements and habitat use of ecologically and commercially important deep-sea fishes on seamounts and slopes, such as black rockfish *Sebastes melanops* (e.g. Green & Starr, 2011), blackspot seabream *Pagellus bogaraveo* (Afonso et al., 2012), and halibut *Hippoglossus stenolepis* (Nielsen & Seitz, 2017). Such studies eventually allowed a new perception of individual variability, detailed tridimensional space use, and its ecological significance, such as for feeding or spawning (Afonso et al., 2014). Space use, site fidelity, and mortality estimates have been useful for understanding effects of fishing and management measures such as MPAs on seamounts, such as endangered bycatch species such as deep-water sharks (e.g. Fauconnet et al., 2023). Satellite telemetry has been mostly used to study the behaviour of large predators around deep-sea environments, including marine mammals, sharks, and fishes (Abecasis et al., 2018; Braun et al., 2022; Hussey et al., 2015). Miniaturisation of PSAT and fast improvements in acoustic transmitter battery life now enable the tagging of smaller fishes for longer periods (e.g. Brownscombe et al., 2022). Studies have increasingly combined multiple tracking techniques with high-resolution and multiple sensors across multiple scales of predator behaviour, from pursuit and tracking of prey on seamounts to deep diving during large-scale migrations (Braun et al., 2022). Therefore, one should expect a substantial increase in the use of biotelemetry in general and acoustic telemetry to fill large knowledge gaps in the biology and ecology of fished species (and other species of importance) on seamounts and in the deep sea.

4.3 | Coastal waters

The European coastal zone is dynamic and diverse, by encompassing a wide range of highly productive ecosystems relevant for fisheries. These ecosystems, including seagrass beds, salt marshes, soft sediments, and biogenic structures, play vital roles as nurseries, breeding areas, and foraging grounds for numerous commercially and ecologically important fish and invertebrate species (Seitz et al., 2014). Despite such unique and intrinsic ecological values, an extensive history of coastal development and continued habitat degradation has drastically reduced the functional capacity of European coastal habitats (Airoldi & Beck, 2007; EEA, 2006; Lotze et al., 2006) with implications for population dynamics and commercial and recreational yields (Arlinghaus et al., 2023; Seitz et al., 2014).

Management of coastal European fisheries has relied heavily on traditional methods, such as stock assessments and conventional mark–recapture programmes to define species distributions and abundance. For example, mark–recapture studies in the early 2000s provided evidence of localised residency and homing of a highly exploited commercial species, the European hake (*Merluccius merluccius*), which resulted in significant changes to stock assessments by the International Council for the Exploration of the Sea (ICES) (De Pontual et al., 2013). However, study limitations, including differential reporting rates among fishing fleets and partial spatial coverage of the population's distribution by tagging, impeded the observation of seasonal movements or spatio-temporal structure potentially exhibited by the target stock with potential implications for estimates of natural mortality (De Pontual et al., 2013). By eliminating the need for fish recapture and providing more detailed information on individual movements, acoustic telemetry can address these and other challenges encountered by conventional mark–recapture studies, while also estimating demographic parameters (e.g., natural mortality, apparent survival, and absolute abundance), sometimes with greater precision (Dudgeon et al., 2015; Lee et al., 2014; Lees et al., 2021).

The Atlantic cod has been a commercially valuable species for decades. Cod are distributed across the continental shelves of the North Atlantic, as distinct self-sustaining populations (ICES, 2020). Cod are economically high in value and are also culturally important (Meager et al., 2018). However, stocks declined due to overfishing and warming temperature, so management plans were developed to promote stock recoveries, with limited success (Kraak et al., 2013). ICES has a long record of research on population structure of cod in the North Sea and adjacent areas, but stock identity remains unclear, with multiple populations in the North Sea that extend into neighbouring areas that complicate assessment of stock status and fisheries management needed to restore healthy stocks (ICES, 2021). Telemetry can help to resolve these issues and improve assessments (Kristensen et al., 2021). For example, cod population structure around the British Isles based on animal tracking to map movements suggested that population structure was at a finer scale than was currently recognised (Neat et al., 2014). Different stocks also experience different environmental conditions that influence life history, growth, and reproduction (Olsen et al., 2023; Reglero et al., 2018). Recent work combining telemetry and genomics identified behavioural ecotypes based on chromosomal inversions in cod (Pampoulie et al., 2022), thereby suggesting that telemetry could identify stocks and predictive tools to understand how different fisheries might selectively harvest genetically distinct ecotypes.

4.4 | Estuaries, lagoons, and fjords

Estuaries, lagoons, and fjords are spatially and temporally complex critical transition zones linking open marine habitats with land and fresh water, where salt water and fresh water mix intra- and inter-annually. Estuaries and lagoons, especially, are highly productive systems used by numerous organisms (Arlinghaus et al., 2023; Beck et al., 2001; Garrido et al., 2011). Despite their ecological significance, estuaries and lagoons are also among the most anthropogenically degraded habitats on Earth (Blaber, 2002; Edgar et al., 2000;

Webster & Harris, 2004), as preferred locations for human settlement because of their natural connections between inland and oversea destinations. Thus, human activities drive pressures on physical functioning, habitats, and ecosystem services in these habitats.

Estuaries, lagoons, and fjords are excellent locations for acoustic telemetry studies because they are spatially explicit and confined. The detection range of acoustic transmissions from tags is limited, so estuaries and lagoons that are smaller than most oceans can be covered effectively by acoustic receivers (Dhellemmes et al., 2023). However, estuaries are mixing areas where temperature, pressure, salinity, and sediments that mix across small spatial scales create barriers to tag detection ranges (Bruneel et al., 2023; Kessel et al., 2014; Reubens, Verhelst, Van der Knaap, Deneudt, et al., 2019). Moreover, flow close to river mouths or tidal velocity in macrotidal estuaries can make receiver deployments challenging, especially as sediments shift and damage or bury receivers (Abecasis et al., 2012). Fish tracking data in estuaries, lagoons, and fjords can be used to inform stakeholders on spawning sites, connectivity, and survival (Aarestrup et al., 2010, 2015; Flink et al., 2023), as when planning locations of open net-pen Atlantic salmon farming (Crossin et al., 2017; Davidsen et al., 2019) or land reclamation (Davidsen et al., 2021).

4.5 | Rivers

Rivers are among the most threatened ecosystems worldwide, with river fragmentation by anthropogenic structures being a primary cause of decline (Grill et al., 2015; Tickner et al., 2020). In Europe, more than 1 million barriers fragment rivers, 68% of which are small barriers with a height of less than 2 m (Belletti et al., 2020). Together with pressures from chemical pollution, invasive species, channelisation, and transportation, rivers differ considerably from those that fish adapted to through millennia (Finlayson et al., 2005). The fast pace of change may not be aligned with evolutionary processes, so behavioural changes are expected to be the first immediate detectable response (Munday et al., 2013). Human-made structures can delay migration and result in retreat behaviour to search for alternative upstream migration routes, as for acoustic-tagged sea lamprey in the River Severn (Davies et al., 2022). Moreover, anadromous species often must pass multiple impediments during freshwater migrations, where telemetry can be used to estimate survival and behaviour of downstream (Aarestrup et al., 1999) and upstream (Davies et al., 2021) migrants. The EU Water Framework Directive considers river connectivity key to good ecological status, so assessing impacts of human-made obstacles and efficacy of mitigation measures is needed when removal is not possible (Water Framework Directive, 2024). Acoustic telemetry, especially if coupled with Passive Integrated Transponder (PIT) or radio telemetry, is a good and well-established tool to undertake such research (Silva et al., 2017; Tummers et al., 2016).

For fisheries management in rivers, acoustic telemetry can inform stock assessments and connectivity. Out-migrating salmon smolts are among the most studied species and life forms (Thorstad et al., 2012). Mortality and out-migration timing has been used directly to inform stock assessments and fisheries management. For example, out-migrating Atlantic salmon smolts and returning adults were counted and tagged to estimate survival at sea at a trap 3.5 km upstream of the ocean in the River Bush, Northern Ireland, although survival of acoustically tagged smolts (32% to 68%) within this short stretch of river suggested that many smolts assumed to have migrated to sea died before reaching the sea (Flávio et al., 2020). Acoustic telemetry studies of seaward migration of European eel, since dramatic population declines that were partly attributed to interactions with human infrastructure, have led to a classification as critically endangered by the International Union for Conservation of Nature and Natural Resources (IUCN) and legislation for their protection (Regulation EC 1100/2007). Tagged European eels migrated using a discontinuous, stepwise migration over an extended period of time, with only 28% migrating clearly downstream (Stein et al., 2016).

4.6 | Lakes, reservoirs, and ponds

Many lakes are threatened by eutrophication, warming, and invasive species. Lake ecosystems may also be entirely human-created, such as ponds, water-supply reservoirs, and gravel-pit lakes. Lakes offer excellent environments for high-resolution tracking and can help elucidate crucial insights for population biology (see review in Lennox et al., 2021).

Telemetry is a powerful tool for management of fish communities in lakes and artificial waters. Recent studies in newly created post-mining lakes, for example, have shown the importance of macrophyte presence on the behaviour and population dynamics of the apex predator, the northern pike (Říha, Gjelland, et al., 2021), besides the potential impact on the overall fish community (Vejříková et al., 2017, 2022). Results were used to modify pike stocking in similar lakes (Peterka, 2021a, 2021b). Another study of space use by three predator fish species (northern pike, pikeperch *Sander lucioperca*, and European catfish *Silurus glanis*) identified specific areas of the reservoir and seasons when predatory fish were most likely to be present and at risk from illegal fishing (Říha, Rabaneda-Bueno, et al., 2021). These findings are of special importance in drinking water waterbodies such as the Římov Reservoir, where the study was conducted and where a long-term predator stocking programme for biomanipulation is applied (Jůza et al., 2022; Říha et al., 2009). For assessing threats, high-resolution telemetry has been used to assess impacts of boating, angling, and handling on several species-specific changes in activity, swimming speed, and behaviour (Jacobsen et al., 2014). For example, temperature-dependent activity of angled pike changed following handling but lasted less than 48 h (Baktoft et al., 2013). High-resolution tracking has also been used to quantify fishery-induced selection (Monk et al., 2021) and study behavioural and fitness outcomes of introduced predators that mimic stocking experiments (Monk et al., 2020). Telemetry can help in the management of carp (*Cyprinus carpio*) in aquaculture by providing a better insight into the feeding activity of the fish and the utilisation of the feeding ground in a pond (Jurajda et al., 2016). Such telemetry studies can help managers better assess how fish cope with human-induced stressors such as angling or stocking, predict likely post-release survival, and infer the potential for fisheries-induced timidity of exploited fish stocks (Arlinghaus et al., 2017; Monk et al., 2021).

4.7 | Marine protected areas (MPAs)

Conventional fisheries management based on maximum sustainable yield (e.g., quotas, minimum landing size, and gear restrictions) has often been insufficient to sustainably manage world fisheries (Pauly et al., 1998; Roberts, 1997). MPAs have been advocated as a tool for fisheries management and conservation, particularly to expand from a conventional species-specific approach to fisheries management to a more ecosystem-based approach (Gaines et al., 2010; Roberts, 1997), to overcome uncertainties of complex interspecific relationships. Importantly, MPAs only function from a conservation perspective if the MPA is large enough to encompass the home range of fish and can only deliver fisheries benefits if fish spill over boundaries (Abecasis et al., 2015; Di Lorenzo et al., 2020). Both issues can be studied well with telemetry.

