Assessing and enhancing ecosystem services provided by diadromous species in a climate change context

Deliverable title:
Case study description and ecosystem services data collection

Deliverable reference: WP 6 – Action 3

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This project is co-financed by the Interreg Atlantic Area Programme through the European Regional Development Fund.

I. Executive summaries in the four languages of the Programme

This report explores the availability of data to quantify the importance of Ecosystem Services (ES) provided by diadromous species in the Atlantic Area using a set of indicators and methods. This report considers a set of nine well-defined case studies engaging the stakeholders to share their empirical ES-related knowledge (EK) around those cases. Those case studies are: (1) the Ulla catchment, (2) Gipuzkoa rivers, (3) Minho catchment, (4) Mondego catchment, (5) Gironde/Garonne/Dordogne system; (6) Loire catchment, (7) Normand-Breton Bay/Gulf, (8) Tamar, Frome, and Taff rivers, and (9) Waterford Harbour with the three sisters rivers. A broad overview on ES is provided per case study by considering the key diadromous species relevant for each case study. The stakeholders´ selection was not based on their use of the ES but more on their knowledge of the biological status of the diadromous species (e.g. biologists, technicians) and/or regional administrations. However, the economic assessment of those ES identified by those stakeholders will be based on both market data and non-market data reflecting the total economic value of the ES provided by the species to the general population/civil society.

Este informe explora la disponibilidad de datos para cuantificar la importancia de los Servicios Ecosistémicos (ES, en terminología inglesa) proporcionados por los peces diádromos en el Área Atlántica utilizando un conjunto de indicadores y métodos. Este informe considera un conjunto de nueve estudios de caso bien definidos, en los que se invita a las partes interesadas a compartir sus conocimientos empíricos relacionados con los servicios ecosistémicos en torno a esos casos. Estos estudios de caso son: (1) la cuenca del Ulla, (2) los ríos de Guipúzcoa, (3) la cuenca del Miño, (4) la cuenca del Mondego, (5) el sistema Gironde/Garonne/Dordogne; (6) la cuenca del Loira, (7) la bahía de Normandía-Breton, (8) los ríos Tamar, Frome y Taff, y (9) el puerto de Waterford. Se ofrece un resumen por cada estudio de caso, que se centra en los servicios ecosistémicos considerando los peces diádromos clave pertinentes para cada estudio de caso. La selección de las partes interesadas (agentes) no se basó en el uso que hacen de estos ES, sino más bien en su conocimiento del estado biológico de los peces diádromos (e.g. biólogos, técnicos) y/o de las administraciones regionales. Sin embargo, la evaluación económica de los ES identificados por esos interesados se basará en datos de mercado y no de mercado que reflejen el valor económico total de los ES proporcionados por la especie considerada al conjunto de la población.

Este relatório explora a disponibilidade de dados para quantificar a importância dos Serviços Ecossistémicos (ES) fornecidos pelos peixes diadromos no Espaço Atlântico, utilizando um conjunto de indicadores e métodos. Este relatório considera um conjunto de nove estudos de casos bem definidos, envolvendo as partes interessadas a partilhar os seus conhecimentos empíricos relacionados com o ES (EK) em torno desses casos. Esses estudos de caso são: (1) bacia hidrográfica do Ulla, (2) rios Guipuzkoa, (3) bacia hidrográfica do Minho, (4) bacia hidrográfica do Mondego, (5) sistema Gironde/Garonne/Dordogne; (6) bacia hidrográfica do Loire, (7) Baía Normand-Breton, (8) rios Tamar, Frome, e Taff, e (9) Porto de Waterford. É fornecida uma visão geral por estudo de caso, que se concentra amplamente no ES, considerando os peixes diadromos chave relevantes para cada estudo de caso. A selecção das partes interessadas não se baseou na sua utilização do ES mas mais no seu conhecimento do estado biológico dos peixes diadrómicos (e.g. biólogos, técnicos) e/ou administrações regionais. Contudo, a avaliação económica dos ES identificados por essas partes interessadas será baseada tanto em dados de mercado como em dados não de mercado que reflictam o valor económico total do ES fornecido pela espécie à população em geral.

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Ce rapport explore la disponibilité des données pour quantifier l'importance des services écosystémiques (ES) fournis par les poissons migrateurs amphihalins dans l'Espace Atlantique en utilisant un ensemble d'indicateurs et de méthodes. Ce rapport considère un ensemble de neuf cas d'étude bien définis, engageant les parties prenantes à partager leurs connaissances empiriques liées aux ES autour de ces cas d'étude. Ces cas d'étude sont : (1) le bassin versant de l'Ulla, (2) les rivières du Pays Basque espagnol, (3) le bassin versant du Minho, (4) le bassin versant du Mondego, (5) le système Gironde/Garonne/Dordogne, (6) le bassin versant de la Loire, (7) le Golfe Normand-Breton, (8) les rivières Tamar, Frome et Taff, et (9) le port de Waterford. Une vue d'ensemble est fournie par cas d'étude, qui se concentre largement sur les ES en considérant les poissons migrateurs amphihalins pertinents pour chaque cas d'étude. La sélection des parties prenantes ne fut pas basée sur leur utilisation des ES mais plutôt sur leur connaissance du statut biologique des poissons migrateurs amphihalins (e.g. biologistes, techniciens) et/ou des administrations régionales. Cependant, l'évaluation économique de ces ES identifiés par ces parties prenantes sera basée sur des données marchandes et non marchandes reflétant la valeur économique totale des SE fournis par l'espèce à la population générale/société civile.

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II. CONTRIBUTION TO ACTION WP6.3

This text was taken from the last validated version of the Project Approved Form (PAF).

Case study descriptions, which synthesise major socio-economic activities linked to diadromous species, will be produced in the first 3 months, and passed to WP4.1 for ecosystem services listing and selection. Then, joint methodologies for ecosystem services valuation defined in WP4.2 will be applied, in the 8 case studies, by MARETEC/IST, AZTI, UoP-MI and Cefas with the help of the other project partners and relevant stakeholders. Data will be finally delivered to WP4 for a global analysis (WP4.3).

Outputs title
Case study descriptions and a joint database

Outputs results
A report compiling the "state-of-the-art" in case studies on socio-economic activities linked to diadromous species will be written. Data gathered following standardized methodologies defined among economic partners will be gathered in a database.

Indicators
• Number of technical and scientific publications produced: 1
• Number of case studies and pilot actions implemented: 8

Expected results title
Improved assessment of ecosystem services data in the AA

Expected results description
Case study data and new methodologies will contribute to a better assessment of ecosystem services provided by diadromous species in the AA, supporting their sustainable provision in the long term. Material will be directly useful to partners and NGOs.

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III. CASE STUDY DESCRIPTIONS

To explore the quantitative importance of Ecosystem Services (ES) provided by diadromous species in the Atlantic Area, this report considers a set of nine well-defined case studies engaging the stakeholders to share their empirical ES-related knowledge (EK) around those cases. Those case studies are: (1) the Ulla catchment, (2) Gipuzkoa rivers, (3) Minho catchment, (4) Mondego catchment, (5) Gironde/Garonne/Dordogne system; (6) Loire catchment, (7) Normand-Breton Bay/Gulf, (8) Tamar, Frome, and Taff rivers, and (9) Waterford Harbour with the three sisters rivers. The stakeholders´ selection was not based on their use of the ES but more on their knowledge of the biological status of the diadromous species (e.g. biologists, technicians) and/or regional administrations. The economic assessment of those ES identified by those stakeholders will be based on market data and non-market data reflecting the total economic value of the ES provided by the species to the civil society.

An overview for each case study and its respective key diadromous species is provided with focus on the following aspects (Table 1):

- ✓ Introduction to the case study indicating its location and main characteristics;
- ✓ Historic and current presence of relevant diadromous species and the ecosystem they support and the indicator data used in the case study. A detailed description of ES supported by each case study is presented as part of the project Deliverable WP4.1 (www.diades.eu);
- ✓ Historic importance and potential future changes of ES provided by diadromous species (e.g. potential ES trajectory under population change related to climate change);
- ✓ Other additional information such as human activities supported by those ES and potential trade-offs with other activities in the area.

Table 1. *Full list of DiadES species*

Nb	Scientific notation	English notation
1a	*Alosa alosa*	Allis shad
1b	*Alosa fallax*	Twaite shad
2a	*Petromyzon marinus*	Sea lamprey
2b	*Lampetra fluviatilis*	River lamprey
3	*Anguilla anguilla*	European eel
4	*Salmo salar*	Atlantic salmon
5	*Salmo trutta*	Sea trout
6	*Acipenser sturio*	European sturgeon
7	*Chelon ramada*	Thin-lipped grey mullet
8	*Osmerus eperlanus*	European smelt
9	*Platichthys flesus*	European flounder

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1. Ulla catchment (Galician area)

River Ulla is located in the North of Spain with a total length of 132 km, and a catchment area around 2803 km^2, mean slope 0.48% (Figure 1). It flows at the height of the town of Carril after having travelled about 132 km, giving rise to the estuary of Arousa. The coastal system is as such formed by two adjacent compartments with peculiar morphological and hydrodynamic characteristics: the "Ría de Arousa" (230 km^2 and 4.54 km^3) and the river Ulla (2804 km^2) (Prego et al., 2008)[1]. The "Ría de Arousa" has a length of 25 km, and an area that varies, according to various researchers, between 200 and 253 km^2 (Mora 1982; Real et al., 1993; Prego et al., 1999, 2006, 2008)[1]. Although the fluvial network of this estuary is made up of two main rivers, the Ulla and the Umia, together with a multitude of streams of lesser importance, the Ulla River is the main continental contributor that discharges an average annual flow of 79 m^3/s into the headwaters of the estuary (Prego et al. 1999, 2006)[1]. The upper part of the estuary of the Ulla River is an area of faunal interest with an approximate length of 19 km, stretching from the island of Cortegada at the level of the town of Carril, as the end of higher salinity, to the town of Padrón, the limit between the influence of tides and fresh water (Real et al. 1993; Prego et al. 2008)[1].

Figure 1 shows the population density in the catchment area of the River Ulla, including major towns with more than 240,000 inhabitants as well as other settlements with more than 10,000 inhabitants. Red colour indicates higher population density (more than 600 habitants/km^2). Urban runoffs as well as economic activities (e.g. agriculture and mining) already caused some environmental damages to this area.

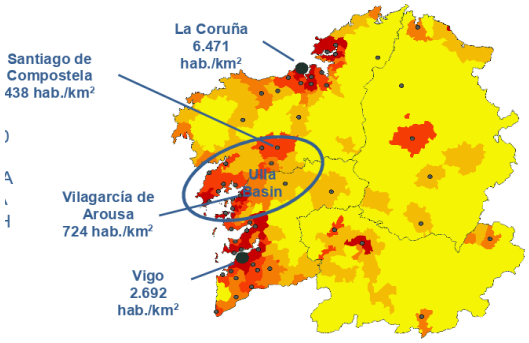

Figure 1. *Ulla river location and population density map*

Provisioning Ecosystem Services. Several of the species of interest supported in the past and also currently the provision of ES in the area: Sea lamprey, European eel, Atlantic salmon, Flounder, Sea trout, and Twaite shad. However, only three of these species are commercially exploited, therewith supporting provisioning ES and are also, relevant as cultural ES: Sea lamprey, European eel and Flounder. These three species are responsible of an average annual provisioning value of about 130 thousand euros.

[1] Mora J. (1982). Consideraciones generales sobre la marcofauna bentónica de la ría de Arousa. Oecologia Aquatica 6: 41-49.
Prego R., Belzunce M.J., Helios-Rybicka E., and Barciela M.C. (1999) Cadmium, manganese, nickel and lead contents in surface sediments of the lower Ulla river and its estuary (northwest Spain). Boletin - Instituto Espanol de Oceanografia 15: 495-500.
Prego R., Otxotorena U., and Cobelo-Garcia A. (2006) Presence of Cr, Cu, Fe and Pb in sediments underlying mussel-culture rafts (Arosa and vigo rías, NW Spain). Are they metal-contaminated areas?. Ciencia Marina 32: 339-349.
Prego R., Belzune M.J., Cobelo A., and Helios-Rynicka E. (2008) Particulate metal in the Ulla River estuary: State and sources of contamination (Arosa Ria, NW Iberian Peninsula). Ciencia Marina. 34: 381-388.
Real C., Barreiro R., and Carballeira A. (1993) Heavy metal mixing behaviour in estuarine sediments in the Riade Arousa (NW Spain). Differences between metals. Science of theTotal Environment 128: 51-67.

