Report on the ecology of diadromous fish at sea

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Synthèse sur les connaissances disponibles sur les migrateurs en mer

Report on the ecology of diadromous fish at sea

Rapport d'étape 1

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04 août 2020

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Niveau géographique : national
Couverture géographique : Ouest Europe
Niveau de lecture : professionnels, experts

• REPORT ON THE ECOLOGY OF DIADROMOUS FISH AT SEA

• ABSTRACT

Very little is known about diadromous fish distribution at sea. Twelve diadromous fish have been found to occur in France. However, numerous species have declined in recent years. Here, we collated a database of 168 904 hauls from 42 fisheries dependent and independent surveys between 1965 and 2019 and analyse data containing information on diadromous fish known to occur within French marine waters.

The aim of this study is to 1) evaluate the use of the existing databases to study diadromous fish, 2) improve understanding of diadromous fish ecology at sea, 3) assess the value of marine protected areas for diadromous fish, and 4) evaluate the risk of capture of diadromous fish from the different surveys and gear types.

• MOTS CLES

Diadromous fish, IUCN red listed species, Species distribution, Europe, Fisheries dependent data, Fisheries independent data, Bycatch, Marine Protected Areas.

• SOMMAIRE

I. Introduction

Diadromous fish migrate between sea and fresh water during their life cycle. Some spend most of their lives at sea and reproduce in fresh water (anadromous species) while other spend most of their time in freshwater and reproduce at sea (catadromous species) (Lassalle et al., 2009, 2008). Twelve diadromous fish have been found to occur in France (Table 1). They have been of economic importance for centuries. However, numerous species have declined in recent years (Béguer et al., 2007; Lassalle et al., 2008). Reasons for their decline has been related to increased demand, increased river pollution, the construction of dams and anthropogenically induced climate change (Lassalle et al., 2009, 2008; Lassalle and Rochard, 2009; Limburg and Waldman, 2009). To date (2020), insufficient information exists to evaluate mortality at sea.

As a consequence of their decline, all 12 species are red listed under the International Union for the Conservation of Nature (IUCN). Numerous species have also been listed under various conventions for their protection: the convention for international trade of endangered species (CITES); the Habitats Directive's annexes; the Bern convention; and the convention for the protection of the marine environment of the North-East Atlantic (OSPAR) (Table 1).

Although the biology and ecology of diadromous fish has been well studied in freshwater (e.g. Béguer et al., 2007; Lassalle et al., 2009, 2008), surprisingly very little is known about the distribution and lives of diadromous fish at sea. Here we analyse existing data containing information on diadromous fish known to occur in French marine waters, with the aim to:

1) evaluate the use of the existing databases analysed to study diadromous fish at sea.
2) assess their spatial distribution according to different life history stage at sea and analyse long-term temporal trends in relative abundance;
3) assess the value of Marine Protected Areas for diadromous fish;
4) evaluate the risk of capture of diadromous fish from the different surveys and gear types.

II. Methods

1) Fisheries independent (International Scientific Bottom Trawl Surveys and French scientific surveys) and French fisheries dependent observer data (ObsMer) were collated from Institut Français pour l'Exploitation de la Mer (IFREMER) and the International Council for the Exploration of the Sea (ICES) the Database of Trawl Surveys (DATRAS) portal (https://www.ices.dk/data/data-portals/Pages/DATRAS.aspx). To gather French scientific surveys, surveys that had information on diadromous fish (https://campagnes.flotteoceanographique.fr/campaign; Table S1 in Appendix) were requested, taking information provided within Regimbart et al, (2018) (Table 2.1).

2) The three datasets were compiled, analysed and diadromous fish distributions mapped in R CRAN free software (version 3.3, http://cran.r-project.org; Table 2.2).

3) Literature reviews on diadromous fish distribution, habitat, their size ranges, maturity and timing of migrations, are being undertaken to match against diadromous fish recordings from the database. Using the literature reviews and expert knowledge, data cleaning is being undertaken, correcting potential miss-identified species and any other obvious errors (Table 2.3-11).

4) Summary reports on species distribution, length, migration, abundance, bycatch and the value of the database are being developed for each species or group of species. Where sufficient data existed species distribution models will be undertaken (i.e. shads, the European eel, the flounder, mullet and smelt; Table 2.3-11).

5) The value of existing Marine Protected Areas (MPAs) for diadromous fish will be analysed from the cleaned data (points iii-iv; Table 2.12).

6) An analysis of diadromous fish catchability will be estimated from information on survey effort and fish capture over the course of the year. The latter will build upon work undertaken by Drogou et al. (2008) (Table 2.13).

7) Finally, there will be an evaluation on the use of the surveys analysed for diadromous fish distribution (Table 2.14).

Refer to Table 2 for estimated timing of delivery.

Table 1. Diadromous fish observed within French marine waters and their conservation status. A = Anadromous, C = Catadromous, - = not listed.

Latin name	EN name	FR name	Type	IUCN FR 2019[1]	IUCN EU 2011[2]	IUCN world[4]	CITES	Habitat Directive	Bern	OSPAR
Acipenser sturio	European sea sturgeon	Esturgeon européen	A	CR	CR	CR	AI	All, AIV*	III	Y
Alosa alosa	Allis shad	Grande alose	A	CR	LC	LC	-	II, V	III	-
Alosa fallax	(Atlantic)Twait shad	Alose feinte atlantique	A	NT	LC	LC	-	II, V	III	-
Alosa agone	Mediterranean twaite shad	Alose feinte méditerranéenne	A	NT	LC	LC	-	II, V	III	-
Anguilla anguilla	European eel	Anguille européenne	C	CR	CR	CR	AII	-	-	Y
Lampetra fluviatilis	European river lamprey /Lampern	Lamproie fluviatile	A	VU	LC	LC	NA	II, V	III	-
Petromyzon marinus	Sea lamprey	Lamproie marine	A	EN	LC	LC	-	II	III	Y
Liza/Chelon ramada	Thinlip mullet	Mulet porc	C	LC	LC	LC	-	-	-	-
Osmerus eperlanus	Smelt	Eperlan	A	NT	LC	LC	-	-	-	-
Platichthys flesus	European flounder	Flet	C	DD	LC	LC	-	-	-	-
Salmo salar	Atlantic salmon	Saumon Atlantique	A	NT	VU[3]	LC	-	II, V	III	Y
Salmo trutta	Sea trout	Truite de mer	A	LC	LC	LC	-	-	-	-

[1] UICN et al, 2019; [2] Freyhof and Brooks, 2011; [3] Nieto et al, 2015; [4] https://www.iucnredlist.org/.

Table 2. Estimated timeline for diadromous fish at sea deliverables.

