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# **Title: A long term overview of freshwater fisheries in France**

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## **Abstract (150 to 250 words no more than 33 pages all included)**

The large-scale production and economy of French freshwater fisheries is not documented in the scientific literature. This article fills this knowledge gap by synthesizing the data collected since the post-war period, including a large part of the grey literature. France presents a wide variety of surface waters, benefiting from a reduction in pollution and a growing population with an emphasis on leisure activities and on locally sourced food products. Despite this favorable geographical, ecological and human situation, French freshwater fisheries have been in decline since the mid-1970s with a chronically negative trade balance for aquatic products. During this period, numbers of commercial fishers have decreased three-fold due to their affiliation to an agricultural status, and to their dependence on migratory species such as eel, shad and lamprey, which are all in decline. Simultaneously, numbers of anglers have also seen a slow but continuous decline, cushioned somewhat in the last 10 years thanks to the creation of sub-annual fishing cards and the expansion of the total to include the younger classes. Vestiges of a non-commercial fishery, similar to recreational subsistence fishing and employing gear such as dip nets, traps, long lines or even gillnets, have been maintained in a much reduced state around large rivers as well as in the marshes and estuaries of the Atlantic coast. In this detailed study of these different categories of fishing practices in the mid-2010s, we estimate numbers of fishers at 2 million active anglers, 4000 subsistence fishers, and 400 commercial fishers. Their catches are roughly 7600, 200 and 1200 tonnes/year, respectively, for a total of 9000 tonnes/year. The major part of the overall economic worth, estimated at 980,000 K€, is attributable to recreational fishers (anglers).

## **Keywords**

Inland Fisheries, Commercial fisheries, Recreational fisheries, Subsistence fisheries, Angler, Fishing effort, Catches, Economic importance

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### **Funding**

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### **Conflicts of interest/Competing interests**

The authors and associated persons in the Acknowledgements participate actively in all the different types of fisheries in France; this article thus provides an overview accepted by all these types of fisheries.

**Availability of data and materials**

All data are taken from published documents available from their authors. Tax numbers are available from the authors' employing organizations.

**Code availability**

Not applicable

**Authors' contribution**

TC collected the data, wrote the text and produced the figures. NS provided the number of taxes since 2006 for commercial fisheries and reviewed/amended the text. PB and CG reviewed/amended the text.

## Introduction

Inland fisheries are essential to the food, economy and culture of millions of people (Welcomme et al. 2010). As both a resource supplier and a guarantee of the good ecological status of the water bodies they exploit, they provide many services that are critical to the achievement of at least five Sustainable Development Goals (No Poverty (SDG 1), Zero Hunger (SDG 2), Clean Water and Sanitation (SDG 6), Responsible Consumption and Production (SDG 12) and Life on Land (SDG 15), according to Lynch et al. 2020). The proceedings of the last Global Conference on Inland Fisheries: Freshwater, Fish and the Future, convened at FAO HQ in January 2015 reported three main issues. First, a lack of interest in inland fisheries over the last 15 years (Welcomme 2016). Second, the current lack of information on these fisheries (Cooke et al. 2016a), and third, the need to improve the management of these fisheries (Cooke et al. 2016b).

Located at the crossroads of oceanic, mountainous, Mediterranean and continental climates, mainland France, taken without its overseas territories, presents a very abundant diversity of surface waters (Pagney 1988; European Environment Agency 2018; see WISE-Freshwater Water Framework Directive (WFD) database for details). Reflecting this natural diversity, continental France still benefits from a wide range of commercially important wild fishing resources detailed by Keith et al. (2020). These resources include native species, primarily diadromous migratory fish such as European eels (*Anguilla anguilla*) in all their forms (yellow, silver and glass eel), two species of shads (*Alosa alosa* and *Alosa fallax*), lamprey (*Petromyzon marinus*), or even Atlantic salmon (*Salmo salar*) and European sea sturgeon (*Acipenser sturio*), the latter authorized for fishing until 1981, followed by resident fish such as perch (*Perca fluviatilis*), European whitefish (*Coregonus spp.*), pike (*Esox lucius*), brown trout (*Salmo trutta*), lake char (*Salvelinus umbla*) also identified as Arctic charr (*Salvelinus alpinus*) and many cyprinids. Alongside these native fishes are species introduced for fishing purposes, such as pike-perch (*Sander lucioperca*) at the beginning of 20th century, European catfish (*Silurus glanis*) at the end of the 20th century, common carp (*Cyprinus carpio*) during the Middle Age and American crayfishes (*Procambarus clarki*, *Pacifastacus leniusculus* and *Faxonius limosus*) during the 20th century.

Even if the ecological status of surface waters is impacted by barriers to connectivity between hydrosystems, the implementation of the WFD has led to a clear improvement in the chemical status of surface waters and to a decrease in polluting discharges from urban drainage and industry, resulting in a stabilization, or even a decrease, in nutrient concentrations in 80% of French sub-basins (French Ministry of Ecological Transition 2020). Although the recent human health crisis related to COVID-19 may have temporarily modulated the following trends (see the dedicated page of INSEE (2022)), the French population is increasing, and with this rise comes an increasing demand for both leisure activities (Bigot et al. 2013) and for locally sourced food products (Dedinger et al. 2021). France is one of the countries where inland fisheries have not been impacted by the COVID-19 crisis (Stokes et al. 2020). Whereas the consumption of fresh fish is decreasing, the purchase price is increasing (FranceAgriMer 2020). Yet France's trade deficit for aquatic products has been chronically negative for over 20 years (FranceAgriMer 2020). Despite the favorable geographical, ecological and human situation, the few easily accessible studies on French freshwater fisheries indicate signs of decline in this sector (see Le Goff and Salanié 2005, Brun 2008 for recreational fisheries and Boisneau et al. 2016 for commercial fisheries). The French consumption of freshwater fishes is dominated by farmed trout and salmon (FranceAgriMer 2020). While traditional demand for other freshwater fish may have existed locally in the past

(eg pike for quenelles or fried carp in eastern France), demand has nevertheless remained very low for over 50 years when compared to the progression of marine fish. On a European scale, the dominance of inland fisheries by recreational fisheries is part of a global movement of decline of small commercial fisheries (Cowx 2015). Currently, the freshwater commercial catches are low and mainly for local consumption. When there is still a specific demand, such as for crayfish, pike-perch or freshwater fry, it is met by imported products.

With regard to French marine fisheries and following the request of Europe, these last 10 years have seen a considerable improvement in both the quantity and the quality of scientific data collected, especially dealing with marine recreational fisheries (Herfaut et al. 2013 ; Hyder 2018 ; FranceAgriMer 2018). As regards French inland fisheries, available data have always been insufficient and this situation may actually have deteriorated for both commercial and recreational fisheries, due to important administrative modifications made since 2006. Starting with the disappearance of the Conseil Supérieur de la Pêche (CSP dissolved by law n°2006-1772), which had maintained a specific administrative link with freshwater fisheries since the 1950s, the progressive agglomeration of all the national management bodies for hunting, fishing and national parks within the Office Français de la Biodiversité (OFB created by law n°2019-773) has resulted in a significant loss of visibility for freshwater fisheries. Locally, the regrouping of the departmental administration within the Direction Départementale des Territoires (DDT) in 2010 has resulted in the loss of many monitoring data. A few studies conducted by official agencies on the French inland fisheries provide updated figures at national scale (ANDI 2009 and ANDI 2018 for commercial fisheries; BIPE 2014 and BIPE 2015 for anglers) but they have not been the subject of any scientific publication.

The aim of this paper is to establish a long-term picture of the state of French freshwater fisheries using accounts provided by the various stakeholders. The authors were thus chosen due to their expert knowledge of the main categories of fishers and/or freshwater environments throughout the country. This description is built on the basis of data available in the grey literature and on new data provided by the authors.

For each category of fishers, we will try to:

- clearly quantify and qualify the fishing effort;
- specify and interpret the present and past tendencies;
- make an assessment of the catches;
- estimate the economy of the activity.

A first preliminary study that presented some of these data was published in French and appears as part of a book with more general scope (Keith et al. 2011; Keith et al 2020). The present review contributes considerable new information and recommendations for the future that were not included in this first study.

### **Preliminary legal and administrative considerations**

As freshwater fishing is a highly regulated activity, it is necessary to specify the legal and administrative conditions under which it is authorized. In this article we will adopt the definition of freshwater fishery as described by French law. This definition makes the distinction between inland and marine fisheries based on water salinity at the site where fishing takes place. In most estuaries, an administrative salt water limit materializes the boundary between the freshwater and the marine domains. All Mediterranean and tidal lagoons are considered to be marine.

In all inland freshwaters connected to the hydrographic network (open waters), fishing requires both membership in a recognized fishing association and the purchase of an individual fee called a tax in France (Article L436-1 of the Environmental Code (EC)). This tax is transferred by the state to the water agencies to aid in financing their actions in favor of aquatic environments (Art. L213-10-12 of the EC). By way of derogation, it is possible to fish tax-free in closed waters (generally private fishing ponds not connected to the hydrographic network or equipped in such a way as to prevent fish from escaping).