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Cultural Ecosystem Services. Gastronomy and gastronomy-related events or festivals are of significant importance in this case study. Also, the recreational fishery around the Atlantic salmon provides important cultural ES considering that the Ulla River is the second most important river in Galicia for recreational anglers. An Atlantic salmon recovery programme, which started at the beginning of the 1990s, supports to maintain this ES for the future. There is also a very restricted and local sport fishing of the Twaite shad as well as Sea trout.

A specific survey on recreational fisheries will be developed in the context of the project to improve the data poor situation. However, a minimum assessment based on market prices is provided for the gastronomic festivals and events around Sea lamprey, European eel, Atlantic salmon and the European flounder reaching an annual cultural average value of about 135 thousand euros. This value is an underestimation of the real value due to missing data. However, only this part of the cultural ES is already similar to the value calculated for provisioning ES.

An additional survey is being prepared under the scope of DiadES assess the economic value of the traditional fishery to residents.

Regulating Ecosystem Services. Diadromous species provide important regulating ES in form of nutrient transportation, and links aquatic systems. DiadES will provide a pilot case about the nutrient transportation regulating service provided by Allis shad (*Alosa alosa*) during their migration for the 9 case-studies considered in the DiadES project (Poulet et al. in press)[2].

[2] Poulet C., O'Malley-Barber B., Lassalle G., and Lambert P. (In press) Quantification of land-sea nutrient fluxes supplied by allis shad across the species' rang. Canadian Journal of Fisheries and Aquatic Sciences.

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2. Gipuzkoa rivers

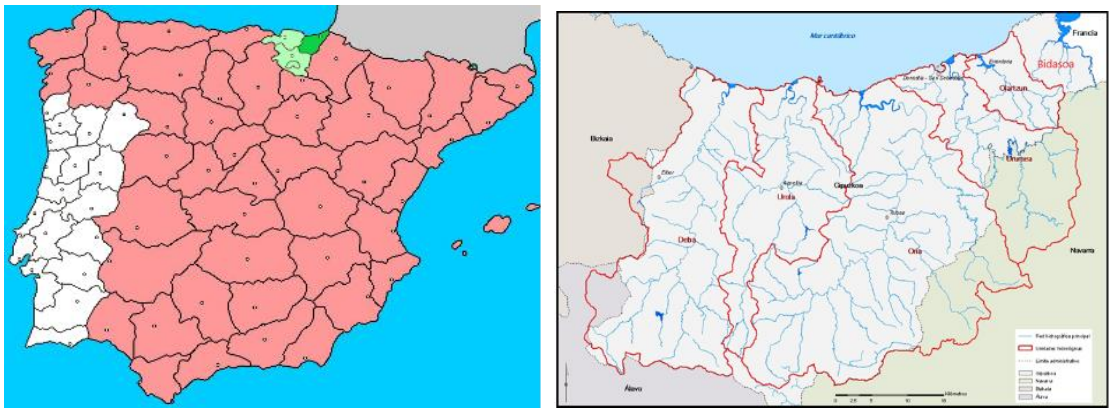

Figure 2. *Gipuzkoa rivers location*

Gipuzkoa rivers, i.e. Deba, Urola, Oria, Urumea, Oiartzun and Bidasoa, are in the North of Spain (Figure 2) covering a small territorial area with 719,282 inhabitants resulting in 354 habitants/km^2. The rivers basin characteristics are presented at Table 2.

Table 2. *River basin characteristics*

River	Basin surface (km^2)	Estuary Surface (km^2)	Length (km)	Q med (m^3/s)
Deba	533.8	0.71	62.4	15.3
Urola	337.5	0.98	63.5	9.5
Oria	882.5	2.05	82.7	25.9
Urumea	279.0	1.34	59.4	13.6
Oiartzun	85.3	0.98	16.6	3.2
Bidasoa	700.0	6.83	69.0	24.7

In this area, 65% of the active population is employed in the service sector, followed by a moderate industry activity involving 25% of the active population in the area. Remaining sectors have a reduced importance (5.0% and 0.6% active population in construction and agriculture/fishery activities, respectively).

Provisioning Ecosystem Services. Most diadromous species disappeared from the rivers of Gipuzkoa before the 80s (Figure 3.a). Thus, all-provisioning ES disappeared as the stocks no longer could support commercial fisheries. Currently, it is legally not allowed to fish most of the diadromous species in the area. Thus, no economic data is needed due to the lack of food provisioning services in the case study. No evidence is observed with regards to potential future commercial exploitation for any diadromous species and therefore, it is not expected to estimate the so-called option value.

Regulating Ecosystem Services. The recovery of the stocks allows considering a great variety of regulating ES such as the nutrient transportation and the regulation of the food web and ecosystems. Thanks to the water quality improvement and the disappearance of the industrial activity in the basins, many diadromous species have returned to the rivers of Gipuzkoa nowadays (Figure 3.a-b). DiadES will provide a pilot case about the nutrient transportation regulating service provided by Allis shad (*Alosa alosa*) during their migration for the 9 case-studies considered in the DiadES project.

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River	Shad	Lamprey	Eel	Salmon	Trout	Sturgeon	Mullet
Deba							
Urola							
Oria							
Urumea							
Oiartzun							
Bidasoa							

(a)

River	Shad	Lamprey	Eel	Salmon	Trout	Sturgeon	Mullet
Deba	?	?		?			
Urola	?	?		?			
Oria		?					
Urumea							
Oiartzun	?	?					
Bidasoa							

(b)

Figure 3a and b. *Biological state of diadromous species from the 80's (a) to nowadays (b) (colours from green to red indicate a decreasing status)*

Cultural Ecosystem Services. Finally, the most important cultural ecosystem services identified is provided by the European eel. This stock supports activities such as gastronomy, recreational fisheries, environmental education, and scientific knowledge. Market-based economic data have been collected if data were available. For example, recreation sport fishing for European eel – total expenditure (due to the licences cost, repair and conservation, oil expenditure, security costs) at market values will be used for the years 2003-2019. Additionally, indicators such as the number of vessels (53), number of land fishers, the number of annual licences and effort in hours will be included. This creates in total an average annual value of about 200 thousand euros. The relevance of this European eel related fishery is very relevant in the studied area as confirmed by the recently (in 2020) creation of the first association of eel fishers in the area (https://www.desveda.info/breve/se-constituye-la-primera-asociacion-de-anguileros-de-euskadi/). In addition, fishermen with a general licence for marine recreational fishing, may catch diadromous species (e.g. Thin-lipped grey mullet and European flounder), although these species are not among their main catches and it is not possible to obtain exact data disaggregated to species level.

In the case of the environmental education, and scientific knowledge, market-based information on public projects related to those topics has been collected, reaching an important value for a set of species (but mainly, for European eel) of an annual average of 152 thousand euros (years 2006-2020). Input-Output model (TIO) coefficients (TIO from Spanish Statistical Institute) are used to allocate the additionally induced value around 92 thousand euros.

Gastronomy around European eel is a relevant cultural ES although the origin of this ES - the commercial fisheries in the Gipuzkoa rivers - is nowadays completely banned. To estimate the demand for local commercial eel fishery, the market prices from local restaurants are taken which provides us with a number of total imports of European eel into the area from other countries (mainly France). Assuming that these imports are meeting the local demand for eel, we can use this number as indicator for the option value for the commercial local eel fishery.

In addition, other non-market based cultural ES services have been identified, such as natural heritage (the existence values around the diadromous species) and spiritual ES (the satisfaction of knowing the

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diadromous species are recolonizing the rivers due to the increase of the habitat quality). Those non-market based ES will not be estimated due to a lack of data.

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3. Minho catchment

The Minho River is an international basin located in the northwest of the Iberian Peninsula (300 km long, basin area of 17 080 km^2, being 95% located in Spain and 5% in Portugal) - The last 77 km is an international stretch (boundary between Portugal and Spain) free of obstacles. The estuary is 40 km long and has a total area of 23 km^2 with a maximum width of 2 km near the mouth. The tidal influence extends upward about 40 km while salt intrusion is limited to the first 16 km (for a comprehensive characterization of the main species and ecological processes, as well as broad understanding of the socio-economic and cultural dimensions see, e.g., Antunes et al. 2016[3]). The latter dimension, namely the economic value of ES provided by the diadromous species that uses the river for completion of certain life cycle stages is a main dimension targeted by DiadES.

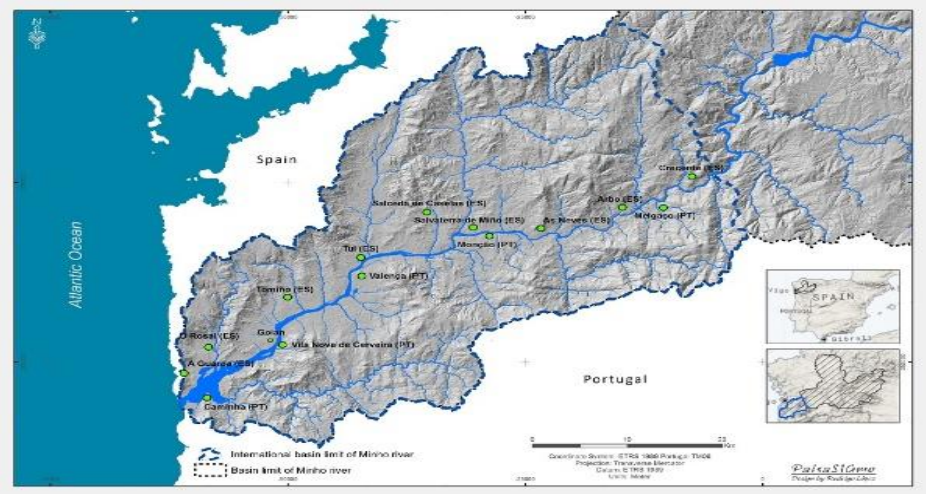

Figure 4. *Location and international River Minho Basin (provided by C Antunes)*

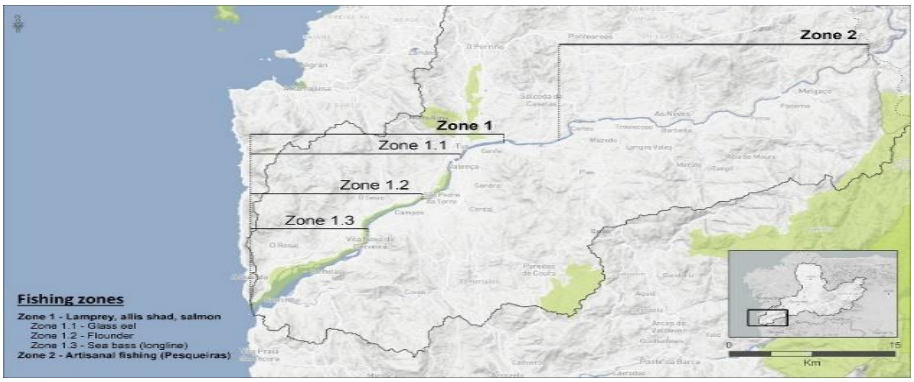

Figure 5. *ZPP in the Minho River (provided by C Antunes)*

Provisioning Services. Sea lamprey (*Petromyzon marinus*), allis shad (*Alosa alosa*) and European eel (*Anguilla anguilla*) are the species most targeted for commercial fisheries in the Minho River (Correia et al. 2018)[4].

[3] Antunes C., Cobo F., and Araujo M.J. (2016) Iberian inland fisheries in J. Craig (Ed.), Freshwater Fisheries ecology (first ed.,), John Wiley & Sons, Ltd, Chichester, West Sussex PO198SQ, UK pp. 268-282.

[4] The glass eel fishery in Portugal was banned in 2000, except for the Minho River. Source: Correia M.J., Costa J.L., Antunes C., De Leo G., and Domingos I. (2018) The decline in recruitment of the European eel: new insights from a 40-year-long time-series in the Minho estuary (Portugal). ICES Journal of Marine Science, 75(6): 1975–1983, https://doi.org/10.1093/icesjms/fsy073.

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Commercial fishing of these species is restricted to certain areas (Zone 1, Figure 5) where specific (and additionally to the national fisheries legislation) fishing regulations apply including a) Number of fishing permits; b) fishing quotas for glass eel; c) Fishing season, per species; d) Authorized fishing methods and fishing gear) (ICES 2015)[5]. The commercial and artisanal fishing zones are represented in Figure 5.