For fisheries, the main benefits of MPAs come from the recruitment effect (net larval export) and the spillover effect (net adult export), which should increase fishing yield outside the MPA, particularly in nearby areas (Russ, 2002). Information on species habitat use, home range areas, and movement is important for designing MPAs, assessing their effectiveness, and implementing adaptive management strategies (Grüss et al., 2011; Pomeroy et al., 2005), but is usually limited to movements of large-sized fish. Efficiency of MPAs is highly dependent on size and target species. For example, acoustic telemetry studies in the Arrábida MPA (Portugal) indicated that the MPA was large enough to protect home ranges of *Diplodus sargus* (Abecasis et al., 2015) and Senegalese sole *Solea senegalensis* (Abecasis et al., 2014), but too small for cuttlefish *Sepia officinalis* (Abecasis et al., 2013). Other studies of European MPAs showed that even small marine reserves provided relevant spatial and temporal protection for commercial and recreational fish species, particularly site-attached species (e.g. Afonso et al., 2016; Alós et al., 2012; Aspillaga et al., 2016; Belo et al., 2016; Koeck et al., 2014; La Mesa et al., 2012; Moland et al., 2011; Villegas-Ríos et al., 2013). Acoustic telemetry studies of other species suggested that a network of MPAs, together with traditional fishing effort management measures, were needed (red porgy *Pagrus pagrus*, Afonso, Fontes, Guedes, et al., 2009; white trevally *Pseudocaranx dentex*, Afonso, Fontes, Holland, & Santos, 2009; and some ray species, Leeb et al., 2021; Morel et al., 2013). Acoustic telemetry holds great potential for elucidating connectivity between MPAs, identifying migration corridors, and understanding density-dependent movements outside of protected areas (Alós et al., 2022). To harness this potential effectively, collaboration and knowledge exchange are needed between researchers and managers, to translate research findings into practical management measures that support long-term conservation and sustainable use of European marine ecosystems (Brownscombe et al., 2019). However, results of studies in European MPAs have seldom been applied to effective protected area or fisheries management (Huserbråten et al., 2013; Marques et al., 2024).

4.8 | Artificial reefs

Protection and restoration of fish habitats is an important component of fisheries management (Brownscombe et al., 2022). Artificial reefs (ARs) have been used for decades around the world for many purposes, such as habitat restoration, stock enhancement, tourism, recreation, fisheries management, and research areas (Addis et al., 2013; FAO, 2015). ARs were first used in Monaco, Europe, in the 1960s and have since been widely used in fisheries management by more than 20 countries, especially in the Mediterranean Sea (FAO, 2015). The recent increase in ARs necessitates development of a management model for artisanal and recreational fishing at these sites (Pioch et al., 2011). Small-scale fisheries on ARs should be controlled using a management model as in other fishing areas (Polovina, 1991; Santos & Monteiro, 2007). Otherwise, establishment of ARs might result in net negative outcomes, rather than ensuring economic and ecological benefits (Becker et al., 2018; Brickhill et al., 2005; Lök et al., 2011). Fisheries are commonly regulated in ARs to ensure sustainability of the reef area by implementing seasonal or spatial closures and fishing gear restrictions (BSGM, 2020). Nevertheless, characteristics of fishing fleets (fishing power, fishery methods, etc.), stakeholders (diving clubs, aquaculture, etc.), socio-economic conditions of the coastal zone, effective area of ARs, home range areas, and movement patterns of reef species, are major factors to be considered in management of ARs (Addis et al., 2013; Koeck et al., 2013; Kramer & Chapman, 1999).

Understanding the home range and residency of reef species can greatly influence success of fisheries management in ARs. Determining the variance of fish behaviour on artificial reefs is essential for evaluating reef design and determining effective conservation and management strategies after the reef is settled (Powell, 2000; Wiens, 2000). Acoustic telemetry has recently been used to detect fine-scale movements of reef species at ARs and in surrounding habitat (Pincock & Johnston, 2012; Voegeli et al., 2001). Acoustic telemetry has been used to investigate behaviour of many fish species in ARs, including common dolphinfish *Coryphaena hippurus* (Josse et al., 2000), yellowfin tuna *Thunnus albacares*, skipjack tuna *Katsuwonus pelamis* (Doray et al., 2006), bigeye tuna *Thunnus obesus* (Hallier & Gaertner, 2008), *Diplodus sargus* (D'Anna et al., 2011), northern red snapper *Lutjanus campechanus* (Topping & Szedlmayer, 2011), copper rockfish *Sebastes caurinus* and Lingcod *Ophiodon elongatus* (Reynolds et al., 2010), bluespotted sea bass *Cephalopholis taeniops* (Lino et al., 2011), Atlantic cod (Reubens et al., 2013), brown meagre *Sciaena umbra* (Özgül et al., 2015), black scorpionfish *Scorpaena porcus*, and red scorpionfish *Scorpaena scrofa* (Özgül et al., 2019). Similar to artificial reefs, telemetry has been used in lakes to study how predators aggregate on artificial structures (Ahrenstorff et al., 2009).

4.9 | Sea cages and other offshore structures

Aquaculture plays a significant role in European waters, with a focus on farming sea gilthead seabream *Sparus aurata* and European sea bass *Dicentrarchus labrax* in the Mediterranean Sea and *Salmon salar* on the Atlantic coast (Barnabé & Dewavrin, 2019; Scientific, Technical and Economic Committee for Fisheries (STECF), 2023). However, escapement of cultured fish from sea cages challenges the aquaculture industry (Arechavala-Lopez et al., 2013; Dempster et al., 2007; Jensen et al., 2010). Cultured fish escape due to various factors, including storms, infrastructure failures, operational errors, and biological causes such as net-biting, and can impact wild fish populations and ecosystems (Jensen et al., 2010). Fish escaping from marine fish farms have always been a major socio-economic and ecological concern, as a vector for genetic introgression, invasive species, and pathogens (Fleming et al., 2000; Heggberget et al., 1993; Naylor et al., 2005). Studies on the prevention or reduction of fish escape are ongoing in many countries (Izquierdo-Gomez & Sanchez-Jerez, 2016). However, the fate of fish escaping from net cages is highly controversial (Arechavala-Lopez et al., 2011, 2012; Izquierdo-Gomez & Sanchez-Jerez, 2016). Acoustic telemetry enables the study of behaviour of different sizes and species escaping from aquaculture facilities (Arechavala-Lopez et al., 2012; Uglem et al., 2010), to inform researchers and fish farms about behaviour of fleeing fish with trials under different conditions, perhaps to capture escaped fish that remain near sea cages (Dempster et al., 2018). Telemetry has also been used to study migration of fish past fish farms to assess the impact of disease and parasites in aquaculture facilities on the mortality of wild fish populations (Vollset et al., 2018). Migratory timing and pathways from telemetry (Vollset et al., 2022) are directly used to inform models of disease transfer (Johnsen et al., 2021; Stige et al., 2022) and to estimate mortality for informing management of these populations.

4.10 | Wind farms

Offshore wind energy is expanding rapidly globally, with significant developments already in shallow waters of the North Sea and along European coastlines (Arapogianni et al., 2011). Significant effects of offshore wind farms (OWFs) on marine ecosystems include changes to local biodiversity and ecosystem functioning (Andersson et al., 2009; Lindeboom et al., 2011). For fish, costs and benefits of wind farms include the exclusion of fisheries (Buyse et al., 2022; Leonhard et al., 2011; Van Hal et al., 2012) and addition of submerged structures as artificial reefs (windmill artificial reefs, WARs) that provide refuge and increase habitat complexity that attract and support production of benthopelagic fish species (Bergström et al., 2013; Langhamer et al., 2009; Methratta & Dardick, 2019; Reubens, De Rijcke, et al., 2014; Winter et al., 2010). Benthic and pelagic fish communities can also be disturbed during construction, operation, and decommissioning of wind farms, in the form of habitat destruction, generation of underwater sound, and human-induced electromagnetic fields (Gill et al., 2005; Raoux et al., 2017; Thomsen et al., 2006).

Small-scale acoustic telemetry studies have revealed strong residency and site fidelity of demersal species, such as Atlantic cod, sole *Solea solea*, and plaice *Pleuronectes platessa* around wind turbines (Buyse et al., 2023; Reubens et al., 2013; Reubens, Degraer, & Vincx, 2014; Winter et al., 2010). However, exposure to sounds produced within these areas (seismic surveys and pile driving) can also alter the behaviour of tagged fish, with potential consequences for individual survival (Van der Knaap et al., 2021, 2022). Continued study of fish movements within and around wind farms will illustrate effects of local attractants and stressors on individual fish (Gimpel et al., 2023; Wang et al., 2023). Details of fish residency, recurrence rates, and fine-scale behaviour from presence–absence data or positional tracking can also reveal the functional role of wind farms in fish life cycles and highlight their potential contribution to ecosystem-based marine spatial planning (MSP) (Hammar et al., 2015). Additionally, acoustic telemetry networks such as the ETN will be essential for observing the potential influence of wind farms on fish distributions and migratory behaviours over broader spatial scales (Reubens, Verhelst, Van der Knaap, Wydooghe, et al., 2019).

5 | TRACKING NETWORKS AND CENTRALISED DATABASES: BENEFITS TO FISHERIES MANAGEMENT

Globally, fish tracking communities are organising themselves into networks. The leading global tracking network is OTN (Ocean Tracking Network), a global aquatic research, data management, and partnership platform with a mission to inform stewardship and sustainable management of aquatic animals by providing knowledge on their movements, habitats, and survival in the face of changing global environments (Iverson et al., 2019). OTN has partner nodes (e.g. the Florida Atlantic Coast Telemetry (FACT), the Integrated Tracking of Aquatic Animals in the Gulf of Mexico (iTAG), and the Acoustic Tracking Array Platform (ATAP)) at different places in the world, which form a large network of tracking infrastructure across the globe. In Australia, the Integrated Marine Observing System Animal Tracking Facility (IMOS ATF) established a permanent array of acoustic receivers around Australia, a centralised national database to foster collaborative research across the user community and quantify individual behaviour across a broad range of taxa that uses animal tracking to support of fisheries management, marine spatial planning, and human health and safety to learn about shark interaction risks (Hoenner et al., 2018). In Europe, a tracking network initiative was long missing (Abecasis et al., 2018), and with

ETN, the network idea was supported in 2018. ETN's mission is to track aquatic animals across Europe to better understand, protect, and manage them. ETN is both an infrastructure and research network that provides necessary capacity building, enhances collaborations, and maintains a centralised database for aquatic animal tracking data (Abecasis et al., 2018). Having such a centralised data system for all aquatic animal tracking data generated across Europe is key to produce necessary knowledge for decision-making related to fisheries management. ETN also offers both the ability to easily access data for meta-analysis (e.g. on a particular species investigated in several places) and legacy analysis over time to investigate decadal changes in movement. Furthermore, linking with larger arrays allows researchers working locally with migratory fish to document survival and behaviour over a larger scale at low extra cost. This may prove valuable particularly for longer migrating species, but also offers new insight into species migration and species normally assumed to be resident. ETN currently maintains movement information of almost 20,000 individuals of over 120 different species tagged by institutes across Europe. By having access to data gathered at the European network level, better and more insights can be generated on movement, migration, important habitats, and species interactions, while linking to environmental factors that might influence presence.

Benefits of tracking networks are maximised by using compatible equipment throughout the network, ensuring easy access to data by all network users, and using common best practices in all network projects. First, equipment must be compatible across different telemetry studies to ensure unique scientific benefits of networking. Open Protocol (OP) advocated by ETN provides robust and energy-efficient transmission protocols that can be used by all manufacturers after signing a memorandum of understanding and a licence agreement. IDs of the protocols are controlled by an independent third party (Reubens et al., 2021). Protocols contribute to standardised data collection, sharing, and collaboration among researchers, institutions, and management bodies in Europe. FAIR data (findable, accessible, interoperable, and reusable) principles ensure access to data by all users by (1) emphasising use of standardised data formats and metadata to ensure consistency and compatibility across different telemetry studies that enables researchers to easily share and integrate data, thereby fostering collaboration and facilitating large-scale analyses, and (2) encouraging data sharing through open-access platforms (FAIRification) by making data openly available, enhancing transparency, reproducibility, and data reuse, to facilitate cross-disciplinary research that supports evidence-based decision-making in aquatic species management. Furthermore, harmonisation of telemetry methodologies and best practices should be promoted within tracking networks, to provide guidelines and recommendations for data collection and standardisation to enhance comparability of results across studies and facilitate development of robust management strategies. By fostering collaboration, standardisation, and data sharing, acoustic tracking networks promote a holistic and informed approach to fisheries management in European waters.

6 | CONCLUSIONS

We reviewed the important role that acoustic telemetry plays in research and management of European aquatic ecosystems, particularly fisheries. We reviewed selected research, studies, and organisational initiatives pertaining to aquatic animal tracking and its utility in fisheries management of European waters. Acoustic telemetry plays a crucial role in informing management of aquatic species in European waters by providing valuable insights into migration patterns, habitat use, behaviour, fishery impacts, and climate change impacts. Incorporating these realms into fisheries and conservation management strategies can help to ensure long-term sustainability and conservation of European aquatic ecosystems.