			Contract 1						Contract 2						Proposed extra					
			2019						2020						2021					
	Topic	Detail	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6
1	Data collation	Collation of fisheries independent and dependent data by Noemi																		
2	Database compilation	Overview of literature and initial cleaning of the data																		
3	Lamprey	R script																		
		Literature research																		
		Writing																		
		Revisions (from team + external - paper)																		
4	Salmonids	R script (as per lamprey + catchability + external data)																		
		Writing																		
		Literature research																		
		Revisions (from team)																		
5	Shads	R script (as per Salmonid + SDM - FI+FD data, + abundance)																		
		Literature research																		
		Writing																		
		Revisions (from team + external)																		
6	Eel	R script (as per Shad + SDM - FI)																		
		Literature research																		
		Writing																		
		Revisions (from team + external)																		
7	Sturgeon	R script (as per lamprey)																		
		Literature research																		
		Writing																		
		Revisions (from team + Bordeaux team)																		
8	Mullet	R script (as per Shad + SDM - FI+FD)																		
		Literature research																		
		Writing																		
		Revisions (from team + external)																		
9	Smelt	R script (as per Salmon +SDM - FI data)																		
		Writing																		
		Literature research																		
		Revisions (from team + external)																		
10	Flounder	R script (as per salmon + SDM - FI+FD)																		
		Literature research																		
		Writing																		
		Revisions (from team + external)																		
11	DF distribution paper	Compiling all the above with seasonal and stage distribution.																		
		Writing																		
		Revisions																		
12	MPAs	Mapping DF and migration within French MPAs - M1 support																		
		Modelling DF presence in MPA -M2 support																		
		Writing																		
		Revisions																		
13	Catchability of diadromous fish	Analyse DF catchability in space and time																		
		Literature research																		
		Writing																		
		Revisions																		
14	Value of the database	What's missing																		
		What could be done to improve																		
		Collecting more recent data & DF update																		

Table 1 key	
DF	Diadromous fish
FD	Fisheries dependent data
FI	Fisheries independent data
MPA	Marine Protected Area
SDM	Species Distribution Model
	Reporting
	Completed
	To complete

III. Results

III.1. Survey data

From the 168 904 hauls out with transitional waters, 10 0617 hauls came from ObsMer data from 2003 to 2019 (Fig. 1.a), 54 865 hauls came from fisheries independent data submitted to ICES DATRAS (Fig. 1.b) between 1965 and 2018 and 13,422 hauls were collected from IFREMER from French scientific surveys (1976 to 2018; Fig. 1.c; Table S1 in Appendix A1). The spatial and temporal coverage for the three different datasets can be found within Appendix A1.

Note, through working with colleagues from French National Institute of Environmental Research and Technology (IRSTEA; Bordeaux) on shad, differences were observed in shad presence and the numbers caught within the ObsMer dataset. Following communication with IFREMER, a new extraction of ObsMer data was provided (31/07/20; Table 2.1-2).

III.2. Species distribution

Varying distributions can be observed from the different datasets (Fig. 2). From analyses of diadromous fish distribution individually, error in species identification and length has been observed (learnt through existing literature on the species and expert knowledge). Due to varying spatial effort (haul duration, vessel size and power, and sampling effort; Fig. 3), precise measures of abundance cannot be performed. To date (04/08/2020) analysis and cleaning of lamprey presence, abundance and length has been completed to the best of our knowledge (Appendix A). However the new ObsMer dataset has not yet been incorporated into Appendix A.

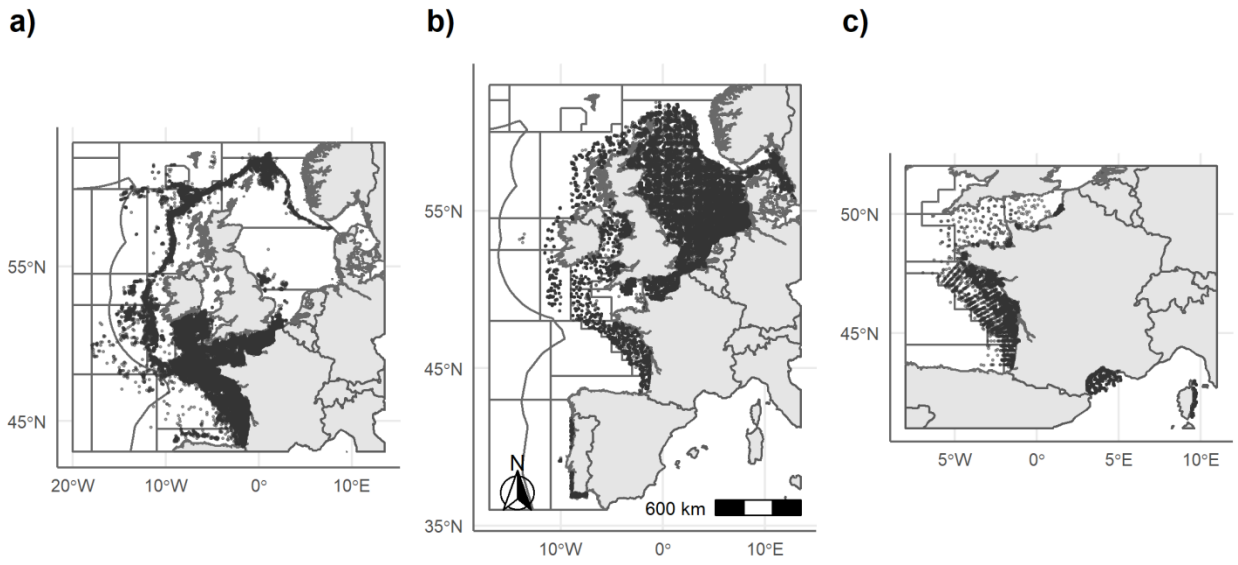

Fig. 1. Haul locations for a) fisheries dependent ObsMer surveys b) fisheries independent ICES DATRAS and c) French national scientific surveys. Black solid lines delineate ICES statistical divisions.

