the Brief
N°7 - May 2013

Trends in fish populations in France from 1990 to 2009

The structure of fish populations and communities reflects ecosystem status and serves as an indicator of anthropogenic pressures, e.g. pollution, damage to river banks, obstacles to flow, excessive water abstractions, overfishing, etc. For these reasons, fish populations are closely monitored. They are listed among the quality elements for river water, notably for Water framework directive (WFD)[1] implementation, similar to the chemical quality of water, the presence of other living species (algae, invertebrates, etc.) and the undisturbed flow of water. In addition, fish lie at the centre of many human activities, including commercial fishing, aquaculture, recreational fishing, aquariums, etc., thus providing many ecological services. They are protected by many laws and regulations, notably the Habitats directive[2] and a number of species-specific programmes (eel-management plan[3], European LIFE Apron programme[4], etc.). The study of fish populations over time is thus of prime importance in setting up management efforts and assessing their effects.

Over 20 years of fish monitoring

Freshwater ecosystems are among the most threatened in that hundreds of animal species are endangered or have already become extinct according to analyses carried out by the IUCN (International union for the conservation of nature). In the latest edition of its red list[5], the IUCN warns that 15 species of freshwater fish risk disappearing from the waters of continental France, i.e. one out of five. Two centuries of industrial and agricultural development have

The 15 species of freshwater fish that may disappear from French waters

Source : UICN France, MNHN, SFI & ONEMA

European sturgeon	Spined loach
European eel	Pike
Lez sculpin	River lamprey
Rhône streber	Burbot
Weather loach	Atlantic salmon
Mediterranean trout	Arctic charr
Allis shad	Grayling
Twaite shad	

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[1] Directive 2000/60/EC (23 Oct. 2000), transposed to France by Law 2004-338 (21 April 2004).
[2] The «Habitats» Directive 92/43/EEC (21 May 1992) deals with the preservation of natural habitats and wild plants and animals.
[3] French decree 2010-1100 on the restoration of eel stocks, pursuant to European regulation 1100/2007.
[4] The LIFE programme is an EU financial instrument supporting environmental policy.
[5] *The Red List of threatened species in France, in the chapter on freshwater fish in continental France*, IUCN France, MNHN, SFI & ONEMA (2010).

resulted in major changes in the use of aquatic environments. Five categories of interactive pressures, namely overfishing, water pollution, hydrological alterations, habitat degradation or destruction, invasion by alien species, have produced a general decline in aquatic biodiversity and a reduction in the ranges of many fish species.

Long-term monitoring is essential to assess and understand ecosystem responses to natural processes and anthropogenic disturbances. They also provide the scientific and technical data required to implement public policies designed to improve environmental quality. Analysis of monitoring data is the means to:

> detect the potential effects of anthropogenic pressures as well as the effects of restoration efforts;

> identify threatened species and set up conservation measures;

> gain information on population dynamics, particularly concerning invasive species.

Monitoring of fish populations started in 1990 via an experiment in Brittany and Normandy, carried out by the CSP (High council on fisheries), an organisation that monitored aquatic environments and fish[6], as well as participating in policing activities (reporting on offences). Monitoring of fish had previously taken place on a more local scale (e.g. sections of a river), primarily at the request of resource managers. Since 1995, monitoring has been expanded to include the entire hydrographic network in continental France (overseas, the CSP was present only on Reunion Island). Approximately 650 sites, representing all fish communities and various degrees of anthropogenic disturbances, were sampled once each year. Electrofishing, considered the most effective non-destructive method to characterise fish populations in small to mid-sized rivers, was used as the sampling technique during the low-flow period (May to October), implementing a standardised protocol[7]. The actual method employed depended on the width and depth of the river, i.e. smaller rivers were completely sampled[8], whereas larger rivers were broken up into sections. In large rivers, a number of protocols were used successively. Early in the 1990s, point abundance sampling (PAS)[9] was employed, followed by the habitat-unit method[10] starting in 1995. Since 2007, Onema (French national agency for water and aquatic environments) has taken over most of the missions previously assigned to the CSP and continues today to monitor certain sites in the framework of the WFD (Water framework directive)[11]. These sites are now included in the 2007-2027 surveillance-monitoring programmes validated by the basin committees. Since the start of the surveillance-monitoring programmes, electrofishing protocols have complied with the recommendations of CEN (European committee for standardisation). Smaller rivers (average width less than 9 metres, ± 1 metre) are completely fished whereas fractional sampling strategies are employed on larger rivers.

This monitoring system produced chronological data series used to characterise interannual variations in fish populations and to detect long-term trends. The series are stored in the BDMAP database on aquatic environments and fish, managed by Onema. The oldest data in the database goes back to the 1970s.