Time series for declared captures and first selling prices for the 3 species are available from local and national authorities (Capitania do Porto de Caminha and Docapesca). Based on literature, it was possible to collect values to illustrate the commercial importance of these species. Sea lamprey is considered a delicacy and can reach considerable prices in Portugal. In the Minho River, the prices range between 10 - 30 euros in retailers and from 50 - 60 euros in restaurants. European eel is also highly valued in market. For instance, in the last three years, the maximum value of 550 euros was reached in December 2017, with average values recorded for the official fishing season of 377 Euros/kg in 2018, 308 Euros/kg in 2019 and 285 Euros/kg in 2020. Allis shad still has important commercial value in the Minho River, although catches decreased after the1950s by about 90 % from the 200 tons reported in the first half of the twentieth century.

Regulating services. Sea lamprey (*Petromyzon marinus*) and European flounder (*Platichthys flesus*) have been reported as main players in nutrients and sediments distribution along the Minho River because of their dietary behaviour. Fresh and decaying detritus from the adjacent riparian vegetation were identified as the main food sources assimilated by sea lamprey ammocoetes in the Minho River according to Dias et al. (2019)[6]. Similar evidence was obtained for the European flounder by Dias et al. (2016, 2020)[7].

Cultural Services

Recreational fishing. The allis shad (A*losa alos*a), twaite shad (*Alosa fallax*), Atlantic salmon (*Salmo salar*) and sea trout (Salmo trutta) are the species targeted for recreational fishing in the Minho River. General recreational fishing licenses are issued by Capitania do Porto de Caminha. For the case of Minho's tributaries (which excludes the species described above), licenses are issued by the ICNF (Instituto da Conservação da Natureza e Florestas). Information on travel costs (only applies to non-residents) and related recreational fishing expenses are not readily available. A survey is being prepared under the scope of DiadES to ascertain on the economic value of recreational fishing.

Gastronomy. The allis shad (*Alosa alosa*), twaite shad (*Alosa fallax*), sea lamprey (*Petromyzon marinus*), European eel (*Anguilla anguilla*) and European flounder (*Platichthys flesus*) are the species associated with high gastronomic interest and several gastronomic festivals occur every year. Information on number of visitants and expenditures are not readily available as the organizers are diverse but, for the case of sea lamprey, data collection would be possible as municipalities are the organizers of such events. It should be stressed that lamprey and Allis shad that are served locally, maybe imported.

Local identity. Pesqueiras (traditional local stone structures for sea lamprey - *Petromyzon marinus*, allis shad - *Alosa alosa*, twaite shad - *Alosa fallax* and Atlantic salmon - *Salmo salar*), occurring in the upper

[5] ICES. (2015) Report of the Workshop on Lampreys and Shads (WKLS), 27-29 November 2014, Lisbon, Portugal. ICESCM2014/SSGEF:13. 206pp.

[6] Dias E., Miranda M.L., Sousa R., and Antunes, C. (2019) Riparian vegetation subsidizes sea lamprey ammocoetes in a nursery area. Aquatic Sciences 81**:** 44. https://doi.org/10.1007/s00027-019-0641-4.

[7] Dias E, Morais P, Cotter A.M., Antunes C., and Hoffman J.C. (2016) Estuarine consumers utilize marine, estuarine and terrestrial organic matter and provide connectivity among these food webs. Marine Ecology Progress Series 554: 21-34.
Dias E., Barros, A.G., Hoffman, J.C., Antunes C., and Morais P. (2020) Habitat use and food sources of European flounder larvae (*Platichthys flesus*, L. 1758) across the Minho River estuary salinity gradient (NW Iberian Peninsula). Regional Studies in Marine Science 34: 101196. https://doi.org/10.1016/j.rsma.2020.101196.

This project is co-financed by the Interreg Atlantic Area Programme through the European Regional Development Fund.

part of the international river Minho, either in Portugal and Spain - are recognized as of high cultural heritage value. The heritage value of Pesqueiras is derived from the artisanal fishing method itself but also from its importance in revealing ancestral rules regarding its use (Domingues-Garcia et al. 2013)[8]. These traditional traps have been jointly proposed by Portugal and Spain to integrate the UNESCO Intangible Cultural Heritage Lists. So far, to the best of our knowledge, there are no monetary estimations for this cultural service associated with migratory fish. A survey is being prepared under the scope of DiadES to assess the economic value of the traditional fishery for residents.

[8] Domínguez-García M.D., Horlings L., Swagemakers P., and Simon Fernandez X. (2013) Place branding and endogenous rural development. Departure points for developing an inner brand of the River Minho estuary. Place Branding and Public Diplomacy 9: 124-140. https://doi.org/10.1057/pb.2013.10.

This project is co-financed by the Interreg Atlantic Area Programme through the European Regional Development Fund.

4. Mondego catchment

The River Mondego is one of the largest Portuguese rivers (234 km). Located in the central region of the country, it drains an area of 6,644 km^2 (Figure 6) with a population estimated at 0.8 million.

It is a highly modified river, with a large hydroelectric dam (450 hm^3) located at 86 km from the river mouth and several multiple-use dams and several small weirs.

At the city of Coimbra, 45 km upstream from the river mouth, a dam was constructed in 1981 for flood control and water supply for human consumption, irrigation, and industry needs, becoming an unsurmountable obstacle for ascending anadromous species. A vertical slot fishway was constructed in 2011 by the Portuguese Environmental Agency (APA) to restore river connectivity at the Coimbra dam. This resulted in the tripling of the available freshwater spawning habitat in the Mondego River basin, moving the upstream limit 40 km further to the Raiva dam at Penacova, thus providing anadromous species access to some important tributaries (Figure 7).

The lower portion of the river (last 35 km) runs in open valleys, in a plain area, and can be divided into two ecologically different stretches: an estuarine and a freshwater environment. The freshwater zone is particularly modified, having a 15 km man-made stretch extending downstream from the Açude-Ponte dam (Almeida et al. 2002; Pereira et al. 2017, 2019; Stratoudakis et al. 2020)[9].

[9] Almeida P., Quintella B.R., and Dias N. (2002) Movement of radio-tagged anadromous sea lamprey during the spawning migration in the River Mondego (Portugal). Hydrobiologia 483: 1-8. https://doi.org/10.1023/A:1021383417816.
Pereira E., Quintella B.R., Mateus C.S., Alexandre C.M., Belo A.F., Telhado A., Quadrado M.F., and Almeida P.R. (2017) Performance of a vertical slot fish pass for the sea lamprey *Petromyzon marinus* L. and habitat recolonization. River Research and Applications 33: 16– 26. https://doi.org/10.1002/rra.3054.
Pereira E, Cardoso G.R., Quintella B.R., et al. (2019) Proposals for optimizing sea lamprey passage through a vertical-slot fishway. Ecohydrology 12: e2087. https://doi.org/10.1002/eco.2087.
Stratoudakis Y., Correia C., Belo A.F., and Almeida P.R. (2020) Improving participated management under poor fishers' organization: Anadromous fishing in the estuary of Mondego River, Portugal. Marine Policy119. https://doi.org/10.1016/j.marpol.2020.104049.

This project is co-financed by the Interreg Atlantic Area Programme through the European Regional Development Fund.

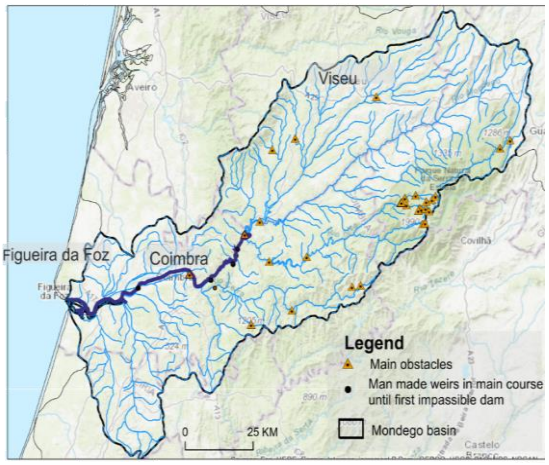

Figure 6 *Mondego River Basin and obstacles on river connectivity*

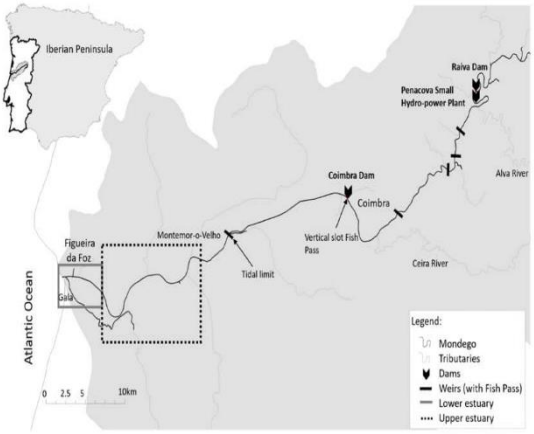

Figure 7 *The Mondego River basin, indicating the two estuarine fishing zones, the tidal limit and the location of defragmentation works in the five weirs and the Coimbra Dam. Source: Stratoudakis et al., 2020*

Provisioning services

One hundred licensed fishers annually target sea lamprey (*Petromyzon marinus*) and shad, in particular, allis *(Alosa alosa*) and twaite (*Alosa fallax*) shad in designated areas in the upper and lower estuary. Fishing seasons are established during the anadromous migration period (December/January – May/June for lamprey and February/March – June/July for shads) (Stratoudakis et al. 2020)[10]. The twaite shad is of less representativeness and the majority of the allis shad captured is exported (e.g., when not consumed locally).

Additionally, European eel, *Anguilla anguilla*, is also an important species for commercial fisheries in this river basin.

Distinct authorities regulate and control the two fishing zones, where underreporting, poaching, and fishing beyond the designated limits is also known to take place.

Regulating services

Despite the general agreement regarding the importance of diadromous species in nutrients and sediments distribution, to the best of our knowledge, there are no estimations obtained for the diadromous populations colonizing the Mondego River. The best option for an economic estimation of this service would rely on extrapolation of biophysical field data (for instance from the Minho River regarding which there is biophysical quantification available – see Minho River case study description in this document) and then estimate the monetary value of the service through a replacement cost approach.

[10] Stratoudakis Y., Correia C., Belo A.F., and Almeida P.R. (2020) Improving participated management under poor fishers' organization: Anadromous fishing in the estuary of Mondego River, Portugal. Marine Policy119. https://doi.org/10.1016/j.marpol.2020.104049.

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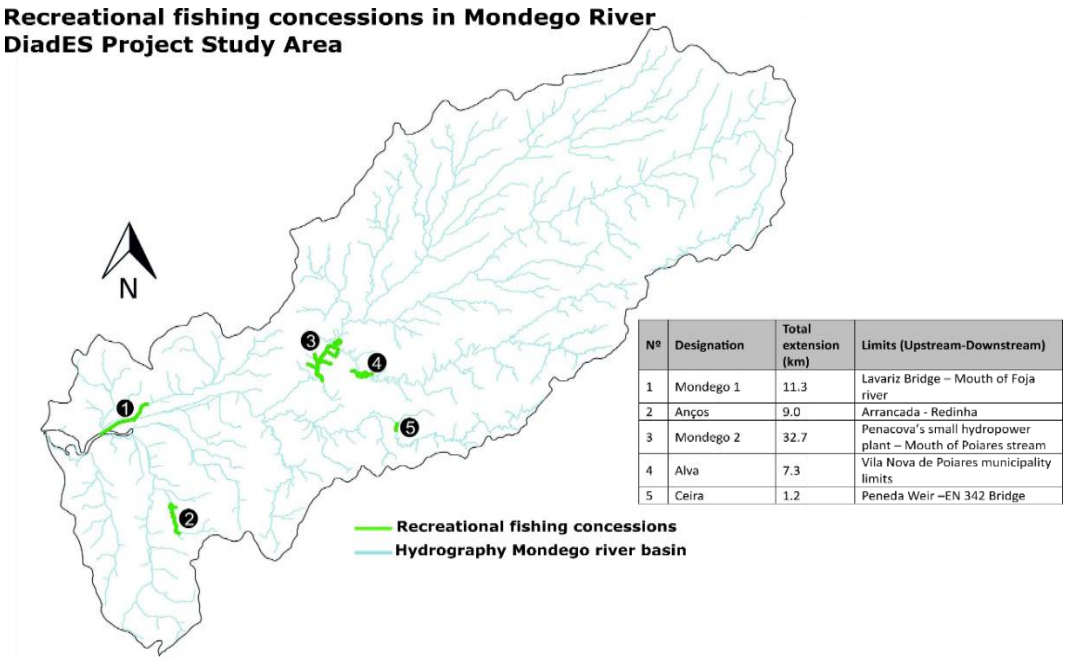
Cultural services

Recreational Fishing. For the case of diadromous species, recreational fishing in the Mondego River (including leisure and angling competitions) is restricted to sea trout (*Salmo trutta*) mostly under the practice of "catch and release". There are also several sport fishing competitions devoted to sea trout (as well as for its holobiotic ecotype, the brown trout). So far, there is no comprehensive data on the economic value of recreational fishing directed to sea trout. Information regarding the number of licenses issued and licence purchase costs are available upon request from licensing authorities. There are two types of licenses: annual (regional or national) and daily (fish concessions) (Figure 8). To the best of our knowledge, there is no estimation of the economic value of sea trout recreational fishing in the Mondego fishing concessions. DiadES, among others, intends to cover this information gap, through a survey that is being designed and tested, aiming to estimate the annually total costs incurred by recreational fishers, as well as their motivations and interests related to this practice.