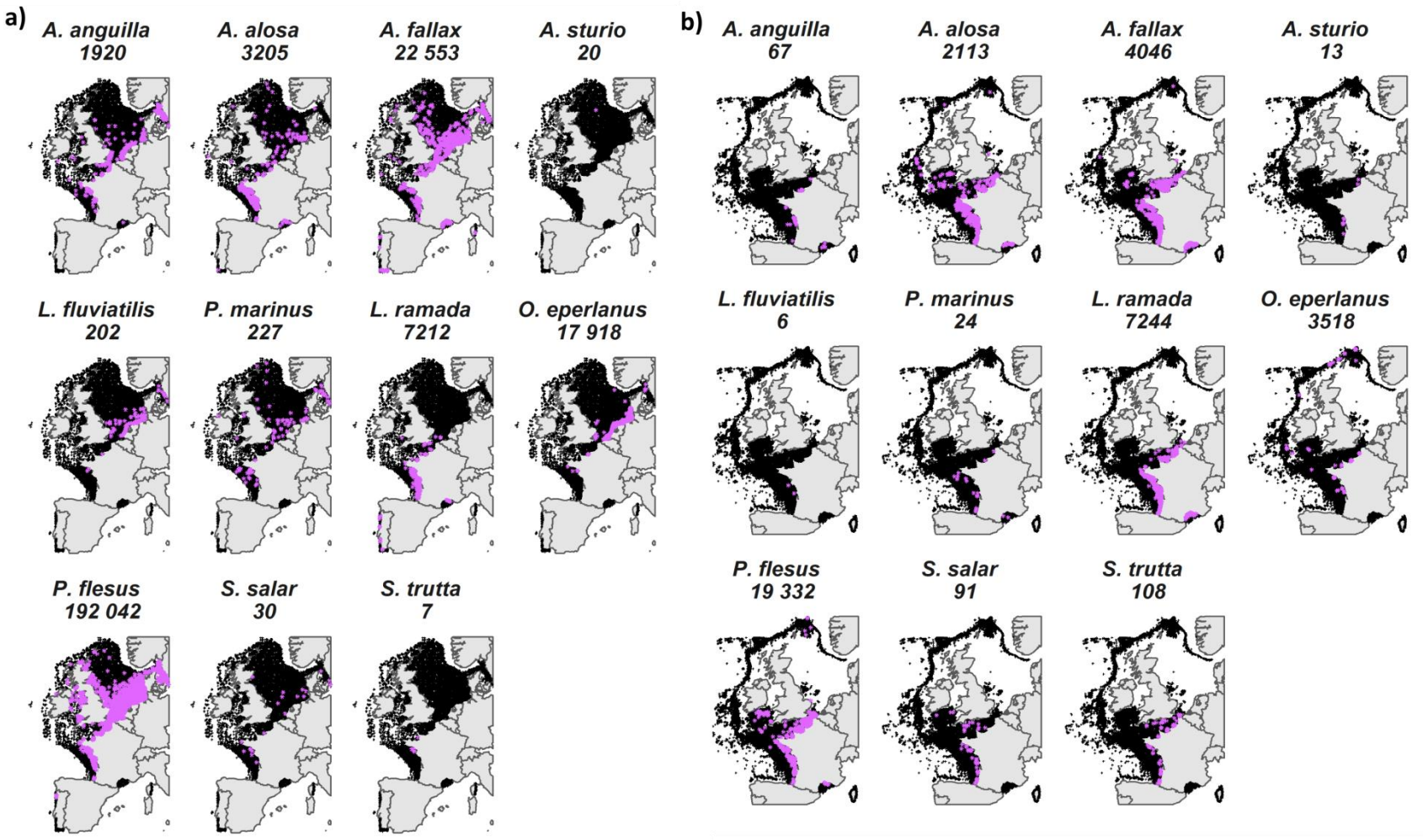

Fig. 2. Presence (violet points) absence (black points) map of diadromous fish using a) Fisheries independent data and b) fisheries dependent data. The numbers under the species names indicate the total number of individuals recorded. **Note, these results have not been verified for errors**.

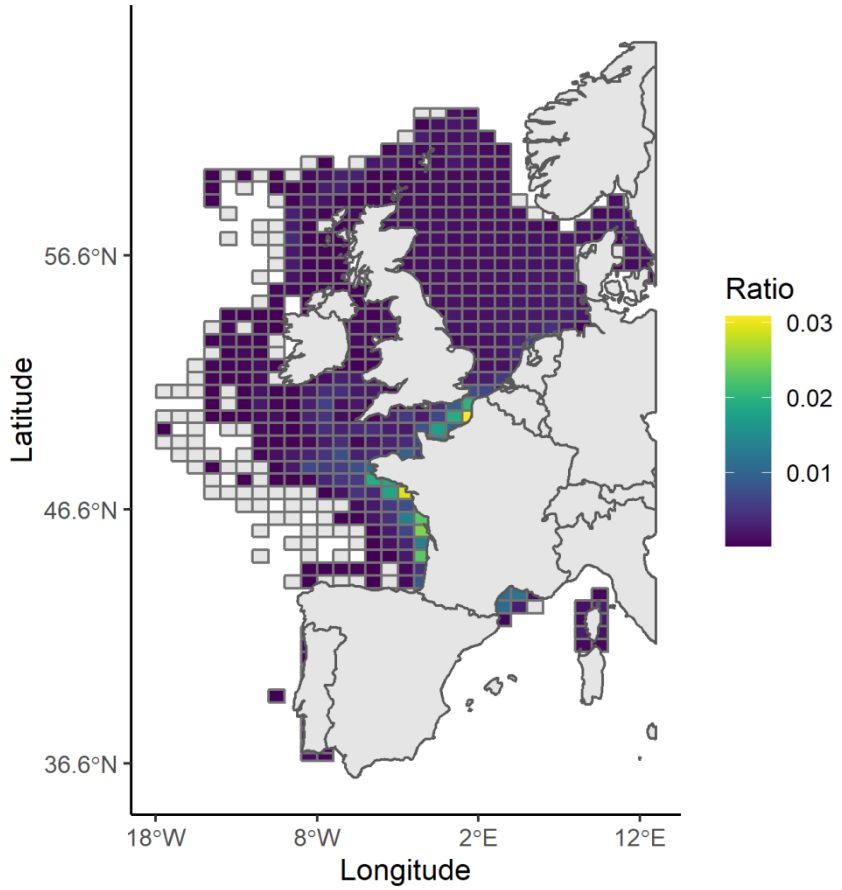

Fig. 3. Proportions of total hauls per ICES rectangle combining ObsMer data (2003-2019), scientific bottom trawl survey data submitted to DATRAS (1965-2018) and French scientific survey data (1976-2018). Grey cells indicate where <0.0001 hauls were undertaken.

IV. Next steps

At present analysis is being undertaken one group of species at a time (Table 2). During species analysis, the data is corrected for species miss-identification and error in lengths. Following the process of data cleaning, species distribution models and relative abundance tendencies will be undertaken where sufficient data exists.

It is planned for a first- and second-year master's student (November 2020 – February 2021 and February – August 2021) to support the project (Table 2) and help forward diadromous fish distribution within MPAs.

Accurate estimations of abundance are not possible with the data provided due to insufficient information on effort. Given the vulnerability of diadromous fish (Table 1) and the lack of information of their migrations at sea and mortality, it is hoped to calculate catchability of each species over the course of the year. The latter will give an indication of their vulnerability to different gear types, in addition to providing information on datasets which may be more useful to continue collating information on

diadromous fish from. An evaluation of the use of fisheries independent and dependent data to inform us on diadromous fish distribution and abundance is being undertaken.

V. Acknowledgements

We are extremely grateful to all those who were involved in collecting and compiling the fisheries dependent and independent surveys. We are also grateful to the French Research Institute for Exploitation of the Sea (IFREMER) and the French marine fisheries and aquaculture administration (DPMA) to have given us access to their data.

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VII. Appendix A[1]

Shedding light on the distribution of lampreys at sea

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Running page head: Lamprey at sea distribution

1 **Note:** This manuscript was submitted to the Journal of Endangered Species for publication as a short note (25/05/20) and is now (04/08/20) being revised to be submitted as a full length paper within the same journal.