To better protect, manage, and monitor European waters, biotelemetry and acoustic telemetry technologies still have an unused potential, particularly in southern Europe, especially in the Mediterranean and Black Seas, and broadly in freshwater and coastal areas. Within ETN, collaboration among researchers from different European countries should increase. Developments are positive. Acoustic telemetry infrastructures are and will be established across Europe with the Strategic Infrastructure for Improved Animal Tracking (STRAITS) project that emerged as a result of the ETN network. Tracking large-scale movements of key species can provide critical information about when, where, and why animals move, when, where, and how much fishing should be allocated, how animals are responding to climate change and other anthropogenic threats, overall health of ecosystems, and provide knowledge needed for industries and policy setters to develop spatial protections and other marine management directives in line with EU policies (e.g. Marine Strategy Framework Directive, Common Fisheries Policy, CFP; Natura 2000 Directives). However, this network established among telemetry researchers across Europe, thanks to ETN, needs to be strengthened and sustained, with particular emphasis on scientific policies for monitoring migratory and endangered species.

ACKNOWLEDGEMENTS

This publication represents a collaborative effort from the European Tracking Network and is based upon work from COST Action—The European Animal Tracking Network (CA18102), supported by COST (European Cooperation in Science and Technology, www.cost.eu). Additionally, J. Reubens acknowledges support from the Research Foundation Flanders (FWO) as part of the Belgian contribution to LifeWatch. M. Prchalová and M. Říha are grateful for the support provided by the project nos. QK23020002 and QK21010131. J. Alós received funding from the METARAOR Project (grant no. PID2022-139349OB-I00) funded by MCIN/AEI/10.13039/501100011033/FEDER, UE. D. Abecasis was funded by the Fundação para a Ciência e a Tecnologia through UIDB/04326/2020, UIDP/04326/2020, LA/P/0101/2020, and DL57/2016/CP1361/CT0036.

CONFLICT OF INTEREST STATEMENT

All authors declare that they have no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

ORCID

Aytaç Özgül https://orcid.org/0000-0001-7706-9012
Kim Birnie-Gauvin https://orcid.org/0000-0001-9242-0560

REFERENCES

Aarestrup, K., Baktoft, H., Thorstad, E.B., Svendsen, J.C., Höjesjö, J. & Koed, A. (2015) Survival and progression rates of anadromous brown trout kelts *Salmo trutta* during downstream migration in freshwater and at sea. *Marine Ecology Progress Series*, 535, 185–195.

Aarestrup, K., Jepsen, N. & Rasmussen, G. (1999) Movements of two strains of radio tagged Atlantic salmon (*Salmo salar* L.) smolts through a reservoir. *Fisheries Management and Ecology*, 6, 97–107.

Aarestrup, K., Thorstad, E.B., Koed, A., Svendsen, J.C., Jepsen, N., Pedersen, M.I. et al. (2010) Survival and progression rates of large European silver eel *Anguilla Anguilla* in late freshwater and early marine phases. *Aquatic Biology*, 9, 263–270.

Abecasis, D., Afonso, P. & Erzini, K. (2014) Can small MPAs protect local populations of a coastal flatfish, *Solea senegalensis*? *Fisheries Management and Ecology*, 21, 175–185.

Abecasis, D., Afonso, P., O'Dor, R.K. & Erzini, K. (2013) Small MPAs do not protect cuttlefish (*Sepia officinalis*). *Fisheries Research*, 147, 196–201.

Abecasis, D., Bentes, L. & Erzini, K. (2012) Movements of *Sarpa salpa* (Linnaeus, 1758) (Sparidae) in a coastal lagoon (Ria Formosa, Portugal). *Journal of Applied Ichthyology*, 28, 126–129.

Abecasis, D., Horta e Costa, B., Afonso, P., Gonçalves, E. & Erzini, K. (2015) Early reserve effects linked to small home ranges of a commercial fish, *Diplodus sargus*, Sparidae. *Marine Ecology Progress Series*, 518, 255–266.

Abecasis, D., Steckenreuter, A., Reubens, J., Aarestrup, K., Alós, J., Badalamenti, F. et al. (2018) A review of acoustic telemetry in Europe and the need for a regional aquatic telemetry network. *Animal Biotelemetry*, 6, 12.

Addis, D.T., Patterson, W.F., Dance, M.A. & Ingram, G.W. (2013) Implications of reef fish movement from unreported artificial reef sites in the northern Gulf of Mexico. *Fisheries Research*, 147, 349–358.

Afonso, P., Abecasis, D., Santos, R.S. & Fontes, J. (2016) Contrasting movements and residency of two serranids in a small Macaronesian MPA. *Fisheries Research*, 177, 59–70.

Afonso, P., Fontes, J., Guedes, R., Tempera, F., Holland, K.N. & Santos, R.S. (2009) A multi-scale study of red porgy movements and habitat use, and its application to the design of marine reserve networks. In: Nielsen, J.L., Arrizabalaga, H., Fragoso, N., Hobday, A., Lutcavage, M. & Sibert, J. (Eds.) *Tagging and tracking of marine animals with electronic devices*. Dordrecht: Springer, pp. 423–443.

Afonso, P., Fontes, J., Holland, K.N. & Santos, R.S. (2009) Multi-scale patterns of habitat use in a highly mobile reef fish, the white trevally *Pseudocaranx dentex*, and their implications for marine reserve design. *Marine Ecology Progress Series*, 381, 273–286.

Afonso, P., Graça, G., Berke, G. & Fontes, J. (2012) First observations on seamount habitat use of blackspot seabream (*Pagellus bogaraveo*) using acoustic telemetry. *The Journal of Experimental Marine Biology and Ecology*, 436(15), 1–10.

Afonso, P., McGinty, N., Graça, G., Fontes, J., Inácio, M., Totland, A. et al. (2014) Vertical migrations of a deep-sea fish and its prey. *PLoS One*, 9(5), e97884.

Ahrenstorff, T.D., Sass, G.G. & Helmus, M.R. (2009) The influence of littoral zone coarse woody habitat on home range size, spatial distribution, and feeding ecology of largemouth bass (*Micropterus salmoides*). *Hydrobiologia*, 623, 223–233.

Airoldi, L. & Beck, M.W. (2007) Loss, status and trends for coastal marine habitats of Europe. *Oceanography and Marine Biology: An Annual Review*, 45, 345–405.

Alfonso, S., Zupa, W., Spedicato, M.T., Lembo, G. & Carbonara, P. (2022) Using telemetry sensors mapping the energetic costs in European sea bass (*Dicentrarchus labrax*), as a tool for welfare remote monitoring in aquaculture. *Frontiers in Animal Science*, 3, 885850.

Alós, J., Aarestrup, K., Abecasis, D., Afonso, P., Alonso-Fernandez, A., Aspillaga, E. et al. (2022) Toward a decade of ocean science for sustainable development through acoustic animal tracking. *Global Change Biology*, 28, 5630–5653.

Alós, J., Cabanellas-Reboredo, M. & Lowerre-Barbieri, S. (2012) Diel behaviour and habitat utilisation by the pearly razorfish during the spawning season. *Marine Ecology Progress Series*, 460, 207–220.

Alós, J., Palmer, M., Rosselló, R. & Arlinghaus, R. (2016) Fast and behavior-selective exploitation of a marine fish targeted by anglers. *Scientific Reports*, 6(1), 1–13.

Andersson, M.H., Berggren, M., Wilhelmsson, D. & Öhman, M.C. (2009) Epibenthic colonization of concrete and steel pilings in a cold-temperate embayment: a field experiment. *Helgoland Marine Research*, 63(3), 249–260.

Arapogianni, A., Moccia, J. & Wilkes, J. (2011) *The European offshore wind industry—key trends and statistics*. Brussels: European Wind Energy Association, p. 31. Available from: https://www.google.com/search?q=The+European+offshore+wind+industry%E2%80%94key+trends+and+statistics+Arapogianni&rlz=1C1YTUH_enNL1028NL1028&oq=The+European+offshore+wind+industry%E2%80%94key+trends+and+statistics+Arapogianni&gs_lcrp=EgZjaHJvbWUyBggAEEUYOTIGCAEQRRg80gEIOTY0ajBqMTWoAgCwAgA&sourceid=chrome&ie=UTF-8

Arechavala-Lopez, P., Sanchez-Jerez, P., Bayle-Sempere, J.T., Uglem, I. & Mladineo, I. (2013) Reared fish, farmed escapees and wild fish stocks—a triangle of pathogen transmission of concern to Mediterranean aquaculture management. *Aquaculture Environment Interactions*, 3, 153–161.

Arechavala-Lopez, P., Uglem, I., Fernandez-Jover, D., Bayle Sempere, J.T. & Sanchez-Jerez, P. (2011) Immediate post-escape behaviour of farmed sea bass (*Dicentrarchus labrax*) in the Mediterranean Sea. *Journal of Applied Ichthyology*, 27, 1375–1378.

Arechavala-Lopez, P., Uglem, I., Fernandez-Jover, D., Bayle-Sempere, J.T. & Sanchez-Jerez, P. (2012) Post-escape dispersion of farmed seabream (*Sparus aurata* L.) and recaptures by local fisheries in the Western Mediterranean Sea. *Fisheries Research*, 121, 126–135.

Arlinghaus, R., Abbott, J.K., Fenichel, E.P., Carpenter, S.R., Hunt, L.M., Alós, J. et al. (2019) Governing the recreational dimension of global fisheries. *Proceedings of the National Academy of Sciences*, 116(12), 5209–5213. Available from: https://doi.org/10.1073/pnas.1902796116

Arlinghaus, R., Laskowski, K.L., Alós, J., Klefoth, T., Monk, C.T., Nakayama, S. et al. (2017) Passive gear-induced timidity syndrome in wild fish populations and its potential ecological and managerial implications. *Fish and Fisheries*, 18, 360–373.

Arlinghaus, R., Rittweg, T., Dhellemmes, F., Koemle, D., van Gemert, R., Schubert, H. et al. (2023) A synthesis of a coastal northern pike (Esox lucius) fishery and its social-ecological environment in the southern Baltic Sea: Implications for the management of mixed commercial-recreational fisheries. *Fisheries Research*, 263, 106663.

Arnold, G.P. & Dewar, H. (2001) Electronic tags in marine fisheries research: a 30-year perspective. In: Sibert, J.R. & Nielsen, J.L. (Eds.) *Electronic tagging and tracking in marine fisheries*. Dordrecht: Kluwer Academic Press, pp. 7–64.

Aspillaga, E., Bartumeus, F., Linares, C., Starr, R.M., López-Sanz, À., Díaz, D. et al. (2016) Ordinary and extraordinary movement behaviour of small resident fish within a Mediterranean marine protected area. *PLoS One*, 11, e0159813.

Baden, C., Christoffersen, M., Flávio, H., Brown, E., Aarestrup, K. & Svendsen, J.C. (2022) Using acoustic telemetry to locate flatfish spawning areas: estuarine migrations of turbot *Scophthalmus maximus* and European flounder *Platichthys flesus*. *Journal of Sea Research*, 183, 102187.

Baktoft, K.H., Aarestrup, K., Berg, S., Boel, M., Jacobsen, L., Koed, A. et al. (2013) Effects of angling and manual handling on pike behaviour investigated by high-resolution positional telemetry. *Fisheries Management and Ecology*, 20(6), 518–525.

Bangley, C.W., Curtis, T.H., Secor, D.H., Latour, R.J. & Ogburn, M.B. (2020) Identifying important juvenile dusky shark habitat in the Northwest Atlantic Ocean using acoustic telemetry and spatial modelling. *Marine and Coastal Fisheries*, 12(5), 348–363.

Barkley, A.N., Fisk, A.T., Hedges, K.J., Treble, M.A. & Hussey, N.E. (2018) Transient movements of a deep-water flatfish in coastal waters: implications of inshore-offshore connectivity for fisheries management. *Journal of Applied Ecology*, 55(3), 1071–1081.

Barnabé, G. & Dewavrin, G. (2019) Mediterranean Mariculture. In: *Encyclopedia of Ocean Sciences (Third Ed.)*. Asterdam: Academic Press, Vol. 2, pp. 436–440. Available from: https://doi.org/10.1016/B978-0-12-409548-9.09556-7

Barry, J., McLoone, P., Fitzgerald, C.J. & King, J.J. (2020) The spatial ecology of brown trout (*Salmo trutta*) and dace (*Leuciscus leuciscus*) in an artificially impounded riverine habitat: results from an acoustic telemetry study. *Aquatic Sciences*, 82, 63.

Beck, M.W., Heck, K.L., Jr., Able, K.W., Childers, D.L., Eggleston, D.B., Gillanders, B.M. et al. (2001) The identification, conservation, and management of estuarine and marine nurseries for fish and invertebrates. *Bioscience*, 51, 633–664.