Nº	Designation	Total extension (km)	Limits (Upstream-Downstream)
1	Mondego 1	11.3	Lavariz Bridge – Mouth of Foja river
2	Anços	9.0	Arrancada - Redinha
3	Mondego 2	32.7	Penacova's small hydropower plant – Mouth of Poiares stream
4	Alva	7.3	Vila Nova de Poiares municipality limits
5	Ceira	1.2	Peneda Weir –EN 342 Bridge

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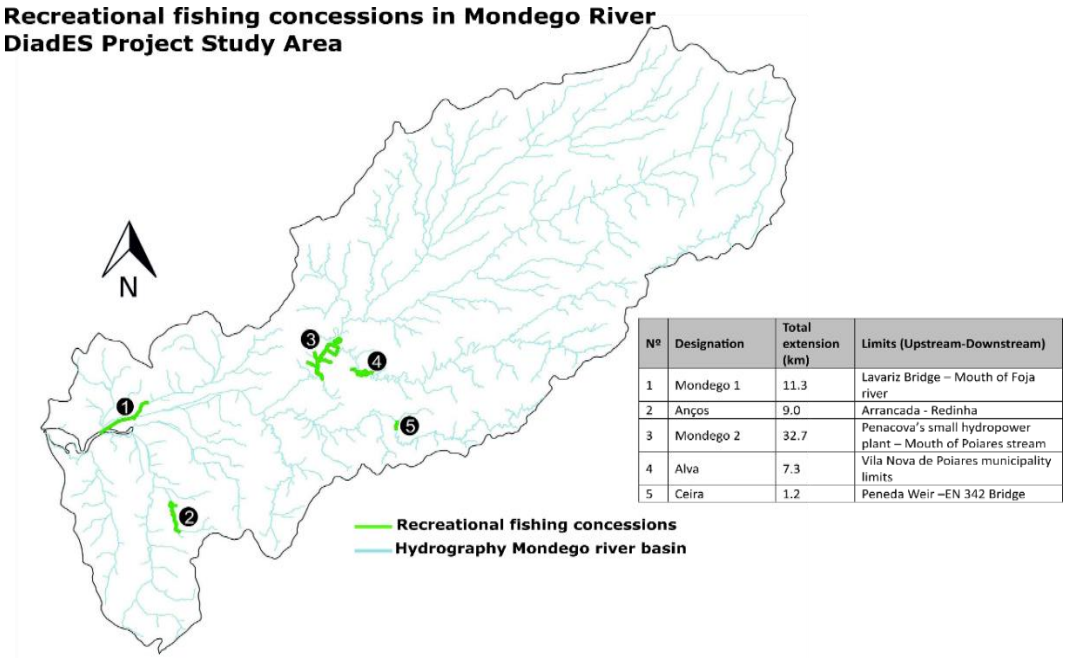

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Figure 8. *Recreational Fishing concessions within the area of DiadES Intervention in the Mondego river basin. Source: Provided by Pedro Almeida.*

Gastronomy around species, emotional brotherhood and Festivals. Among the migratory fish species present in Mondego River, sea lamprey (*Petromyzon marinus*), allis shad *(Alosa alosa*) and European eel (*Anguilla anguilla)* are among the most valued species and enrolled in several gastronomy events. The high emotional involvement of the population is highlighted by the existence of a sea lamprey brotherhood.

Research and environmental education. Research opportunities provided by or related to diadromous populations in the Mondego River can be an indicator of its importance. Several previous or on-going research projects have targeted these populations, through an integrated approach, namely sea lamprey, shad, eel, trout and thin-lipped grey mullet. Some of the projects mentioned are identified below (not exhaustive):

- Habitat restoration for diadromous species in River Mondego (2013-15) – PROMAR
- AN@DROMOS.PT (ongoing)
- DCF (Data Collection Framework) (ongoing)
- SUDOANG (ongoing)
- LIFE Águeda (ongoing)

Public funding can be a proxy of society willingness to pay to improve ecological knowledge of perceived important ecosystems from a conservation perspective. Although, and since there are different funding entities (and beneficiaries carrying out research), only a qualitative assessment of this service can be carried out.

There is also evidence of environmental education events of knowledge transfer related to functioning and importance of the species conservation. These events can have different organizers, but the level of outreach is still unknown. The Portuguese Environment Agency (APA) - (DiadES associated partner) annually runs several environmental education events. Through their records and systematic data collection on this topic it is possible to assess, at least in a quantitative way, the importance of diadromous species in the Mondego River.

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Heritage and cultural identity. The heritage and cultural identity value derived from diadromous species, namely the European eel and even more so the sea lamprey is patent on several publications highlighting how the species shaped local livelihoods and traditions that are still present in local communities. This evidence can be ascertained from published books devoted to the topic. Accurate estimations of the economic value of this ecosystem service are difficult to obtain though one should at least highlight the available evidence, like the number of regional books dedicated to Mondego. Below, we provide a few examples of published books (Figure 9). A survey is being prepared under the scope of DiadES to assess the economic value of the traditional fishers to local residents.

Figure 9. *Non-exhaustive collection of published books devoted to local traditions associated with lamprey*

Regulating and supporting services

Redistribution of fluxes, nutrient regulation. Considering the expert knowledge available, the literature related with the impact of migratory fish species on marine-derived nutrient transference or redistribution of fluxes, and the data collected from Coimbra fish passage monitoring, all the diadromous species present are expected to have a high impact on this river basin.

Biological cycle. Thin-lipped grey mullet's migration to freshwater begins in March /April and the peak of downstream migration to estuaries and then spawning grounds in coastal areas occurs mainly between September / October, period in which sea lamprey juveniles begin their trophic migration towards the sea. Thus, thin-lipped grey mullet are one of their first hosts during their initial migration.

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5. Gironde, Garonne, and Dordogne system

This French case study, represented in Figure 10, covers a total surface area of 80,000 km^2 over 20 departments with a population density around 70 inhabitants/km^2.

Important diadromous species-related commercial and recreational fishing activities provide key food provisioning and cultural ES in the region. Sea lamprey, European glass eel and yellow eel, and Allis shad have contributed to the food provision with around 5,000 thousand euros annually since 1975 (i.e. Allis shad: 1,000 thousand euros; Glass eel: 2,700 thousand euros; Yellow eel: 275 thousand euros; and Sea lamprey 970 thousand euros). For example, Allis shad's contribution to food provisioning reached an average annual value of about 1,000 thousand euros with 189 fishers before the fishery was banned in 2008. In comparison, the recreational fishery for Twaite shad contributed to cultural ES around 124 thousand euros for an average of 264 fishers in recent years. In addition, Allis shad and sea lamprey also provide cultural ES with regards to gastronomic events and festivals, but these are rather minor values. Nonetheless, collecting data on gastronomic events and festivals could be improved as only few municipalities answered to the cases-study leader requests.

The conservation statuses of these species in the area have experienced dramatic changes due to multiple anthropogenic pressures. Considering Allis shad, this species is surrounded by a high level of future uncertainty due to the observed decrease of its stock until the year 2008 when a ban was introduced (Figure 11) and no recovery was observed since then. Therefore, it is not expected to maintain the same amount of ES provisions in the future for this species. On the contrary, this case study will check the possibility of developing new food provisioning ES in the future due to the favourable Twaite shad stock evolution, currently providing under-documented and probably limited services. Option values will be used to provide economic assessment attached to these future opportunities. All diadromous species in the area provide regulating ES. However, the present assessment will only provide the contribution for Allis shad to the nutrient fluxes between marine and fresh waters (Poulet et al. in press)[11].

The current and future provision of diadromous species ES is being impacted by the state of the freshwater ecosystems and marine habitats. These habitats are affected by various economic activities such as hydroelectricity production, irrigated agriculture with chemical inputs, gravel extraction activities for different purposes, and various industries polluting rivers with the special case of cadmium and zinc pollution due to historical zinc mining extraction on the banks of the Garonne River (Jouanneau et al. 1993)[12].

An important science and research activity around diadromous species is taking place in the area, contributing to the cultural ES, with almost 1,000 thousand euros. Around half of this budget is devoted to the Action plan for the European sturgeon (research). Remaining budget is used for knowledge improvement about European eel, Atlantic salmon, Sea trout, Allis shad, Twaite shad, Sea lamprey and, River lamprey. Surveys are being prepared under the scope of DiadES to fill data gaps and assess the economic value created by the recreational fishers as well as the cultural value of traditional fishers to local residents.

[11] Poulet C., O'Malley-Barber B., Lassalle G., and Lambert P. (In press) Quantification of land-sea nutrient fluxes supplied by allis shad across the species' rang. Canadian Journal of Fisheries and Aquatic Sciences.

[12] Jouanneau J.M., Lapaquellerie Y., and Latouche C. (1993) Origin and pathways of Cadmium Contamination in the Gironde estuary, Garonne river and tributaries. Studies in Environmental Sciences 55: 373-389. https://doi.org/10.1016/S0166-1116(08)70302-9.

This project is co-financed by the Interreg Atlantic Area Programme through the European Regional Development Fund.

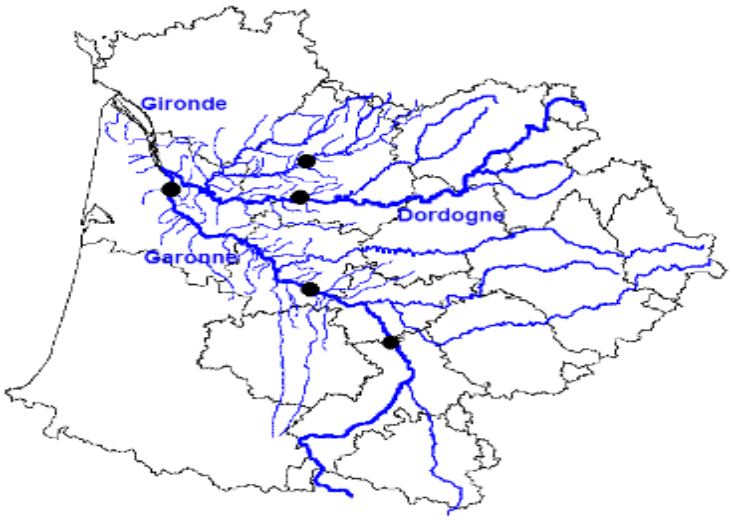

Figure 10. *Gironde, Garonne and Dordogne case study in the south west of France*

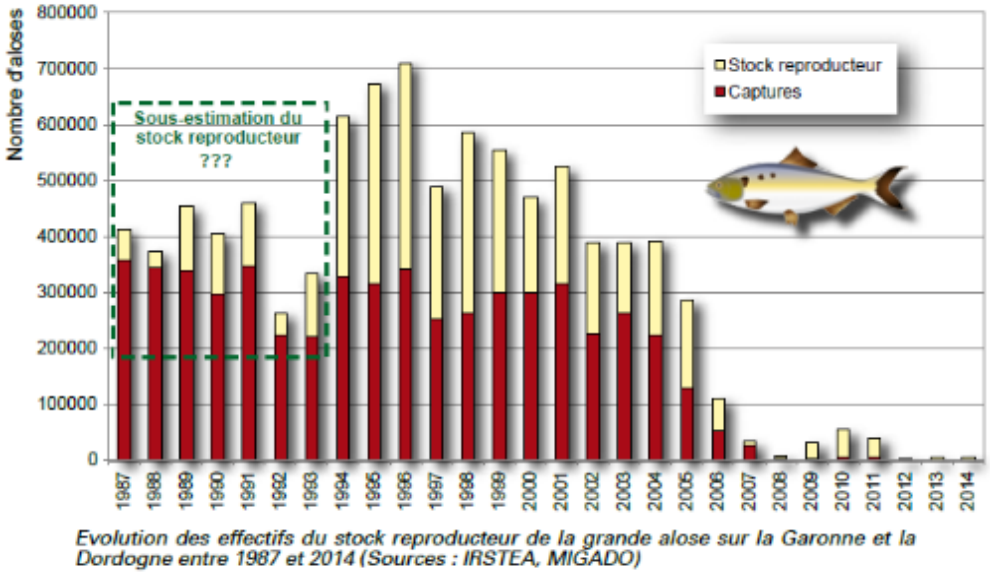

Figure 11. *Allis shad stock evolution in Garonne and Dordogne between 1987 and 2014*

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6. Loire catchment

The Loire Catchment covers about 128,000 km^2 and its main stem is about 1200 km long, being among the largest rivers of Western Europe, covering four large urban areas which implies more than 10 million habitants (Figure 12). All diadromous species covered in DiadES (Table 1) are found in the Loire catchment, except for the European sturgeon which is already extinct. Some restocking actions were done in the area for European eel and Atlantic salmon.
Those diadromous species provide a large set of ES. For example, Allis shad, Twaite shad, Sea lamprey, River lamprey, European eel, and Thin-lipped grey mullet support food provisioning ES. These commercial and artisanal fisheries involve in average about 300 fishers. These species also contribute to the cultural ES such as traditional know-how, and support also gastronomy events, and research-related activities.