ABSTRACT

Almost nothing is known about lamprey distribution at sea. In this paper, we collated a database of 150,758 hauls from fisheries dependent and independent surveys between 1965 and 2018. A total of 238 sea lamprey *Petromyzon marinus* and 208 European river lamprey *Lampetra fluviatilis* were identified. Sizes ranged from 13 cm to 80 cm and 14 cm to 42 cm (respectively). Presences were recorded throughout the greater North Sea, the Bay of Biscay and the Celtic sea. The largest proportion of lampreys were observed within the Skagerrak and North Sea (ICES divisions 3.b, 4.b and 4.c), from North Sea International Bottom Trawl Surveys. For both lampreys, there was an increase in size with depth of capture. A higher proportion of lamprey was detected in spring and autumn. Seasonal length variations were observed for *L. marinus* but not for *L. fluviatilis*. These new observations provide unprecedented information about lamprey at sea, and highlight study locations and surveys within north western European waters, which may be more pertinent for lamprey observations at sea.

KEY WORDS: Endangered species, Lamprey, *Lampetra fluviatilis*, *Petromyzon marinus*, Distribution, Ecology, Growth, Surveys

1. INTRODUCTION

Lampreys are primitive jawless vertebrates with particularly complex life histories (Kelly and King, 2001). They occur within temperate waters of both the northern and southern hemisphere (Kelly and King, 2001; Renaud, 1997). Three semelparous anadromous lamprey species have been identified in north western European waters: the sea lamprey *Petromyzon marinus;* the Artic lamprey *Lethentreron japonicum* (only observed in Sweden) (Maitland, 1980); the European river lamprey *Lampetra fluviatilis*. Very little is known on the distribution at sea of *P. marinus* and *L. fluviatilis*.

The population status of *P. marinus* and *L. fluviatilis* is of major concern. During the late twentieth century, the culmination of both increased demand for lamprey, increased river pollution, and the construction of dams led to their decline (Kelly and King, 2001; Mateus et al., 2012). Both *P. marinus* and *L. fluviatilis* are listed under the Habitat Directive (92/43/EEC), the Bern convention (Appendix III) and the Barcelona convention. *P. marinus* is also listed under the OSPAR

convention. While considered as ‘least concern’ in the international union for conservation of nature (IUCN) red list in Europe (Freyhoff and Brooks, 2011), both species are threatened in many countries (Mateus et al., 2012).

Life cycles of *P. marinus* and *L. fluviatilis* are only partially known. The marine phase remains largely a black box (ICES, 2015). Improving knowledge on the biology and ecology of lamprey at sea is critical. Adults *P marinus* and L. *fluviatilis* migrate upstream to spawn around April May (Beamish, 1980; Farmer, 1980; Maitland, 1980). The young larvae begin to swim downstream and between three and eight years later, where they metamorphosize, mature and migrate to marine waters (11-16 cm) during late autumn winter (Beamish, 1980; Beamish and Potter, 1978; Youson and Potter, 1979). During their marine phase they become parasitic adults for 18 to 28 months (Beamish, 1980; Farmer, 1980). Lamprey parasitize a range of hosts from bony fish, elasmobranchs to mammals (Halliday, 1991; Kelly and King, 2001; Lança et al., 2013; Maitland, 1980). Adults of *L. fluviatilis* range between 20 and 50 cm (Kelly and King, 2001), whereas the larger *P. marinus* ranges between 60 and 90 cm (Beaulaton et al., 2008).

Given their recent declines in population status, a better understanding of their ecology at sea is essential. To improve our knowledge on lamprey distribution at sea, we collated an unprecedented database of 150 758 hauls from fisheries independent and French fisheries dependent data taking place throughout Northern European waters. From this database, we analysed the distribution of *P. marinus* and *L. fluviatilis* between 1965 and 2018, seasonal and depth length relationships, and survey and gear type capture rate.

2. METHOD

Fisheries independent data are available from International Council for the Exploration of the Sea (ICES) the Database of Trawl Surveys (DATRAS) portal (https://www.ices.dk/data/data-portals/Pages/DATRAS.aspx), French scientific surveys (excluding data available through DATRAS) and French fisheries dependent observer data (ObsMer; more details in Fauconnet et al., (2015)) were analysed (Fig. 1; Table S1). To gather French scientific surveys, surveys undertaken by Institut Français pour l’Exploitation de la Mer (IFREMER) that may have information on diadromous fish (https://campagnes.flotteoceanographique.fr/campaign; Table S1)

were requested, taking information provided within Regimbart et al, (2018). Only hauls downstream of transitional waters were taken into account.

Lampreys were only present in a very small minority of hauls (0.003 % presence). Biological information containing the fish captured, their number and lengths were recorded. Due to the limited number of presence observations and difficulties in taking into account spatio-temporal heterogeneity, only simple robust statistical analysis was performed to avoid over-interpretation of the data. All mapping and length frequency analysis was undertaken within R CRAN free software (version 3.3, http://cran.r-project.org). Within this study, we also compared our data to Halliday's (1991) data (1979-1990) on *P. marinus* length in relation to depth and month, off the coast of northeast America.

3. RESULTS

From the 150,758 hauls out with transitional waters which were analysed, a lamprey presence of 0.16 % was observed. A total of 446 lampreys were identified between 1965 and 2018 (Table 1; Table S1) from 68,287 hauls from scientific trawl surveys and 82,471 hauls from French fishing vessels (Fig. 1). From both the fisheries dependent and independent data, *Petromyzon marinus* was recorded more frequently (11 and 227 respectively) than *Lampetra fluviatilis* (6 and 202 respectively) (Table 1). Both species had an overlapping distribution in space and depth (Fig. 2, Table 1-2). Excluding ICES divisions which had relatively few hauls (3.b and 7.b), highest lamprey presence was within 3.a, 4.b, 4.c (the Skagerrak Sea and the North Sea along the Dutch and western German coasts; Table 2; Fig. 2). 2252 hauls took place within the Mediterranean Sea, albeit no lampreys were observed (Fig. 1 and 2, Table S1).

From the fisheries independent data, relatively more lampreys were identified within North Sea International Bottom Trawl Surveys (NS-IBTS; Table 1; Fig. 2). From the ObsMer dataset a higher capture rate of both species was recorded from set longline gear type (Table 1).

P. marinus length range was between 13 and 80 cm (mean 26.56 cm, Standard error (SE) ± 2.35 cm), whereas *L. fluviatilis* length range was between 14 and 42 cm (mean 29.89 cm, SE ± 0.89 cm) (Fig. 3). An increase in *P. marinus* and *L. fluviatilis* length with depth was detected ($P < 0.001$, DF = 3, LL = -1023.16, deviance explained 26%; $P < 0.01$, DF = 3, LL = -603.22, deviance explained = 8.99%

respectively; Fig. 4.a). From the survey data collected in this study, no lamprey was identified deeper than 170 m (Fig. 4.a-c).