The legislation makes the distinction between two types of activity: recreational and professional (commercial) fishing. Recreational fishing includes all non-commercial practices (i.e. it prohibits any form of sale of catches). Concerning recreational practices, a distinction is drawn between two types of fishers according to the authorized fishing method they employ: anglers are limited to line fishing, and amateur fishers have a wider variety of gear at their disposal, such as fish traps, dip nets and sometimes gillnets. There are therefore three different categories of fishers: anglers, amateur fishers, and professionals. Anglers must hold an associative fishing card to practice where their association has obtained the fishing rights. Amateur fishers and professional fishers hold fishing licenses attached to specific waterbodies where they are authorized to fish. As mentioned above, all three types must pay a tax, a term we use instead of 'license' or 'permit' in the following, because it applies to all fishers.

The number of freshwater fishers can only be deduced from the number of taxes sold, which has been monitored precisely, department by department, since the post-war period. Detailed knowledge of fishing practices and their economic importance is, however, much less well understood. Indeed, the only data available come from a few surveys and/or studies which have been carried out infrequently on an *ad hoc* basis in space or time.

## **Angling**

Fishers of this category use at least one line mounted on a rod, usually with one to three hooks (Art. R436-23 of the EC). This fishing technique requires the permanent presence of the angler in the vicinity of the rod to monitor the hook. Angling is almost always carried out during the day, between 30 minutes before sunrise and 30 minutes after sunset (Art. L.436-13 of the EC).

### Angling practices

This definition covers very different practices which, for the sake of clarity, have been categorized into three groups according to the main target species family, following the method of two different national surveys conducted more than 20 years apart (Gamond 1991; Savidan and Berger 2014). The fish caught are not always the target species (ANSES 2012), but this grouping summarizes the means and techniques used, which we detail below. When assessing catches, this grouping produces more stable yields than if we were to consider only the target species, which are, by definition, less likely to be released.

### *Angling for Salmonids and migratory fishes*

Salmonid fishing in rivers is a very mobile way to fish, involving a single line and a wide variety of natural bait items (e.g. insects, earthworms, dead fish) or artificial devices (e.g. spoons, flies, fish lures). Many different techniques are used, such as casting, "toc", fly line casting, etc., which will be adapted to the particular river. All

Salmonids are possibly eaten and a bag limit exists of 10 individuals per day (Art. R436-21 and R436-22 of the EC). There is also a minimum legal size below which they must be released. These legal sizes are generally defined at the national level (Art. R436-18 and 19 of the EC) and can be locally modulated to correspond to the adult size, meaning the size at first reproduction. The principal target species is brown trout (*Salmo trutta*, national legal size (NLS) 23 cm) but other introduced species such as rainbow trout (*Oncorhynchus mykiss*, NLS 23 cm) or brook trout (*Salvelinus fontinalis*) are also fished by anglers, with this last species being fished especially in high altitude small streams.

Between 1991 and 2014, trout fishing in France increased from 32% to 38% of freshwater angling, and is now considered to be the most important activity for this category, with a preferential distribution in the south of France, around the Central Alps and in the Pyrenees.

Trout angling is an intermediate yield fishery (1 adult trout per 2.5 h, according to Gallet 1998; 1 trout greater than the legal size limit for each 2 h of fishing, according to Delacoste (1997), i.e. 100 g/h for an average weight of 200 g per trout). Numerous fish stocking events maintain this fishery locally in sectors where the resource is not naturally abundant, particularly in northern France. When the wild population abundance is low and there is no supportive stocking the time required to catch a trout over the legal size limit rises (3 h 48 min on average, according to Ledouble and Changeux (2005).

Other targeted Salmonidae include grayling (*Thymallus thymallus*, NLS 30 cm), usually caught by fly-fishing, and lake Salmonidae (lake char (*Salvelinus umbla*), Coregonidae (*Coregonus spp*, NLS 30 cm), lake trout (*S. trutta*) and sometime the introduced lake trout (*Salvelinus namaycush*, NLS 35 cm)), which are fished from boats in large peri-alpine lakes or caught by casting from the bank in high altitude lakes. The fishery for migrating salmonids includes sea trout (anadromous *Salmo trutta* NSL 35 cm) or Atlantic salmon (*Salmo salar* NSL 50 cm). It is limited to several rivers in Brittany, Normandy and in the south-west of France (Adour River), but is currently closed in the Loire and Garonne-Dordogne river catchments. Similarly, Twaité shad (*Alosa fallax* NSL 30 cm) fishing has developed downstream of large rivers dams despite the moratorium on Allis shad (*Alosa alosa* NSL 30 cm), in place since 2008 in the Garonne River. By extension, eel (*Anguilla anguilla*) fishing can also be tied to these practices, with the unusual technique of clodding, involving using a ball of worms with no hooks: however, this practice has been prohibited at night since 2011, following the implementation of the Eel Management Plan started in 2009 following the application of European Council regulation (EC) n° 1100/2007 (Anonymous 2018).

### *Coarse fishing*

Coarse fishing was long ranked as the most popular fishing method. It targets fish of low cultural value such as the Cyprinidae, and is practiced from a fixed position on the bank, with a rod at least 3 m long. Common roach (*Rutilus rutilus*), bream (*Abramis brama* and *Blicca bjoerkna*) and other Cyprinidae 'coarse fish' are angled in the still waters of large rivers, channels and ponds. Coarse fishing usually involves ground baiting to attract fish. There is no bag or minimum legal size limit for coarse fishes.

Practiced by 46% of anglers in 1991, fishing for Cyprinidae accounted for only 28% of freshwater anglers in 2014, allocating this fishery to second place, behind Salmonidae fishing. Cyprinidae anglers are distributed primarily in the north and east of the country. Their numbers are declining yearly, despite the very abundant available natural resource (Buil 2021). This is a high-yield fishery (122g/h per line according to Bohn et al.

1998, 152g/h according to Changeux (1996), 260g/h according to Changeux (1990), but it must be noted that the fish are often released.

The most common current target species are small Cyprinidae (fry or whitebait) for consumption or for use as bait (14% in 2014). The angler is equipped with a shorter rod and so is more mobile and able to follow the movements of fish schools, or even to attract them by unsettling the bottom through the movement of their feet, which brings out the invertebrates on which the coarse fish feed.

Finally, waggler fishing, called « pêche à l'anglaise » in French, uses one or more rods equipped with a reel for long distance casts (from 15 m to 50 m or more) to reach places that have previously been groundbaited. The float is attached to the line at the lower end only. The specific search for large carp using a leaded line is a similar practice and has been developing strongly since the early 1990s: it accounted for 12% of anglers in 2014 and is permitted at night in some areas.

### *Angling for large predatory fish*

Large predatory fish angling targets principally pikeperch (*Sander lucioperca*), or pike (*Esox lucius*). It is practiced from the shore or from a boat using one or more reel-equipped rods and either live bait, dead fish or artificial bait (fish lures). These fish are often eaten, and the daily bag limit for pikeperch, pike and black bass (*Micropterus salmoides*) is fixed at three, including a maximum of two pikes. (Art. R436-21). The NLS is 50 cm for pike, 40 cm for pikeperch, and 30 cm for black bass (Art. R436-18).

This fishery increased from 18% to 24% of freshwater anglers between 1991 and 2014, which represents as big an increase as for trout fishing, but this type of angling remains in third place. Pike angling was well established in the east, and pikeperch angling was common on all the major rivers and lowland reservoirs.

This fishery has much lower yields than the others, especially for pike. To catch a pike over legal fishing length requires an average of from 20 to 30 h of fishing according to Chancerel (1998), 29 h 28 min of fishing according to Ledouble and Changeux (2005), and 25 h per line according to Barbey (1997), corresponding to 56 g/h for an average weight of 1.4 kg per pike.

Given the low yields, anglers who fish predatory fishes modulate their fishing effort according to the abundance of the available resource and by fishing other species. Perch (*Perca fluviatilis*) fishing may be abundant in certain bodies of water (peri-alpine lakes, and water bodies in eastern France), and targeting black bass may be frequent locally in the south of the country. The spread of the European catfish (*Silurus glanis*) throughout France during the 1990s has led to the development of a very popular branch of big-game fishing which takes place primarily in large rivers and reservoirs.

### Number, evolution and distribution

#### *Total number of anglers*

Counting the exact number of freshwater anglers in France became more complicated in the early 1990s due to the multiplication of different tax regimes and after the disappearance of the Conseil supérieur de la pêche (CSP) in 2006, which had carried out this task since the 1940s. In the early 2000s, the total number of freshwater anglers was estimated at about 1.4 million, based on the total taxes paid in France (Ernst & Young 2011; Cowx 2015).