Other economic activities in the river are important to consider the current and future impact on this aquatic system, and the future provision of ES from diadromous species. Physical and chemical contaminations from the large urban areas together with the pollution from specific industries in the area, and agriculture, are severe. In addition to the contaminant problem, the habitat destruction is a critical threat due to activities such as sand extraction, or dredging, water supply and wetland reclamation. Finally, the river fragmentation downstream and upstream is also affecting the diadromous species habitat due to hydropower plants, cities, or navigation and other irrigation activities in the area. Invasion by non-indigenous species as the bivalves *Corbicula sp* and the freshwater mussel *Dreissena polymorpha,* have deeply modified the structure of the trophic network. The invasion by the Giant Catfish (*Silurus glanis*) is strongly suspected to predate anadromous species on their upstream migration, notably when they are blocked or slowed by dams and on their spawning sites.

A number of initiatives have been conducted to restore river continuum on the Loire River and tributaries, by removing dams, building fish passes and adapting water gates management in lowland waterbodies. This is associated to an economy of the “ecological restoration” industry. A multi-million project is currently ongoing to restore the morphology, and natural lateral habitats of the river between Nantes and Pont-de-Cé.

Figure 12. *Loire catchment*

This project is co-financed by the Interreg Atlantic Area Programme through the European Regional Development Fund.

7. Normand-Breton Bay

The Normand Breton Gulf and its tributaries are located at the corner of Brittany and Normandy. It includes marine areas from Cherbourg to Paimpol and the Channel Islands which are part of the commonwealth. This area counts a number of rivers that host all diadromous species studied under DiadES (Table 1), except the European Sturgeon and European Smelt. Catches of Sturgeons and Smelts have been recorded in the Marine Area.

In the present study, the focus was on the south-eastern part of the Normand-Breton Gulf including Mont Saint Michel's Bay and the "Côte d'Emeraude" in which flow 7 rivers with a catchment covering >50 km^2. The Frémur River is a 60 km^2 catchment, and the main stem is c.a. 17 km long. The river has historically been managed with weirs and watermills that have fragmented the river since the 11th century. Moreover, the slope is genuine, and it has likely never been a salmon river in the recent history. This situation became more severe during World War 2, because the German army built high dams to create ponds to defend the city of Saint-Malo against a hypothetic landing of allied army in Brittany. After the war, these dams and reservoirs were maintained to ensure drinking water supply in the area. Later in 1996, a 14 m high dam was built to increase the volume of raw drinking water to satisfy the local requirements.

On the Bois-Joli dam, the first eel lift was built to enable upstream migration. However, nothing was anticipated to allow the downstream migration of silver eels.

On this occasion, a survey was undertaken to measure the effects of the dam and the efficiency on the fish passes that were built from the estuary to the Bois Joly Dam (3 dams in all). This survey has continued since then and the Frémur is now one of the Index Rivers of the French eel management plan. The survey has shown that the eel recruitment and eel population has dropped as everywhere else in Europe. But, more dramatically, it was recently shown that practically none of the silver eels produced in the catchment were able to escape to the sea because the management of the dams was inappropriate and led to a definitive stop of the migration behaviour. This situation was shown to be representative of a more general situation of dams. This survey is symbolic of the relations between drinking water supply and diadromous conservation issues.

There are no professional fishermen on the Frémur catchment nor in the estuary. Anglers mostly focus on trout in the running reaches of the river and on carps, pikes in the reservoirs. Some occasionally catch eels.

The Sélune River is 85 km long and drains a 1030 km^2 catchment. The river still hosts one of the most important population of Salmons in France that is estimated to c.a. 1000 fish of the Mont Saint Michel Bay that is shared between 3 rivers (the Sélune, the Sée and the Couesnon) that all flow out to the sea in the vicinity of the Mount Saint Michel. There is also a population of sea lampreys, and shads are occasionally observed in the estuary. Eels, mullets and flounders are abundant.

Two major dams were built on the Sélune at the beginning of the 20th century to produce electricity. The "Roche qui Boit" dam is 14m high. It sits at c.a. 7 km from the river mouth and stops all upstream migration. And it therefore marks the upstream limit of the distribution of diadromous species, so most of the catchment is inaccessible. Moreover, a second dam, called "Vezins" was built in the same period upstream in the same period.

For this reason, the distribution of eels, salmon and sea trout are constrained to downstream reaches and tributaries. An ongoing survey of the salmon, sea trout and eel population started c.a. 30 years ago and is operated by INRAE of Rennes. There is a monitoring station at the outlet of the tributary in a former mill that was equipped with downstream and upstream traps. Electrofishing surveys and tagging operations are conducted on a yearly basis.

This project is co-financed by the Interreg Atlantic Area Programme through the European Regional Development Fund.

The survey shows that eels and salmons feature very slow growth and survival because of density dependant processes. The researchers hypothesised that migratory species will colonise the upstream reaches of the Sélune catchment as soon as the Roche qui Boit dam will be destroyed in 2021. Indeed, a national plan was implemented to destroy the dams of the Sélune. Vezins was destroyed in 2020, and "La Roche qui Boit" will be destroyed in 2021. The main reason that leads to this decision was to restore the salmon population in the river.

An extensive research project has been initiated to analyse over a 10-year period the effects of the re-connexion of the upstream stems of the catchment. This is a significant economical outcome.

There is no professional fishery in the Sélune Catchment. Anglers focus on salmon and sea trout catches. The catches are limited to c.a. 100 salmons per year.

Eels, flounders and mullets are occasionally fished by anglers in the estuary. Recreational gill net fisheries also operate in the estuary, mainly for mullets. The exact catches are not known.

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8. Tamar, Frome and Taff rivers

Tamar

The Tamar is located in southwest England, on the border between Devon and Cornwall. The river is about 98 km long and the estuary mouth enters into the Plymouth Sound. With respect to DiadES, the Tamar is home to, among others, salmon, sea trout, eel, flounder, lamprey, smelt and thin-lipped grey mullet, lamprey and smelt. In recent years provisioning ES are only associated with commercial landings of salmon, eel and mullet, although landings of salmon and eel have ceased in most recent years due to regional and international declines in stocks. Cultural ES are supported by recreational fishing for salmon, sea trout (fly fishing), sea/estuary angling for flounder. Recent and historical fisheries for salmon and eel used traditional methods, with plans for the clinker-built vessels used in salmon netting held by the National Maritime Museum, Greenwich, London, due to their regional importance. Presence of diadromous species, such as salmon and sea trout also support cultural services, such as physical and experiential interaction with outdoor spaces, contributing to wellbeing benefits to river users including walkers, boaters, kayakers, and education activities. Regulating ES, in particular exchange of nutrient form marine to freshwater environments are provided by all diadromous species present in the Tamar site, as are roles in biological cycles and contribution of genetic material. Whilst the current and recent historical ES can be valued, option values should also be considered, based on the commercial, ecological and cultural importance of diadromous species within the site.

Historically, the Tamar valley and surrounding area has supported mining since the Bronze age, for cooper and tin, and in more recent times for tungsten, lead and silver. Plymouth has been a major port throughout history, with current value of fish landed by commercial fisheries within the top 7 UK ports by landings value, and top 3 English ports (MMO 2019)[13]. Devonport on the Tamar estuary also contains Western Europe's largest naval base. Much of the Tamar watershed beyond the city of Plymouth is agricultural land.

Human activities over the course of the Tamar's history have led to pressures on diadromous species stocks. Water quality issues, due to contamination from pollutants leaching from disused mines, have created heavy metal pollution above background levels. Nutrient enrichment, related to water treatment works and combined sewer overflows in urban areas, as well as run-off from agricultural land, have led to the Tamar Estuary water body not achieving WFD targets (Environment Agency 2019). Engineering infrastructures such as weirs have also prevented species such as Allis shad reaching spawning sites (Natural England 2015).

Due to the historic mining activity, in particular in the valley of Tavistock, the river is registered as UNESCO World Heritage Site. An area of about 195 km^2 on the lower Tamar is further registered as Area of Outstanding Natural Beauty (AONB). The Plymouth Sound and the estuaries far inland on the Tamar are assigned European Special Areas of Conservation (SAC) with presence of the Annex II species Allis shad being amongst the habitat and species features the site is designated to conserve. The Tamar-Tavy estuary is further declared as site of special scientific interest (SSSI) due to his high biodiversity and varying habitats for marine birds. With designation as a Special Protection Area (SPA) for Avocet and Little Egret (Tamar Estuaries Complex SPA). The unique biodiversity and cultural importance of the Tamar and Plymouth area has led to a drive to create the UK's first national marine park, centred on Plymouth Sound.

The commercial and recreational catch of fish in the river, estuaries and close coastal waters is recorded by the Environmental Agency (EA), while the commercial catch in the sea is managed by the Marine

[13] Marine Management Organisation (2019) U.K. sea fisheries statistics.

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Management Organization (MMO). The EA provided data for the Tamar River on commercial catch and the licences sold and days fished for salmon by net and fixed engines for the years 1971-2019. Further, EA provided numbers of catch, recreational licence (Rod and line fishery) and effort for the recreational fisheries on salmon in the Tamar for the years 1994-2018. The eel fishery was recently closed in UK except in East Anglia, hence data on commercial catch is limited to 2005-2018. Similar data on recreational catch for sea trout is recorded by the EA but has been provided only for the years 2018-19. There are anecdotical evidence for recreational fishing for flounders in Plymouth Sound and estuaries, even holding competitions, however, data on the catch is not available similar to data on the recreational catch on thin-lipped grey mullet. Available data is limited to the commercial catch of flounders and mullet registered by MMO which is aggregated to ICES rectangle and species group (i.e. mullet is not further specified) and commercial fisher only have to fill out sales note when they selling more than 25kg of the species. Hence, data is not comprehensive but available for the years 2008-2019. A survey is being prepared under the scope of DiadES to fill data gaps and assess the economic value created by the recreational fishers.

The Rivers Trust further developed a tool to assess the natural capital of habitats supported by diadromous species. Although this tool is not catchment specific, it should be used to inform the regulating ES supported by diadromous species in the area.

Frome

The River Frome is an about 48 km long chalk stream in southwest England mouthing into Poole Harbour as a wide, shallow estuary. Originally mainly used as trade route, the river is now famous for its dramatic decline in salmon population. A Salmon & Trout Research Centre at East Stoke was founded by the Game and Wildlife Conservation Trust to research the cause of the decline of the fish population and how to reverse it.

The River Frome is home to salmon, sea trout, eel, lamprey, thin-lipped grey mullet and flounder. Similar to the Tamar, the river, estuary and coastal area is managed by the Environmental Agency (EA) and the marine area by the Marine Management Organization, which can provide data on the recreational and commercial catches. For Frome, EA collected data on commercial catches, issued licences, days fished for salmon for the year 1971-2019. Recreational catch numbers, issued licences, days fished are provided for the year 1994-2018. In addition, EA provided data on the commercial catch of eel for the years 2005-2018. Similar to the River Tamar, recreational catch data on sea trout is collected by the EA and was provided for the year 2018-19 only. For the other species of interest, e.g. mullet and flounder, data is only available for the commercial catch as provided in an aggregated form by the MMO for the years 2008-2019. Recreational catch data is only very sparsely available, mainly provided by specialized angler clubs surveys.