Becker, A., Taylor, M.D., Folpp, H. & Lowry, M.B. (2018) Managing the development of artificial reef systems: the need for quantitative goals. *Fish and Fisheries*, 19, 740–752.

Begg, G., Friedland, K. & Pearce, J. (1999) Stock identification and its role in stock assessment and fisheries management: an overview. *Fisheries Research*, 43, 1–8.

Begg, G.A. & Waldman, J.R.A. (1999) Holistic approach to fish stock identification. *Fisheries Research*, 43, 35–44.

Belletti, B., Garcia de Leaniz, C., Jones, J., Bizzi, S., Börger, L., Segura, G. et al. (2020) More than one million barriers fragment Europe's rivers. *Nature*, 588(7838), 436–441.

Belo, A.F., Pereira, T.J., Quintella, B.R., Castro, N., Costa, J.L. & De Almeida, P.R. (2016) Movements of *Diplodus sargus* (Sparidae) within a Portuguese coastal marine protected area: are they really protected? *Marine Environmental Research*, 114, 80–94.

Benaka, L.R., Sharpe, L., Anderson, L., Brennan, K., Budrick, J.E., Lunsford, C. et al. (2014) *Fisheries release mortality: identifying, prioritizing, and resolving data gaps*. U.S. Dep. Commerce. NOAA Tech. Memo. NMFS-F/SPO-142, 84 p.

Bergman, J.N., Raby, G.D., Neigel, K.L., Rennie, C.D., Balshine, S., Bennett, J.R. et al. (2022) Tracking the early stages of an invasion with biotelemetry: behaviour of round goby (*Neogobius melanostomus*) in Canada's historic Rideau Canal. *Biological Invasions*, 24(4), 1149–1173.

Bergström, L., Sundqvist, F. & Bergström, U. (2013) Effects of an offshore wind farm on temporal and spatial patterns in the demersal fish community. *Marine Ecology Progress Series*, 485, 199–210.

Blaber, S.J.M. (2002) Fish in hot water: the challenges facing fish and fisheries research in tropical estuaries. *Journal of Fish Biology*, 61, 1–20.

Block, B.A., Whitlock, R., Schallert, R.J., Wilson, S., Stokesbury, M.J., Castleton, M. et al. (2019) Estimating natural mortality of Atlantic bluefin tuna using acoustic telemetry. *Scientific Reports*, 9(1), 4918.

Braun, C.D., Arostegui, M.C., Thorrold, S.R., Papastamatiou, Y.P., Gaube, P., Fontes, J. et al. (2022) The functional and ecological significance of deep diving by large marine predators. *Annual Review of Marine Science*, 14, 129–159.

Brickhill, M.J., Lee, S.Y. & Connolly, R.M. (2005) Fishes associated with artificial reefs: attributing changes to attraction or production using novel approaches. *Journal of Fish Biology*, 67, 53–71.

Brownscombe, J.W., Griffin, L.P., Brooks, J.L., Danylchuk, A.J., Cooke, S.J. & Midwood, J.D. (2022) Applications of telemetry to fish habitat science and management. *Canadian Journal of Fisheries and Aquatic Sciences*, 79, 1347–1359. Available from: https://doi.org/10.1139/cjfas-2021-0101

Brownscombe, J.W., Lédée, E.J., Raby, G.D., Struthers, D.P., Gutowsky, L.F., Nguyen, V.M. et al. (2019) Conducting and interpreting fish telemetry studies: considerations for researchers and resource managers. *Reviews in Fish Biology and Fisheries*, 29, 369–400.

Bruneel, S., Goossens, J., Reubens, J., Pauwels, I., Moens, T., Goethals, P. et al. (2023) Turning the tide: understanding estuarine detection range variability via structural equation models. *Animal Biotelemetry*, 11, 38.

BSGM. (2020) *5/1 fisheries notification (No: 2020/20). RG: 22.08.2020 and No: 31221*.

Bultel, E., Lasne, E., Acou, A., Guillaudeau, J., Bertier, C. & Feunteun, E. (2014) Migration behaviour of silver eels (Anguilla Anguilla) in a large estuary of Western Europe inferred from acoustic telemetry. *Estuarine, Coastal and Shelf Science*, 137, 23–31.

Buyse, J., Hostens, K., Degraer, S. & De Backer, A. (2022) Offshore wind farms affect the spatial distribution pattern of plaice *Pleuronectes platessa* at both the turbine and wind farm scale. *ICES Journal of Marine Science*, 79(6), 1777–1786.

Buyse, J., Reubens, J., Hostens, K., Degraer, S., Goossens, J. & De Backer, A. (2023) European plaice movements show evidence of high residency, site fidelity, and feeding around hard substrates within an offshore wind farm. *ICES Journal of Marine Science*, 80, fsad179. Available from: https://doi.org/10.1093/icesjms/fsad179

Byrne, M.E., Cortés, E., Vaudo, J.J., Harvey, G.C.M., Sampson, M., Wetherbee, B.M. et al. (2017) Satellite telemetry reveals higher fishing mortality rates than previously estimated, suggesting overfishing of an apex marine predator. *Proceedings of the Royal Society B: Biological Sciences*, 284(1860), 20170658.

Cabanellas-Reboredo, M., Alós, J., Palmer, M., March, D. & O'Dor, R. (2012) Movement patterns of the European squid *Loligo vulgaris* during the inshore spawning season. *Marine Ecology Progress Series*, 466, 133–144.

Cameron, L.W., Roche, W., Green, P., Houghton, J.D. & Mensink, P.J. (2018) Transatlantic movement in porbeagle sharks, *Lamna nasus*. *Fisheries Research*, 207, 25–27.

Carr, S.D., Tankersley, R.A., Hench, J.L., Forward, R.B., Jr. & Luettich, R.A., Jr. (2004) Movement patterns and trajectories of ovigerous blue crabs *Callinectes sapidus* during the spawning migration. *Estuarine, Coastal and Shelf Science*, 60, 567–579.

Clavero, M., Franch, N., Bernardo-Madrid, R., Lopez, V., Abello, P., Queral, J.M. et al. (2022) Severe, rapid and widespread impacts of an Atlantic blue crab invasion. *Marine Pollution Bulletin*, 176, 113479.

Cooke, S.J., Auld, H.L., Birnie-Gauvin, K., Elvidge, C.K., Piczak, M.L., Twardek, W.M. et al. (2022) On the relevance of animal behavior to the management and conservation of fishes and fisheries. *Environmental Biology of Fishes*, 106, 1–26. Available from: https://doi.org/10.1007/s10641-022-01255-3

Cooke, S.J., Brownscombe, J.W., Raby, G.D., Broell, F., Hinch, S.G., Clark, T.D. et al. (2016) Remote bioenergetics measurements in wild fish: opportunities and challenges. *Comparative Biochemistry* *and Physiology—Part A: Molecular and Integrative Physiology*, 202, 23–37.

Costa-Pereira, R., Moll, R.J., Jesmer, B.R. & Jetz, W. (2022) Animal tracking moves community ecology: opportunities and challenges. *Journal of Animal Ecology*, 91, 1334–1344.

Cowx, I.G., Arlinghaus, R. & Cooke, S.J. (2010) Harmonizing recreational fisheries and conservation objectives for aquatic biodiversity in inland waters. *Journal of Fish Biology*, 76, 2194–2215.

Crossin, G.T., Heupel, M.R., Holbrook, C.M., Hussey, N.E., Lowerre-Barbieri, S.K., Nguyen, V.M. et al. (2017) Acoustic telemetry and fisheries management. *Ecological Applications*, 27, 1031–1049.

Daley, R.K., Williams, A., Green, M., Barker, B. & Brodie, P. (2015) Can marine reserves conserve vulnerable sharks in the deep sea? A case study of *Centrophorus zeehaani* (Centrophoridae), examined with acoustic telemetry. *Deep Sea Research Part II: Topical Studies in Oceanography*, 115, 127–136.

D'Anna, G., Giacalone, V.M., Pipitone, C. & Badalamenti, F. (2011) Movement pattern of white seabream, *Diplodus sargus* (L., 1758) (Osteichthyes, Sparidae) acoustically tracked in an artificial reef area. *The Italian Journal of Zoology*, 78(2), 255–263.

Davidsen, J.G., Eldøy, S.H., Meyer, I., Halvorsen, A.E., Sjursen, A.D., Rønning, L. et al. (2019) *Anadromous brown trout and Arctic charr in the Skjerstad Fjord – marine migrations, area use and population genetics*. NTNU Vitenskapsmuseet naturhistorisk rapport 2019–5:1–80.

Davidsen, J.G., Power, M., Knudsen, R., Sjursen, A.D., Kjærstad, G., Rønning, L. et al. (2020) Marine trophic niche use and life history diversity among Arctic charr *Salvelinus alpinus* in southwestern Greenland. *Journal of Fish Biology*, 96, 681–692.

Davidsen, J.G., Sjursen, A.D., Rønning, L., Davidsen, A.G., Eldøy, S.H., Daverdin, M. et al. (2021) *Construction of new E6 highway at Hellstranda – area use of anadromous brown trout and Atlantic salmon og suggestions for compensatory measures*. NTNU Vitenskapsmuseet naturhistorisk rapport 2021-10:1-63.

Davies, P., Britton, J.R., Nunn, A.D., Dodd, J.R., Bainger, C., Velterop, R. et al. (2021) Cumulative impacts of habitat fragmentation and the environmental factors affecting upstream migration in the threatened sea lamprey, *Petromyzon marinus*. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 31(9), 2560–2574. Available from: https://doi.org/10.1002/AQC.3625

Davies, P., Britton, R.J., Nunn, A.D., Dodd, J.D., Bainger, C., Velterop, R. et al. (2022) Individual movement variation in upstream-migrating sea lamprey *Petromyzon marinus* in a highly fragmented river. *Freshwater Biology*, 67, 643–656. Available from: https://doi.org/10.1111/fwb.13869

De Pontual, H., Heerah, K., Goossens, J., Garren, F., Martin, S., Ru, L.L. et al. (2023) Seasonal migration, site fidelity, and population structure of European seabass (*Dicentrarchus labrax*). *ICES Journal of Marine Science*, 80(6), 1606–1618.

De Pontual, H., Jolivet, A., Garren, F. & Bertignac, M. (2013) New insights on European hake biology and population dynamics from a sustained tagging effort in the Bay of Biscay. *ICES Journal of Marine Science*, 70(7), 1416–1428.

Dempster, T., Arechavala-Lopez, P., Barrett, L.T., Fleming, L.A., Sanchez-Jerez, P. & Uglem, I. (2018) Recapturing escaped fish from marine aquaculture is largely unsuccessful: alternatives to reduce the number of escapees in the wild. *Reviews in Aquaculture*, 10, 153–167.

Dempster, T., Moe, H., Fredheim, A., Jensen, Ø. & Sanchez-Jerez, P. (2007) Escapes of marine fish from sea-cage aquaculture in the Mediterranean Sea: status and prevention. *CIESM Work-Shop Monographs*, 32, 55–60.

Dhellemmes, F., Aspillaga, F., Rittweg, T., Alós, J., Moller, P. & Arlinghaus, R. (2023) Body size scaling of space use in coastal pike (*Esox lucius*) in brackish lagoons of the southern Baltic Sea. *Fisheries Research*, 260, 106560.

Di Lorenzo, M., Guidetti, P., Di Franco, A., Calò, A. & Claudet, J. (2020) Assessing spillover from marine protected areas and its drivers: a meta-analytical approach. *Fish and Fisheries*, 21, 906–915.

Díaz, S., Settele, J., Brondízio, E.S., Ngo, H.T., Agard, J., Arneth, A. et al. (2019) Pervasive human-driven decline of life on earth points to the need for transformative change. *Science*, 366, eaax3100.

Donaldson, M.R., Hinch, S.G., Patterson, D.A., Hills, J., Thomas, J.O., Cooke, S.J. et al. (2011) The consequences of angling, beach seining, and confinement on the physiology, post-release behaviour and survival of adult sockeye Salmon during upriver migration. *Fisheries Research*, 108, 133–141.

Doray, M., Josse, E., Gervain, P., Reynal, L. & Chantrel, J. (2006) Acoustic characterisation of pelagic fish aggregations around moored fish aggregating devices in Martinique (Lesser Antilles). *Fisheries Research*, 82, 162–175.

Dudgeon, C.L., Pollock, K.H., Braccini, J.M., Semmens, J.M. & Barnett, A. (2015) Integrating acoustic telemetry into mark–recapture models to improve the precision of apparent survival and abundance estimates. *Oecologia*, 178(3), 761–772.

