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Sustainable development and responsible exploitation. As an example, the management and exploitation of diadromous species in the context of small-scale fisheries

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Abstract: The sustainable development policy is a negotiation process among actors. Some are strong, others weak or absent. Some are directly concerned for their social and economic future by the productivity of the natural environment while others not. Some are never present at the negotiation table such as future generations and Nature itself. The Precautionary principle is included in the French Constitutionality Corpus in 2005 but, with some modifications. In particular, the notions of "economically bearable cost" and "effective and proportionate measures" have been added. In that context, the sustainable exploitation of aquatic living resources is more and more difficult to achieve in accordance with the Maximum Sustainable Yield, the level of which continues to decline with the degradation of continental, estuarine and coastal environment under the pressure of many anthropogenic factors. It is the reason why the fisher communities prefer to speak about 'responsible exploitation' rather than 'sustainable exploitation'. A more socio-ecosystem-based approach is needed. This is possible at the local scale for implementation of a genuine environmental governance, (fourth sustainable development component) and to take into account a fifth component which is Culture in the sense of knowledge and know-hows as the expression of intergenerational solidarity.

Keywords : *sustainable development, responsible exploitation, small scale fisheries, diadromous fishes*

1. Introduction

Sustainable development has been primarily defined in a report of the World Commission for Environment and Development (WCED): Our Common Future (WCED, 1987). The well-known diagram of that concept appeared in 1987

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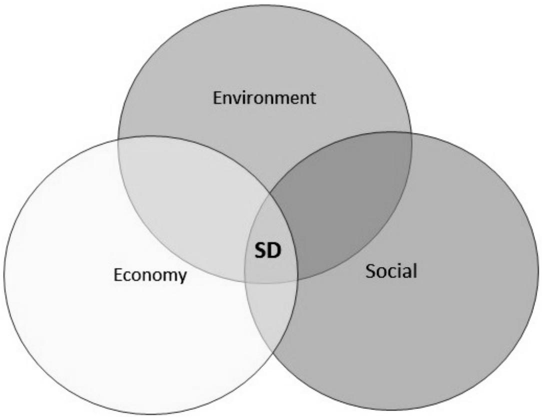

Fig. 1 Diagram of sustainable development (SD) after WCED (1987).

(Fig. 1) and placed sustainable development at the convergence of three areas of equal interest: economy, social and environment.

Responsible exploitation of fisheries resources is a term occasionally used in the academic literature. Scientists, managers and NGOs prefer the term "sustainable exploitation" referring to a fishery biology indicator used by the scientific community and called "the Maximum Sustainable Yield" (GRAHAM, 1935; RICKER, 1954, 1975). The community of fishers prefers to use the term "responsible exploitation" as the sustainability of a given commercial activity based on the productivity of natural environment is a complicated concept that depends on a large diversity of factors, most of these factors are not under the fishers control (BOGASSON, pers. com., 2009; PROUZET, 2010; PROUZET *et al.*, 2019). In fact, the sustainability of their fishing activity is largely driven by the productivity of the aquatic environment (habitat quality and ecological connectivity) constrained by natural and anthropogenic pressures.

In this communication, through the example of diadromous species and more widely of small-scale fisheries, we will show the non-efficiency of sectoral policies in the implementation of the sustainable development as defined by the WCED and the need to implement a more systemic approach at a territorial or local scale as mentioned by the Millennium Assessment (REID *et al.*, 2005). In that socio-ecosystem approach, responsible exploitation and traditional knowledge and know-hows of fishers communities are of particular importance to develop environmental watch, capacity building to observe the trend of aquatic populations and awareness-raising activities in connection with scientists, managers and NGOs. It matches with the foundation of the "Satoumi concept" developed in Japan (YANAGI, 2020; TANAKA and FURUKAWA, 2020; KOMATSU *et al.*, 2020) and the aim of the "Nature and Culture" project defined by the French-Japanese Oceanographic Societies of France and Japan in cooperation with national committees of professional fishers and shellfish farmers. (http://socfjp.com/en/french-japanese-society-of-oceanography/).

2. A genuine sustainable development

The definition of a sustainable development policy is a negotiation among actors characterized by different social and economical status that use the goods and services of the environment. Some are strong, others weak or even absent such as future generations or the Nature itself. In 1995, the Barnier Law (Loi n° 95-101 du 2 février 1995 dite loi Barnier) incorporated in the French legislation, three key principles: the Precautionary principle, the Prevention principle and the Polluter-pay principle. But the text of the Precautionary principle agreed by the French legislator has been somewhat modified from the original definition adopted in the 1992 Earth Summit. In particular, the notions of "economically bearable cost" and "effective and proportionate measures" have been added. On 2

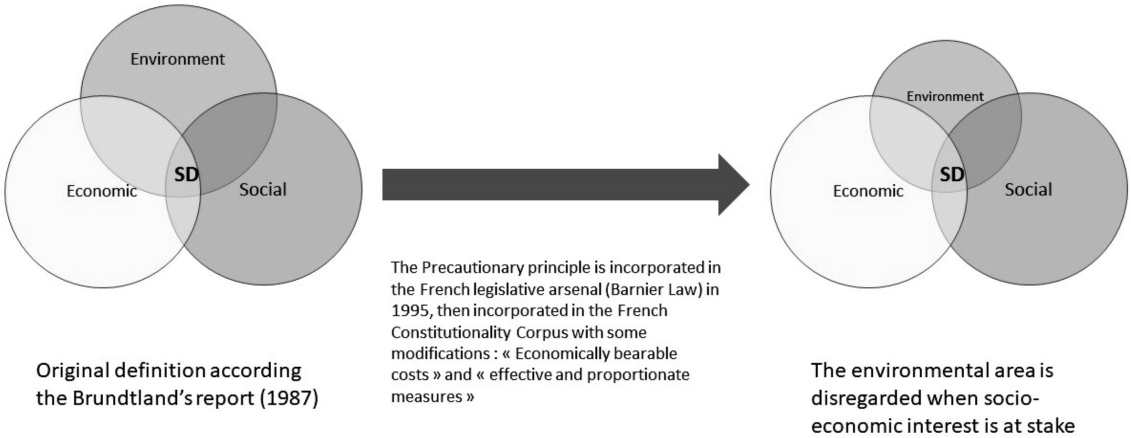

Fig. 2 Shift from balanced to socio-economically centred negotiation (source: PROUZET, 2021).

September 2002, the French President Chirac said to the plenary assembly of the fourth Earth Summit at Johannesburg: "our house is burning and we are looking elsewhere". In 2005, the Precautionary principle is included with the Charter for the Environment in the French Constitutionality Corpus in order to have an equality of treatment with the fundamental 1789 human and civil rights and with the 1946 economic and social rights (LAQUIÈZE, 2012). Despite the inclusion of the Precautionary principle in the French Constitutionality Corpus, it is important to recognize at present the unbalance between environmental and socio-economical needs. Fig. 2 is a schematic description of how sustainable development is considered today: the environmental sphere is disregarded when socio-economic interest is at stake and the balance between the three sustainable development components -economic, social and environmental- is not respected.

In negotiating the definition and implementation of sustainable development policy, weak actors such as communities of professional fishers or fish and shellfish farmers, are usually dependent on the productivity of aquatic environment for their own survival. For hydropower producers or farmers, only the quantity of water available is important, but not its quality. Estuary channelization, protections against floods and rising sea level for urban and tourism development, result in the destruction of functional habitats for many terrestrial or aquatic species (FUSTEC and LEFEUVRE, 2000; ADAM *et al.*, 2008; LE PAPE *et al.*, 2003a; PROUZET, 2010; LE LUHERNE *et al.*, 2016). Many fish species have their spawning and/or their nursery areas in coastal, transition ad continental waters (LE PAPE *et al.*, 2003b; Halpern *et al.*, 2008; ROCHETTE *et al.*, 2010; PROUZET and MICHELET, 2019; FEUNTEUN and PROUZET, 2020) and that destruction has a direct impact on the productivity of fish communities. A mere regulation of fishing without the protection and restoration of degraded or depleted habitats, cannot lead to the sustainability of this age-old activity (PROUZET *et al.*, 2019).