This is consistent with relative total values of freshwater and sea anglers in the French population (including occasional fishers) in the 1990s as reported by Tendron (1998), and if updated with the 2011-2013 figures concerning sea anglers, is estimated at 1.3 million by Levrel et al. (undated) as reported in Table 1. In the mid-2010s, the number of anglers having fished in freshwater or marine habitats at least once in their life was estimated at about 6.3 million only (Table 1), compared to 7.2 million in the early 2000s (Keith et al. 2011). Five million freshwater anglers (7.8% of total French population) remain today, of whom 3 million are clearly occasional fishers who practice 5 days or less per year (Table 1). This figure of 5 million freshwater anglers is comparable to the 7% of the French population, or 4.4 million people, who stated that they "still fish in freshwater" in a 2005 independently conducted telephone survey (Anonymous 2005). Within the group of regular and highly regular anglers, i.e. those who fish for 6 days or more per year, are 1.2 million, or 1.9% of the total French population, who pay annual taxes, and 0.3 million, or 0.5% of the total French population, who pay part-time taxes to ensure membership in a recognized local fishing association, as reported in Table 1 (Menanteau-Bendavid and Bourdeau 2005). By subtraction between the telephone survey and the tax sales Ribein (2005) estimated at 0.5 million the number of freshwater anglers practicing in closed waters outside the recognized association system and mostly in private fishing ponds. This represents a truly substantial 0.8% of the total French population (Table 1).

**Table 1** Number of anglers in mainland France during the middle of the 2010s (from Levrel et al. (undated) for marine angling, and adapted from Pinet (1997), Tendron (1998), Ribein (2005) and BIPE (2014) for freshwater angling). The percentage of French population is calculated considering a total of 64.3 million people in 2015 (Pison 2015). Occasional anglers practice 5 days or less per year in freshwater and 3 days or less per year in sea water.

Number of anglers (in millions of individuals)	Fishing domain		Total
	Marine	Freshwater	
Paying an annual tax	NA	1.2 (1.9%)	1.2 (1.9%)
Paying a part-time tax	NA	0.3 (0.5%)	0.3 (0.5%)
Outside the associative system	NA	0.5 (0.8%)	0.5 (0.8%)
<b>Total regular or highly regular</b>	<b>0.9 (1.4%)</b>	<b>2.0 (3.1%)</b>	<b>2.9 (4.5%)</b>
Occasional	0.4 (0.6%)	3.0 (4.7%)	3.4 (5.3%)
<b>Grand total</b>	<b>1.3 (2.0%)</b>	<b>5.0 (7.8%)</b>	<b>6.3 (9.8%)</b>

NA : not applicable

Finally, considering the assessments above, we can consider that mainland France counts 2.9 million active (regular or highly regular) anglers: 0.9 million at sea, and 2 million in freshwater (Table 1). This has been a relatively stable figure since the 2010s. It is lower than the 5 million recreational marine and freshwater fishers estimated by Arlinghaus et al. (2015) and the 1.319 million recreational marine fishers calculated by Hyder et al. (2017), but is in total accordance when occasional anglers are included.

#### *Evolution of number of angling taxes (Fig. 1A)*

The number of angling taxes payed has been known precisely, department by department, since 1942, even if this number represents only 75% of the true number of active anglers. The evolution of the number of taxes sold

since 1945 (Fig.1A) shows three main periods: (1) from 1945 to 1964, (2) from 1964 to 2005 and (3) from 2006 to 2016. The first period is marked by the introduction of the associative system, with a strong growth in the number of taxes collected. This implementation was less rapid in the south of France (Pinet 1996a). In 1964, the number of taxes peaked at nearly 3 million. During this period, the growth in sales of "complete" taxes, necessary for cast fishing with a reel, reflects the progressive increase of the technical nature of angling equipment. The second period is characterized by the continuous erosion in the number of taxes, a decline that began rapidly in the north of the country (Pinet 1996a). To compensate for this initial loss, a "supplementary" tax was made compulsory for fishing in first category rivers (where salmonids are dominant) from 1968 onwards. It is therefore possible to follow salmonid anglers in particular, who were very numerous in the south where they remained prominent until 1984. From that date, all the curves can be seen to decrease. The proportion of "basic" taxes decreases under the effect of a convergence of price with the "complete" tax in order to achieve a single tariff. After decreasing slightly from 2001 to 2003, the number of taxes sold has fallen by more than 5% a year since 2004. From 1995 to 2006, data concerning tax sales indicate that the number of anglers decreased by 553,911 individuals, i.e. a decrease of 31% over 10 years (Menanteau-Bendavid & Bourdeau 2006). In 2007, despite a re-organization of the management and licensing arrangements in this sector, no great impact can be seen on the number of anglers. Changes made included modifying the name given to the principal annual fishing tax, replacing "complete" with "full age", "youth" with "underage" and with the creation of a tax for women in 2008, and one for children under 12 years old in 2014. The trend in total anglers is still declining, but has slowed down considerably. While the number of adult anglers paying their taxes on a year-round basis continues to decrease, there was a 29% increase between the "youth" tax in 2006 and the "underage" tax in 2016. Finally, a simultaneous increase in the number of seasonal taxes, called "vacation" and "daily" taxes, can be observed, corresponding to more occasional fishing practices throughout the year.

To better analyze the situation, the profile of the typical angler has been drawn up several times (Gamond 1991; Pinet 1996a and b; Anonymous 2005; BIPE 2014). In France, fishing is essentially a male leisure activity (97% male) where seniors (over 65 years old) are well represented and with 2/3 of anglers starting fishing between 5 and 15 years of age.

The time devoted to fishing is highly variable from one angler to another, to the point that no significant difference appears between the different fishing techniques (Gamond 1991).

The activity of angling has been divided into three parts and profile-types: the general public fishery, the sport fishery and the wild fishery (Richard 1998). First, the general public fishery that accounts for 50% of the demand. These anglers are people who are concerned with obtaining an easy and immediate result. Their activity is centered on catching "*ready-to-fish*" fish. They rarely travel more than 30 km from their place of residence or their resort in order to fish. Second, sport fishing which accounts for 25% of the demand. These anglers are sensitive to the appearance of the fish, which must not show the signs of farmed fish (small, worn fins, uniform color, obese body, etc.). They rarely travel more than 50 km from their place of residence to fish. Finally, wild fishing represents 25% of the demand. These anglers are looking for wild fish and a natural setting. They are willing to travel long distances and they constitute the bulk of clients in the fishing tourism sector.

### *Geographic distribution of angling taxes (Fig. 1B)*

Fishing taxes are sold together with association membership cards. Each of the 1 400 associations transmits the revenues at the departmental level to departmental fishing federations where the statistics are updated annually. The distribution of taxes by department (Fig. 1B) reveals five major areas of high concentration: the Hauts-de-France region (Nord, Pas-de-Calais, Somme), the lower Loire (Indre-et-Loire, Maine-et-Loire and Loire-Atlantique), the South-West (Gironde, Dordogne and Haute-Garonne), the lower Saône (Saône-et-Loire, Côte-d'Or and Ain) and the East (Bas-Rhin, Meurthe-et-Moselle). These departments have in common particularly rich surface water networks including the canals of the North, the Rhine, the Loire, the Saône, the Garonne and the Dordogne Rivers. The role played by large river fishing in the Public River Domain (PRD) is diminishing, yet its continuing importance is affirmed here, since this fishery determines the major trends in the distribution of taxes in metropolitan France. The Paris conurbation is a sector of minor importance because the anglers of the capital practice their sport outside their region of residence, taking advantage of the different reciprocal interdepartmental agreements, and paying their taxes either in person or online directly to the local associations they fish with. Certain overseas collectivities such as Saint-Pierre and Miquelon (510 annual taxes) or La Réunion (1,202 annual taxes), follow the same tax system but their numbers of taxes are well below the lowest metropolitan levels, at 3,000 annual taxes sold.

The difference by department (Fig. 1C) between annual taxes in 2016 and in 2006 confirms areas of decreasing tax sales in the Haut de France, where fishing for Cyprinidae was practiced. Fig 1C also reveals two areas where tax sales were increasing, the first to the south of a diagonal running roughly from Bordeaux to Belfort, and the second in the west, where Salmonidae are sought after. The very small variations observed at this border correspond to the demographic 'empty diagonal' (Oliveau and Doignon, 2016). Finally, on the departmental level, a significant positive correlation can be seen between the percentage of "Young" (less than 16 years old) or "Less than 12 years old" holders of a fishing tax in 2006 and the relative difference of the total numbers of tax payers between 2016 and 2006 (Fig 1D and E), showing the positive long-term effect of the presence of young anglers.

Finally, individual data from online card purchases show that in a given department, up to 39% of members may not renew their fishing card the following year, despite the total number of annual fishing cards in the department remaining more or less stable, thanks to the arrival of new fishers. This high turnover of anglers, made possible by the reciprocal interdepartmental agreements, demonstrates the significant mobility of anglers who practice in different departments from one year to the next.

### *Economic importance of anglers*

In 1996, the economic value of freshwater angling was estimated at 549 million € turnover per year, including closed water (mostly private fishing ponds) anglers (Pinet 1997). This figure is a direct function of the number of anglers and of the individual angler's budget. In 1990, about 50% of fishers had an annual fishing budget amounting to less than 76 € (Gamond 1991). However, the large expenditures made by some anglers brought the average to 196 € (about 208 € in today's money). Equipment, card price, and transportation appear to be the principal expenses. Spread across the number of fishing trips per year, the average cost of a trip can be calculated as the equivalent of two cinema tickets, but for twice the length of time. Pinet (1997) estimated that one fishing trip was equal to one cinema ticket, the average price of which has remained constant since 1991, with inflation

taken into account (FNCF 2020). The angler's annual budget was thus six times less than that of a hunter (1,174 €). When comparing the three-fold higher annual turnover generated from hunting (1.68 billion € per year), it must be noted that angling involves at least twice as many individuals.