Indications of two length modes were detected for *P. marinus* over the course of the year (Fig. 5.i.a and b.). Growth of smaller individuals can be observed from winter to autumn for *P. marinus* ($P < 0.001$, DF = 3, LL = -1080.03, deviance explained 8.88 %; Fig. 5.i.a-b.). Results suggested a bimodal distribution of length (Fig. 3.b.) for *L. fluviatilis*. No evidence of growth over the course of the year (Fig 5.ii.a and b). For both lampreys, there was a higher proportion of presence in spring and autumn (Fig. 5.c.).

4. DISCUSSION

Presence of lamprey was reported in only 0.16 % of hauls, which confirms the rarity of lampreys at sea. More *Petromyzon marinus* were observed than *Lampetra fluviatilis*. This result is inconsistent with Maitland, (1980) and Thiel et al., (2009), who reported more abundant *L. fluviatilis*. However, their analysis was based on a greater proportion of coastal surveys than in our database. Both species were found to have overlapping distributions. Nonetheless due to similar morphological characteristics miss-identification may have taken place (Renaud, 1997). A higher proportion of both species was found within ICES divisions 3.a and 4.b-c, within the Skagerrak Sea and the North Sea along the Dutch and German coast. No lampreys were recorded in the Mediterranean Sea, where they are known to inhabit (Bianco, 2014).

A greater proportion of lampreys were observed from the fisheries independent data than the dependent data. It is thought that lampreys may detach themselves from their hosts at the time of capture (Halliday, 1991). Longer hauls from fisheries dependent data, may therefore report less observations as a result of a higher detachment rate. In addition, fisheries dependent observations were scarce within the North Sea and absent within the Baltic Sea where presence was greater. Thiel et al., (2009) analysed lamprey catch from commercial and published records and also recorded high numbers of *P. marinus* and *L. fluviatilis* within the Baltic Sea.

More lampreys were recorded from NS-IBTSs, likely due to the higher presence of lampreys within this ICES division 3.a and 4.b-c. Lamprey observations from the fisheries dependent data were mainly from set long lines. Insufficient survey information was available to calculate Catch Per Unit Effort (CPUE) for each gear

type. It should be noted that none of the surveys were designed to target lamprey species.

Length ranges within our dataset were in line with previous literature (Beamish, 1980; Kelly and King, 2001; Maitland, 1980). However, smaller *P. marinus* were measured that expected (Beaulaton et al., 2008). The latter may be because of a large number of small individuals in shallow waters. The increase in length with depth corroborates with Beamish (1980) and Halliday (1991).

Recently metamorphosized lampreys are supposed to migrate to their marine habitat late autumn winter. Mature adults return to freshwater habitats to reproduce around April May (Beamish, 1980; Farmer, 1980; Stratoudakis et al., 2016). We observed two presence peaks in line with this literature. Nonetheless, smaller individuals had a higher presence in spring than autumn. The latter maybe due to the few large lamprey caught. It is thought that larger lamprey parasitize larger fish (e.g. cetaceans and larger elasmobranchs) (Halliday, 1991), which are rarely caught in fisheries dependent and independent surveys. Furthermore, cetaceans and elasmobranchs often migrate long distances and into deeper waters, which our data does not cover. Alternatively, the lower number of large individuals may be because of high natural death rate of lampreys at sea. Mortality from fishing activity is thought to be low (Stratoudakis et al., 2016).

P. marinus appeared to have a bimodal length tendency, with an increase in size of juvenile lampreys over the course of the year, and another mode of larger individuals. Various hypotheses exist for the length of time that lamprey are supposed to inhabit marine waters (1-2.5 years) (Halliday, 1991; Silva et al., 2013). Our results suggest the existence of two length modes which corroborates with Silva et al. (2013) hypothesis, that sea lamprey occupy marine waters for approximately one year.

4.1. CONCLUSION

Our analysis synthetises an unprecedented database of fisheries dependent and independent data and provides insight into the mystery of lamprey at sea. This study highlights regions of higher lamprey presence at sea within north western European waters, indicates survey and gear type capture rate, and provides seasonal, depth and length relationships. Conservation measures have been set up across the globe to try and restore populations (e.g. rebuilding programs, improved river connectivity,

removal of barriers and weirs etc.) (Renaud, 1997; Thiel et al., 2009). Greater awareness is needed in both fisheries dependent and independent surveys to be able to collect data on lampreys during their marine phase, to improve our understanding, and implement better protection measures.

Acknowledgements

We are extremely grateful to all those who were involved in collecting and compiling the fisheries dependent and independent surveys. We are also grateful to the French Research Institute for Exploitation of the Sea (IFREMER) and the French marine fisheries and aquaculture administration (DPMA) to have given us access to their data.

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Table 1. Lamprey at sea records between 1966 and 2018 using fisheries dependent and independent data. SE = Standard Error, LLS = Set longlines, OTB = Otter beam Trawl, GTR = Trammel nets, PTM = mid- water pair trawl, GNS = set gillnets. Survey full names, dates and haul numbers within Table S1.

Species	Data type	Total number of hauls	Total number	Percent presence (%)	Year	Mean length ± SE (cm)	Length range (cm)	Seabed depth range (m)	Gear type / survey	Total number	Percent presence relative to catch (%)	Target species
Petromyzon marinus	ObsMer	82,471	11	0.012	2009-2017	26.78 ± 8.17	21-34	5-170	LLS GTR OTB PTM GNS	5 2 2 1 1	0.160 0.012 0.007 0.028 0.013	Bass 0.10 Prawns 0.59 Sea bream 0.09 Meagre 0.14 European Hake 0.15 Sole 0.01
	ICES Datras	54,865	199	0.153	1980-2017	26.55 ± 0.8	13-80	5-162	NS-IBTS DYFS SWC-IBTS FR-CGFS EVHOE	175 11 10 2 1	0.231 0.229 0.130 0.037 0.039	NA
	French scientific surveys	13,422	28	0.201	1977-2018	NA	NA	5-157	PECO/PECOS Sold PELGAS	9 5 14	1.136 1.412 0.701	NA
Lampetra fluviatilis	ObsMer		6	0.002	2012 & 2015	24.5 ± 2.35	14-29	13-50	LLS PTM	5 1	0.040 0.028	Meagre 0.14 Whiting 0.04
	ICES Datras		198	0.208	1973-2018	30.05 ± 0.34	19-42	0-104	NS-IBTS DYFS BTS	135 56 7	0.195 1.246 0.050	NA
	French scientific surveys		4	0.030	1981-2018	NA	NA	1.8-45	Bargip/Nourdem Nurse Sold	2 1 1	1.026 0.041 0.282	NA

Table 2. Summary table of lampreys observed from 1966 to 2018 within International Council for the Exploration of the Sea (ICES) divisions from fisheries dependent and independent data.