Edgar, G.J., Barrett, N.S., Graddon, D.J. & Last, P.R. (2000) The conservation significance of estuaries: a classification of Tasmanian estuaries using ecological, physical and demographic attributes as a case study. *Biological Conservation*, 92, 383–397.

Edwards, J.E., Hedges, K.J. & Hussey, N.E. (2022) Seasonal residency, activity space, and use of deep-water channels by Greenland sharks (*Somniosus microcephalus*) in an Arctic fjord system. *Canadian Journal of Fisheries and Aquatic Sciences*, 79(2), 314–330.

Edwards, J.E., Pratt, J., Tress, N. & Hussey, N.E. (2019) Thinking deeper: uncovering the mysteries of animal movement in the deep sea. *Deep Sea Research Part I: Oceanographic Research Papers*, 146, 24–43.

EEA. (2006) *The changing faces of Europe's coastal areas. EEA report 6/2006*. Luxembourg: OPOCE. Available: http://reports.eea.europa.eu/eea_report_2006_6/en/eea_report_6_2006.pdf (accessed 14 June 2022).

Eggers, F. (2013) *Metapopulation dynamics in Atlantic herring (Clupea harengus L.) along the coast of southern Norway and in the local area of Landvikvannet*. MSc thesis, University of Bergen.

Eggers, F., Moland Olsen, E., Moland, E. & Slotte, A. (2015) Individual habitat transitions of Atlantic herring Clupea harengus in a human-modified coastal system. *Marine Ecology Progress Series*, 520, 245–256. Available from: https://doi.org/10.3354/meps11103

Eldøy, S.H., Bordeleau, X., Crossin, G.T. & Davidsen, J.G. (2019) Individual repeatability in marine migratory behaviour: a multi-population assessment of anadromous brown trout tracked through consecutive feeding migrations. *Frontiers in Ecology and Evolution*, 7, 1–12.

Espinoza, M., Lédée, E.J., Smoothey, A.F., Heupel, M.R., Peddemors, V.M., Tobin, A.J. et al. (2021) Intra-specific variation in movement and habitat connectivity of a mobile predator revealed by acoustic telemetry and network analyses. *Marine Biology*, 168(6), 1–15.

FAO. (1997) *Fisheries management. FAO technical guidelines for responsible fisheries. No. 4*. Rome: FAO, p. 82.

FAO. (2015) Practical guidelines for the use of artificial reefs in the Mediterranean and the Black Sea. In: Fabi, G., Scarcella, G., Spagnolo, A., Bortone, S.A., Charbonnel, E., Goutayer, J.J. et al. (Eds.) *Studies and reviews*. Rome: GFCM. No. 96.

Fauchald, P., Arneberg, P., Debernard, J.B., Lind, S., Olsen, E. & Hausner, V.H. (2021) Poleward shifts in marine fisheries under Arctic warming. *Environmental Research Letters*, 16(7), 074057.

Fauconnet, L., Catarino, D., Das, D., Giacomello, E., Gonzalez-Irusta, J.M., Afonso, P. et al. (2023) Challenges in avoiding deep-water shark bycatch in Azorean hook-and-line fisheries. *ICES Journal of Marine Science*, 80(3), 605–619.

Finlayson, M., Cruz, R.D., Davidson, N., Alder, J., Cork, S., Groot, R.S. et al. (2005) *Millennium ecosystem assessment: ecosystems and human well-being: wetlands and water synthesis*. Washington, DC: Island Press.

Flávio, H., Kennedy, R., Ensing, D., Jepsen, N. & Aarestrup, K. (2020) Marine mortality in the river? Atlantic salmon smolts under high predation pressure in the last kilometres of a river monitored for stock assessment. *Fisheries Management and Ecology*, 27(1), 92–101.
Fleming, I.A., Hindar, K., Mjølnerød, I.B., Jonsson, B., Balstad, T. & Lamberg, A. (2000) Lifetime success and interactions of farm salmon invading a native population. *Proceedings of the Royal Society of London Series B*, 267, 1517–1523. Available from: https://doi.org/10.1098/rspb.2000.1173
Flink, H., Tibblin, P., Hall, M., Hellström, G. & Nordahl, O. (2023) Variation among bays in spatiotemporal aggregation of Baltic Sea pike highlights management complexity. *Fisheries Research*, 259, 106579.
Florko, K.R.N., Davidson, E.R., Lees, K.J., Hammer, L.J., Lavoie, M.F., Lennox, R.J. et al. (2021) Tracking movements of decapod crustaceans: a review of a half-century of telemetry-based studies. *Marine Ecology-Progress Series*, 679, 219–239.
Gaines, S.D., White, C., Carr, M.H. & Palumbi, S.R. (2010) Designing marine reserve networks for both conservation and fisheries management. *Proceedings of the National Academy of Sciences*, 107, 18286–18293.
Galil, B.S., Mienis, H.K., Hoffman, R. & Goren, M. (2021) Non-indigenous species along the Israeli Mediterranean coast: tally, policy, outlook. *Hydrobiologia*, 848(9), 2011–2029.
Garrido, J., Pérez-Bilbao, A. & Benetti, S.J. (2011) Biodiversity and conservation of coastal lagoons. In: Grillo, O. & Venore, G. (Eds.) *Ecosystems biodiversity*. London: InTechOpen Publishers, pp. 1–28.
Giacalone, V.M., Zenone, A., Badalamenti, F., Ciancio, J., Buffa, G., Gristina, M. et al. (2019) Homing and home range of the European spiny lobster, *Palinurus elephas* (Decapoda, Palinuridae) acoustically tracked. *Crustaceana*, 92(4), 463–476.
Gill, A.B., Gloyne-Phillips, I., Neal, K.J. & Kimber, J.A. (2005) *Electromagnetic fields. Review. The potential effects of electromagnetic fields generated by sub-sea power cables associated with offshore wind farm developments on electrically and magnetically sensitive marine organisms-a review*. COWRIE 1.5 Electromagnetic Fields, Final Report. Silsoe: Cranfield University, p. 128.
Gimpel, A., Haslob, H., Werner, K.M., Bockelmann, F.D., Schaber, M., Kloppmann, M. et al. (2023) Ecological effects of offshore wind farms on Atlantic cod (*Gadus morhua*) in the southern North Sea. *Science of the Total Environment*, 878, 162902.
Golani, D. (2021) An updated checklist of the Mediterranean fishes of Israel, with illustrations of recently recorded species and delineation of Lessepsian migrants. *Zootaxa*, 4956, 1–108.
Green, K.M. & Starr, R.M. (2011) Movements of small adult black rockfish: implications for the design of MPAs. *Marine Ecology Progress Series*, 436, 219–230.
Grill, G., Lehner, B., Lumsdon, A.E., MacDonald, G.K., Zarfl, C. & Liermann, C.R. (2015) An index-based framework for assessing patterns and trends in river fragmentation and flow regulation by global dams at multiple scales. *Environmental Research Letters*, 10(1), 015001.
Grubich, J.R. & Odenkirk, J. (2014) Initial observations of movement patterns in the apex fish predator, the Nile perch (*Lates niloticus*), in Lake Nasser, Egypt. *Egyptian Journal of Aquatic Research*, 40, 65–69.
Grüss, A., Kaplan, D.M., Guénette, S., Roberts, C.M. & Botsford, L.W. (2011) Consequences of adult and juvenile movement for marine protected areas. *Biological Conservation*, 144, 692–702.
Gutmann Roberts, C., Hindes, A.M. & Britton, J.R. (2019) Factors influencing individual movements and behaviours of invasive European barbel *Barbus barbus* in a regulated river. *Hydrobiologia*, 83, 213–228.
Hallier, J.P. & Gaertner, D. (2008) Drifting fish aggregation devices could act as an ecological trap for tropical tuna species. *Marine Ecology-Progress Series*, 353, 255–264.
Halvorsen, A.E. (2019) *Marine migratory behaviour of anadromous brown trout and Arctic char in a Norwegian fjord system*. Master's thesis, (p. 46). Oslo: University of Oslo.
Hammar, L., Perry, D. & Gullström, M. (2015) Offshore wind power for marine conservation. *Open. Journal of Marine Science*, 6(1), Article 1.
Hammer, L.J., Hussey, N.E., Marcoux, M., Pettitt-Wade, H., Hedges, K., Tallman, R. et al. (2022) Arctic char *Salvelinus alpinus* movement dynamics relative to ice breakup in a high Arctic embayment. *Marine Ecology Progress Series*, 682, 221–236.
Harris, L.N., Yurkowski, D.J., Malley, B.K., Jones, S.F., Else, B.G.T., Tallman, R.F. et al. (2022) Acoustic telemetry reveals the complex nature of mixed-stock fishing in Canada's largest Arctic char commercial fishery. *North American Journal of Fisheries Management*, 42, 1250–1268.
Heggberget, T.G., Johnsen, B.O., Hindar, K., Jonsson, B., Hansen, L.P., Hvidsten, N.A. et al. (1993) Interactions between wild and cultured Atlantic salmon: a review of the Norwegian experience. *Fisheries Research*, 18, 123–146.
Hightower, J.E. & Harris, J.E. (2017) Estimating fish mortality rates using telemetry and multistate models. *Fisheries*, 42(4), 210–219.
Hoenner, X., Huveneers, C., Steckenreuter, A., Simpfendorfer, C., Tattersall, K., Jaine, F. et al. (2018) Australia's continental-scale acoustic tracking database and its automated quality control process. *Scientific Data*, 5, 170206.
Holbrook, C.M., Bergstedt, R.A., Barber, J., Bravener, G.A., Jones, M.L. & Krueger, C.C. (2016) Evaluating harvest-based control of invasive fish with telemetry: performance of sea lamprey traps in the Great Lakes. *Ecological Applications*, 26, 1595–1609.
Huserbråten, M.B.O., Moland, E., Knutsen, H., Olsen, E.M., André, C. & Stenseth, N.C. (2013) Conservation, spillover and gene flow within a network of northern European marine protected areas. *PLoS One*, 8(9), e73388.
Hussey, N.E., Hedges, K.J., Barkley, A.N., Treble, M.A., Peklova, I., Webber, D.M. et al. (2017) Movements of a deep-water fish: establishing marine fisheries management boundaries in coastal Arctic waters. *Ecological Applications*, 27, 687–704.
Hussey, N.E., Kessel, S.T., Aarestrup, K., Cooke, S.J., Cowley, P.D., Fisk, A.T. et al. (2015) Aquatic animal telemetry: a panoramic window into the underwater world. *Science*, 348(6240), 1255642.
ICES. (2020) Workshop on stock identification of North Sea cod (WKNSCodID). *ICES Scientific Reports*, 2, 89. 82. Available from: https://doi.org/10.17895/ices.pub.7499
ICES. (2021) Benchmark workshop on North Sea stocks (WKNSEA). *ICES Scientific Reports*, 3, 25. 756. Available from: https://doi.org/10.17895/ices.pub.7922
Ingvaldsen, R.B., Assmann, K.M., Primicerio, R., Fossheim, M., Polyakov, I.V. & Dolgov, A.V. (2021) Physical manifestations and ecological implications of Arctic Atlantification. *Nature Reviews Earth and Environment*, 2(12), 874–889.
Iverson, S.J., Fisk, A.T., Hinch, S.G., Flemming, J.M., Cooke, S.J. & Whoriskey, F.G. (2019) The ocean tracking network: advancing frontiers in aquatic science and management. *Canadian Journal of Fisheries and Aquatic Sciences*, 76(7), 1041–1051.
Izquierdo-Gomez, D. & Sanchez-Jerez, P. (2016) Management of fish escapes from Mediterranean Sea cage aquaculture through artisanal fisheries. *Ocean and Coastal Management*, 122, 57–63.
Jacobsen, L., Baktoft, H., Jepsen, N., Aarestrup, K., Berg, S. & Skov, C. (2014) Effect of boat noise and angling on lake fish behaviour. *Journal of Fish Biology*, 84(6), 1768–1780.
Janssen, J., Jude, D.J., Edsall, T.A., Paddock, R.W., Wattrus, N., Toneys, M. et al. (2006) Evidence of lake trout reproduction at Lake Michigan's mid-lake reef complex. *Journal of Great Lakes Research*, 32(4), 749–763.
Jensen, Ø., Dempster, T., Thorstad, E.B., Uglem, I. & Fredheim, A. (2010) Escapes of fishes from Norwegian sea-cage aquaculture: causes, consequences and prevention. *Aquaculture Environment Interactions*, 1, 71–83.
Johnsen, I.A., Harvey, A., Sævik, P.N., Sandvik, A.D., Ugedal, O., Ådlandsvik, B. et al. (2021) Salmon lice-induced mortality of Atlantic

salmon during post-smolt migration in Norway. *ICES Journal of Marine Science*, 78(1), 142–154.