The angler's budget established by Brun and Pinet (1998) was re-evaluated upwards by Ribein (2005) who estimated total average expenses at 336 € for 2004, bringing the turnover of freshwater angling (including closed water angling) to 575 million €. In 2011, a new national study calculated the French freshwater angler's budget at an average of 681 € per year (BIPE 2014) with a gross domestic product (GDP) of 920 million € revised to 962.9 million € for the year 2017, as can be seen in Table 2. The same study estimated the global economic impact of the angling sector at 2.1 billion € including direct (material...), indirect (tertiary and industrial), induced (salaries of employees of direct and indirect activities) and catalytic (accommodation, catering, transport).

Thus, from 1996 to 2011, the freshwater angler's expenditure increased from 262 € per year (value of 208 € in constant 2011 euros) to 681 € per year, a multiplication of 2.6. This is considerable, especially when compared to the annual budget of the sea angler, which was estimated at 146 € per year in 2011-2013 (Levrel et al. undated). The fact that freshwater anglers spent much more money than marine anglers is understandable, considering the cost of the fishing card - sometimes more than 100 € per year - and the costs of transportation. Nevertheless, in 2014, the same consultancy firm (BIPE 2015) estimated the budget of the hunter at 1,136 € per year with an economic impact of 3.6 billion €, including 2.1 billion € GDP. In fifteen years, the gap that existed with hunting has therefore narrowed considerably, with the annual budget of the hunter going from a factor of 6 to a factor of 1.7 when compared to the budget of the freshwater angler.

#### Quantification of anglers' catches

Catches by freshwater anglers have rarely been estimated. However, the number of anglers and the average fishing times in our possession do allow to make a first approximation by distinguishing the different fishing yields according to the species sought (Table 2). In total, we obtain 12,709 tonnes per year in the middle of the 2010s: this is lower than the values estimated by Charpy (1958) or Arrignon (1991), who referred to the larger population of fishers who mainly targeted Cyprinidae, fish which have a better yield than the other families of fish. With the rise of Salmonidae anglers, Cyprinidae no longer make up the majority of catches. Indeed, catches must be differentiated from removals, as it is known that these fish are very often returned to the water (ANSES 2012) in the context of a developing trend among French trout anglers towards catch-and-release fishing, under the name "No Kill".

#### **Amateur fishing**

Amateur fishers have long been grouped together with professional fishers who use similar techniques and who often seek the same species. However, amateurs are restricted by the number and size of the gear allowed to ensure that the scale of their catches remains non-commercial. Their activity is similar to subsistence fishing, which is still widespread in the Nordic countries of Europe.

## The techniques of amateur fishers using gear

These amateur fishers are rarely authorized to use nets, but when they are, they are restricted to nets with a maximum cumulative length of 60 m (Art. R436-24 of the EC). The number of nets allowed is often limited to three, sometimes to six. On the other hand, many amateur fishers still use gear that has been abandoned by professional fishing, such as cast nets, dip nets, or wicker fish traps, and as such, they are the last practitioners of many old traditional fisheries.

## Number, evolution and distribution

The number of amateur fishers is only accurately known through specific taxes in use on the Public River Domain (PRD). Fig. 2 shows a concentration in regions already highlighted as areas frequented by anglers: the Gironde (and neighboring departments), the Lower and Estuarine Loire (and neighboring departments), and the Lower Saône (and departments in the Rhône basin).

The 4,179 amateur fishers counted in 2016 on the PRD adhered to anglers' federations by the 1984 law. They were previously admitted, under a special status, called "Petite pêche" license holders and "Compagnon", (companions, or fishers' helpers). The trend of number of taxes sold reveals two periods (Fig. 2). The first period, from 1952 to 1976, evidences a stable number of individual taxes at around 15,000; and the second period, from 1976 to the present day, shows the number of amateurs decrease more and more (-20% in 10 years from 1995 to 2005, -34% in 10 years from 2006 to 2016); with a peak in 1990, due to the erroneous inclusion of troll fishers from the Landes lakes (which are outside the PRD). The introduction of a specific additional tax for glass eels shows that this activity has remained minimal compared to all amateur fishers on the PRD. Glass eel fishing was banned in 2010 (Art. R436-65-3 of the EC), as the economic value of this resource was too high and was incompatible with a non-commercial activity.

In some French departments, amateur fishers in the private domain may simply pay a full angler's tax (Figure 2B), or exceptionally, pay no tax at all in cases of inherent rights based on title (according to Art. L431-7 1st of the EC). These incorrectly counted fishers appeared to be far more numerous than amateur fishers on the PRD. In 2000, it was estimated that there were 15,000 such amateurs fishing for eels (Changeux 2002). Even though 230 of them who were targeting downstream eel in the private domain were no longer renewed as of 2003, in 2005 there was still an estimated more than 10,000 trap and net fishers in the private domain associated with the three main sectors highlighted in the distribution of amateur licenses in the PRD. In 2009 when the Eel Management Plan was introduced, this value was re-estimated following a detailed count at around 1,000 only (Anonymous 2018).

## Economic importance

There has been no global study of the economic importance of this activity. However, several local studies (Annecy Lake, Rhone basin) conducted in the 1990s do allow us to evaluate the average budget of an amateur fisher using gear at 721 €, (updated to 2017 values of the euro). This expenditure is close to that of an angler. The motorized boat as well as its maintenance and fuel represent the main difference with the angler. This cost includes the refurbishment and fitting of the gear, which is usually done by the amateur himself. Applied to the 4,179 amateur fishers of the PRD, this results in an annual expenditure of 3 million € (Table 2).

## Quantification of catches

Although declaring catches by amateur fishers of the PRD has been compulsory since 1988, it was not enforced until 1999, when national monitoring of gear fishing was set up. Prior to 2005, this monitoring provided an overall view of the activity and the systematic exploitation of amateur fishers' declarations.

The suspicion of selling high-value resources such as glass eels, large eels or pikeperch was long an obstacle to the implementation of enforced declarations in sectors where amateur fishers were numerous or where they were authorized to use nets, against the advice of anglers. In sectors where the atmosphere was less conflictual (Rhône basin, Saône), or where effective means of control had been put in place (peri-alpine lakes), records covering more than 15 years were compiled and used regularly for management purposes.

By multiplying the yield of 50 kg per fisher per year (or 4 kg per session), as obtained by monitoring throughout the period 1999-2002, the average total annual catch by amateur fishers of the PRD was estimated at 209 tonnes in 2016, compared with 309 tonnes in the mid-2000s (Changeux in Keith et al. 2011). This decrease in catch volume takes into account the decrease in the number of fishers only, given that there was probably also a decrease in yield that cannot be quantified due to the accelerated ageing of this category of fisher, more and more of whom retain their fishing licenses without using them.

## Professional fishing

Among all freshwater fishers, professional fishers are the only ones authorized to sell their catches (Art. L436-13 of the EC). They may work full- or part-time (Art. R434-40 of the EC), provided they undertake to spend at least 600 h per year freshwater fishing. The most recent available academic work on professional fishers dates back more than 25 years (Babin 1994).

### Types of professional fisheries

These fishers are allowed in three main types of aquatic environments: estuaries, peri-alpine lakes, and large rivers, including the associated floodplain water bodies (small lakes and side arms).

#### *Estuarine fisheries*

Estuaries shelter a rich and diverse fauna consisting of resources of marine origin, migratory fish and also resident fish. Professional estuary fisheries essentially target migratory fish and follow the passage of the targeted fish species (Holl and Auxière, 2013). The season begins in November with the arrival of glass eels which are caught using small-mesh dip nets called "sieves" (1.2 m diameter, mesh size (MS) between 1 and 2 mm). This fishery starts earlier the further south one goes because the glass eel, migrating from the Sargasso Sea, reaches the European continent from south to north following the Gulf Stream current. This fishing is prohibited in the Mediterranean. The beginning of the year is marked by the arrival of lamprey and mullet, and fishing for these species continues until spring. Very quickly, shad take their place along with the salmon, for which fishing is only authorized in the Adour River. The end of the summer is an off-season except in the Gironde, where white shrimp are fished. It was possible to fish yellow eel all year round until 2008. However, since 2009 and the implementation of the Eel Management Plan (EMP) in application of the European regulation 1100/2007 for the recovery of eel stocks (Anonymous, 2018), yellow eel fishing has been limited to one or more

periods of 5 months in total per year, while fishing of the silver eel is limited to a few areas from late summer to mid-February (see order of February 5, 2016 in application of Art. 436-65-4 and 5 of EC). For the same reasons as yellow eel, the fishery for silver eel, which represent future spawners, has been even more strictly restricted since 2009.