An assessment of this sustainable development policy at a large scale shows that environmental protection objectives are far from being achieved and this is not only due to climate change. In France but also in Europe, since the second half of the 20th century, the organic

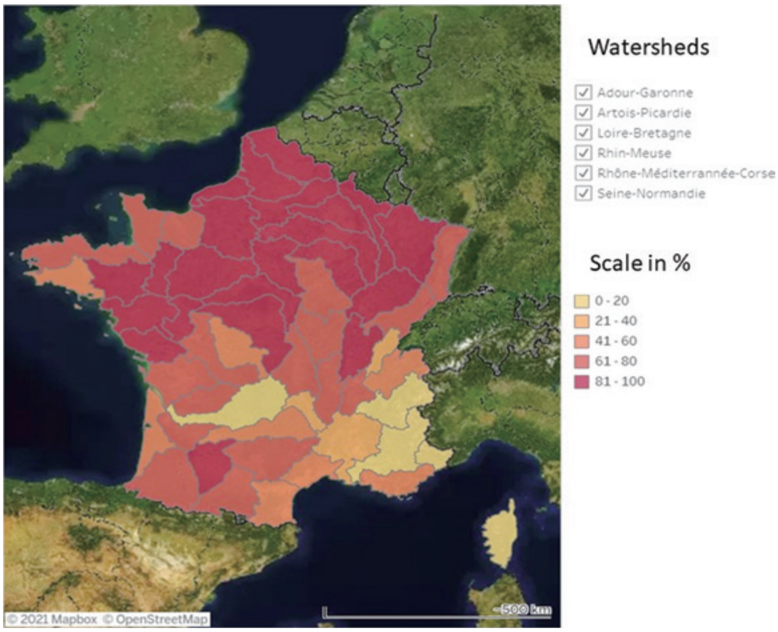

Fig. 3 Level of the ecotoxicity risk index by watershed on the period from 2015 to 2017 (source: http://www.eaufrance.fr/).

pollution is aggravated by the increasing production and use of synthetic chemical products (RABIC *et al.*, 2009; TCHILIAN, 2009). Around 100,000 chemicals are produced, imported and used in the European market and 5,000 of them (5%) are considered dangerous for humans and the natural environment (LOIZEAU and TUSSEAU-VUILLEMIN, 2014; PETIT *et al.*, 2014). France is one of the largest consumers of pesticides in the world, namely, the third country in the world in 2003, with 100,000 t of which 90% was used for agriculture. So, the current water quality assessment is not encouraging. As mentioned in a report of the French Senate (ANONYMOUS, 2003), we can find in freshwater some very high concentrations of phytosanitary products one hundred times higher than the standard for drinking water. In France between 20 and 40% of water masses are in poor chemical status (STAUB, 2021). Fig. 3 shows the ecotoxicity risk index at watershed level. This index indicates a ratio of the substance concentration on its concentration without foreseeable effect on the environment. The larger the number and higher than 1, the higher the risk to the environment. This index does not take into account the cocktail effect of the chemical substances.

Fig. 3 shows the percentage of samples with an index higher than 1 for the different watersheds. We can notice the predominance of dark colours with a level greater than 60% indicating a high risk of ecotoxicity on a great number of watersheds. At a larger scale in Europe, it is the same situation. In 2018, according to the European Environment Agency (EEA) only 40% of the European rivers achieve a good ecological status and 38%, a good chemical status. The objective of the Water Framework Directive (WFD) was to reach the good state of the European water masses by 2015. It is far from being achieved in 2021, shifting the new target to 2027.

Along with the deterioration of the quality of continental water masses, the damage inflicted on functional habitats of aquatic species and ecological connectivity between varied ecosystems, hinder the proper functioning of the life cycle of aquatic species. In 1994, the Bernard report (BERNARD, 1994) mentioned that 2/3 of wetlands in France have disappeared during the last century. The definition of wetlands, here, is given by TURNER (1992): "Any element of the continuum connecting the aquatic environment to the terrestrial environment". These natural ecosystems are not only important for the regulation of river flow or filtration of organic or chemical substances (FUSTEC and LEFEUVRE, 2000), but also for the completion of the life cycle of endangered species such as the European eel (*Anguilla anguilla*) (FEUNTEUN and PROUZET, 2020). Such wetlands loss is a general fact in Europe and even in the World (TURNER, 1992; FUSTEC and LEFEUVRE, 2000, BERNARD, 1994). In addition, many estuaries have been channelized in France and in Europe. For example, the Seine estuary, before 1846, had a marshland area of 250 km^2, the channelization of the estuary, the urbanisation and industrialisation of its banks have reduced the area to 30 km^2, resulting in an irreversible loss of very important habitats for many marine species in the Channel (LE PAPE *et al.*, 2003; LE LUHERNE *et al.*, 2016). LEFEUVRE (1985) and LEFEUVRE *et al.* (2000) indicated that the natural banks of the Loire River have been reduced by channelling and urbanization from 300 to 30 km^2. In Brittany (north western part of France), 65% of the salt marshes have disappeared in less than 50 years by land draining, dyking and land reclamation (PONCET, 1984). The lost of an important part of these wetlands have a direct impact on the productivity of marine and continental aquatic ecosystems. TEAL (1962) showed that 45% of the organic matter produced in the saltmarshes were exported to coastal waters. ODUM (1980) confirms Teal's work and shows that salt marshes are the source of the wealth of coastal marine waters. According to DUGAN (1992), 2/3 of the fish consumed in the World spent part of their life cycle in wetlands.

The edification of many big dams on the rivers since, at least, the beginning of the 20th century has led to the fragmentation of ecosystems and the hindrance of the free movement of migratory fishes: salmon (*Salmo salar*), sea trout (*Salmo trutta*), twaite shad (*Alosa fallax*), allis shad (*Alosa alosa*), European eel (*Anguilla anguilla*), sea lamprey (*Petromyzon marinus*) (PROUZET and MICHELET, 2019; FEUNTEUN and PROUZET, 2020). The improvement of ecological connectivity takes times, costs a lot of money and France, like many countries in Europe that have artificialized their rivers mainly for hydroelectric needs or for water supply, has not achieved the objectives it had set for the restoration of hydrological and ecological balances. Thus, the report of the French National Assembly (ANONYMOUS, 2016) is clear: "France has not given itself the means to achieve its ambition". It was not until the transposition of the Water Framework Directive (WFD-D/2000/60/CE) into French law in 2006 that ecological continuity was really taken into account. Despite this, improvements are slow and in order to achieve the objectives set under the WFD (good status of water bodies) in 2020, the rate of equipment to improve migratory transparency of the remaining 15,000 dams would have to be six times higher than that previously adopted. This is unfortunately not the case. In 2018, the French National Plan for Eel (in the framework of the Council regulation 1100/2007) mentioned that only 19.6% of barriers located on eel critical habitats had been equipped with fish ladders

(ANONYMOUS, 2018). This lack of lateral and longitudinal ecological continuity is a major hindrance to the production of young eels in the lower and middle parts of the catchment areas, which then supply all the functional habitats of the species by diffusion or active migration of young individuals (PROUZET *et al.*, 2019).

Considering the extent of the degradation of continental aquatic ecosystems and its impact on the quality of coastal waters, the objectives of good ecological status foreseen in Marine Strategy Framework Directive (D/2008/56/CE) by 2020 could not be achieved. In 2015, just over 50% of the 179 coastal water bodies are in good or very good ecological status (LESUEUR, 2019).

As already mentioned, the intensification in France, but also in many countries, of the migration of human populations and economic activities to coastal areas, and of protection against sea level rise, is leading to increased artificialisation and urbanisation of these areas to the expense of important marine species production areas (ANONYMOUS, 2014).