Johnston, E.M., Mayo, P., Mensink, P.J., Houghton, J.D.R. & Eric, S. (2019) Serendipitous re-sighting of a basking shark *Cetorhinus maximus* reveals inter-annual connectivity between American and European coastal hotspots. *Journal of Fish Biology*, 95, 1530–1534.

Johnston, F.D., Beardmore, B. & Arlinghaus, R. (2015) Optimal management of recreational fisheries in the presence of hooking mortality and noncompliance—predictions from a bioeconomic model incorporating a mechanistic model of angler behavior. *Canadian Journal of Fisheries and Aquatic Sciences*, 72, 37–53.

Josse, E., Dagorn, L. & Bertrand, A. (2000) Typology and behaviour of tuna aggregations around fish aggregating devices from acoustic surveys in French Polynesia. *Aquatic Living Resources*, 13, 183–192.

Jupiter, S.D., Epstein, G., Ban, N.C., Mangubhai, S., Fox, M. & Cox, M. (2017) A social–ecological systems approach to assessing conservation and fisheries outcomes in Fijian locally managed marine areas. *Society and Natural Resources*, 30(9), 1096–1111.

Jurajda, P., Adámek, Z., Roche, K., Mrkvová, M., Štarhová, D., Prášek, V. et al. (2016) Carp feeding activity and habitat utilisation in relation to supplementary feeding in a semi-intensive aquaculture pond. *Aquaculture International*, 24, 1627–1640.

Jůza, T., Blabolil, P., Čech, M., Draštík, V., Frouzová, J., Sajdlová, Z. et al. (2022) Fish stock mass reduction is indicated in standard abundance and biomass estimates from gillnets and hydroacoustics. *Fisheries Research*, 253, 106389.

Källo, K., Baktoft, H., Kristensen, M.L., Birnie-Gauvin, K. & Aarestrup, K. (2022) High prevalence of straying in a wild brown trout (*Salmo trutta*) population in a fjord system. *ICES Journal of Marine Science*, 79(5), 1539–1547.

Kessel, S.T., Cooke, S.J., Heupel, M.R., Hussey, N.E., Simpfendorfer, C.A., Vagle, S. et al. (2014) A review of detection range testing in aquatic passive acoustic telemetry studies. *Reviews in Fish Biology and Fisheries*, 24, 199–218.

Kessel, S.T., Hussey, N.E., Crawford, R.E., Yurkowski, D.J., O'Neill, C.V. & Fisk, A.T. (2016) Distinct patterns of Arctic cod (*Boreogadus saida*) presence and absence in a shallow high Arctic embayment, revealed across open-water and ice-covered periods through acoustic telemetry. *Polar Biology*, 39, 1057–1068.

Koeck, B., Alós, J., Caro, A., Neveu, R., Crec'hriou, R., Saragoni, G. et al. (2013) Contrasting fish behavior in artificial seascapes with implications for resources conservation. *PLoS One*, 8(7), e69303.

Koeck, B., Pastor, J., Saragoni, G., Dalias, N., Payrot, J. & Lenfant, P. (2014) Diel and seasonal movement pattern of the dusky grouper *Epinephelus marginatus* inside a marine reserve. *Marine Environmental Research*, 94, 38–47.

Kornis, M.S., Mercado-Silva, N. & Vander Zanden, M.J. (2012) Twenty years of invasion: a review of round goby *Neogobius melanostomus* biology, spread and ecological implications. *Journal of Fish Biology*, 80, 235–285.

Kourantidou, M., Cuthbert, R.N., Haubrock, P.J., Novoa, A., Taylor, N.G., Leroy, B. et al. (2021) Economic costs of invasive alien species in the Mediterranean basin. The economic costs of biological invasions around the world. *NeoBiota*, 67, 427–458.

Kraak, S.B., Bailey, N., Cardinale, M., Darby, C., De Oliveira, J.A., Eero, M. et al. (2013) Lessons for fisheries management from the EU cod recovery plan. *Marine Policy*, 37, 200–213.

Kramer, D.L. & Chapman, M.R. (1999) Implications of fish home range size and relocation for marine reserve function. *Environmental Biology of Fishes*, 55, 65–79.

Kristensen, M.L., Olsen, E.M., Moland, E., Knutsen, H., Grønkjær, P., Koed, A. et al. (2021) Disparate movement behavior and feeding ecology in sympatric ecotypes of Atlantic cod. *Ecology and Evolution*, 11(16), 11477–11490.

La Mesa, G., Consalvo, I., Annunziatellis, A. & Canese, S. (2012) Movement patterns of the parrotfish *Sparisoma cretense* in a Mediterranean marine protected area. *Marine Environmental Research*, 82, 59–68.

Langhamer, O., Wilhelmsson, D. & Engström, J. (2009) Artificial reef effect and fouling impacts on offshore wave power foundations and buoys – a pilot study. *Estuarine, Coastal and Shelf Science*, 82(3), 426–432.

Le Pichon, C., Trancart, T., Lambert, P., Daverat, F. & Rochard, E. (2014) Summer habitat use and movements of late juvenile European flounder (*Platichthys flesus*) in tidal freshwaters: results from an acoustic telemetry study. *Journal of Experimental Marine Biology and Ecology*, 461, 441–448.

Lédée, E.J.I., Heupel, M.R., Taylor, M.D., Harcourt, R.G., Jaine, F.R.A., Huveneers, C. et al. (2021) Continental-scale acoustic telemetry and network analysis reveal new insights into stock structure. *Fish and Fisheries*, 22(5), 987–1005.

Lee, K.A., Huveneers, C., Gimenez, O., Peddemors, V. & Harcourt, R.G. (2014) To catch or to sight? A comparison of demographic parameter estimates obtained from mark-recapture and mark-resight models. *Biodiversity and Conservation*, 23(11), 2781–2800.

Leeb, K., Villegas-Ríos, D., Mucientes, G., Garci, M., Gilcoto, M. & Alonso-Fernández, A. (2021) Drivers of spatial behaviour of the endangered undulate skate, *Raja undulata*. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 31, 3466–3479.

Lees, K.J., MacNeil, M.A., Hedges, K.J. & Hussey, N.E. (2021) Estimating demographic parameters for fisheries management using acoustic telemetry. *Reviews in Fish Biology and Fisheries*, 31(1), 25–51.

Lenhardt, M.B., Smederevac-Lalić, M.M., Spasić, S.Z., Honţ, Ş., Paraschiv, M., Iani, M.I. et al. (2021) Seasonal changes in depth position and temperature of European catfish (*Silurus glanis*) tracked by acoustic telemetry in the Danube River. *International Review of Hydrobiology*, 106, 191–201.

Lennox, R.J., Aarestrup, K., Alós, J., Arlinghaus, R., Aspillaga, E., Bertram, M.G. et al. (2023) Positioning aquatic animals with acoustic transmitters. *Methods in Ecology and Evolution*, 14(10), 2514–2530.

Lennox, R.J., Blouin-Demers, G., Rous, A.M. & Cooke, S.J. (2016) Tracking invasive animals with electronic tags to assess risks and develop management strategies. *Biological Invasions*, 18, 1219–1233.

Lennox, R.J., Engler-Palma, C., Kowarski, K., Filous, A., Whitlock, R., Cooke, S.J. et al. (2019) Optimizing marine spatial plans with animal tracking data. *Canadian Journal of Fisheries and Aquatic Sciences*, 76(3), 497–509.

Lennox, R.J., Junge, C., Reubens, J., Omar, A., Skjelvan, I. & Vollset, K.W. (2022) Strategic importance of the Bergen-Shetland corridor to marine biology and oceanography of the Atlantic Ocean. *Fisheries Oceanography*, 31(5), 471–479.

Lennox, R.J., Westrelin, S., Souza, A.T., Šmejkal, M., Říha, M., Prchalová, M. et al. (2021) A role for lakes in revealing the nature of animal movement using high dimensional telemetry systems. *Movement Ecology*, 9, 40.

Leonhard, S.B., Stenberg, C. & Støttrup, J.G. (2011) *Effect of the horns rev 1 offshore wind farm on fish communities: follow-up seven years after construction*. Danish Energy Authority. https://core.ac.uk/download/pdf/13793315.pdf?fbclid=IwAR3pvEmY35qXVzvQgv22F

Lindeboom, H.J., Kouwenhoven, H.J., Bergman, M.J.N., Bouma, S., Brasseur, S., Daan, R. et al. (2011) Short-term ecological effects of an offshore wind farm in the Dutch coastal zone; a compilation. *Environmental Research Letters*, 6(3), 035101.

Lino, P.G., Bentes, L., Abecasis, D., Dos Santos, M.N. & Erzini, K. (2009) Comparative behavior of wild and hatchery reared white sea bream (*Diplodus sargus*) released on artificial reefs off the Algarve (southern Portugal). In: Nielsen, J.L., Arrizabalaga, H., Fragoso, N., Hobday, A., Lutcavage, M. & Sibert, J. (Eds.) *Tagging and tracking of marine animals with electronic devices*. Dordrecht: Springer, pp. 23–34.

Lino, P.G., Bentes, L., Oliveira, M.T., Erzini, K. & Santos, M.N. (2011) The African hind's (*Cephalopholis taeniops*, Serranidae) use of artificial reefs off Sal Island (Cape Verde): a preliminary study based on acoustic telemetry. *Brazilian Journal of Oceanography*, 59, 69–76.

Lipták, B., Kouba, A., Patoka, J., Paunović, M. & Prokop, P. (2023) Biological invasions and invasive species in freshwaters: perception of the general public. *Human Dimensions of Wildlife*, 29(1), 1–16.

Lök, A., Düzbastılar, F.O., Gül, B., Özgül, A. & Ulaş, A. (2011) The role of artificial reefs in fisheries management in Turkey. In: Bortone, S.A., Brandini, F.P., Fabi, G. & Otake, S. (Eds.) *Artificial reefs in fisheries management CRC*. Florida: Press Taylor and Francis Group, Marine Biology Series., pp. 155–166.

Lotze, H.K., Lenihan, H.S., Bourque, B.J., Bradbury, R.H., Cooke, R.G., Kay, M.C. et al. (2006) Depletion, degradation, and recovery potential of estuaries and coastal seas. *Science*, 312(5781), 1806–1809.

Lucas, M.C. & Baras, E. (2000) Methods for studying spatial behaviour of freshwater fishes in the natural environment. *Fish and Fisheries*, 1, 283–316.

Lukyanova, O., Dhellemmes, F., Dennenmoser, S., Nolte, A.W. & Arlinghaus, R. (2024) *Combining movement ecology and genetics to understand the ecology and evolution of a freshwater top predator (northern pike, Esox lucius) that has colonized brackish lagoons in the southern Baltic Sea: implications for management and conservation of weakly connected metapopulations. PREPRINT (version 1) available at Research Square*. https://doi.org/10.21203/rs.3.rs-3767242/v1

Mancinelli, G., Chainho, P., Cilenti, L., Falco, S., Kapiris, K., Katselis, G. et al. (2017) The Atlantic blue crab *Callinectes sapidus* in southern European coastal waters: distribution, impact and prospective invasion management strategies. *Marine Pollution Bulletin*, 119, 5–11.

Marques, R., Brazo, A., Aspillaga, E., Zimmermann, M., Hereu, B., Saragoni, G. et al. (2024) Movements and spatial distribution of an endangered fish (*Sciaena umbra*) within a marine protected area. *Scientific Reports*, 14, 3103.

Marsden, J.E., Ellrott, B.J., Claramunt, R.M., Jonas, J.L. & Fitzsimons, J.D. (2005) A comparison of lake trout spawning, fry emergence, and habitat use in lakes Michigan, Huron, and Champlain. *Journal of Great Lakes Research*, 31, 492–508.

Matley, J.K., Klinard, N.V., Barbosa Martins, A.P., Aarestrup, K., Aspillaga, E., Cooke, S.J. et al. (2022) Global trends in aquatic animal tracking with acoustic telemetry. *Trends in Ecology & Evolution*, 37, 79–94.

McCauley, D.J., Pinsky, M.L., Palumbi, S.R., Estes, J.A., Joyce, F.H. & Warner, R.R. (2015) Marine defaunation: animal loss in the global ocean. *Science*, 347, 1255641.