#### *Peri-alpine lake fisheries*

In peri-Alpine lakes (Lake Annecy, Lake Bourget and Lake Geneva) the main targeted species are perch and Salmonidae that are caught from January or February to October, with exact dates depending on the lake. Lake char are caught with bottom nets; lake trout and European whitefish are targeted with a type of pelagic net called a “pic” (120 m long, from 14 m to 20 m in height, and minimal mesh size (MS) of 45 mm: these pelagic nets are sometimes left to drift in 30 to 130 m deep open water). In Lake Geneva, perch are targeted with 4 m<sup>3</sup> fishing traps (2 m in length and height, and 23 mm MS). The off-season from October or November to January or February is marked by the closure of the Salmonidae fishery. The off-season for perch is from the end of April to the end of May for Lake Geneva and Lake Bourget.

#### *Large river fisheries*

With the increasing scarcity of eel populations, the fisheries of large rivers and their associated waterbodies are now mainly oriented towards resident fish. The season starts in June with predatory fishes (pikeperch, pike, perch and coarse fishes (Cyprinids)). From July onwards, whitebait of small Cyprinidae species is more particularly targeted and this continues until the autumn, particularly on the Saône River for common bleak (*Alburnus alburnus*) and the Loire River for gudgeon (*Gobio gobio*). The autumn is marked by the downstream migration of silver eels. In the Loire they are fished using “guideau” nets, trawl-shaped fishing nets measuring 25 m long with a 10 m wide by 5 m high mouth and an MS of between 160 and 10 mm ; these nets are deployed in the channel using a large boat. In the Rhône River, “gangui” nets, 20 m long fyke nets with very tight mesh (between 20 and 10 mm MS) and a rigid frame, are used. In winter, predatory and coarse fish are still targeted. There is little fishing activity in the spring, when fish are left to reproduce.

#### *Number, evolution and distribution*

In contrast to recreational activities, professional fishing is very strictly regulated by the law and controlled by the local administration (Direction Départementale des Territoires in French). The number of fishers in 2006 was precisely 605, including 67 companions (helpers) and fell to 387, including 18 companions, in 2016. In fact, professional fishers are allowed to call upon the services of one or more companions to fish in their absence (Art. R435-10 of the EC), provided that the companion devotes at least 152 hours to fishing (Art. R434-40 of the EC). This dramatic fall in numbers represented an overall drop of 35% over 10 years, from 2006 to 2016, and can be explained by two simultaneous crises: (1) the rediscovery of contamination by Polychlorinated Biphenyls (PCBs) in the aquatic environment and certain fish stocks, which led to bans on the selling and consumption of fish between 2007 and 2011 in more than 100 locations (Robin des bois 2013), and (2) the Eel Management Plan, which decreed the reduction of professional fishing pressure by least 50% for eels. In order to support those professionals in the greatest difficulty, the government set up financial assistance for cases of cessation of activity between 2014 and 2016.

Professional river fishers' associations are found throughout France, including in the departments where this type of fishing is not allowed locally (contrary to what Fig. 3 may suggest, only a few départements have professional fishers). The initial division by basin has taken on complexity to better respect the specificities of estuaries. There are currently 10 different associations. The Alpine lakes and the Adour basin concentrate 42% of the freshwater professional fishers (Fig. 3). Behind this leading group are the Loire-Atlantique and Garonne-Dordogne sectors, along with the Gironde, where numbers fell by 50% from 2006 to 2016. Behind these associations with intermediate numbers come the fisheries associations covering the large rivers: the Middle Loire and Saône-Doubs, the Upper and Lower Rhône, and lastly, the Seine and Rhine basins. The concentration of professional fishers in the Atlantic estuaries is less marked than was the case in 2006, due to the drastic decline observed in the Gironde and Adour. This decline also concerns marine fishers of the same estuaries (in blue in Fig. 3), who are authorized to go upstream, where they become the local majority rather than riverine fishers, as in the Loire-Atlantique department. In 2006, the number of licenses issued was 988 compared with just 492 in 2016, i.e. 50% fewer. Finally, from 2006 to 2016, only the sectors of the Alpine lakes (mainly Lake Geneva), Loire-Brittany and the Rhône and Rhine basins remained stable.

In the longer term, and despite the major changes brought about by the 1984 fishing law, it is possible to compare the evolution of the number of professional fishers and auxiliary fishers called "Compagnon" with the evolution of the "Adjudicataire" and "Co-fermier" from 1981 to 1984, and then with that of the "Permissionnaires de grande pêche" and "Petits adjudicataires" before 1981 (Fig. 3). These different tax regimes correspond to two distinct statuses: that of the main fisher ("Professionnal", "Adjudicataire" and "Permissionnaire de grande pêche") and that of the auxiliary fisher ("Compagnon", "Co-fermier", "Petit adjudicataire") who operates as an assistant to the main fisherman. The trends are the same as those observed for amateur fishers using gear, since these two categories were managed jointly. The abrupt break occurred in 1976, when fishers were asked to take an agricultural status with contributions to the national mutual insurance for agricultural activities.

#### Economic importance

The national annual turnover of professional freshwater fishing was estimated between 5.8 and 8.8 million € in 1989 (Babin 1991), between 13.7 and 14.5 million € in 1997 (Champion 1999) and at 10.5 million € in 2009 (ANDI 2009). In comparison, it was estimated to be eighty-one times lower than the value of marine fisheries sales (14.5 vs 1,182.4 million € in 2007 following INSEE 2010). The latest available study on inland fisheries (ANDI 2018) lacks a sufficient return rate to provide a global figure. It only estimates the mean annual turnover of a fishing business at 37,988 €, with 58.4% pre-tax income, resulting in 2,208 € per month per full-time equivalent. This is 22% higher than the 1997 figure in constant euros. However, this figure hides great diversity depending on the geographical location of the business, with Alpine lakes fishers appearing as those with the highest annual turnover (67 K€). This leads us to be confident about the future of the sectors that remain untouched by the Eel Management Plan or by PCBs, because sales prices, with the exception of glass eels, are generally on the rise (ANDI 2018).

The conversion of the mean values of overall turnover into 2017 values gives 11.33 million € in 1989, 18.37 million € in 1997 and 11.39 million € in 2009. These few figures spread over 20 years show how dependent the freshwater fishery turnover has been on the price of the glass eel. The highest values are found for 1997 and



correspond to a situation where migratory fish (eels, lampreys, shad and mullet) accounted for 74% of turnover (Boisneau & Mennesson-Boisneau 2001). Glass eels alone accounted for 42.7% of the total. However, the price of glass eels has since risen dramatically (Boisneau et al. 2016): a purchase price of less than 15 € per kg in local food markets during the 1970s had already risen by the 1980s to an average export price of 60 € per kg to Spain. The appearance of Chinese farms coming to France for supplies began in the mid-1990s, which at times raised the price to over 150 € per kg (Anonymous 1998). In the Loire Estuary, from 1995 to 2005, the average price rose from 50 to 500 € per kg (Steinbach and Lapoirie 2005). It then fell with the implementation of the Eel Management Plan from 2009, and the price of glass eels returned to the level of the mid-1990s, at around 277 € per kg (ANDI 2018).

### Quantification of catches

Professional catch declarations are regularly used for management purposes in the most important sectors. At the end of the 1980s, catches were between 1,200 and 1,700 tonnes (Babin 1991). Over the period 1999-2002, they were estimated at an average of 1,251 tonnes, and in 2009 they were estimated at 1,186 tonnes (ANDI 2009). In comparison, catches were estimated to be 246 times lower than marine fisheries catches in 2007 (491.1 thousand tonnes vs 2.0 thousand tonnes according to INSEE (2010), which slightly overestimates professional freshwater fishery catches).

No detailed global figures are available on catch volumes since 2009 with the exception of in the Alpine lakes, in the eel fishery and in certain specific sectors. However, figures available for these sectors suggest that: 1) the decline in eel tonnages has probably continued, and 2) in peri-alpine lakes, lake char catches have never returned to the levels of the mid-1990s, despite the supportive stocking provided (Caudron et al., 2014), while whitefish catches have increased close to fourfold in Lake Geneva during this period, with a record figure of 761 tonnes for the French professional fishery alone in 2014 (Anneville et al. 2017). Whitefish catches rapidly decreased to less than the previous level with 144 tonnes in 2021 (data from the Lake Geneva fisheries consultative commission (LGFCC, 2022, Bourinet et al., 2023)).

### Conclusion and perspectives

The decrease we observe in all categories of freshwater fishers is in total conformity with the findings of Cowx (2015), who concluded that freshwater fishing had been in general decline for 25 to 30 years at the European scale. This situation of decline has also been observed since the fifties in the USA (Funge-Smith 2018). In the following, we will make a diagnosis and specify some expected solutions per fishing category for France in the European context, using data from the only exhaustive study available (Ernst & Young 2011), and conclude with some transversal perspectives for all categories.

#### Diagnosis and expected solutions by category

##### *Angling*

A comparison of the results in Table 2 shows that angling dominates the sector at all levels for France. In terms of value, it is sixty-seven times higher than the other two categories of fishing combined. In terms of volume, angling catches are about nine times higher.