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The collected data have served for a wide range of bioassessment projects, i.e. efforts to determine water quality based on a combination of parameters concerning the biological community in a given environment. They have also served for the development of pressure-impact models, i.e. methods to quantitively analyse the relationships between anthropogenic disturbances and the ecological status in view of defining the relevant spatial and temporal scales for management of aquatic environments. For example, the data were called on to design the fish-distribution models used to define the French and European bioassessment tools (IPR, IPR+, FAME, EFI+) and to validate the pressure-impact models required notably for efforts to restore rivers.

The BDMAP database today

Source : Onema

The BDMAP currently contains the results of almost 26 900 monitoring operations carried out using standardised protocols at approximately 11 800 sampling sites. The operations resulted in the capture of several million fish that were systematically identified, counted and measured (with the exception of batches that were only partially measured). The data will subsequently be incorporated in the future National database on the quality of continental surface waters (Naïades).

[6] Article R. 434-14 in the Environmental code.
[7] *Electrofishing operations in networks monitoring fish populations* - Guide, Onema (2012)
[8] Generally a two-pass removal by wading in the river.
[9] *A new method to study fish populations in large rivers using point abundance sampling.* (In French). Nelva, A., Persat, H. & Chessel, D. - C. R. Acad. Sci. Paris 289, 679–791 (1979).
[10] This method was formally presented in *Réseau hydrobiologique et piscicole* - Cahier des charges techniques, CSP (1998).
[11] Directive 2000/60/EC (23 Oct. 2000), transposed to France notably by Law 2004-338 (21 April 2004).

This document presents the latest data on temporal trends in fish populations in the rivers of continental France, the first step in revising the conservation status of fish species and identifying any threatened or potentially invasive species. It discusses in particular the richness, occurrence and density of the various species on the national scale. It is important to note the following points.

> The results must be interpreted on the national level. This is because the observed trends are not necessarily valid for each river basin, which remains the most relevant unit for the management of species and aquatic environments. For this reason, the trends in numbers for each species and sampling site are presented in map form.

> A total of 590 sampling sites offering at least eight years of data (between 8 and 20 with an average of 12) were selected for the study, representing a total of 7 746 sampling operations.

> Over the 20-year span studied, nine years had over 500 sampling operations and another four years had over 300. The effects of the new monitoring networks set up for WDF implementation became clearly apparent in 2005. A number of sampling sites were abandoned and the sampling method for large rivers was changed, with as a result a break in many data series.

> A majority of sampling sites are located on small to mid-sized rivers (Strahler ranks 2, 3 and 4). Very small rivers are underrepresented because most are not home to fish.

> The study is based on 48 taxa[12].

> The maps show the spatial distribution of trends in various species over the study period. They do not accurately show the distribution of species because, given the selection of sampling points and the limits to electrofishing in large rivers, they underestimate certain species (e.g. Wels catfish). They do not accurately indicate the size of populations either, because the detection of just a few more fish within a small population can result in a statistically significant increase.

Distinct range strategies for each species

Mapping of the average occurrence (number of times a species is present on the sampling sites) and density (number of individuals present on a single sampling site) of each species over the period 1990-2009 revealed four set of species.

> Common and often abundant species such as minnows (*Phoxinus spp.*), stone loach (*Barbatula barbatula*), gudgeons (*Gobio spp.*), chub (*Squalius cephalus*) and brown trout (*Salmo trutta*).

> Common but rarely abundant species such as eels (*Anguilla anguilla*), perch (*Perca fluviatilis*), rudd (*Scardinius erythrophthalamaus*), tench (*Tinca tinca*) and pike (*Esox lucius*).

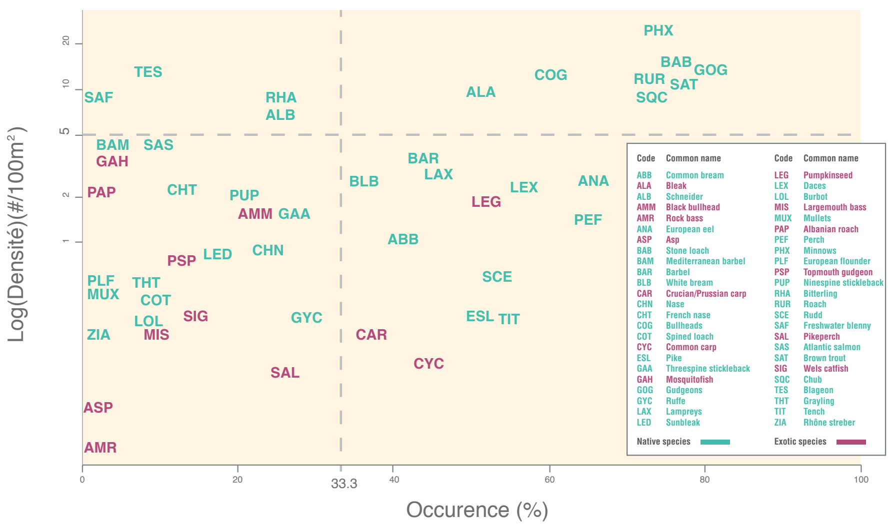
> More rare and less abundant species such as rock bass (*Amblopites rupestris*), asp (*Aspius aspius*), burbot (Lota lota) and Rhône streber (*Zingel asper*).