		Petromyzon marinus		***Lampetra fluviatilis***	
Area	**Hauls**	**Total number**	**Presence (%)**	**Total number**	**Presence (%)**
2.a	302	0	0.000	0	0.000
3.a	3513	53	**1.621**	36	**0.832**
3.b	18	5	11.111	0	0.000
3.c	60	0	0	0	0
4.a	11900	9	0.034	0	0.000
4.b	20544	76	**0.131**	93	**0.248**
4.c	9219	40	**0.206**	69	**0.532**
5.b	550	0	0.000	0	0.000
6.a	6746	0	0.000	0	0.000
6.b	84	0	0.000	0	0.000
7.a	2033	4	0.098	0	0.000
7.b	232	6	0.431	0	0.000
7.c	416	0	0.000	0	0.000
7.d	22251	7	0.022	2	0.009
7.e	11144	1	0.009	0	0.000
7.f	1344	0	0.000	0	0.000
7.g	5721	1	0.017	0	0.000
7.h	8577	0	0.000	0	0.000
7.j	2296	0	0.000	0	0.000
7.k	572	0	0.000	0	0.000
8.a	25232	26	0.099	7	0.012
8.b	13853	10	0.065	1	0.007
8.c	410	0	0.000	0	0.000
8.d	868	0	0.000	0	0.000
8.e	47	0	0.000	0	0.000
9.a	574	0	0.000	0	0.000
Mediterranean	2252	0	0.000	0	0.000

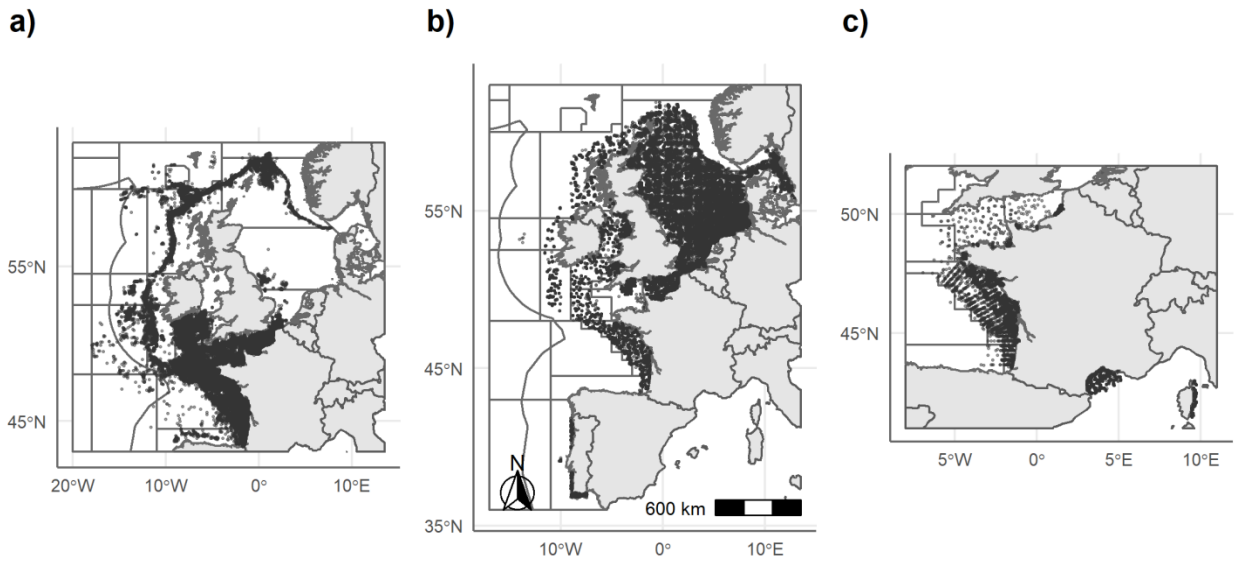

Fig. 1. Haul locations for a) fisheries dependent ObsMer surveys b) fisheries independent ICES Datras and c) French national scientific surveys analysed for the presence of lamprey. Black solid lines delineate ICES statistical divisions.

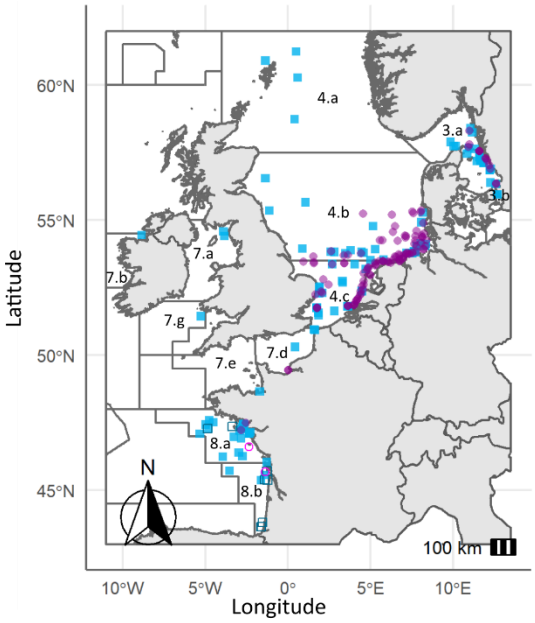

Fig. 2. Presence locations of *Petromyzon marinus* (blue squares) and *Lampetra fluviatilis* (purple circles) caught by fisheries dependent (hollow symbols) and independent (filled in symbols) data. Black solid lines delineate ICES statistical divisions and their coded names.

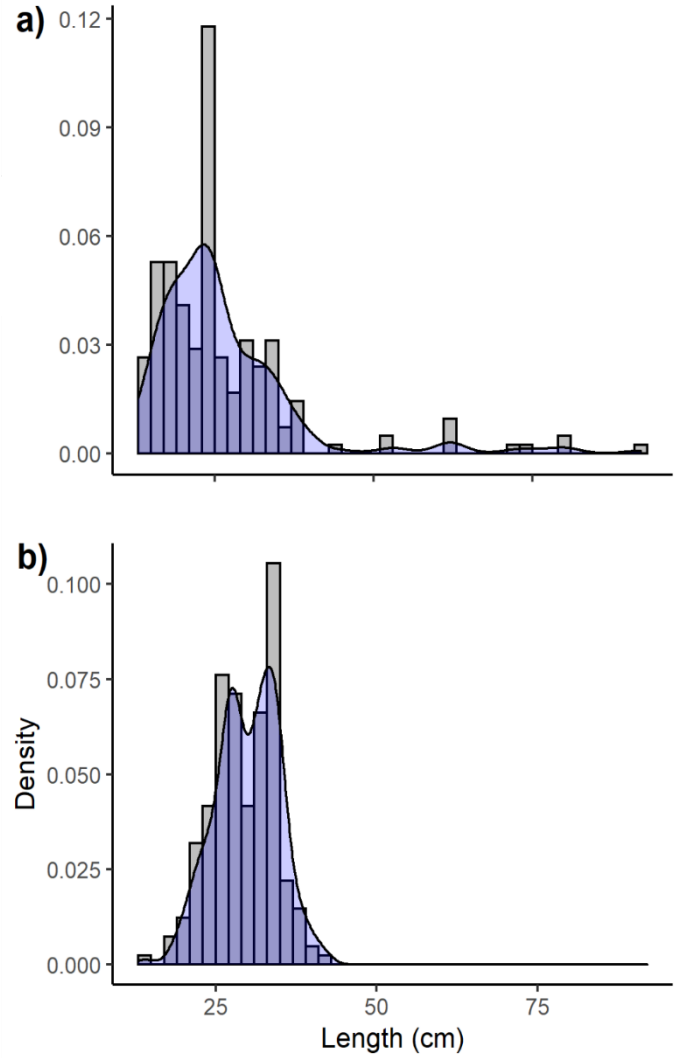

Fig. 3. Kernel smoothed density length histograms for a) *Petromyzon marinus* and b) *Lampetra fluvialitis*, combining both fisheries dependent and independent datasets.