Table 2: Comparison of the different French freshwater fisher categories during the middle of the 2010s.

<b>Freshwater fishing by category</b>	<b>Yield (kg/h)</b>	<b>Effort (h/year)</b>	<b>Number*</b>	<b>Catches (kg)</b>	<b>Economic importance**</b>
Angling: Salmonids and migratory fishes	0.1	67.6	760,000	5,137,600	
Angling: Coarse fish	0.152	67.6	560,000	5,754,112	
Angling: Predator fish	0.056	67.6	480,000	1,817,088	
<b>Recreational fishing total</b>			<b>2,000,000</b>	<b>12,708,800</b>	<b>962,900,000 €</b>
<b>Amateur fishing with gear and nets</b>			<b>4,179</b>	<b>209,000</b>	<b>3,000,000 €</b>
<b>Professional fishing</b>			<b>387</b>	<b>1,251,000</b>	<b>11,390,000 €</b>
<b>Total</b>			<b>2,004,566</b>	<b>14,168,800</b>	<b>977,290,000 €</b>

\* in 2016, \*\* in 2017 €

Table 3: Comparison of French anglers and commercial fishers' data with 20 other European Union member states during the middle of the 2010s. Sources: - Inhabitants: Pison G (2015) - Number of anglers: European Anglers Alliance (2003) in Ernst & Young (2011) - Number of commercial fishers: Ernst & Young (2011).

Member state	Inhabitant (Million)	Anglers						Commercial fishers						Anglers /Commercial			
		Number	Rank	per inhabitant	Rank	Catches (tonnes)	Rank	Number	Rank	per 1000 inhabitants	Rank	Catches (tonnes)	Rank	Value (€)	Rank	Ratio	Rank
Austria	8.6	300,000	13	3.49%	10	520	11	100	19	1.16	16	400	17	3,500,000	13	3,000	7
Bulgaria	7.2	180,000	17	2.50%	13	NA	NA	1,500	3	20.83	2	1,200	11	1,835,000	17	120	18
Czech Republic	10.6	330,000	11	3.11%	11	4,095	7	4	21	0.04	21	24	21	57,300	21	82,500	1
Denmark	5.7	616,000	9	10.81%	2	NA	NA	19	20	0.33	20	30	19	141,600	20	32,421	2
Estonia	1.3	50,000	20	3.85%	9	NA	NA	963	5	74.08	1	2,748	6	3,570,000	12	52	20
Finland	5.5	1,493,000	4	27.15%	1	31,676	2	945	6	17.18	3	4,498	1	9,276,000	4	1,580	9
<b>France</b>	<b>64.3</b>	<b>1,400,000</b>	<b>5</b>	<b>2.18%</b>	<b>14</b>	<b>15,500</b>	<b>4</b>	<b>431</b>	<b>12</b>	<b>0.67</b>	<b>19</b>	<b>1,186</b>	<b>12</b>	<b>10,470,000</b>	<b>3</b>	<b>3,248</b>	<b>5</b>
Germany	81.1	1,500,000	2	1.85%	16	9,230	5	932	8	1.15	17	3,256	4	11,300,000	2	1,609	8
Greece	11.5	NA	NA	NA	NA	NA	NA	400	14	3.48	10	887	13	2,481,000	16	NA	NA
Hungary	9.8	324,000	12	3.31%	12	4,749	6	304	15	3.10	11	2,275	7	3,867,500	11	1,066	11
Ireland	4.6	200,000	15	4.35%	8	NA	NA	624	10	13.57	4	27	20	675,000	19	321	15
Italy	62.5	900,000	7	1.44%	18	NA	NA	3,600	1	5.76	9	3,915	3	9,054,000	5	250	16
Latvia	2	150,000	19	7.50%	6	1,660	10	231	17	11.55	6	349	18	820,000	18	649	13
Lithuania	2.9	170,000	18	5.86%	7	3,000	8	300	16	10.34	7	1,594	10	2,500,000	15	567	14
Poland	38.5	600,000	10	1.56%	17	45,000	1	755	9	1.96	14	3,057	5	5,205,700	8	795	12
Portugal	10.3	235,000	14	2.28%	15	NA	NA	940	7	9.13	8	800	14	7,500,000	7	250	17
Romania	19.8	200,000	16	1.01%	20	NA	NA	2,677	2	13.52	5	4,284	2	4,712,400	10	75	19
Spain	46.4	646,000	8	1.39%	19	NA	NA	500	11	1.08	18	800	15	3,000,000	14	1,292	10
Sweden	9.8	1,000,000	6	10.20%	3	18,000	3	193	18	1.97	13	1,615	9	7,580,000	6	5,181	3
The Netherlands	16.9	1,500,000	3	8.88%	4	NA	NA	400	13	2.37	12	1,672	8	13,000,000	1	3,750	4
United Kingdom	65.1	4,000,000	1	6.14%	5	1,730	9	1,276	4	1.96	15	542	16	4,957,000	9	3,135	6
<b>Total</b>	<b>419.3</b>	<b>11,794,000</b>		<b>2.81%</b>				<b>15,818</b>		<b>3.77</b>		<b>35,159</b>		<b>105,502,500</b>		<b>746</b>	
<b>France (our study)</b>	<b>64.3</b>	<b>2,000,000</b>	<b>2</b>	<b>3.11%</b>	<b>13</b>	<b>12 709</b>	<b>4</b>	<b>387</b>	<b>15</b>	<b>0.60</b>	<b>19</b>	<b>1251</b>	<b>11</b>	<b>11,390,000</b>	<b>2</b>	<b>5,168</b>	<b>4</b>

An earlier study underestimated the number of French anglers by examining only the number of taxes, i.e. 1.4 million (Ernst & Young 2011). With our estimate of 2 million, France moves up from 5th place, behind the UK, Germany, Holland and Finland, to second place behind the UK (Table 3). Despite this lead, when divided by the number of inhabitants, our study still puts France in 13<sup>th</sup> place with only 3.11% of the population practicing angling, far behind more northerly countries such as Finland, Denmark, and Sweden where above 10% of the population of the country are anglers (Table 3). The values of the other European angler's fisheries are not sufficiently known to be comparable. Of the eleven countries for which angler catches are known, France ranks 4<sup>th</sup>, just ahead of Germany but behind Poland, Finland and Sweden (Table 3). Despite its large population and favorable ecological situation, French anglers are positioned behind the Nordic countries in the Western average, alongside Germany, but ahead of the southern European countries.

The decline in number observed across all French inland fisheries is interpreted for anglers in particular as being a consequence of:

- the constant decrease in the number of urban and rural laborers and farmers in the French population, which are socio-professional categories that traditionally included many fishers (Barthélémy 2013);
- competition from other leisure activities that have a better image or that can be enjoyed with limited travel, because fishing is associated with animal suffering, and is practiced far from urban centers;
- the development of fishing outside the approved associative system (private fishing ponds);
- increases in the price of the tax and the association fee;
- the negative image of the state of aquatic environments (pollution);
- the image of a complicated leisure activity, due to regulations and techniques.

The current long-term development strategy for the associative angling sector is based on:

- the establishment of a network of fishing schools to train new anglers;
- the improvement of the image of fishing;
- the maintaining, or even lowering, of the price of angling cards;
- the generalization of online purchase of the fishing card;
- the development of fishing services in relation to demand, in particular, the creation of courses dedicated to the various groups of anglers.

We can also consider the five essential tenets put forward by Arlinghaus et al. (2019) to ensure the sustainability of this activity. First, the use of bioeconomical models taking into account the opportunities and the quality of angling rather than the maximum sustainable yield (MSY), is not yet underway. The specific estimation of the value of wild vs. stocked fish established by Changeux et al. (2001) to evaluate management plans was a first step towards this process. But it is clear that the few species currently managed (salmon, eels), are protected species and their management is based on thresholds established only by demographic studies (Anonymous 2018, Prévot and Chaput 2001). Secondly, the association of recreational fishers with management is a principle that has long been respected, even prioritized, albeit somewhat less so since the disappearance of the CSP. Third, the consideration of a landscape approach enabling management of a diversity of fishing opportunities is quite effective in France. Indeed, if the main rules (legal sizes, bag limits, fishing seasons, etc.) are established on a national scale, it is always possible, and even recommended, to make local adaptations. Fourth, giving anglers a clear indication of the value of their activity through an appropriate management system using monetary or nonmonetary cost signals is a long-term principle. For species that are particularly vulnerable, management

controls on fishing are increasingly stringent. The tagging of salmon catches has been mandatory since 1987. Amateur glass eel fishing has been banned since 2010. Implementing the declaration of eel catches by recreational fishers remains very difficult. Fifth and lastly, the implementation of more generalized monitoring among recreational fishers is indeed difficult to envisage, even if there are many local examples, but rarely published, voluntary fishing logbooks (e.g. Gerdeaux and Janjua, 2009).

However, the possibilities offered by the mandatory purchase of fishing cards online and smartphone applications are promising possibilities that are still underexploited in France (see Venturelli et al. 2017 for apps), even if these practices are currently beginning at the local (FISHOLA for peri-alpine lakes) and national levels (log book associated with “Génération pêche” Smartphone app).