McIntyre, T. (2014) Trends in tagging of marine mammals: a review of marine mammal biologging studies. *African Journal of Marine Science*, 36(4), 409–422.

Meager, J.J., Fernö, A. & Skjæraasen, J.E. (2018) The behavioural diversity of Atlantic cod: insights into variability within and between individuals. *Reviews in Fish Biology and Fisheries*, 28(1), 153–176.

Methratta, E.T. & Dardick, W.R. (2019) Meta-analysis of finfish abundance at offshore wind farms. *Reviews in Fisheries Science & Aquaculture*, 27(2), 242–260.

Moland, E., Olsen, E.M., Andvord, K., Knutsen, J.A. & Stenseth, N.C. (2011) Home range of European lobster (*Homarus gammarus*) in a marine reserve: implications for future reserve design. *Canadian Journal of Fisheries and Aquatic Sciences*, 68, 1197–1210.

Monk, C.T., Bekkevold, D., Klefoth, T., Pagel, T., Palmer, M. & Arlinghaus, R. (2021) The battle between harvest and natural selection creates small and shy fish. *Proceedings of the National Academy of Sciences*, 118(9), e2009451118.

Monk, C.T., Chéret, B., Czapla, P., Hühn, D., Klefoth, T., Eschbach, E. et al. (2020) Behavioural and fitness effects of translocation to a novel environment: whole-lake experiments in two aquatic top predators. *Journal of Animal Ecology*, 89(10), 2325–2344.

Moore, J.S., Harris, L.N., Kessel, S.T., Bernatchez, L., Tallman, R.F. & Fisk, A.T. (2016) Preference for nearshore and estuarine habitats in anadromous Arctic char (*Salvelinus alpinus*) from the Canadian high Arctic (Victoria Island, Nunavut) revealed by acoustic telemetry. *Canadian Journal of Fisheries and Aquatic Sciences*, 73(9), 1434–1445.

Morato, T., Watson, R., Pitcher, T.J. & Pauly, D. (2006) Fishing down the deep. *Fish and Fisheries*, 7(1), 24–34.

Morel, G.M., Shrives, J., Bossy, S.F. & Meyer, C.G. (2013) Residency and behavioural rhythmicity of ballan wrasse (*Labrus bergylta*) and rays (*Raja* spp.) captured in Portelet Bay, Jersey: implications for marine protected area design. *Journal of the Marine Biological Association of the United Kingdom*, 93, 1407–1414.

Mueter, F., Bouchard, C., Hop, H., Laurel, B. & Norcross, B. (2020) Arctic gadids in a rapidly changing environment. *Polar Biology*, 43(8), 945–949.

Munday, P.L., Warner, R.R., Monro, K., Pandolfi, J.M. & Marshall, D.J. (2013) Predicting evolutionary responses to climate change in the sea. *Ecology Letters*, 16, 1488–1500.

Muñoz, L., Aspillaga, E., Palmer, M., Saraiva, J.L. & Arechavala-Lopez, P. (2020) Acoustic telemetry: a tool to monitor fish swimming behavior in sea-cage aquaculture. *Frontiers in Marine Science*, 7, 645.

Nakayama, S., Doering-Arjes, P., Linzmaier, S., Briege, J., Klefoth, T., Pieterek, T. et al. (2018) Fine-scale movement ecology of a freshwater top predator, Eurasian perch (*Perca fluviatilis*), in response to the abiotic environment over the course of a year. *Ecology of Freshwater Fish*, 27, 798–812.

Nathan, R., Monk, C.T., Arlinghaus, R., Adam, T., Alós, J., Assaf, M. et al. (2022) Big-data approaches lead to an increased understanding of the ecology of animal movement. *Science*, 375, 734.

Naylor, R., Hindar, K., Fleming, I.A., Goldburg, S., Williams, S., Volpe, J. et al. (2005) Fugitive salmon: assessing the risks of escaped fish from net-pen aquaculture. *Bioscience*, 55(5), 427–437.

Neat, F.C., Bendall, V., Berx, B., Wright, P.J., Ó Cuaig, M., Townhill, B. et al. (2014) Movement of Atlantic cod around the British Isles: implications for finer scale stock management. *Journal of Applied Ecology*, 51(6), 1564–1574.

Nielsen, J.K. & Seitz, A.C. (2017) Interannual site fidelity of Pacific halibut: potential utility of protected areas for management of a migratory demersal fish. *ICES Journal of Marine Science*, 74(8), 2120–2134.

O'Farrell, M.R. & Botsford, L.W. (2006) The fisheries management implications of maternal-age-dependent larval survival. *Canadian Journal of Fisheries and Aquatic Sciences*, 63, 2249–2258.

Olsen, E.M., Karlsen, Ø. & Skjæraasen, J.E. (2023) Large females connect Atlantic cod spawning sites. *Science*, 382(6675), 1181–1184.

Özgül, A., Lök, A., Tansel Tanrıkul, T. & Alós, J. (2019) Home range and residency of *Scorpaena porcus* and *Scorpaena scrofa* in artificial reefs revealed by fine-scale acoustic tracking. *Fisheries Research*, 210, 22–30.

Özgül, A., Lök, A., Ulaş, A., Düzbastılar, F.O., Tanrıkul, T.T. & Pelister, C. (2015) Preliminary study on the use of the Vemco positioning system to determine fish movements in artificial reef areas: a case study on *Sciaena umbra* Linnaeus, 1758. *Journal of Applied Ichthyology*, 31, 41–47.

Pampoulie, C., Berg, P.R. & Jentoft, S. (2022) Hidden but revealed: after years of genetic studies behavioural monitoring combined with genomics uncover new insight into the population dynamics of Atlantic cod in Icelandic waters. *Evolutionary Applications*, 16, 223–233.

Pauly, D., Christensen, V., Dalsgaard, J., Froese, R. & Torres, F. (1998) Fishing down marine food webs. *Science*, 279, 860–863.

Peterka, J. (2021a) *Fish community assessment of the Chabařovice Lake in 2020/Komplexní průzkum rybí obsádky jezera Chabařovice v roce 2020*. Report of the IHB, BC CAS, 43 p. (in Czech).

Peterka, J. (2021b) *Fish community assessment of the Most Lake in 2020/ Komplexní průzkum rybí obsádky jezera Most v roce 2020*. Report of the IHB, BC CAS, 43 p. (in Czech).

Pettitt-Wade, H., Loseto, L.L., Majewski, A. & Hussey, N.E. (2021) Cod movement ecology in a warming world: circumpolar Arctic gadids. *Fish and Fisheries*, 22, 562–591. Available from: https://doi.org/10.1111/faf.12536

Pincock, D.G. & Johnston, S.V. (2012) Acoustic telemetry overview. In: Adams, N.S., Beeman, J.W. & Eiler, J.H. (Eds.) *Telemetry techniques: a user guide for fisheries research*. Bethesda, Maryland: American Fisheries Society.

Pioch, S., Raynal, J.C., Lasserre, G. & Aliaume, C. (2011) An integrated coastal area management strategy to deploy artificial reefs. In: Bortone, S.A., Brandini, F.P., Fabi, G. & Otake, S. (Eds.) *Artificial reefs in fisheries management*. Florida: CRC Press, pp. 65–75.

Polovina, J.J. (1991) Fisheries applications and biological impacts of artificial habitats. In: Seaman, W., Jr. & Sprage, L.M. (Eds.) *Artificial habitats for marine and freshwater fisheries*. Florida – USA: Academic Press, pp. 153–176.

Pomeroy, R.S., Watson, L.M., Parks, J.E. & Cid, G.A. (2005) How is your MPA doing? A methodology for evaluating the management effectiveness of marine protected areas. *Ocean and Coastal Management*, 48, 485–502.

Powell, R.A. (2000) Animal home ranges and territories and home range estimators. In: Boitani, L. & Fuller, T.K. (Eds.) *Research techniques in animal ecology: controversies and consequences*. New York: Columbia University Press, pp. 65–110.

Punt, A.E., A'mar, T., Bond, N.A., Butterworth, D.S., De Moor, C.L., De Oliveira, J.A.A. et al. (2014) Fisheries management under climate and environmental uncertainty: control rules and performance simulation. *ICES Journal of Marine Science*, 71, 2208–2220.

Ramsden, S., Cotton, C.F. & Curran, M.C. (2017) Using acoustic telemetry to assess patterns in the seasonal residency of the Atlantic stingray *Dasyatis sabina*. *Environmental Biology of Fishes*, 100(2), 89–98.

Raoux, A., Tecchio, S., Pezy, J.-P., Lassalle, G., Degraer, S., Wilhelmsson, D. et al. (2017) Benthic and fish aggregation inside an offshore wind farm: which effects on the trophic web functioning? *Ecological Indicators*, 72, 33–46.

Reglero, P., Ortega, A., Balbín, R., Abascal, F.J., Medina, A., Blanco, E. et al. (2018) Atlantic bluefin tuna spawn at suboptimal temperatures for their offspring. *Proceedings of the Royal Society B: Biological Sciences*, 285(1870), 20171405.

Reubens, J., Aarestrup, K., Meyer, C., Moore, A., Okland, F. & Afonso, P. (2021) Compatibility in acoustic telemetry. *Animal Biotelemetry*, 9, 33. Available from: https://doi.org/10.1186/s40317-021-00253-z

Reubens, J., Verhelst, P., Van der Knaap, I., Deneudt, K., Moens, T. & Hernandez, F. (2019) Environmental factors influence the detection probability in acoustic telemetry in a marine environment: results from a new setup. *Hydrobiologia*, 845(1), 81–94.

Reubens, J., Verhelst, P., Van der Knaap, I., Wydooghe, B., Milotic, T., Deneudt, K. et al. (2019) The need for aquatic tracking networks: the permanent Belgian acoustic receiver network. *Animal Biotelemetry*, 7(1), 2. Available from: https://doi.org/10.1186/s40317-019-0164-8

Reubens, J.T., De Rijcke, M., Degraer, S. & Vincx, M. (2014) Diel variation in feeding and movement patterns of juvenile Atlantic cod at offshore wind farms. *Journal of Sea Research*, 85, 214–221.

Reubens, J.T., Degraer, S. & Vincx, M. (2014) The ecology of benthopelagic fishes at offshore wind farms: a synthesis of 4 years of research. *Hydrobiologia*, 727(1), 121–136.

Reubens, J.T., Pasotti, F., Degraer, S. & Vincx, M. (2013) Residency, site fidelity and habitat use of Atlantic cod (*Gadus morhua*) at an offshore wind farm using acoustic telemetry. *Marine Environmental Research*, 90, 128–135.

Reynolds, B.F., Powers, S.P. & Bishop, M.A. (2010) Application of acoustic telemetry to assess residency and movements of rockfish and lingcod at created and natural habitats in Prince William sound. *PLoS One*, 5(8), e12130.

Righton, D., Quayle, V., Hetherington, S. & Burt, G. (2007) Movements and distribution of cod (Gadus morhua) in the southern North Sea and English Channel: results from conventional and electronic tagging experiments. *Journal of the Marine Biological Association of the United Kingdom*, 87(2), 599–613.

Říha, M., Gjelland, K.Ø., Děd, V., Eloranta, A.P., Rabaneda-Bueno, R., Baktoft, H. et al. (2021) Contrasting structural complexity differentiate hunting strategy in an ambush apex predator. *Scientific Reports*, 11, 17472.

Říha, M., Kubečka, J., Seďa, J., Matěna, J., Hladík, M., Čech, M. et al. (2009) Long-term development of fish populations in the Římov reservoir. *Fisheries Management and Ecology*, 16, 121–129.

Říha, M., Rabaneda-Bueno, R., Jarić, I., Souza, A.T., Vejřík, L., Draštík, V. et al. (2021) Dynamics of the habitat use of three predatory freshwater fish in a lentic ecosystem. *BioRxiv*. https://doi.org/10.1101/2021.12.16.471647

Roberts, C.M. (1997) Ecological advice for the global fisher crisis. *Trends in Ecology & Evolution*, 12, 35–38.

Russ, G.R. (2002) Yet another review of marine reserves as reef fishery management tools. In: Sale, P.S. (Ed.) *Coral reef fishes: dynamic and diversity in a complex ecosystem*. San Diego, CA: Elsevier, pp. 421–443.

Sandlund, O.T., Berntsen, H.H., Fiske, P., Kuusela, J., Muladal, R., Niemelä, E. et al. (2019) Pink salmon in Norway: the reluctant invader. *Biological Invasions*, 21, 1033–1054.