On the coasts, but also in all the seas and oceans, there are large amounts of plastic (estimated at 268,940 t for the number of fragments of 5,250 billion), 80% of which are land-based. However, these estimations made during the period 2007-2013, are underestimated given that global plastic production reached 288 million tonnes in 2012, i.e. 625% more than that produced in 1975. The plastic waste is dispersed in 5 main areas of accumulation found in the North and South Pacific Oceans; the North and South Atlantic Oceans and the Indian Ocean (ERIKSEN *et al.*, 2014). Much of these plastics come from the mismanagement of urban waste, which was estimated to have been released into the environment between 5 and 13 million tonnes in 2010. If nothing is done, projections for 2025 could be between 50 and 130 million tonnes.

As plastic particles come in different sizes and are found in all marine ecosystems, they can carry invasive species or be ingested by various components of the food chain. Some absorbed compounds are bio-available and can be bio-accumulated with concentration levels of up to 100,000, which can lead to the contamination of many living resources (ROCHMAN, *et al.*, 2013).

If we add the effects of climate change to the anthropogenic pressures, we have many constraints on ecosystems (especially aquatic ones) and the goods and services that these ecosystems provide. The latest IPBES report (IPBES, 2019) lists the main factors influencing biodiversity loss at the global level. Climate change is an important pressure factor, but less than the effects of changes in the use of marine and terrestrial ecosystems or those caused by the direct exploitation of resources or, in certain environments, the effects of pollution.

In this context, we cannot have a sectoral approach that allows one use (agriculture, industry, urbanization) to make expenses of nature that jeopardize the future of uses that depend directly on the natural productivity of environment (case of small-scale fishing for example).

Hence the need for implementation of a sustainable development policy, to introduce into the negotiation process a fourth dimension which is that of environmental governance based on the principle of responsibility defined by Hans JONAS (1990): "to act in such a way that the effects of your action are compatible with the permanence of an authentically human life on earth". Its objective is to minimise the ecological footprints of different uses on the environment and not just those of the weakest actors (PROUZET *et al.*, 2019).

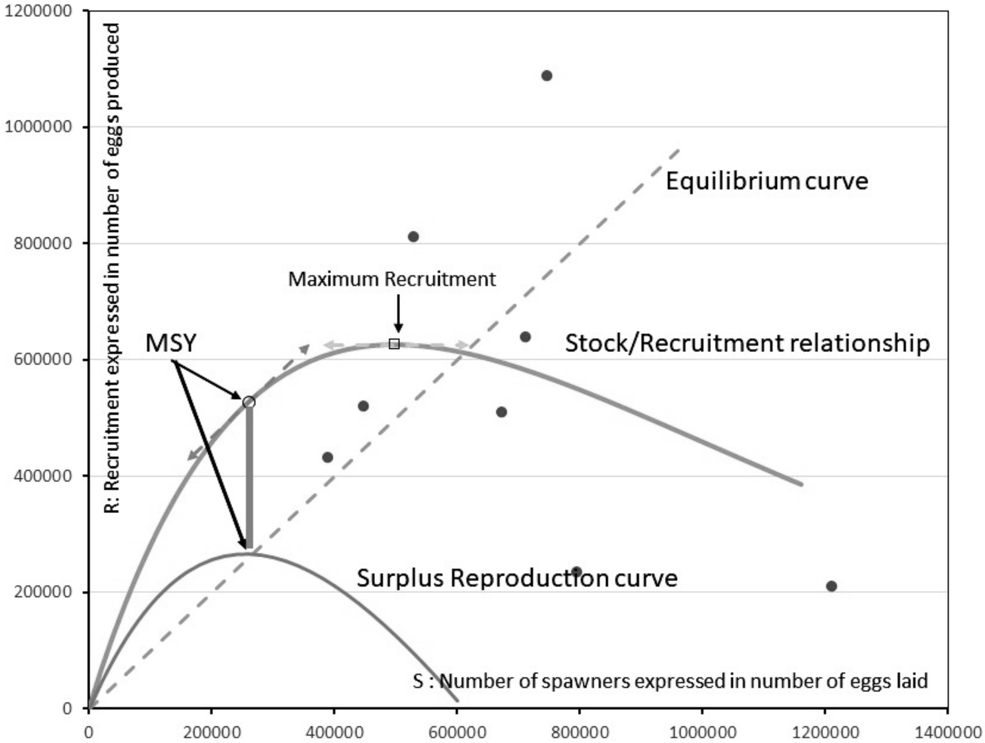

Fig. 4 Example of a Stock-Recruitment curve (S/R curve) and a Surplus Reproduction curve expressed according the RICKER's model showing the position of the MSY (Maximum Sustainable Yield) on the S/R curve corresponding to the maximum of the Surplus Reproduction Curve.

3. Sustainable versus responsible exploitation.

3.1. The Stock-Recruitment (S/R) relationship and the Maximum Sustainable Yield (MSY)

From a scientific point of view, a sustainable exploitation of fish resources is a fishing activity that respect a total amount of catch for a given species around the Maximum Sustainable Yield (MSY) defined by the S/R relationship.

From a schematic viewpoint, there exists two types of S/R relationships defined either by a dome-shaped curve (RICKER, 1954, 1975) or a plateau-shape (BEVERTON and HOLT, 1957). In most reports using this fish biology indicator, the MSY is defined according to a dome-shape relationship as mentioned in Fig. 4.

In that example drawn from Dumas' data (DUMAS and PROUZET, 2003), the observed values are in blue solid circle and expressed in number of salmon eggs. The S/R curve is estimated from a non-linear optimization procedure (PROUZET 2010) and the S/R equation is expressed as follows Eq. (1):

$$R=3.418\, S^{[-2.01\times 10^{-6}\times s]}, \tag{1}$$

where R and S are the number of eggs produced and the number of eggs laid by the salmon population of the Nivelle River (southwestern part of France) a given year, respectively.

So, the sustainable exploitation is to harvest in a sustainable manner from the population a maximum number of catches equal to the MSY. However, the level of the MSY depends on the shape of the *S/R* curve mainly defined by the carrying capacity of the environment (and especially for that type of *K*-population of the accessibility and quality of spawning and nursery areas) (MILLER *et al.*, 2015; RIGHTON *et al.*, 2021). Here, *K* is the optimised carrying capacity of the environment. In the original definition of the MSY given by Michael Graham (GRAHAM, 1935), the coordinates of MSY for equation $SY = \mathrm{f}\ (K)$, where SY and K are sustainable yield and carrying capacity (unfished stock biomass), respectively. Then, MSY is positioned at $x = K/2$ and $y = r * K/4$ where r is intrinsic population growth rate.

3.2. The MSY value depends mainly on the environmental productivity

To illustrate the importance of the productivity of the environment and the need for a less sectoral approach, we will take, as an example, the history and population dynamics of the salmon stock of the Adour-Gaves basin. The Atlantic salmon (*Salmo salar* L.) has been exploited by a professional fishery on this basin since very old times (CUENDE, 2003; PROUZET *et al.*, 2009; PROUZET, 2013). Accurate data on the characteristics of captured salmon, importance of catches and kind of fishing gears used have been recorded since the late 19^{th} century (CUENDE and PROUZET, 1992; MARTY and BOUSQUET, 2000; CUENDE, 2003; PROUZET *et al.*, 2009; PROUZET, 2013). The surface of spawning areas as well as smolt production areas and their variations during the end of the previous century have been estimated (SANTAL *et al.*, 2012) with a significant extension of the surface of spawning areas in the upstream course at the beginning of the 21^{st} century. Here, "smolt" means salmon juvenile ready to migrate at sea. On the Adour catchment, the downstream migration of juvenile salmon usually takes place in spring after one or two winters in the river. The egg survival under gravel was estimated from different salmon spawning grounds of the Adour-Gaves basin (DUMAS *et al.*, 2007; BARRACOU, 2007). The fry survival was evaluated in experimental streams (BEALL and MARTY, 1983) and estimated from eggs deposal and parr production in some different areas of the Gave d'Oloron catchment (BARRACOU, 2007). Fig. 5 shows that a part of the spawning areas located on the Gave d'Oloron watershed (downstream the town of Oloron Sainte-Marie) was and is still a poor-quality spawning area. This is also the case for another salmon tributary: the Saison (Fig. 5). However, since 2002 and after the opening to spawning grounds located upstream of Oloron Sainte-Marie on the Gave d'Aspe and Gave d'Ossau, it has been noted a tendency for salmon to spawn more upstream on better-quality areas (BARRACOU, 2007) (Fig. 6). This migration of spawners to areas further upstream where the permeability of spawning grounds is higher, results in a predominance of the juvenile production on the tributaries of the upper course of the Gave d'Oloron basin with, in addition, an increase in total juvenile production compared to the end of the 90s as shown in Fig. 7.