#### *Amateur subsistence fishing*

If we consider international terminology, amateur gear fishers belong to subsistence fishing for which no European data are available. In France, their non-commercial status has been highlighted by their separation from professional fishers and by the ban on their access to glass eels, as well as by their inclusion in the recreational fishers’ structure. This was achieved, however, at the cost of a sharp drop in numbers due to the hostility of anglers who accuse amateur gear fishers of depleting the resource with fishing methods to which they have no access.

In fact, our study scale and the current state of our knowledge indicate that amateur gear fishers do not actually catch much fish by weight. They do nevertheless contribute to the maintenance of traditional fishing practices and knowledge (Luneau et al. 2003), which is an essential yet often neglected dimension (Youn et al. 2016), particularly in Europe with the exception of the Nordic countries (Mustonen and Huusari 2020). These traditional practices are maintained primarily in two situations. First, on the public river domain (PRD), where the administration has preserved the memory of these practices and adapted them to the evolution of resources. Secondly, in certain areas where private bank or pond owners want to maintain their right to fish with gear, in which case, anglers may be refused access to the fishing sites. The future of this category of fishers will depend on their ability to clearly maintain the activity's non-commercial status and low impact on the resource, while enhancing its contribution to the rural heritage.

#### *Professional commercial fishing*

Professional fishing, despite its very small numbers of fishers, makes a significant contribution to catches and to the economy (Table 2), given the limited space in which it is allowed, and under-estimations linked to the non-inclusion of the economy it generates (tourism, filleting companies, restaurants, etc.).

Compared with the Ernst & Young study (2011) conducted across 21 EU member states, our slight underestimation of the number of commercial fishers (387 vs. 431 in Table 3) can be linked to the fact that this study refers to a situation prior to the middle of the 2010s. Whatever the figure used, the number of fishers places France in the second half of countries (12<sup>th</sup> or 15<sup>th</sup> position) with the lowest number of fishers, and among the last countries (in 19<sup>th</sup> position) when divided by number of inhabitants. The ratio between number of anglers and commercial fishers is as high as in the northern countries if the Czech Republic, with its particularly low number of commercial fishers, is omitted. Commercial catches are related to the number of fishers, and fall to between 12<sup>th</sup> and 11<sup>th</sup> position (Table 3). On the contrary, the value is much higher (in 2<sup>nd</sup> or 3<sup>rd</sup> position) due to

a high proportion of high priced species such as glass, yellow and silver eels plus other diadromous species from estuarine fisheries, as well as Coregonidae from peri-alpine lake fisheries.

The ban on Atlantic salmon fishing in the Loire and Garonne-Dordogne along with the scarcity of eels and the control on the international glass eel market have prompted fishers in upstream areas to target abundant resident species, mainly Cyprinidae. Value is added to their catches through processing into gutted whitebait or fish terrine. In these geographic sectors, which were originally not very popular, the fishers have resisted better to the decline in numbers, thanks to a major commitment in resource management and habitat restoration, and through reconnecting with local consumers. Full recovery may be possible because: 1) some areas within these sectors are expected to be reopened as PCB concentrations fall, due to the cessation of pollution sources and the removal of contaminated sediments to the sea by river floods; and 2), some non-native, introduced species such as European catfish or American crayfishes, as well as abundant resources such as large Cyprinidae, have been shown to have real commercial potential when processed (ANDI 2018).

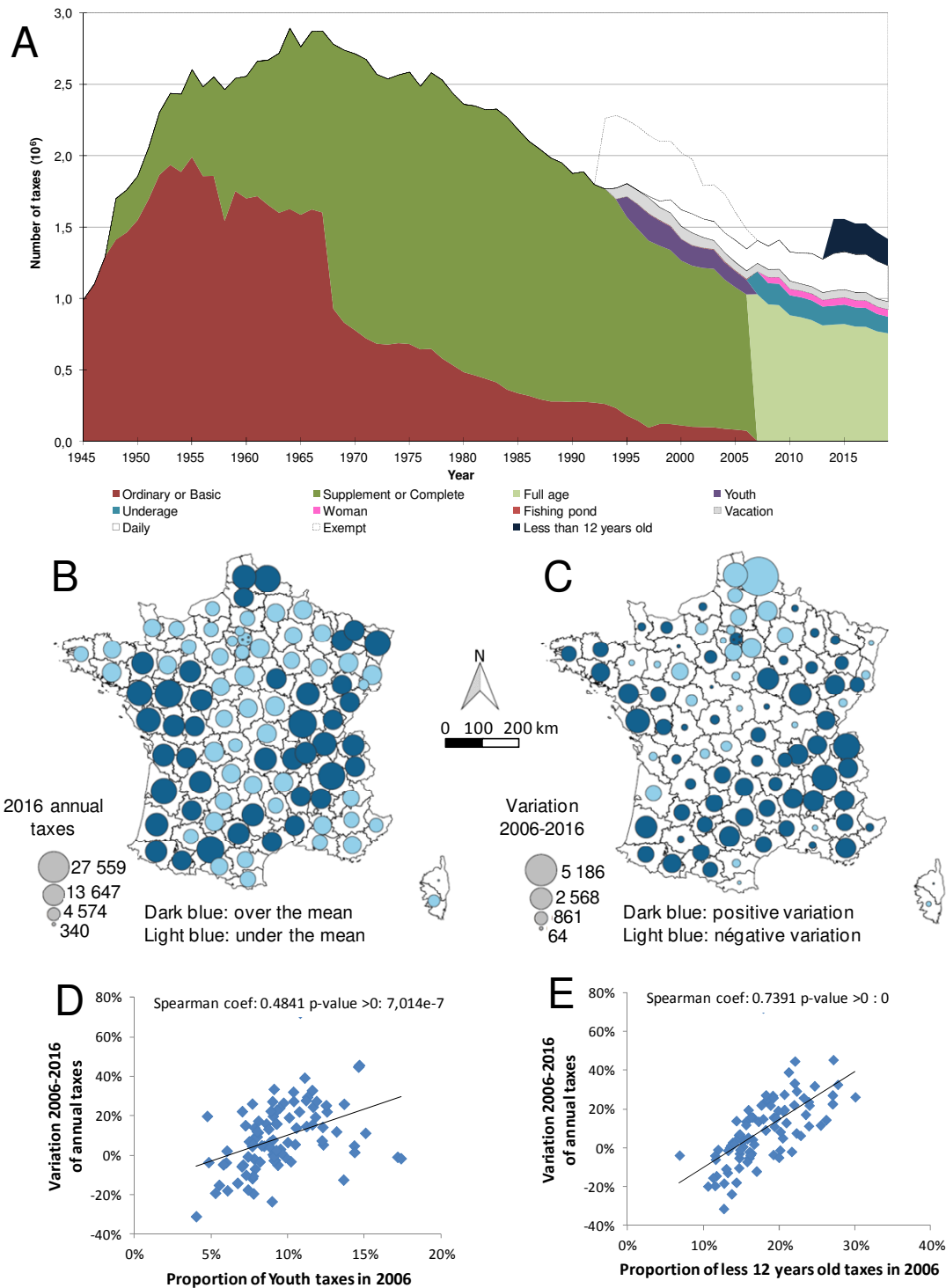
Professional fishers should therefore play a decisive role in local management and in the economy. Through their permanent presence on the waterways and the recording and declaration of catches, they are also witnesses of environmental changes in continental ecosystems (Boisneau et al. 2016).

#### Transversal perspectives

In order to consider the future of freshwater fishing, with all types of activity taken together, it is necessary to react against the various impacts of the global changes to which freshwater ecosystems are particularly exposed (Oberdorff 2022). In addition to the direct anthropogenic factors such as land use change, habitat fragmentation, invasive species and overexploitation, chemical contamination has already strongly affected freshwater fisheries (Costa et al. 2021). After several episodes during the 1980s, the consumption, marketing and sometimes even fishing of certain fish were banned beginning in the summer of 2007 in several rivers and lakes in the Rhône, Seine, Vilaine, Loire, Garonne and Rhine basins. Indeed, the catches revealed PCB concentrations above the health standard, and it was shown that this contamination, which often results from old pollution, concerned mainly large benthic feeders (Babut et al. 2012). Nor are predatory fish free of heavy metals (mercury, cadmium, cesium, lead) and arsenic (Noël et al. 2013): we must therefore consider that in the long term, the fate of all fishing and consumer aquaculture, including at sea, will be linked to the success of pollution control. The reopening of commercial fishing in most inland basins is clearly encouraging in this respect.