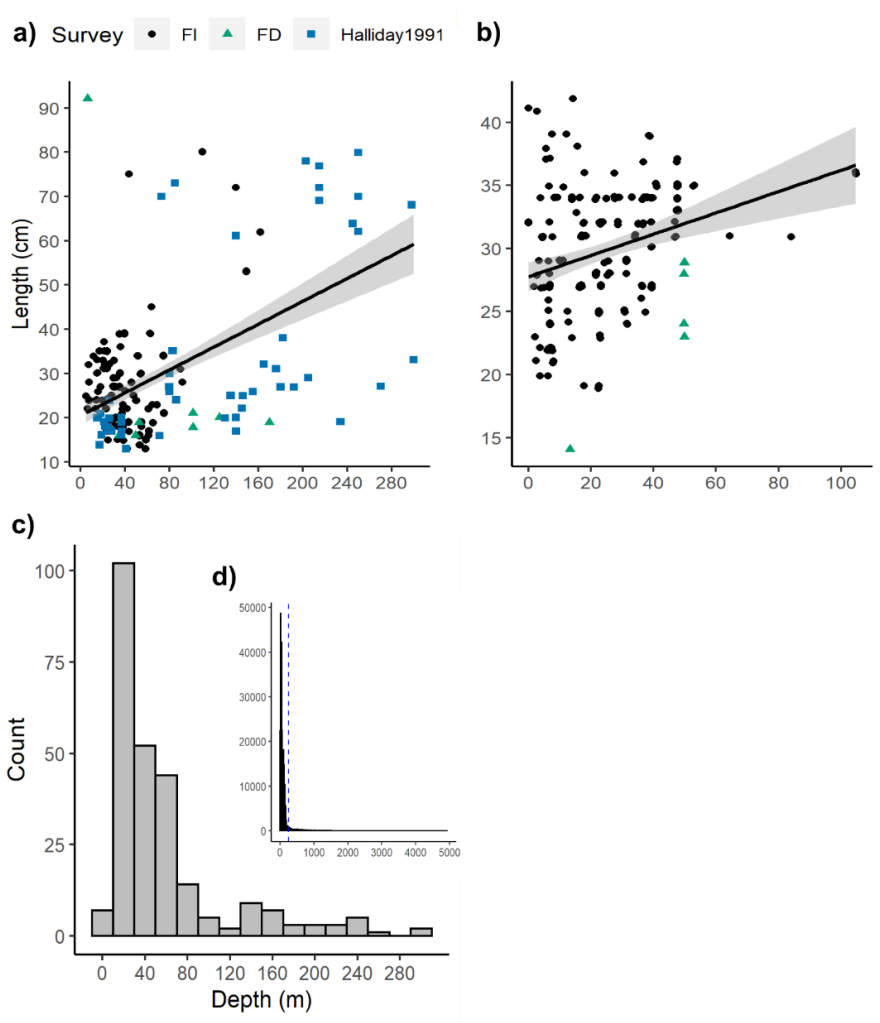

Fig.4. Lengths of a) *Petromyzon marinus* and b) *Lampetra fluvialitis* with depth, from fisheries independent (FI) and fisheries dependent (FD) data within north eastern Atlantic waters and data from Halliday (1991; north western Atlantic waters), with the model fitted lines and the shaded area indicating ±95% confidence intervals. Note, three points were removed from Halliday (1991) data that were > 1000 m. Depth histograms for c) hauls lamprey were observed within and d) all hauls. Dashed vertical line indicates the maximum depth lamprey observed (c).