Salmon tagging on an index river: the Nivelle and characterization of the life cycle of the species have resulted in the development of a stochastic model, based on the RICKER model (RICKER, 1975), to simulate the fate of this population under various constraints: quality of spawning grounds impacting egg survival under gravel, surface of production areas influencing juvenile survival and population size, rate of return of salmon after their marine migration (DUMAS and PROUZET 2003, PROUZET 2010). All this knowledge has enabled this model to be

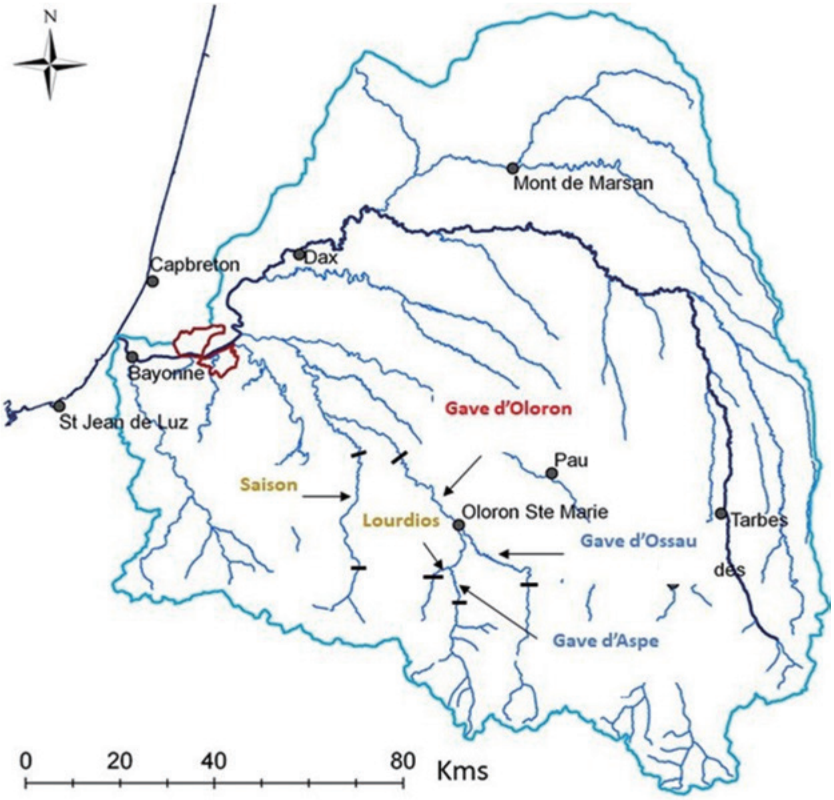

Fig. 5 Distribution of the spawning beds on the Gave d'Oloron catchment and its tributaries, main sub-catchment for the production of Atlantic salmon. The colour indicates the quality of the spawning area: poor quality in red; medium in yellow and good in blue (source: BARRACOU, 2007 and Migradour data).

adapted to the condition of the Adour-Gaves salmon stock and to simulate its fate under various constraints with 3 assumptions of survival rate of fry and migratory constraints with an initial state of abundance corresponding to an egg stock of 10,000,000 units (Table 1).

Case 1 corresponds to optimum quality spawning beds on the entire potential spawning areas; Case 2 is the situation that corresponded to that of the period 1970–1990 with spawning grounds of bad quality confined in the lower course of the Gave d'Oloron and its main tributaries; Case 3 is considered to be the current situation of the salmon population on the Adour-Gaves basin, with good quality spawning grounds in the upstream part (Gave d'Aspe and Gave d'Ossau) but of poor quality in the downstream part of the spawning area (downstream Oloron Sainte-Marie on the Gave d'Oloron).

Fig. 8. Ricker reproduction curves for the Atlantic Salmon population of the Adour-Gaves catchment according 3 scenarios defined in Table 1: Case 1; Case 2 and Case 3. The purple diamond shows the MSY (Maximum Sustainable Yield) for Case 2; the green square the MSY for Case 1 and the red circle, the MSY for case 3. The black circle indicates the starting point of the simulation for the 3 cases. The dispersion of

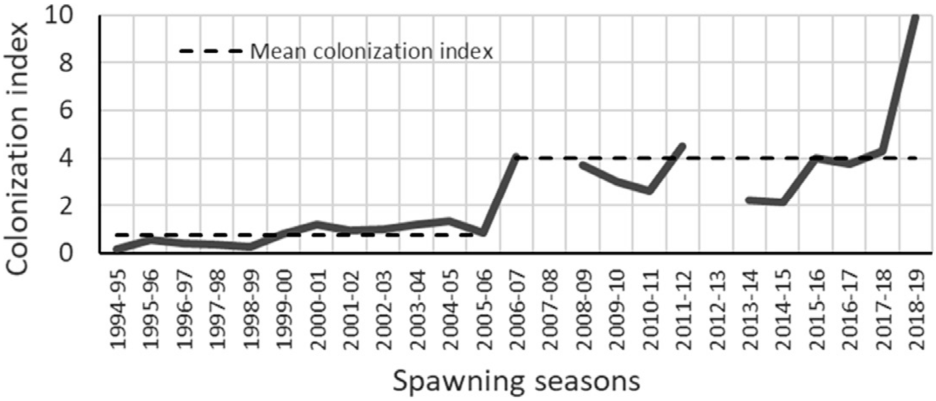

Fig. 6 Trend of the colonization index on the Gave d'Oloron watershed. The colonization index is the ratio of the number counted downstream Oloron Sainte-Marie on the number counted upstream (on the Gave d'Aspe and Gave d'Ossau) (source: Migradour data). More the ratio is high and more the spawning takes place in the upstream part.

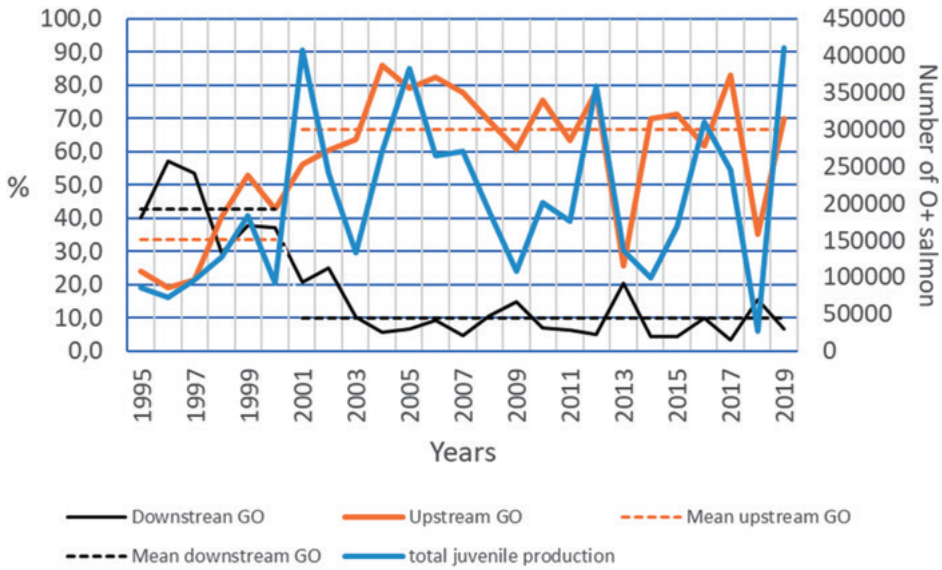

Fig. 7 Trends in % of the annual parr production on areas located downstream (black) and upstream (orange) the Gave d'Oloron (GO) watershed and in number of the total salmon parr (0 +) production (blue) during the period from 1995 to 2019 (source: Migradour data).

points along the reproduction curves is in black for the Case 2, in red for the Case 1 and in yellow for the Case 3.