Surveys are being prepared under the scope of DiadES to fill data gaps and assess the economic value created by the recreational fishers and the cultural value of traditional fishing (Poole harbour canoe) for thin-lipped grey mullet.

The Rivers Trust further developed a tool to assess the natural capital of habitats supported by diadromous species. Although this tool is not catchment specific, it should be used to inform the regulating ES supported by diadromous species in the area.

Taff

River Taff is a river in Wales which starts off as the Taf Fechan (Little Taff) and the Taf Fawr (Greater Taff) before they are join each other to create the River Taff which mouth at Cardiff in the River Severn estuary. The river is known for its population of Atlantic salmon (*Salmo salar*) and migratory brown trout – sea trout (*Salmo trutta*), eel, but also hosts lampreys. Although the Cardiff Bay barrage limits commercial fisheries

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thin-lipped grey mullet (*Chelon ramada*), European eel (*Anguilla anguilla*) and flounder (*Platichthys flesus*) occur in the site.

Provisioning ES are limited, by declines in diadromous species populations and lack of fisheries operating inside the barrage. However, older generations have shared knowledge with local environmental resource charities (South East Wales Rivers Trust) on how they previously fished in the rivers. Cultural ES provided by diadromous species, include recreational angling, with fly fishing for Atlantic salmon (*Salmo salar*) and migratory brown trout – sea trout (*Salmo trutta*) supporting clubs and membership and a lot of interest. Diadromous species are also of interest to people undertaking recreational activities on the river, especially in Cardiff where swimming, stand up paddle boarding and canoeing brings people into contact with diadromous species.

The recreational fishery is managed by Natural Resources Wales (NRW). The Environmental Agency provided us with data on recreational catches, number of licenses and days fished for salmon for the year 1993-2018 and for sea trout for 2018-2019.

The Taff runs thorough one of the largest areas of historical coal mining and industry, as well as the largest city in Wales, Cardiff. Pollution related to industrial activities as well as barriers to migration had significant impacts on the health, and even presence of diadromous species. Although having a large economic impact on the region, the closing of the Coal Mines in 1980 heralded the biggest improvement in river quality. Sewerage pollution and invasive weeds as well as some siltation problems are still prevalent, but water quality is greatly improved. The Taff system including the River Ely flows into Cardiff Bay, where the Cardiff Bay barrage, constructed between 1994 and 2001, crosses the mouth of Cardiff Bay. The barrage features locks and bridges, sluice gates and a fish pass but movement of certain diadromous species is still restricted. The head waters contain many water supply reservoirs, and these will continue to be a factor in fish production. Invasive non-native species are also a threat to native biodiversity, including, red clawed cray fish, invasive shrimp species. Lack of water in dry weather also leads to late runs of salmon, with the main reservoirs restricting much of the natural flow that would occur.

A survey is being prepared under the scope of DiadES to fill data gaps and assess the economic value created by the recreational fishers.

The Rivers Trust further developed a tool to assess the natural capital of habitats supported by diadromous species. Although this tool is not catchment specific, it should be used to inform the regulating ES supported by diadromous species in the area.

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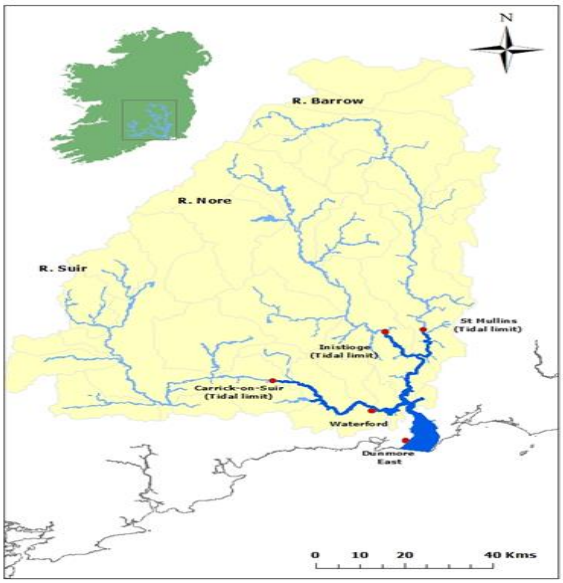
9. Waterford harbour and three-sisters rivers



Waterford Harbour is the location of one of the largest estuarine systems in Ireland. It is where the Three Sisters, the rivers Nore, Barrow and the Suir converge at Cheekpoint and continue into the Celtic Sea (Figure 13). The Three Sisters are relatively long rivers in an Irish context with moderate gradient; their tidal limits extend up to Carrick on Suir on the Suir, Saint Mullins on the Barrow and Inishtioge on the Nore. The total catchment area is 9,100 km², and comprise circa 20% of national wetted area of accessible riverine habitat for salmon (Mc Ginnitty et al, 2003)[14].

Figure 13. *Waterford Harbour*

The catchment area contains important salmon habitat and Special Areas of Conservation (SAC) including the Lower River Suir SAC and River Barrow and Nore SAC. The catchment contains several diadromous species including; Atlantic salmon (*Salmo salar*), migratory brown trout – sea trout (*Salmo trutta*), European eel (*Anguilla anguilla*), Twaite shad (*Alosa fallax*), Sea lamprey (*Petromyzon marinus*), River lamprey (*Lampetra fluviatilis*), Smelt (*Osmerus eperlanus*) and Thin-lipped grey mullet (*Chelon ramada*). Provisioning services related to diadromous species were supported by salmon and eel populations, however these have declined due to conservation regulations linked to reduced regional and international populations. Commercial fishers in the region, based at ports such as Dunmore East, land insignificant catches of mullet and flounder, from analysis of landings statistics, but specific location and species level data are not available. Commercial fishing for salmon in the region has, until 2014, supported culturally important traditional methods, whose origins can be traced back to the 1500s. This fishery supported the fishing method of 'snap netting', using a net fished between two small flat bottomed narrow boats ('cotts'), that is traditional to the Waterford area and the 3 Sisters estuaries. This fishery operated exclusively for salmon, but shad (both twaite and small numbers of Allis shad) comprised a bycatch. Snap netting however, remains important in relation to cultural ES provision. Heritage status has been granted to this fishing method by the relevant Government Department but it can only operate where a surplus of salmon over the conservation limit is available. The eel fishery was suspended in 2009 following the implementation of an Eel Management Plan under the EC Eel Regulation (1100/2007). Historical data on the commercial eel fishery is incomplete. Data are available from 2001 to 2007. The eel commercial fishery was only carried out in a number of locations in transitional waters and lagoons with the majority of effort focused on lakes and rivers. Eel fishing in Waterford consisted of baited pots. Until the 1960s the pot used in Waterford was a wicker basket about 1 meter long and 50 cm in diameter. In the late 1960s, a visiting Dutch fisherman introduced gear known locally as the 'beck', a trap made from nylon mesh

[14] McGinnity P., Gargan P., Roche W., Mills P., and McGarrigle M. (2003). Quantification of the freshwater salmon habitat asset in Ireland using data interpreted in a GIS platform. Irish Freshwater Fisheries, Ecology and Management Series: Number 3, Central Fisheries Board, Dublin, Ireland. ISSN: 1649-265X.

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supported on plastic hoops. These must be baited with freshly caught small estuarine fish such as herring or sprat. Food and cultural events and festivals were not recorded in the region in relation solely to diadromous species.

Cultural ES are also supported by leisure angling, in particular shad (*Alosa fallax), which* is targeted by generalist and specialist anglers in May during their migration into the site. Specimen hunters target the River Barrow at St. Mullins for shad > 1.2kg for specimen recording purposes (ISFC, 2019)[15], which is fished on a catch and release basis. This fishery also provides a basic measure of population status. Salmon angling is permissible and, as applies for the commercial fishery, a harvest is only allowed when there is a surplus of fish over its river-specific conservation limit. In recent years, salmon fishing has been mainly limited to catch & release. Limited sea trout angling is available, and catches are low. While thick-lipped (*Chelon labrosus*) and thin-lipped grey mullet (*Chelon ramada)* are present, the recreational fisheries for both receive little, if any, pressure. The Conservation of Eel Fishing Bye-law limits the recreational catch of eel to bycatch and effectively is a catch and release. Other diadromous species also support interest to anglers. Educational activities are supported by interest in diadromous species – the Barrow at St. Mullins is the main spawning site in Ireland for twaite shad and the presence of species is also of interest to water users such as canoeists and visitors to river side walking routes. One diadromous species in the region, the salmon, is long associated with Irish folk lore and mythology through the salmon of knowledge. In the Fenian Cycle of Irish mythology, tales dated to the 7th century and likely long before, tell of a salmon that had gained all the world's knowledge, and that, the first person to eat of its flesh would in turn gain this knowledge.

Data on commercial salmon fisheries were available for years the fishery was open. Data on eel fisheries in recent years were available from 2001 to 2007 and landings of mullet and flounder (although with limited species and spatial data) are available for all years eg. 2010-2020. A survey designed jointly by University of Plymouth and IFI and undertaken by IFI provided data on angler perceptions and spend related to recreational shad angling (we intend to produce a final report within the project as it is a useful study). Data on educational events were provided by IFI along with information on number of angling clubs and details of their membership. Valuation and data on the wider recreational angling activity, in addition to the existing shad data will be collected as part of the DiadES recreational angling expenditure survey.

In the present day, the city of Waterford is the largest urban centre, with a population of 53,000 inhabitants. The Port of Waterford is a port of national significance, while the main commercial fishing industry is based at Dunmore East, on the western shore of the mouth of Waterford Harbour, where landings are the 2nd highest in Ireland. Water quality pressures occur in relation to the urban centres. Although treatment works have been constructed to limit severest sewage, industrial effluents and leachates, there remain isolated areas of poor water quality close to cities, as well as limited incidences of high nutrients from run-off in rural sites (Environment Protection Agency 2013).

[15] ISFC (2019) Annual report of the Irish specimen fish committee. www.irish-trophy-fish.com.

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Table 3. Ecosystem services across case studies: opportunities and challenges from stakeholders

CS name	Species supporting ES	human activities supported by ES	Ecosystem services already assessed – before DIADES (ecological and/or economic, theoretical/application)	Stakeholder group involved (NGOs, administration, fishers, scientific, …)	trade-offs between ES related activities and other activities using the same habitats (e.g. environmental impacts affecting the ES)	New opportunities. Any research-policy-practice link?
Gipuzkoa rivers	European eel, being the most relevant	* Glass eel recreational fishery * Glass eel traditional dish on Christmas and events * Use of the fish passes and stocking actions for environmental education * Social relations linked to the fishery *Diadromous related scientific groups	Not yet for diadromous species However, the Basque regional administration has a broad programme to assess the Basque ES (land and water related ES) at a very broadly scale https://www.euskadi.eus/informacion/naturaleza-base-del-bienestar/web01-a2ingdib/es/	Scientific, and Regional administration		The ES concept is well established in the Basque region at a broadly level (administration). Specific and more detailed information can be added to the already existing information.
Gironde-Garonne-Dordogne watershed	Charismatic species: Allis shad, European sturgeon, Marine lamprey, and European eel	*Fisheries (commercial and recreational), *catering industry, *Science and environmental management sectors…	Multi-species commercial fisheries with a focus on sturgeon and glass eel (Gérard Castelnaud work) Survey on the recreational fishery of twaite shad (2019) (angling) (behaviour/preferences and related expenses) Survey of yellow eel recreational fishery (angling) (number of anglers, captures…)	Professional fishermen Recreational fishermen and their federations	Overexploitation Irrigated agriculture Gravel extraction in rivers PCBs pollution – banned consumption (eel) Other pollutions (nitrate, cadmium (zinc industry),…) River connectivity loss / turbine mortality Climate change/ smelt extirpation Introduced species	Regional network (BIOSENA) – federating the willingness to work on biodiversity and ES at the regional scale
Mondego river	Sea lamprey, Allis shad, Twaite shad, European eel, Sea trout, Thin-lipped grey mullet, European flounder	*Commercial fisheries income (lamprey and allis shad) Recreational fisheries (trout, eel) *Environmental education and research *Sports (e.g., fishing, kayaking, high performance centre for canoeing, paddling, nature trail rail centre) *Restaurants income (lamprey, eels, shads) *Birdwatching *River beaches	Surveys to local fishermen in the project AN@DROMOS.PT was a first approach to this issue in Mondego (Stratoudakis et al. 2020). But an economic assessment is missing	Universities, National and Regional administrations Local Fisherman and Anglers associations	Flood control (dams and weirs) Electricity production Dredging. River channelization Agriculture (water abstraction and pollution) Domestic treated effluents Poaching	To obtain a better knowledge of local resources income, and in consequence a better management of these resources. However, an important challenge: Upper estuary (Baixo Mondego) fishing for anadromous under inland administration jurisdiction with limited participation in associations