Santos, M.N. & Monteiro, C.C. (2007) A fourteen-year overview of the fish assemblages and yield of the two oldest Algarve artificial reefs (southern Portugal). *Hydrobiologia*, 580, 225–231.

Scientific, Technical and Economic Committee for Fisheries (STECF). (2023) In: Nielsen, R., Virtanen, J. & Guillen Garcia, J. (Eds.) EUR 28359 EN, *Scientific, Technical and Economic Committee for Fisheries (STECF) – Economic Report on the EU aquaculture (STECF-22-17)*. Luxembourg: Publications Office of the European Union. ISBN 978-92-76-99317-9, https://doi.org/10.2760/51391, JRC132648.

Seitz, R.D., Wennhage, H., Bergström, U., Lipcius, R.N. & Ysebaert, T. (2014) Ecological value of coastal habitats for commercially and ecologically important species. *ICES Journal of Marine Science*, 71(3), 648–665.

Silva, S., Lowry, M., Macaya-Solis, C., Bryatt, B. & Lucas, M.C. (2017) Can navigation locks be used to help migratory fishes with poor swimming performance pass tidal barrages? A test with lamprey. *Ecological Engineering*, 102, 291–302.

Simberloff, D. (2003) How much information on population biology is needed to manage introduced species? *Conservation Biology*, 17(1), 83–92.

Smedbol, R.K. & Stephenson, R. (2001) The importance of managing within-species diversity in cod and herring fisheries of the northwestern Atlantic. *Journal of Fish Biology*, 59, 109–128.

Sollmann, R., Gardner, B., Parsons, A.W., Stocking, J.J., McClintock, B.T., Simons, T.R. et al. (2013) A spatial mark–resight model augmented with telemetry data. *Ecology*, 94(3), 553–559.

Song, H.C., Mikhalevsky, P.N. & Baggeroer, A.B. (2014) Transarctic acoustic telemetry. *Journal of the Acoustical Society of America*, 136, 1491–1494.

Stein, F., Doering-Arjes, P., Fladung, E., Brämick, U., Bendall, B. & Schröder, B. (2016) Downstream migration of the European eel (*Anguilla Anguilla*) in the Elbe River, Germany: movement patterns and the potential impact of environmental factors. *River Research and Applications*, 32(4), 666–676.

Stephenson, R.L. (1999) Stock complexity in fisheries management: a perspective of emerging issues related to population sub-units. *Fisheries Research*, 43, 247–249.

Stige, L.C., Helgesen, K.O., Viljugrein, H. & Qviller, L. (2022) Modelling salmon lice-induced mortality of wild salmon post-smolts is highly sensitive to calibration data. *Aquaculture Environment Interactions*, 14, 263–277.

Sundby, S. & Nakken, O. (2008) Spatial shifts in spawning habitats of Arcto-Norwegian cod related to multidecadal climate oscillations and climate change. *ICES Journal of Marine Science*, 65, 953–962.

Svendsen, E., Føre, M., Økland, F., Grans, A., Hedger, R.D., Alfredsen, J.A. et al. (2021) Heart rate and swimming activity as stress indicators for Atlantic salmon (*Salmo salar*). *Aquaculture*, 531, 735804.

Thomsen, F., Lüdemann, K., Kafemann, R. & Piper, W. (2006) Effects of offshore wind farm noise on marine mammals and fish. *Biola, Hamburg, Germany on Behalf of COWRIE Ltd*, 62, 1–62.

Thorstad, E.B., Whoriskey, F., Uglem, I., Moore, A., Rikardsen, A.H. & Finstad, B. (2012) A critical life stage of the Atlantic salmon *Salmo salar*: behaviour and survival during the smolt and initial post-smolt migration. *Journal of Fish Biology*, 81(2), 500–542.

Tickner, D., Opperman, J.J., Abell, R., Acreman, M., Arthington, A.H., Bunn, S.E. et al. (2020) Bending the curve of global freshwater biodiversity loss: an emergency recovery plan. *Bioscience*, 70(4), 330–342.

Topping, D.T. & Szedlmayer, S.T. (2011) Home range and movement patterns of red snapper (*Lutjanus campechanus*) on artificial reefs. *Fisheries Research*, 112, 77–84.

Trancart, T., Carpentier, A., Acou, A., Danet, V., Elliott, S. & Feunteun, E. (2020) Behaviour of endangered European eels in proximity to a dam during downstream migration: novel insights using high accuracy 3D acoustic telemetry. *Ecology of Freshwater Fish*, 20, 266–279.

Trancart, T., Feunteun, E., Danet, V., Carpentier, A., Mazel, V., Charrier, F. et al. (2018) Migration behaviour and escapement of European silver eels from a large lake and wetland system subject to water level management (grand-lieu lake, France): new insights from regulated acoustic telemetry data. *Ecology of Freshwater Fish*, 27(2), 570–579.

Tummers, J.S., Winter, E., Silva, S., O'Brien, P., Jang, M.H. & Lucas, M.C. (2016) Evaluating the effectiveness of a Larinier super active baffle fish pass for European river lamprey *Lampetra fluviatilis* before and after modification with wall-mounted studded tiles. *Ecological Engineering*, 91, 183–194.

Uglem, I., Bjørn, P.A., Mitamura, H. & Nilsen, R. (2010) Spatiotemporal distribution of coastal and oceanic Atlantic cod *Gadus morhua* sub-groups after escape from a farm. *Aquaculture Environment Interactions*, 1, 11–19.

Ünal, V., Göncüoğlu, H., Durgun, D., Tosunoğlu, Z., Deval, C. & Turan, C. (2015) Silver-cheeked toadfish, *Lagocephalus sceleratus* (Actinopterygii: Tetraodontiformes: Tetraodontidae), causes a substantial economic losses in the Turkish Mediterranean coast: a call for decision makers. *Acta Ichthyologica et Piscatoria*, 45(3), 231–237. Available from: https://doi.org/10.3750/AIP2015.45.3.02

Ünal, V., Tıraşın, E.M., Dimech, M. & Vasconcellos, M. (2018) *Initiatives for the ecosystem approach to fisheries management in Turkey: is there hope for a successful implementation? The 3rd international congress on Applied Ichthyology & Aquatic Environment, 8–11 November 2018, Volos, Greece, 286–290*.

Van der Knaap, I., Reubens, J., Thomas, L., Ainslie, M.A., Winter, H.V., Hubert, J. et al. (2021) Effects of a seismic survey on movement of free-ranging Atlantic cod. *Current Biology*, 31(7), 1555–1562.

Van der Knaap, I., Slabbekoorn, H., Moens, T., Van den Eynde, D. & Reubens, J. (2022) Effects of pile driving sound on local movement of free-ranging Atlantic cod in the Belgian North Sea. *Environmental Pollution*, 300, 118913.

Van Hal, R., Couperus, A.S., Fassler, S.M.M., Gastauer, S., Griffioen, B., Hintzen, N.T. et al. (2012) *Monitoring-and evaluation program near shore wind farm (MEP-NSW): fish community*. Wageningen: IMARES, p. 201. Available from: https://library.wur.nl/WebQuery/wurpubs/reports/437693

Vejříková, I., Eloranta, A.P., Vejřík, L., Šmejkal, M., Čech, M., Sajdlová, Z. et al. (2017) Macrophytes shape trophic niche variation among generalist fishes. *PLoS One*, 12, e0177114.

Vejříková, I., Vejřík, L., Čech, M., Říha, M. & Peterka, J. (2022) Succession of submerged vegetation in a hydrologically reclaimed opencast mine during first 10 years. *Restoration Ecology*, 30, e13489.

Verhelst, P., Aarestrup, K., Hellström, G., Jepsen, N., Koed, A., Reubens, J. et al. (2022) The effect of externally attached archival data loggers on the short-term dispersal behaviour and migration speed of European eel (*Anguilla anguilla* L.). *Animal Biotelemetry*, 10(9), 1–8.

Villegas-Ríos, D., Alós, J., March, D., Palmer, M., Mucientes, G. & Saborido-Rey, F. (2013) Home range and diel behaviour of the ballan wrasse, *Labrus bergylta*, determined by acoustic telemetry. *Journal of Sea Research*, 80, 61–71.

Villegas-Ríos, D., Freitas, C., Moland, E., Thorbjørnsen, S.H. & Olsen, E.M. (2020) Inferring individual fate from aquatic acoustic telemetry data. *Methods in Ecology and Evolution*, 11(10), 1186–1198.

Vivian, M.N., Young, N. & Cooke, S.J. (2017) Applying a knowledge–action framework for navigating barriers to incorporating telemetry science into fisheries management and conservation: a qualitative study. *Canadian Journal of Fisheries and Aquatic Sciences*, 75(10), 1733–1743.

Voegeli, F.A., Smale, M.J., Webber, D.M., Andrade, Y. & O'Dor, R.K. (2001) Ultrasonic telemetry, tracking and automated monitoring technology for sharks. *Environmental Biology of Fishes*, 60, 267–281.

Vollset, K.W., Qviller, L., Skår, B., Barlaup, B.T. & Dohoo, I. (2018) Parasitic sea louse infestations on wild sea trout: separating the roles of fish farms and temperature. *Parasites and Vectors*, 11, 609.

Vollset, K.W., Urdal, K., Utne, K., Thorstad, E.B., Sægrov, H., Raunsgard, A. et al. (2022) Ecological regime shift in the Northeast Atlantic Ocean revealed from the unprecedented reduction in marine growth of Atlantic salmon. *Science Advances*, 8, eabk2542.

Walters, S., Lowerre-Barbieri, S., Bickford, J. & Mann, D. (2009) Using a passive acoustic survey to identify spotted seatrout spawning sites and associated habitat in Tampa Bay, Florida. *Transactions of the American Fisheries Society*, 138(1), 88–98.

Wang, Y., Huang, L. & Xing, B. (2023) Experimental study on the effect of sound stimulation on hearing and behavior of juvenile black rockfish (*Sebastes schlegelii). Frontiers in Marine Science*, 10, 1257473.

Wartzok, D., Sayegh, S., Stone, H., Barchak, J. & Barnes, W. (1992) Acoustic tracking system for monitoring under-ice movements of polar seals. *Journal of the Acoustical Society of America*, 92, 682–687.

Wassmann, P. & Reigstad, M. (2011) Future Arctic Ocean seasonal ice zones and implications for pelagic–benthic coupling. *Oceanography*, 24, 220–231.

Water Framework Directive. (2024) The EU Water Framework Directive. https://ec.europa.eu

Webster, I.T. & Harris, G.P. (2004) Anthropogenic impacts on the ecosystems of coastal lagoons: modelling fundamental biogeochemical processes and management implications. *Marine and Freshwater Research*, 55, 67–78.

Weinz, A.A., Matley, J.K., Klinard, N.V., Fisk, A.T. & Colborne, S.F. (2020) Identification of predation events in wild fish using novel acoustic transmitters. *Animal Biotelemetry*, 8, 1–14.

Weiperth, A., Bláha, M., Szajbert, B., Seprős, R., Bányai, Z., Patoka, J. et al. (2020) Hungary: a European hotspot of non-native crayfish biodiversity. *Knowledge and Management of Aquatic Ecosystems*, 421, 43.

Wiencke, C. & Hop, H. (2016) Ecosystem Kongsfjorden: new views after more than a decade of research. *Polar Biology*, 39(10), 1679–1687.

Wiens, J.A. (2000) Ecological heterogeneity: an ontogeny of concepts and approaches. In: Hutchings, M.J., John, E.A. & Stewart, A.J.A.

(Eds.) *The ecological consequences of environmental heterogeneity*. Oxford: Blackwell Science, pp. 9–31.

Winter, H.V., Aarts, G.M. & Van Keeken, O.A. (2010) *Residence time and behaviour of sole and cod in the offshore wind farm Egmond aan zee (OWEZ)*. IMARES Wageningen UR. https://library.wur.nl/WebQuery/wurpubs/422187

Young, A.H., Tytler, P., Holliday, F.G.T. & MacFarlane, A.A. (1972) Small sonic tag for measurement of locomotor behaviour in fish. *Journal of Fish Biology*, 4, 57–65.

How to cite this article: Özgül, A., Birnie-Gauvin, K., Abecasis, D., Alós, J., Aarestrup, K., Reubens, J. et al. (2024) Tracking aquatic animals for fisheries management in European waters. *Fisheries Management and Ecology*, 31, e12706. Available from: https://doi.org/10.1111/fme.12706