The analysis of Fig. 8 and Table 2 provides many important considerations for the restoration and management of this salmon

Table 1 Main parameters used and their values for the 3 examples of simulation.

Main parameters	Case 1	Case 2	Case 3
Initial abundance in number of deposited eggs	10,000,000	10,000,000	10,000,000
Surface of juvenile production area in m^2	1,092,000	500,000	1,092,000
Average survival rate from eggs to 0 + parr in % (σ)	5.0 (2.0)	0.5 (0.25)	1.92 (0.98)
Rate of return of 1 SWF in % (σ)	5.5 (2)	5.5 (2)	5.5 (2)
Rate of return of 2 SWF in % (σ)	1.1 (0.3)	1.1 (0.3)	1.1 (0.3)
Rate of return of 3 SWF in % (σ)	0.5 (0.2)	0.5 (0.2)	0.5 (0.2)

1 SWF: One sea winter fish: 2 SWF: Two sea winter fish; 3 SWF : Three sea winter fish

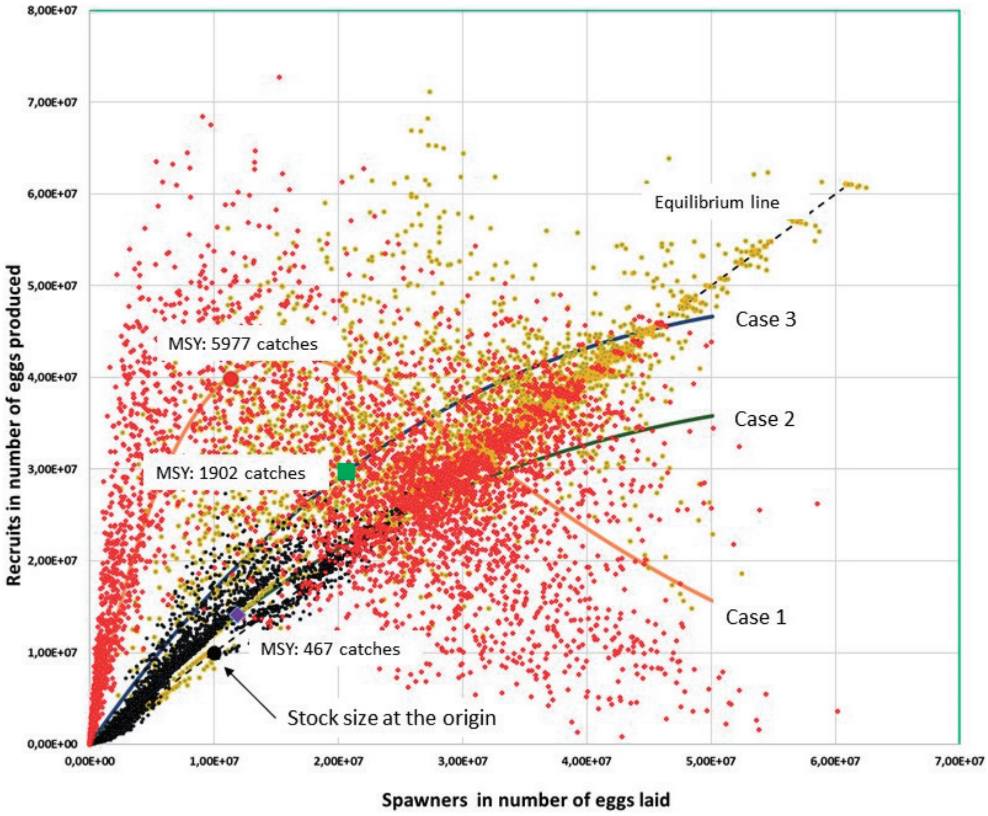

Fig. 8 RICKER reproduction curves for the Atlantic Salmon population of the Adour-Gaves catchment according 3 scenarios defined in Table 1: Case 1; Case 2 and Case 3. The purple diamond shows the MSY (Maximum Sustainable Yield) for Case 2; the green square the MSY for Case 1 and the red circle, the MSY for case 3. The black circle indicates the starting point of the simulation for the 3 cases. The dispersion of points along the reproduction curves is in black for the Case 2, in red for the Case 1 and in yellow for the Case 3.

Table 2 Some characteristics of the reproduction curve for the 3 simulated cases.

	Case 1: optimal situation	Case 2: deteriorated situation	Case 3: current situation
Prob (Stock > 10,000,000 eggs)	78.1	26.4	95.1
Optimal exploitation rate	71.4%	15.7%	30.4%
Maximum Equilibrium Catch (MSY) in number of salmon*	5977	467	1902
Reproduction curve equation	$R=P\exp[1.9756(1-3.17^{-8}P)]$	$R=P\exp[0.328(1-4.03^{-8}P)]$	$R=P\exp[0.667(1-2.21^{-8}P)]$

Mean reproductive potential: 4,750 eggs per salmon (Prouzet and Michelet, 2019)

population:

- Case 2 is the "deteriorated situation". The size of the population, as shown by the black scatterplot, is small and its maximum sustainable yield is low and does not allow a high rate of exploitation.
- Case 3 is the "current state" of this population. The improvement of the free movement of fishes upstream has allowed an increasing part of the salmon population to migrate to better-quality spawning grounds and to increase the production of juveniles from the early years 2000 (cf. Figs. 6 and 7). This resulted in an increase in the productivity of this population with a maximum sustainable yield around 2,000 salmon and an optimum exploitation rate of about 30% (the situation observed presently).
- Case 1 is the "Optimal situation". It could be achieved by the improvement of the quality of spawning grounds in the whole area colonized by salmon spawners. This would increase the maximum sustainable yield (around 6,000 fishes) and the optimum exploitation rate, but the size of the population is more variable due to too high densities of fish on the spawning areas some years.
- The only regulation of the fishery cannot change the shape of the curve and the level of the MSY is linked to the productivity of the population constraints by pressures affecting the quality, the number and dimension of suitable habitats for the species. Only an improvement in the quality of the essential habitats for salmon and the restoration of ecological connectivity make it possible to recover a situation which, historically, would correspond to that which was known in the first half of the 20th century.