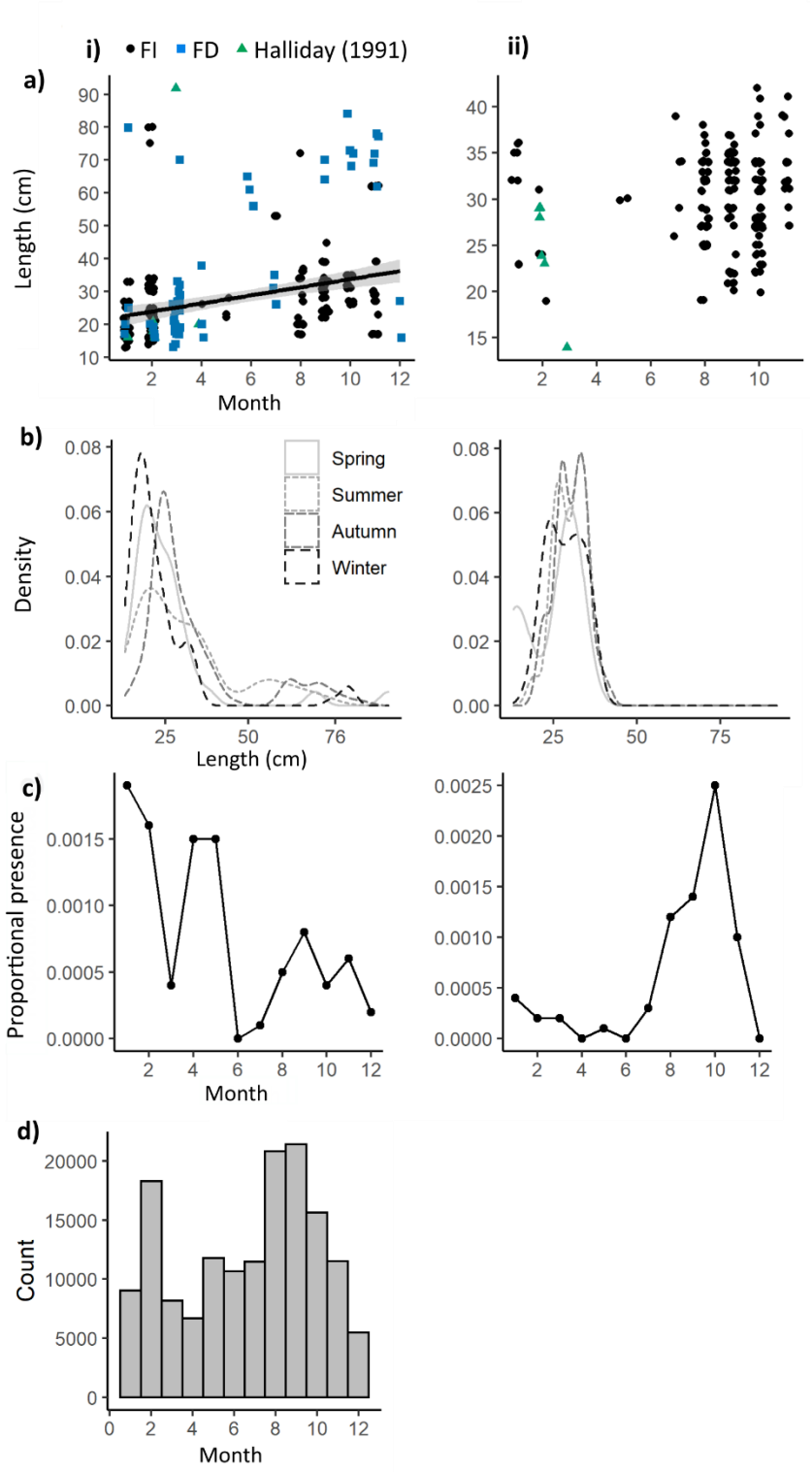

Fig. 5. Lengths of i) *Petromyzon marinus* and ii) *Lampetra fluvialitis* from marine waters by a) month using records from fisheries independent data (FI), Fisheries dependent data (FD) and data from Halliday (1991). b) Lamprey Kernel density plots by season. c) Proportion of lamprey presence per month. d) Histogram of the number of total hauls per month.

Appendix A1. Supplementary data

Table S1. Surveys extracted to be able to assess Lamprey presence. Note to all surveys took place every year.

	Survey category	Full name (where available)	Acronym	Geographical region	Years	Number of hauls	Source
1	ICES Datras	Bottom Trawl Survey	BTS	Greater North Sea and Celtic Sea	1987 - 2018	12,054	10.7489/1967-1
2		Bottom Trawl Survey	BTS-VIII	Bay of Biscay	2011-2017	455	http://datras.ices.dk
3		Demersal Young Fish Survey	DYFS	Greater North Sea	2002-2017	3932	http://datras.ices.dk
4		Evaluation Halieutique Ouest de l'Europe	EVHOE	Celtic sea and Bay of Biscay	1997-2017	2575	10.7489/1958-1 Not
5		French Channel Ground Fish Survey	FR-CGFS	Eastern English Channel	1988-2018	2678	DOI: 10.18142/11
6		North Sea International Bottom Trawl Survey	NS-IBTS	Greater North Sea	1965-2018	30,290	DOI: 10.7489/1922-1
7		Portuguese International Bottom Trawl Survey	PT-IBTS	Bay of Biscay and the Iberian coast	2002-2017	574	10.7489/1963-1
8		Scottish West Coast Bottom Trawl Survey	SWC-IBTS	Celtic sea	1985-2010	2307	10.7489/1957-1 10.7489/1924-1
9	French scientific surveys	Nourriceries démersaux	Arca	Bay of Biscay	1995-1996	38	Ifremer
10			Nourdem Bargip/	Channel and Bay of Biscay (Loire and Seine)	2015-2018	195	Le Goff et al, 2017

11	Etude de l'impact des marées noires de l'Erika	Black	Bay of Biscay	2000	130	Ifremer
12	Nurse (nourriceries) sur la Baie du mont Saint-Michel	BMSM2003	Bay of Biscay	2003	12	Ifremer
13	Nurse (nourriceries) sur la baie de Bourgneuf	Bour	Bay of Biscay	1980-1984	136	Ifremer
14	CAmpagne MANche OCcidentale pluridisciplinaire	CAMANOC	English Channel	2014	86	DOI: 10.17600/14001900
15	Campagne de comparaison de racasseurs lourds et legers sur la sélectivité des soles	Captusol01	Bay of Biscay	1984	76	Ifremer
16		CLA08_	Bay of Biscay	2008	25	DOI: 10.17600/8040050
17	Analyse des peuplements de crépidules en baie de bourgneuf	CREBOUR	Bay of Biscay	2006	41	Ifremer
18	EPIfaune BENthique du GOlfe du Lion	EPIBENGOL	Mediterranean	2018	10	DOI: 10.17600/18000589
19		Giro	Western English Channel	1997	1	Ifremer
20	Campagne sur les gradients de production côte-large incluant la baie de Vilaine et la rade de Brest	Isobaie09	Bay of Biscay	2009	23	Ifremer

21	Nurse (nourriceries) en estuaire externe de la Loire	Loir	Bay of Biscay	1980-1986	136	Ifremer
22		Marika	Bay of Biscay	2005	31	Ifremer
23	Mediterranean trawl survey - Corse	MEDITS-CORSE	Mediterranean	1994-2017	504	http://www.ifremer.fr/SIH-indices-campagnes/
24	Mediterranean trawl survey – Golfe du Lion	MEDITS-LION	Mediterranean	1994-2018	1628	http://www.ifremer.fr/SIH-indices-campagnes/
25	Nurse (nourriceries) en 2003	MISOLRE	Bay of Biscay	2003	133	Ifremer
26	Nurse (nourriceries) dans le golfe du Morbihan	Morb	Bay of Biscay	1995-1996	78	Ifremer
27	Nurse (nourriceries) dans le pertuis breton	Nonamebreton	Bay of Biscay	1987	40	Ifremer
28	Nurse (nourriceries) dans la Vilaine	Nonamvillaine	Bay of Biscay	1996	36	Ifremer
29	Nourriceries en Méditerranée	NOURMED	Mediterranean	2018	91	DOI: 10.17600/18000588
30	Nourriceries Baie de Somme	NOURSOM	Channel	1987-2018	1609	https://sextant.ifremer.fr/record/98ac17c5-8d70-455e-9496-aafb0dd4ae17/
31	Nourriceries golfe de Gascogne	Nurse	Bay of Biscay	1981-2016	2428	Ifremer
32	Nurse (nourriceries) dans la Vilaine	Nurvil	Bay of Biscay	2004-2005	128	Ifremer
33		Peco/PECOS	Bay of Biscay and Western English	1976-2006	792	Ifremer

				Channel			
34		Pélagiques Gascogne	PELGAS	Bay of Biscay	2000-2018	1854	DOI: 10.17882/59809
35		Nurse (nourriceries) dans les pertuis (breton et antioche)	Pertuis	Bay of Biscay	1986-1987	168	Ifremer
36		Campagnes pour la compréhension des communautés sur les habitats à Haploops	Ploops	Bay of Biscay	2009-2010	48	Ifremer
37			RESSGASC	Bay of Biscay	1984-2002	2344	Ifremer
38		Nurse (nourriceries) en baie de Vilaine mais en hiver (winter)	RetroB	Bay of Biscay	2008	48	Ifremer
39		Suivi des Effets bioLogIques de la contamination chimique en Méditerranée	SELIMED-1	Mediterranean	2016	19	DOI: 10.17600/16011900
40		Répartition de la distribution des soles sur la radiale cote-large de la baie de Vilaine	Sold	Bay of Biscay	1988-1989	354	Ifremer
41			Typo	Bay of Biscay	1996-1997	180	Ifremer
42	Fisheries dependent data	French fisheries observer data	Obsmer	Greater North Sea, Celtic Sea, Bay of Biscay	2003-2017	82,471	Ifremer / DPMA

Avec le soutien financier de :

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