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CS name	Species supporting ES	human activities supported by ES	Ecosystem services already assessed – before DIADES (ecological and/or economic, theoretical/application)	Stakeholder group involved (NGOs, administration, fishers, scientific, …)	trade-offs between ES related activities and other activities using the same habitats (e.g. environmental impacts affecting the ES)	New opportunities. Any research-policy-practice link?
Ulla river	Sea lamprey, European eel, Atlantic salmon, European flounder, Sea trout, Twaite shad, Thin-lipped grey mullet	*Professional fishing *Recreational fishing *Tourism, hotels and restoration			Degradation of estuarine and freshwater ecosystems through dam and diffuse organic (from agriculture), chemical pollution (from open pit-mining) and, urban spills 45 low-head obstacles of variable size, 20 of which are artificial obstructions constructed for lamprey fishing Exotic species introduction Specifically, the construction in 2005 of a fish ladder has dramatically affected the salmon recreational fishery catches	The vulnerable conservation status of some of these species as well as the intense dependence and exploitation by coastal communities. To obtain a better knowledge of local resources and in consequence a better management of this resources. Increases the ability of ecological claim.
Loire river	Atlantic salmon (a ban is currently in progress), Sea trout, Sea lamprey, River lamprey, Twaite shad, Allis shad, European smelt, Thin-lipped grey mullet, European flounder, European eel	* Income for traditional fisheries, * restaurants, * fish mongers, managers, researchers, … ~300 small scale professional fishermen 20 tons glass eels per year and 5 tons silver eels per year, but also yellow eels, shads, lamprey, mullets A major habitat restoration project. A hatchery and nursery are funded by public funds to sustain the salmon fishery		NGOs (Loire Vivante), National and regional administrations, Professionnal fishermen associations (AAPPED44, COREPEM Pays de la Loire et AAPPBLB). Recreational fishermen associations, LOGRAMI, and Fédérations départementales de pêche), Office Français Pour la Biodiversité, DREAL Centre et DREAL Pays de Loire	**River fragmentation.** - Downstream and upstream hydropower upstream and in tributaries, irrigation, navigation, physical and chemical inputs from cities, dredging for navigation in the Estuary **Pollution** - Industry -Agriculture - Waste water (medicine) **Habitat destruction** - Sand extraction - Wetland Reclamation **Alien species introduction**: Giant Catfish, Bivalves, Plants, fish, crayfish **Fishery mortality**	

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CS name	Species supporting ES	human activities supported by ES	Ecosystem services already assessed – before DIADES (ecological and/or economic, theoretical/application)	Stakeholder group involved (NGOs, administration, fishers, scientific, …)	trade-offs between ES related activities and other activities using the same habitats (e.g. environmental impacts affecting the ES)	New opportunities. Any research-policy-practice link?
Waterford Harbour –	Atlantic salmon, Sea trout, European eel, Twaite shad, Sea lamprey, River lamprey, European smelt, Thin-lipped grey mullet	Former commercial fisheries now stopped due to regulations (Salmo salar; Anguilla anguilla) (peak of 4071 salmon landed in2013, value € 247,313.25) (peak of eel landed 2007 10,323kg). Small-scale commercial fishery flounder and mullet (landings to Dunmore East average per year flounder € 122; combined, Liza ramada and Chelon labrosus € 108). Restricted artisanal fishing (snap netting for salmon), Recreational fishing (angling) (Alosa spp; Liza ramada; Salmo salar, Salmo trutta; other species may be caught by recreational anglers but not targeted by specialists e.g. Anguilla anguilla). Water sports and riverside trails. Education and symbolic cultural importance also supported by species.			Thermal power station 464MW Great Island Clean Cycle Gas Turbine (CCGT) Commercial port (2016 Lo-Lo 43,240 teu & 1,0M tonnes) Regular maintenance dredging of shipping lanes Commercial fishing port Recreational angling venue – shore (and boat) Tourism/boating – cruisers/kayaking etc Agriculture (abstraction/pollution) Domestic treated effluent	
Rivers Tamar, Frome & Taff, UK	Atlantic salmon, Sea trout, Allis shad, European smelt, European eel, Sea Lamprey	Former commercial fisheries (Salmo salar; Anguilla anguilla). Salmon using traditional methods. Small-scale commercial landings mullet (spp unknown) and flounder (Tamar and Frome only). Recreational fishery for Salmo salar, Salmo trutta; other species may be caught by recreational anglers but not targeted by specialists (mullet, flounder and eel)			Pollution (rural and urban) including sediment and chemicals Channel modification/habitat loss Physical barriers Abstraction	
River Minho	European eel, Atlantic salmon, Sea trout, Allis shad, Twaite shad, Thin-lipped grey mullet, European flounder	Commercial fishing Sport fishing Food trade (restaurants)		Capitania porto, Caminha, DGRM, ICNF, Fishermen Associations, CIIMAR-UP, Aquamuseu do Rio Minho, Comandancia Naval Miño, Dirección Geral Patrimonio, Natural, Consellería do Mar, USC	River fragmentation (dams) Exotic species introduction Pollution Illegal fishing	

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CS name	Species supporting ES	human activities supported by ES	Ecosystem services already assessed – before DIADES (ecological and/or economic, theoretical/application)	Stakeholder group involved (NGOs, administration, fishers, scientific, …)	trade-offs between ES related activities and other activities using the same habitats (e.g. environmental impacts affecting the ES)	New opportunities. Any research-policy-practice link?
Norman Breton Gulf rivers	Frémur : European eel, Sélune: European eel, Atlantic salmon, Sea trout, European flounder, Sea lamprey, River lamprey, Thin-lipped grey mullet.	Sport fishing River restoration Scientific studies. A major restoration project of the Sélune (destruction of 2 dams) to restore the diadromous populations		Electricity board (EDF), Drinkable water supply companies, Local collectivities, Departments, Region, Scientists (MNHN, OFB), Ecosystem Management authorities (DREAL, DDTM)	River fragmentation (Dams, for hydroelectricity; freshwater supply, leisure); pollutant inputs by agriculture. Alien species introduction (Catfish, crayfish)	

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IV. JOINT DATABASE

Ecosystem services provided by diadromous species in Atlantic area: data collection and challenges linked to it. The EU Atlantic Area´s (AA´s) rivers support diadromous populations which provide numerous benefits to society through what we known as ecosystem services (ES). The ES benefits provide value from uses such as fish sold as food and, values that do not relate to current or future uses, such as maintaining a resource for future generations or cultural importance. In this research, developed under the framework of the INTERREG Atlantic Area DiadES Project, ES linked to diadromous species are identified (work package 4) through reviewing existing evidence and considering ES provided in a set of case studies across the AA (from Gipuzkoa rivers in Spain, Loire and Mondego rivers in France and Portugal, to Rivers Tamar, Frome & Taff in UK). This Action 3 under work package 6 deals with the main challenges encountered in the cited case studies when trying to operationalize a common monetary assessment of the ES, that is, the difficulty of getting data. Main problems could be related to data inaccessibility or lack of empirical evidence given the lack of time-series of socioeconomic data. This research will finally identify which economic data is available for each ES across species and case studies.

10. Main challenges

To explore the socioeconomic data availability needed to develop the ES monetary assessment, we organized personal interviews with each of the case-study leaders. The information needed from each case study broadly focused on a set of indicators identified in the next section.

Before identifying the data-collection needs and data availability, it is important to point out the challenges arising with respect to the data collection for the valuation of diadromous species. We follow the approach of Drakou et. al. (2018) who already identified key data related challenges:

- **Knowledge gap**:
  (i) On how it is the river and marine ecosystem components functioning and interactions. A lack of scientific expertise and modelled data results to be a very common gap across the case studies in the AA. And therefore, this important gap limits the possibility of providing assessment of the regulating ES, except for the nutrient cycling ES for shad species. In this latter case, a biological model is being developed covering this diadromous species across all case studies.
  (ii) Also, in general, it is difficult to overcome the understanding problem surrounding both the regulating and cultural ES. Stakeholders find difficult to understand the intermediate regulating ES, and also, the cultural ones not based on real markets (i.e., spiritual experience).

- **Lack of data gap.** In general, the lack of both modelled and empirical data for each case study makes it difficult to derive the expected values of provisioning and cultural ES. Data collection, like the one underpinning this project, often occurs sporadically and is part of on-going research project which has seldom continuity in time and/or location. However, for a high-quality ES assessment and valuation spatio-temporal data good quality are essential and therefore the lack of it is one of the main challenges. Moreover, data availability and quality differ highly between the indicator for each of the ES categories:

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- **Provisioning ES:** both, the temporal and the spatial scale are often missing for indicators such as the biomass/abundance of fish, catches or landings and, the costs of the commercial fisheries. Only for some of the diadromous species included in this research projects good spatial-temporal scale is available. For most of the others, however, it is often only possible to find, for example, catch data at particular times and places. It is even more difficult to find cost data for the commercial fishery. An economic data collection is needed to address these data gaps. However, it should be noted that this kind of survey faces its own challenges as existing data quality varies highly by species and case study and is also often driven by monitoring programmes in place (i.e. part of a legal requirement) and may not be in a format needed for this project.

- **Cultural ES:** Difficulties to access already existing indicator with regards to market and non-market values for certain cultural ES. The key difficulty is to implement non-market valuation methodologies and assessment due to the high level of human and economic resources needed.

11. Data needs

To select indicators/models helping in the ES valuation, firstly, a technical workshop was hold in Sukarrieta (Spain) in 2019. Secondly, a set of interviews with case studies leaders were conducted.

The main criterion in selecting the respective indicator was *measurability*. In addition, other criteria emphasized by Hattam et. al. (2015)[16] were considered, such as (1) *sensitivity,* i.e. can the indicators detect changes of the ES level over time, (2) *specificity*, i.e. is the indicator able to reveal responses of the ES to local changes in management over time as opposed to natural variability, (3) *scalability*, i.e. can the indicator be aggregated or disaggregated to a different scale, and (4) *transferability*, i.e. is the indicator a good measure on more than one location.

Table 4 summarizes the data needed for ES valuation of the ES identified for each of the respective species and cases. In Table 4, the information about each diadromous species is not reported to allow a simplified and easier to understand display of the ES provided by each species in each case study. All the specified indicators will be assessed respectively following the same approach in all case studies across the AA.

[16] Hattam C., Atkins J.P., Beaumont N., Börger T., Böhnke-Henrichs A., Burdon D., de Groot R., Hoefnagel E., Nunes P.ALD., Piwowarczyk J., Sastre S., Austen M.C. (2015) Marine ecosystem services: Linking indicators to their classification. Ecological Indicators49: 61-75. https://doi.org/10.1016/j.ecolind.2014.09.026.