3.3. 'Responsible' instead of 'sustainable exploitation'

In 2021, the European fishing fleet consisted of 81,071 vessels in marine waters, to which should be added the fishing vessels operating in the EU inshore waters (Breuer and Dinkel, 2021). According to Eurostat (2021) 88% of the fishing boat have an engine power less than 149 KW. These fishing boats belong to the small-scale fishing fleet and fish in coastal, estuarine or inland areas and represents an important social and economic weight for the European fisheries sector (Macfadyen *et al.*, 2011). Landing values (2006–2008 average) of artisanal (vessel length

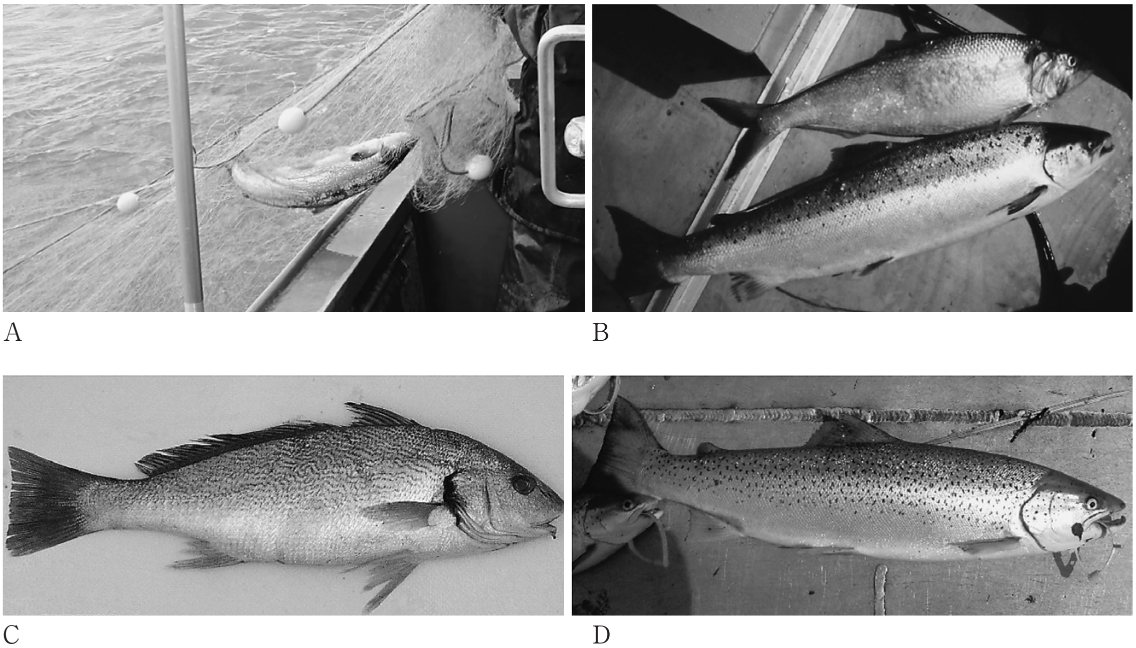

Fig. 9 Photos showing Atlantic salmon catch with trammel net in the Adour estuary (A), Allis shad and Atlantic salmon (B), Meager (C) and Sea trout (D).

< 12 m) and industrial (vessel length >= 12 m) fishing fleets were €297 million and €582 million, respectively. The artisanal and industrial fishing fleets employed 89,492 and 77,763 people (2006–2008 average), respectively. Five European countries - Greece, Italy, France, Spain and Portugal - account for 85% of landing value and 75% of the artisanal workforce (Table 29 on p. 68 in Macfadyen *et al.*, 2011).

In view of what has been said in the preceding paragraphs, it is understandable why professional fishermen of this segment of the UE fleet do not talk about sustainable exploitation, which is not under their sole control, but about responsible exploitation (Prouzet *et al.*, 2010; Boisneau *et al.*, 2016). This responsible exploitation has several aspects: producers of food for society, whistle-blowers, environmental watchers and living resources managers.

3.3.1. Producers of high-quality food for Society

The main social function of professional fisheries is to provide products from the sea or aquatic environments to society at an affordable price for the greatest number of people in compliance with the rules laid down by the European Union and its member states. The landings of this small scale fishery are generally local, fresh fish and for certain species with a high commercial and gustatory value contribute to the gastronomic reputation of certain territories: line hake (*Merluccius merluccius*), atlantic salmon (*Salmo salar*) and sea trout (*Salmo trutta*) from the Basque country; sea lamprey (*Petromyzon marinus*) and meager (*Argyrosomus regius*) from the Gironde; allis shad (*Alosa alosa*) and pikeperch (*Sander lucioperca*) from the Loire; glass-eel (*Anguilla anguilla*) from the Atlantic coast or yellow and silver eels (*Anguilla

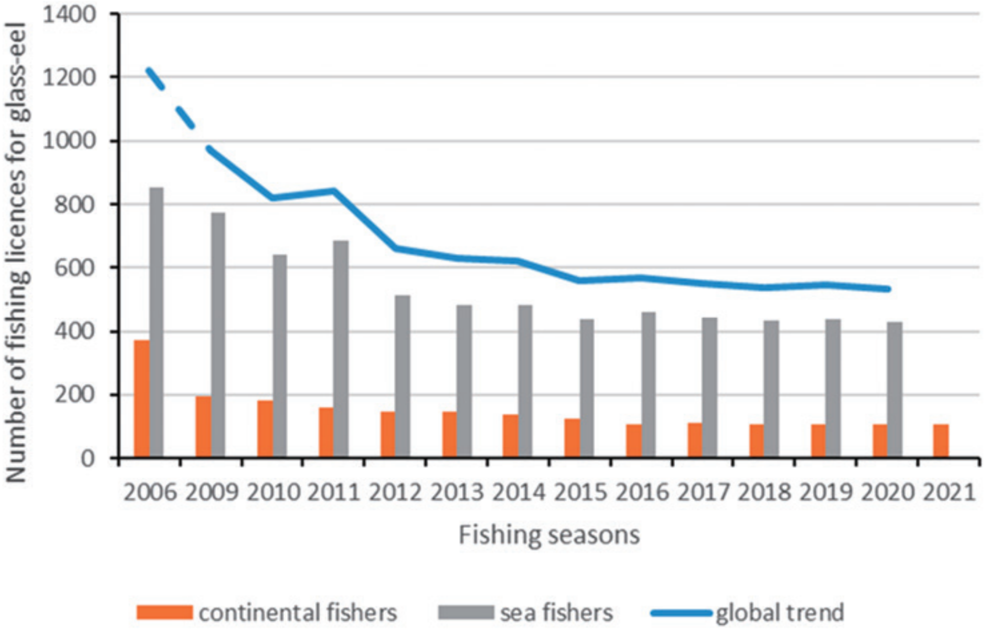

Fig. 10 Trends of the number of glass-eel licenses for the continental and marine fishers from 2006 to 2020 (source: CONAPPED and CNPMEM data).

anguilla) from the Loire or the Mediterranean sea ; king scallop (*Pecten maximus*) from the Channel or whitefish (*Coregonus lavaretus*) from the Alpine lakes or line sea bass (*Dicentrarchus labrax*) from Brittany (north western part of France) (Fig. 9).

Very strict regulations are applied to this type of fishery, which is sometimes managed not only by quotas but also by licences, the number of which is limited. Codes of good conduct are adopted for specific fisheries. This is the case for the glass eel fishery, which defines a maximum fishing speed as well as a maximum power of vessels, a maximum size and number of fishing gears (sieves) used, as well as the presence on board of sorting equipment to separate by-catches (discarded alive immediately after capture) from glass eels, and fish tanks to keep living fish in good conditions, some of them are used for restocking (*Guide de bonnes pratiques pour la filière pêche civelière et la mise en place d'un programme de repeuplement à l'échelle communautaire* https://www.comite-peches.fr/wp-content/uploads/2014/07/GBP-Plaquette-V3.pdf).

For some species, such as the European eel, which is on the IUCN red list and is the object of a restoration plan at European level (EC1100/2007), efforts to reduce the fishing pressure by 60% have been requested by the European Union and accepted by these small-scale fishing communities.

The importance of that reduction in number of glass-eel licenses for the French professional fishery on the period 2006–2020 is 56.4% as shown in Fig. 10.

Unfortunately, regarding the other pressure factors, for which the reduction was to be 75%, it has not been the case, far from it, as shown above on wetland protection and restoration of ecological continuity.

3.3.2. Whistle-blowers

Because of their exploitation of a wide variety of ecosystems: coastal areas, estuaries, ponds, lakes and rivers, as well as the practice of a job that makes them very receptive to any environmental change and also to changes in abundance of resources, fishers in small-scale maritime and freshwater fisheries are able to alert the public authorities to the risks incurred by the degradation of ecosystems as they exploit them.