In addition to this direct anthropogenic factor, climate change is one of the primary drivers underlining patterns of biodiversity in freshwater ecosystems. The impact of climate change - mainly rising temperature-, is already noticeable on French freshwater fish. Species are moving 61 m upstream per year (Comte and Grenouillet 2013). This concerns principally thermophilic species (Daufresne and Boët 2007). The distribution of cold-water fish is expected to drastically reduce (Buisson et al. 2010), and it is estimated that by 2080, trout may have disappeared from 37 % of the range it occupied in the early 2000s (Buisson et al 2008). In peri-alpine lakes, anticipated continued warming of winter temperatures may negatively impact spawning success of cold water fish (Kelly et al., 2020, Stewart et al 2021, Desgué-Itier et al., 2022). Effects of this change on the reproductive phenology of fish in these lakes has already been observed (Gillet et Quéting, 2006, Anneville et al., 2013). The recent drought/heat wave of summer 2022 has led to a ban on fishing in more than 30% of departments, mainly in small rivers dominated by trout where waters have stopped flowing and/or temperatures rose too high (Jerome Guillouet personal communication). The average size of fish is also expected to decrease,

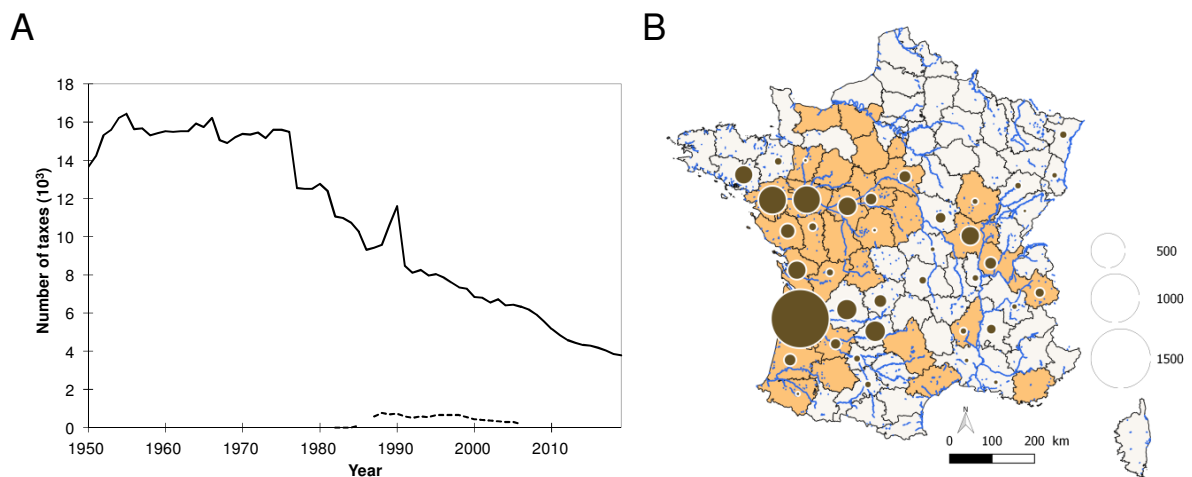
resulting in a reduction of the overall biomass (Daufresne et al 2009). These foreseeable situations can be mitigated by management measures, including fishing restrictions. Freshwater fishing will thus have to adapt by targeting thermophilic species and by moving towards more resilient environments such as lakes and reservoirs.



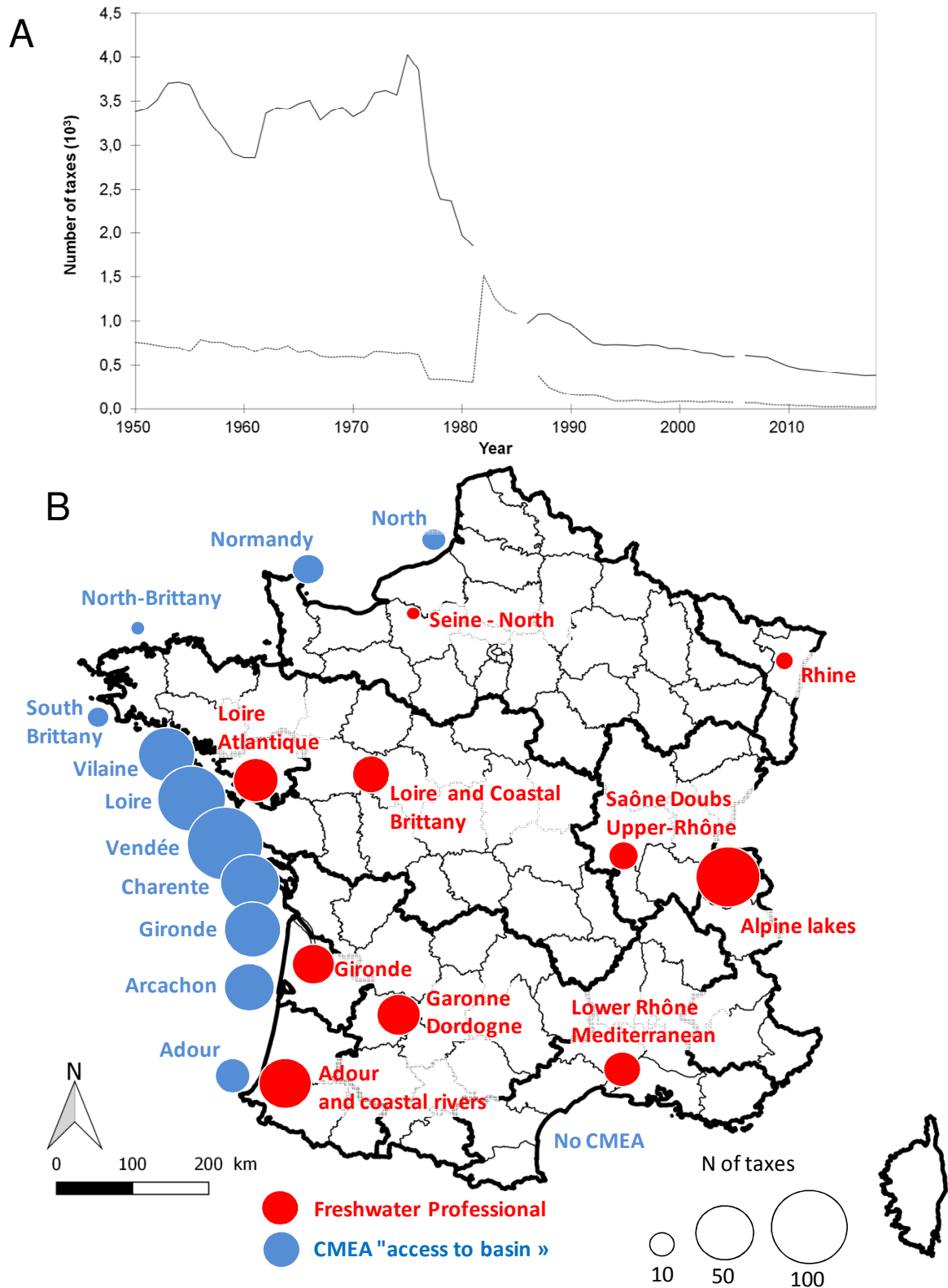
**Fig. 1:** French freshwater angler statistics. A) Number of taxes: evolution since 1945. Annual taxes are in color, part time in white, and exonerated in white with a dotted line. In 1994, Supplement and Ordinary taxes merged into a Complete tax. In 1995, the Ordinary tax was replaced by the Basic tax and both are shown together. In 1998, the Basic tax was replaced by the Reduced 1 which, when added to the Reduced 2, was equivalent to the Complete tax. In 2007, the Full Age tax replaced the Complete tax, the Underage replaced the Youth tax (less than 16 years old). In 2008, a Women's tax was created, and in 2014 the Less than 12 years old tax appeared. B)



Distribution of annual taxes by department in 2016 with a distinction made between low (light blue) vs. high (dark blue) numbers of taxes. C) Variations of annual tax sales by department between 2006 and 2016 with a distinction made between negative (light blue) vs. positive (dark blue) tax variations. D) Relationship between young tax sales in 2006 and the variation of annual tax sales between 2006 and 2016 in the same department. Spearman's rank correlation coefficient is significant. Each point represents a department and all the figures are expressed as a percentage of the total number of taxes sold in the department in 2006. E) Relationship between 12-year old tax sales in 2006 and the variation of annual tax sales between 2006 and 2016 in the same department. Spearman's rank correlation coefficient is significant. Each point represents a department and all the figures are expressed as a percentage of the total number of taxes sold in the department in 2006.



**Fig. 2:** French freshwater subsistence fishing statistics. A) Number of taxes sold for fishing with gear and nets: evolution since 1950. Before 1985 is figured the sum of “Petite pêche” and “Compagnon” taxes. The dotted line shows the number of glass eel taxes. B) Distribution of annual taxes by department in 2016. Departments colored yellow are areas where holders of a “Complete” tax are authorized to fish with gear in some listed water bodies (Ministerial Decree of 1987/12/24).



**Fig. 3:** French freshwater commercial fishing statistics. A) Number of Professional fishers (solid line) and accompanying fishers “Compagnon” (dotted line) taxes since 1950. Before 1982, the solid line refers to the “Permissionnaire de grande pêche” tax and “Petit adjudicataire” tax. Before 1986, the dotted line refers to “Adjudicataire” tax and “Co-fermier” tax. B) Distribution of annual taxes in 2016 by freshwater Professional

associations in red (department group limits in bold, Corsica belonging to Lower Rhône Mediterranean) and by estuary in blue (Number of Migratory Species and Estuaries Commission (CMEA) licenses).

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