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Table 4. *Data (variables, indicators, models) required to estimate monetary values of the ES provided by diadromous species*

ES identification				Data needed for each ecosystem services
ES classification	**CICES 5.1 Division/group/class**	**ES**	**Nb.**	
Provisioning services	**Biomass** (wild animals and their outputs)	**Food provision**	1	- *1.1Biomass or abundance of fish (from biological model)* - *1.2 Estimated harvest based on abundance of fish* - 1.3 Market prices *(first sales prices) – catch and/or prices* - *1.4 Cost information on the commercial diadromous fisheries (fixed/variables costs)* - 1.5 Others: *Input-output general models:* multiplier effects *for the catchment areas* - 1.6 Others*:* Social vulnerability Index (SVI) - 1.7 Other: descriptor indicators such as: number of jobs, licences
		Option value (food provision)	2	- 2.1 Similar information as cited for food provision - 2.2 Others: variables needed to apply an option value model (interest rate, first level prices trend and volatility parameters, ...)
		Leather provision	3	- *Knowledge gap exists. Insufficient information exists to estimate any indicator, variable and to apply any option value model.*
		Option value (molecules provision)	4	
Cultural services	**Physical and experiential interactions with natural environment** **Intellectual and representative interactions with natural environment**	**Recreation sport fishing**	5	- 5.1 Total expenditure needed to develop the recreational fishery (for each species). In some cases, more than one species is part of the same recreational fishery - 5.2 Others: *Input-output general models:* multiplier effects - 5.3 Willingness to Pay (WTP) (travel cost methodology to be applied). - 5.4 Proxies: rent or purchase of permits before recreational fishing – sale of fishing licences, number boats, employment - 5.5 Elasticity of prices or effort when possible
		Sport fishing competitions	6	- 6.1Total expenditure based on market values
	Spiritual, symbolic and other interactions with natural environment	**Spiritual experience (including emotional benefits**	7	- 7.1Willingness to Pay (WTP)
	Intellectual and representative interactions with natural environment – Characteristics of living systems that are resonant in terms of culture or heritage	**Gastronomy around species and emotional brotherhood**	8	- 8.1/9.1/10.1Market values for Gastronomy: - 8.2/9.2/10.2Retail prices at restaurants 8.3/9.3/10.3Quantity (Kg) sold at restaurants - 8.4/9.4/10.4Number of gastronomic festival or events - 8.5/9.5/10.5Number of people attending/participants the festival or events - 8.6/9.6/10.6Expenditure related to the festival or event - 8.7/9.7/10.7Number of representations of Art and folklore - 8.8/9.8/10.8 Others: *Input-output general models:* multiplier effects
		Gastronomic festival or events	9	
		Art and folklore	10	
		Local identity art benefits (songs, literature, painting, city emblems…)	11	- 11.1 Descriptor indicators: number of songs, painting, city emblems - 11.2Analytical hierarchy process (AHP)
Cultural		**Traditional know-how,**	12	- 12.1Descriptor indicators: number of traditional know-how representations - 12.2Analytical hierarchy process (AHP)

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ES identification				Data needed for each ecosystem services
ES classification	**CICES 5.1 Division/group/class**	**ES**	**Nb.**	
services	**Characteristics or features of living systems that have an existence value**	**Natural heritage and natural diversity – the existence value**	13	- 13.1Willingness to Pay (WTP)
	Characteristics of living systems that enable scientific investigation or the creation of traditional ecological knowledge **Characteristics of living systems that enable education and training**	**The potential for environmental education and research**	14	- *14.1Publicly available data on public project financed on diadromous* - *14.2Publicly available data on environmental education action costs* - *14.3Private cost on different environmental education actions* - *14.4Other descriptor indicators such as: the number of beneficiaries/participants from the environmental education actions*
Regulating services	**Food web control**		15	- *Knowledge gap exists. Insufficient information exists to estimate any indicator, variable and to apply any option value model.*
	Redistribution of fluxes, nutrient regulation (i.e. energy and matter, upstream, downstream inputs,)		16	- *16.1A replacement cost approach will be used (estimating the cost of replacing the provide services).* - *Nutrients transportation (amount of net imported nutrient – nitrogen…)* - *General prices of fertiliser (nitrogen-based fertiliser, …) or alternatively, energy prices*
	Biological cycle (i.e. other species biological cycle participation)		17	- *Knowledge gap exists. Insufficient information exists to estimate any indicator, variable and to apply any option value model.*
			18	- *Knowledge gap exists. Insufficient information exists to estimate any indicator, variable and to apply any option value model.*
	Habitat formation		19	- *Knowledge gap exists. Insufficient information exists to estimate any indicator, variable and to apply any option value model.*
	Sediment formation		20	- *Knowledge gap exists. Insufficient information exists to estimate any indicator, variable and to apply any option value model.*

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12. Data collected

Table 5. Ecosystem Services from diadromous species across AA cases: grey - no quantification is available, green - data available to provide monetary (or non-monetary) assessment, orange: uncertainty concerning the possibility of getting any assessment

ES identification				Species		Case Studies Atlantic Area								
MEA classification	CICES 5.1 Division/group/class	ES (expert knowledge)	Nb.	Diadromous species	Nb.	Ulla catchment	Gipuzkoa rivers	Minho catchment	Mondego catchment	Gironde/Garonne/ Dordogne system	Loire catchment	Normand-Breton Bay/Gulf	Tamar (T), Frome (F) and Taff (Ta) rivers	Waterford harbour and the three sisters' rivers
						8	1	2	3	4	5	6	7	9
Provisioning services	**Biomass** (wild animals and their outputs)	**Food provision**	1	Allis shad	1a			1.3 catch and market prices	1.3 catch and market prices	1.3, 1.5, 1.7	1.3, 1.7			
				Twaite shad	1b									
				Sea lamprey	2a	1.3 catch and market prices		1.3 catch and market prices	1.3 catch and market prices	1.3, 1.5, 1.7	1.3,, 1.7			
				River lamprey	2b						X			
				European eel	3	1.3 catch and market prices		1.3 catch and market prices		1.3, 1.5, 1.7	1.1, 1.2, 1.3, 1.7	1.1	(T, F, Ta) 1.3 (catch), 1.7 (licences number)	
				Atlantic salmon	4			1.3 catch and market prices				1.1, 1.2	(T, F)* 1.3 (catch weight, number), 1.7 (licences number)	
				Sea trout	5							1.1	(T,F)* 1.7 (licences number)	
				European sturgeon	6									
				Thin-lipped grey mullet	7						1.3, 1.7		(T) 1.3 (catch weight)	combined as 'mullet' with other species. No spatial detail of catch inside estuary
				European smelt	8									
				European flounder	9	1.3 catch and market prices		1.3 catch and market prices		1.3, 1.5, 1.7			(T) 1.3 (catch weight)	no spatial detail of catch inside / outside estuary
		Option value (food provision)	2	Thin-lipped grey mullet	7									

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ES identification				Species		Case Studies Atlantic Area								
MEA classification	CICES 5.1 Division/group/class	ES (expert knowledge)	Nb.	Diadromous species	Nb.	Ulla catchment	Gipuzkoa rivers	Minho catchment	Mondego catchment	Gironde/Garonne/ Dordogne system	Loire catchment	Normand-Breton Bay/Gulf	Tamar (T), Frome (F) and Taff (Ta) rivers	Waterford harbour and the three sisters' rivers
		Option value (Leather provision)	3											
		Option value (molecules provision)	4	Sea lamprey	2a									
Cultural services	Physical and experiential interactions with natural environment Intellectual and representative interactions with natural environment	Recreation sport fishing	5	Allis shad	1a			survey						
				Twaite shad	1b			survey		2.1, 2.2				
				Sea lamprey	2a									
				River lamprey	2b									
				European eel	3		1.3 (catch and market prices), 5.1. expenditure, 5.2, 5.3 and 5.4 (number of fishers, licences)							
				Atlantic salmon	4			survey					(T, F, Ta)	
				Sea trout	5		not relevant	survey	survey 5.4 number of licences				(T, F, Ta)	Recreational angling survey
				European sturgeon	6									
				Thin-lipped grey mullet	7		not relevant							Recreational angling survey
				European flounder	9		not relevant							Recreational angling survey
				Other species	---									
		Sport fishing competitions	6	Atlantic salmon	4								Ta	
				Sea trout	5								Ta	
		Option value (fishing competitions)	7	European flounder	9								T, F	
	Spiritual, symbolic, and other interactions with natural environment	Spiritual experience (including emotional benefits	8	European eel	3									
				Alll species										Shad.
	Intellectual and representative interactions			Allis shad	1a									

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ES identification				Species		Case Studies Atlantic Area								
MEA classification	CICES 5.1 Division/group/class	ES (expert knowledge)	Nb.	Diadromous species	Nb.	Ulla catchment	Gipuzkoa rivers	Minho catchment	Mondego catchment	Gironde/Garonne/ Dordogne system	Loire catchment	Normand-Breton Bay/Gulf	Tamar (T), Frome (F) and Taff (Ta) rivers	Waterford harbour and the three sisters' rivers
Cultural services	with natural environment – Characteristics of living systems that are resonant in terms of culture or heritage	Gastronomy around species and emotional brotherhood	9	Twaite shad	1b									
				Sea lamprey	2a				X 9.4					
				River lamprey	2b									
				European eel	3		imports		X 9.4					
				Atlantic salmon	4									
		Gastronomic festival or events	10	Allis shad	1a					8.1				
				Twaite shad	1b									
				Sea lamprey	2a	9.1, 9.2, 9.4. 9.5, 9.6, 9.8		9.5, 9.6, maybe imports						
				European eel	3	9.1, 9.2, 9.4. 9.5, 9.6, 9.8								
				European flounder	9	9.1, 9.2, 9.4. 9.5, 9.6, 9.8								
		Art and folklore	11	Allis shad	1a								T	
				Sea lamprey	2a									
				Atlantic salmon	4									
				European Smelt	8								T	
		Local identity art benefits (songs, literature, painting, city emblems…)	12	Allis shad	1a			Cultural heritage Survey						
				Twaite shad	1b			Cultural heritage Survey						
				Atlantic salmon	4			Cultural heritage Survey						
				Sea lamprey	2a			Cultural heritage Survey	11.1					
				European sturgeon	6					potential survey				
			13	Sea lamprey	2a	potential survey								

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ES identification				Species		Case Studies Atlantic Area								
MEA classification	CICES 5.1 Division/group/class	ES (expert knowledge)	Nb.	Diadromous species	Nb.	Ulla catchment	Gipuzkoa rivers	Minho catchment	Mondego catchment	Gironde/Garonne/ Dordogne system	Loire catchment	Normand-Breton Bay/Gulf	Tamar (T), Frome (F) and Taff (Ta) rivers	Waterford harbour and the three sisters' rivers
		Traditional know-how,		European eel	3	potential survey	X potential survey			potential survey				
				Atlantic salmon	4								X(T, F)	
				Sea trout	5								X(F)	
				Diadromous species	--								Potential survey (mullet)	
	Characteristics or features of living systems that have an existence value	Natural heritage and natural diversity – the existence value	14	Allis shad	1a									
				Twaite shad	1b									
				Sea lamprey	2a									
				European eel	33									
				Thin-lipped grey mullet	7									
				All species (full assemblage of fishes)	----					potential survey			(T,F,Ta)	
	Characteristics of living systems that enable scientific investigation or the creation of traditional ecological knowledge Characteristics of living systems that enable education and training	The potential for environmental education and research	15	Allis shad	1a					14.2			(T)	
				Twaite shad	1b									
				Sea lamprey	2a									
				European eel	3		14.1, 14.2, 14.3						(T,F,Ta)	
				Atlantic salmon	4		14.1, 14.2, 14.3						(T,F,Ta)	
				Sea trout	5								(T,F)	
				Thin-lipped grey mullet	7									
Regulating and Supporting services	Food web control		16	European eel	3								(T,F,Ta)	
				Atlantic salmon	4								(T,F,Ta)	
	Redistribution of fluxes, nutrient regulation (i.e. energy and matter, upstream, downstream inputs,)		17	Allis shad	1a	16.1								
				Twaite shad	1b									
				Sea lamprey	2a								(T,F,Ta)	
				European eel	3								(T,F,Ta)	
				Atlantic salmon	4								(T,F,Ta)	
				Sea trout	5								(T,F,Ta)	

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ES identification				Species		Case Studies Atlantic Area								
MEA classification	CICES 5.1 Division/group/class	ES (expert knowledge)	Nb.	Diadromous species	Nb.	Ulla catchment	Gipuzkoa rivers	Minho catchment	Mondego catchment	Gironde/Garonne/ Dordogne system	Loire catchment	Normand-Breton Bay/Gulf	Tamar (T), Frome (F) and Taff (Ta) rivers	Waterford harbour and the three sisters' rivers
				Thin-lipped grey mullet	7									
				European smelt	8								(T)	
				European flounder	9									
	Biological cycle (i.e. other species biological cycle participation)		18	Allis shad	1a								X(T)	
				Twaite shad	1b									
				Sea Lamprey	2a								X (T,F,Ta)	
				European eel	3								X (T,F,Ta)	
				Atlantic salmon	4								X (T,F,Ta)	
				Sea trout	5								X (T,F,Ta)	
				Thin-lipped grey mullet	7				X					
				European Smelt	8								X(T)	
	Sediment turnover and formation		19	Sea lamprey	2a								X (T,F,Ta)	
				River lamprey	2b								X (T,F,Ta)	
				Atlantic salmon	4								X (T,F,Ta)	
				Sea trout	5								X (T,F,Ta)	

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