For instance, it was through their actions in cooperation with the scientific community that, in 1984, the eel was no longer considered a harmful species in salmonid waters by the management structures in France. In 2000, they asked European authorities to implement a management plan for European eel at the scale of its natural distribution area. The plan was adopted in 2007 as Eel regulation plan (CE1100/2007) for the recovery of the stock of European eel. They agreed to include eel in Appendix II of CITES to control the market for this species at international level (BOISNEAU *et al.*, 2016). Europe and its member states will align themselves with the CITES regulations, but in a stricter manner by prohibiting the export of this species outside the European area. Europe and French government will greatly penalise the economic activity of the French eel industry, which was mainly supported by the Asian market.

In recent years, global warming has been a source of concern, not only because of the rise in temperature that it causes, but also because of the hydrological changes that it generates. All these disturbances seem to strongly favour the proliferation of species such as the wels catfish (*Silurus glanis*) which, near dams, sills or in fish ladders, is a major predator of local migratory species such as shads, migratory salmonids or sea lamprey (PAZ-VINAS and SANTOUL, 2019; BOULÊTREAU *et al.*, 2020; ANONYMOUS, 2021). It was at the instigation of professional fishermen that the public authorities initiated studies to assess the impact of the development of these non-native but now acclimatised species on the development of local species, the exploitation of which is sometimes prohibited for professional fishermen for reasons of resource protection (Fig. 11). The direct and indirect costs of such an introduction have not been estimated in France as for 90% of the non-native species introduced in this country. It is probably very important as suggested in the publication of RENAULT *et al.* (2021).

In 2020, for the World Fish Migration Day (https://www.lepecheurprofessionnel.fr/wp-content/uploads/2020/09/Note_compl%C3%A9mentaire_V13.08.2020.pdf), they denounce an over sectoral vision of the management of our ecosystems which has led to a loss of functional habitats for many continental and estuarine aquatic species. This excessively sectoral approach of public policies had already been highlighted by the BERNARD (1994) report. This sectoral policy often results in the impact of small scale fishing being used as an adjustment variable to limit the effects and impacts of others anthropogenic pressures on aquatic biodiversity (see negotiation between strong and weak actors § 2).

In 2021, for the UICN world congress, a leaflet titled "Decline of migratory species as a scapegoat" with a subtitle "Reconcile sustainable development, environmental governance and responsible fishing activity" (https://www.lepecheurprofessionnel.fr/wp-content/uploads/2021/08/LIvret-UICN-CONAPPED-2021-VF.pdf) is published. The brochure denounces the joint use of the IUCN red list and the Precautionary principle to argue against the continuation of professional fishing, without taking into account the constant degradation of aquatic environments by agriculture, hydropower production,

Fig. 11 Catfish regulation fishery on the Dordogne and Garonne rivers - tributaries of the Gironde estuary, France) (source: AAPPD Gironde).

urbanisation and insufficient waste treatment.

3.3.3. Environmental watchers and resources management

Investigating estuarine and continental ecosystems characterized by a wide range of habitats is not easy. Techniques used by research structures are very often based on fish inventories using electro-fishing equipment, which is very efficient in shallow waters, but not in deep waters. Counts carried out in capture traps are also methods that can be efficient for migratory species, but for some species fish counters are often placed too far upstream from the habitats they usually colonise for their reproduction (e.g. sea lamprey or allis shad).

Hence the interest in using professional fishing gears to sample and assess the abundance of fish populations or to capture living fishes for tagging to estimate exploitation rates or to study their migratory behaviour. Some examples among many others show the importance of cooperation between scientists and professional fishers and are given below.

- *Acipenser sturio* (European sea sturgeon), anadromous species that breeds in river, was a common species in the Gironde estuary and its tributaries until the middle of the twentieth century (Darlet and Prioux, 1950). A too intensive fishing exploitation in estuary, which has been prohibited since 1982 in France, along the European coasts (bycatch) associated with a degradation of its breeding and nursery areas has led to a quasi-extinction of that species in the Gironde watershed and in Europe. It is now

Fig. 12 Sampling of juvenile European sturgeons in the Gironde estuary by the professional fishery (drift net used to catch meagre in the Gironde estuary in June 2021) and then released alive (source: CAPENA)

listed as critically endangered on the IUCN Red List. In 2007, an action plan for the restauration and conservation of the European sea sturgeon is adopted by the Standing Committee of the Berne Convention. the first French national plan is defined and implemented from 2011 to 2015. It is followed by a conservation plan from 2020 to 2029 (ANONYMOUS, 2019). In June 2007, CEMAGREF (*Centre du Machinisme Agricole et du Génie Rural des Eaux et des Forêts, presently INRAe : Institut National de Recherche pour l'Agriculture, l'Alimentation et l'Environnement*) carried out for the first time the artificial reproduction of the European sea sturgeon, then regularly between 2008 and 2014 (LAURONCE *et al.*, 2014; 2015, 2016). This success in artificial reproduction is a real boost for implementation of a restoration plan which is managed by a steering committee that includes the two official structures for maritime and continental professional fishing. These two official structures contribute to the protection of the species by reducing the impact of their activities (release of by-catch) and to the improvement of knowledge on the distribution of the European sea sturgeon at different stages of its life cycle in the natural environment. They also carry out awareness-raising work at European level with fishing communities. From 2007 to 2015, more than 1.8 million hatchery-produced juveniles were released into the Garonne and Dordogne rivers, both tributaries of the Gironde. Many observations have been collected by professional fishermen in the framework of this environmental monitoring (ANONYMOUS, 2021) (Fig. 12). Between 2006 and 2020, 1,748 sturgeons have been caught by the commercial fishery in the French coastal waters, 99% have been released alive

Fig. 13 Release of glass eels in the Aureilhan lake by professional fishers (South western part of France) (source: ARA France).

(Lise Mas, pers. com.).

・*Anguilla anguilla* (European eel), anadromous species that spawns at sea and has a growth phase in fresh, brackish or coastal waters. Formerly very abundant and classified in France as a harmful species in salmonid waters, it has been considered since 1984 as a species to be protected in response to requests from professional fishers and scientists. Its rarefaction is linked to numerous anthropogenic pressure factors now been identified by research studies coordinated at European level such as the INDICANG project (ADAM *et al.*, 2008). This project made it possible to pool academic and traditional knowledge and know-how and thus to develop techniques for assessing the abundance of this species at different stages of its life cycle. Within this framework, professional fishermen provided technical expertise to implement fish sampling and abundance assessment plans in large river basins (Loire, Adour and Gironde): estimates of the abundance of glass-eel stocks on the Adour estuary (BRU *et al.*, 2009) or in the Loire or Isle River (ADAM *et al.*, 2008); estimates of the abundance of silver eel stocks on the Loire River (BOISNEAU and BOISNEAU, 2014; 2015). Contribution of professional fishers to the EELIAD project to investigate the migratory behaviour of European eel at sea from tagging of eels caught in Mediterranean lagoon (AMILHAT *et al.*, 2016) or in the Loire River (RIGHTON, 2008; AARESTRUP *et al.*, 2009; RIGHTON *et al.*, 2016; BOURILLON *et al.*, 2020), then released in the sea near the shore.

Within the framework of the French eel restoration plan approved by the European Community, 60% of the glass eel quota allocated to the professional fishery must be used to restock continental aquatic environments in Europe. Part of this quota is used to stock aquatic environments in France under the responsibility of an association created by the professional fishing industry: *Association pour le Repeuplement de l'Anguille en France* (ARA France: Association for the Eel restocking in France), which has developed a code of good practices for catching, keeping,

Fig. 14 Tagging of salmon with an acoustic tag on the Adour estuary (source: PROUZET).

transporting and releasing the fry with a maximum efficiency (Fig. 13) (RABIC and GORNET, 2020).

- *Salmo salar* (Atlantic salmon) anadromous species that spawns in freshwater and has a growth phase in river as juvenile (parr), then migrates downstream to the sea as smolt and spends between 1 to 3 years (sometimes 4 years) at sea before to return and spawn in its home river (GUEGUEN and PROUZET, 1994). In 1999 and 2000, a large project of salmon tagging had been undertaken to catch salmon alive and to tag them with radio and acoustic transmitters. The aim of this project undertaken by *Centre National de la Recherche Scientifique* (CNRS: National Centre for Scientific Research), Institut National de la Recherche Agronomique (INRA: National Institute for Agricultural Research) and *Institut français de recherche pour l'exploitation de la mer* (Ifremer: French Research Institute for Exploitation of the Sea) in cooperation with professional fishers and Institution Adour which is a public structure in charge of management of the Adour Basin and its ecosystems was to study the salmon behaviour during its upstream migration in the Adour estuary (BEGOUT *et al.*, 2001) and to estimate the migration speed in estuary in order to adapt the fishing legislation to get a compromise between protection of salmon from gillnet in the estuary and economical loss of the estuarian fishery. The results obtained showed that in average salmon cross the estuary in two days (around 30 km). This made it possible to adapt the legislation of gillnet fishing in the estuary by shifting the weekly time window during which the estuary was free of nets by one day between the mouth and the upper part of the estuary in order to decrease the fishing pressure on migrating salmon. The contribution of professional fishers was to catch the fish alive, to participate to fish tagging and to track tagged salmon with an acoustic receiver (Fig. 14) (MAHAUT and PROUZET, 2009).

4. Conclusion: Need to introduce culture as the fifth dimension of the sustainable development.

As early as 1972, the UNESCO General Convention adopted a resolution for the protection of the world's cultural and natural heritage and underlined the need to maintain the balance between natural and cultural goods.

In *Ethical Issues of the Fisheries*, FAO (2005) defined the ethics of fishing as values, rules, duties and virtues relevant to both the welfare of the human being and the good state of the ecosystem. Many studies conclude that artisanal fishery is more a way of life than a profession. Partners of the DIMPAT project "*DIMension PATrimoniale dans la définition de la durabilité des modes d'exploitation des ressources aquatiques*" (the heritage dimension in the definition of the sustainability of exploitation of aquatic resources) talk about "*local, maritime and continental fishing communities that are the holders of local culture and heritage, the richness and diversity of which have been nourished over centuries by external contributions of people, techniques and knowledge*" (BERNARD *et al.*, 2012; PROUZET, 2014).

Thus, knowledge is fundamental in the definition of a new environmental governance through collective learning, crossing of scientific and traditional knowledge, plurality of value systems (not only based on economic value) and construction of shared common knowledge.

It is clear that governance as defined in the classical framework of sustainable development based on a so-called balance between the three spheres of interest: economic, social and environmental is a failure both socially and environmentally (REID *et al.*, 2005; ROCKSTRÔM *et al.*, 2009; PROUZET *et al.*, 2019). As mentioned previously, the compromises for implementation of a sustainable development policy have too often been made at the expense of weak actors, i.e. those who live directly off the goods and services of Nature. However, it is these actors who often integrate into their culture (in the sense of knowledge and know-how) and their heritage, the cross-generational links that take future generations into account in the negotiation process *via* the transmission of knowledge and respect for Nature, a non-human actor very often absent from these negotiations. These traditional communities are also custodians of historical knowledge which is currently very often lacking for the definition of pristine references.

CHARLES (2011) proposed to develop cultural and human rights based-approaches to co-management and then considered each fishery in terms of its local characteristics and its social, economic and historical context. In that context, heritage is defined in such a way as to differentiate it from the notion of capital: one manages a capital to increase it, and one manages a heritage to transmit it to future generations (PROUZET *et al.*, 2020).

Unfortunately, the current vision remains too sectoral. Cultural practices as a support territories identity and local traditional knowledge of Nature are not sufficiently mobilised. It is here that the cultural dimension takes on its full meaning as a reflection on life in these natural and man-made spaces (MELIN, 2011).

In 1996, WACKERNAGEL and REES (1996) defined *the ecological footprint* as the aggregate land area required for a given population to live in a sustainable manner. MELIN (2011) proposed to add another less quantitative indicator measuring *the cultural footprint* of territories in order to assess the impact of cultural practices, beliefs and knowledge on the good or poor state of territories. The introduction of this new indicator makes it possible, in the long term, to encourage participative democracy and, first and foremost,

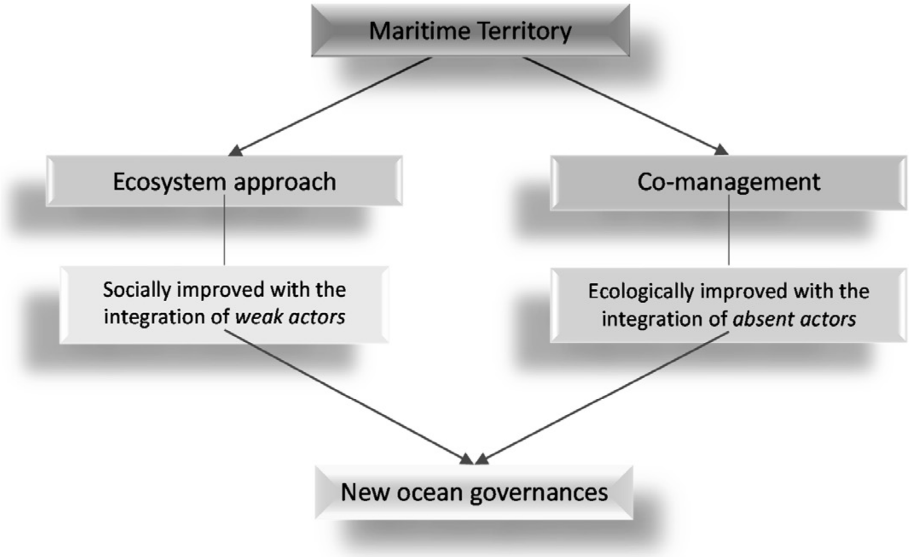

Fig. 15 Proposition of a framework to enhance new ocean governances (source: PROUZET *et al.* 2019).

to hear the voices of all the stakeholders directly concerned by environmental change.

Hence the idea of identifying maritime and non-maritime territories for the implementation of a genuine sustainable development policy, in order to better take into account this diversity of knowledges and practices that strengthen the cultural footprint (SÉBASTIEN, 2014) and by integrating differently the sectorial policies (HENOCQUE and KALAORA, 2014). It is this notion of maritime territory that is put forward by PROUZET *et al.* (2019) as a scale "combining an ecosystem approach socially improved with a co-management approach ecologically enhanced" (Fig. 15).

It is the aim of the project defined by the two Japanese-French Oceanographic Societies of France and Japan in 2018: "*Project Nature and Culture - on the five pillars of sustainable development and the five senses*". The objective of this project is to demonstrate through different examples of cooperation between France and Japan that it is possible to minimize our ecological footprint while enhancing our cultural footprint. The environments chosen for this project are also spaces of social and cultural expression that take into account the realities of the territory. For instance, a cooperation project between a certain site in the Seto Inland Sea (Japan) and the Arcachon Basin (France) has been outlined around the restoration of eelgrass beds and the diversity of oyster farming practices. More precisely, this project is undertaken with the Satoumi Research Institute, the Arcachon Basin Natural Marine Park, the Arcachon-Cap Ferret regional committee for Shellfish Aquaculture, New-Aquitania region and Europe and the two SFJOs. Another project on the eel is being developed and will focus on the restoration of the species and its habitats as well as its enhancement.

Here, the territorial scale is very important because it allows for the identification on a "human" scale of not only the goods and services of the natural ecosystems that make up the territory, but also the enhancement of local cultures and their territorial manifestations: handicrafts, leisure activities, product development, fishing activities, aquaculture, agriculture, gastronomy, museography... It also allows the proposal to be placed in a historical context that is nourished by the knowledges and skills of local communities, which are the fruit of an ancient and perennial practice of these natural and cultural environments.

As HENOCQUE and KALOARA (2014) pointed out, "good governance is first and foremost a matter of democracy, with a central question: how to ensure that Nature or non-human actors are integrated into the political community".

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