> Rare but locally abundant species such as freshwater blenny (*Salaria fluviatilis*), blageon (*Telestes soufia*), bitterling (*Rhodeus amarus*) and schneider (*Alburnoides bipunctatus*).

In general, exotic species are rarely caught and are not abundant. However, some are more frequent, e.g. common carp (*Cyprinus carpio*) and Crucian/Prussian carp (*Carassius spp.*), and others are more rare but occasionally abundant, such as mosquitofish (*Gambusia holbrooki*), Albanian roach (Pachychilon pictum) and black bullhead (*Ameiurus melas*). Only one exotic species would appear to be both frequent and locally abundant, namely pumpkinseed (*Lepomis gibbosus*).

Status of fish species from 1990 to 2009

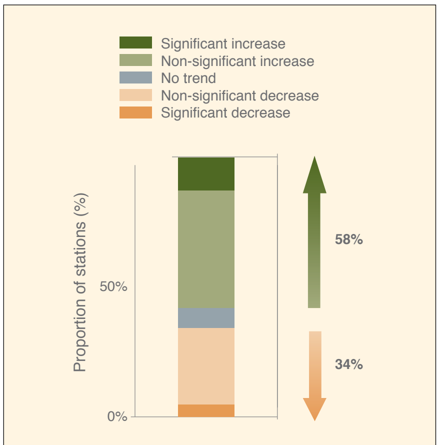
Source : BDMAP (Onema) – May 2011



[12] Taxa are the hierarchical levels used in biological classification systems to group species having shared traits (e.g. class, order, family, genus, species).

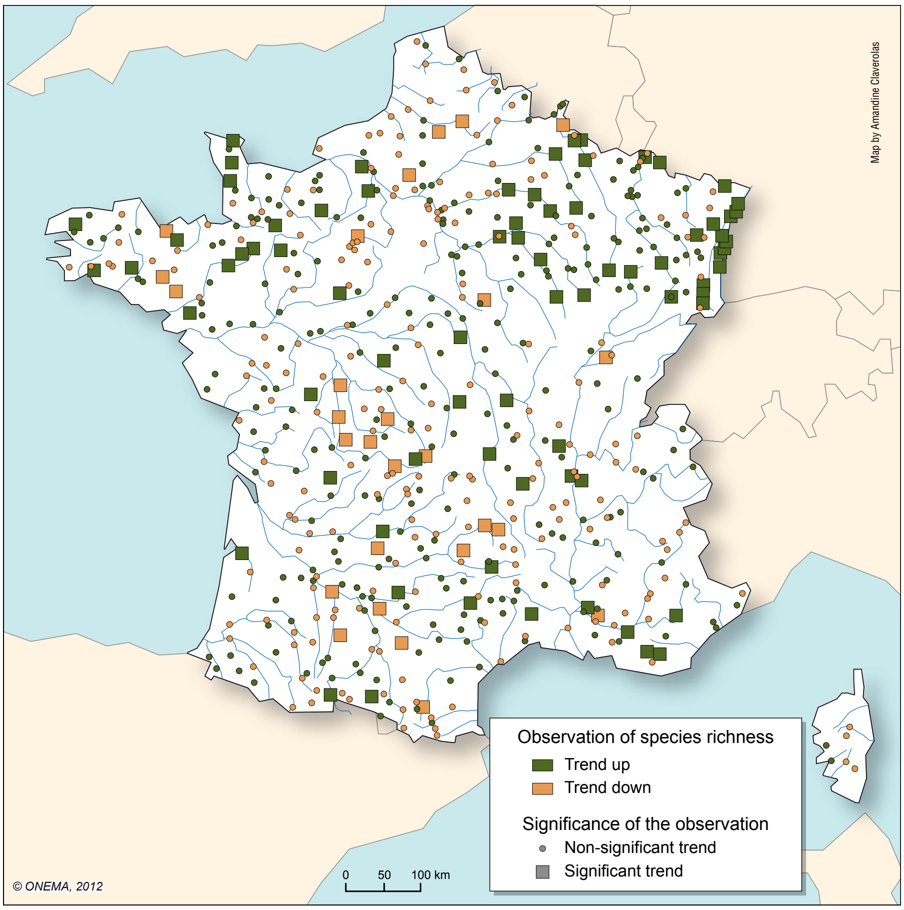
A general increase in species richness

The number of species has increased significantly on the national level, from 8.1 on average in 1990 to 9.5 in 2009. Among the 590 sampling sites, 343 exhibited a rising trend (including 77 with a significant[13] increase) and 202 a declining trend (including 27 significantly). Though these results are valid for the country as a whole, the richness in certain basins has decreased, e.g. the Vienne and Garonne basins. Conversely, the north-eastern section of the country and the Rhine and Meuse basins in particular exhibit a clear increase in species richness.



Species richness from 1990 to 2009

Source : BDMAP (Onema) – May 2011

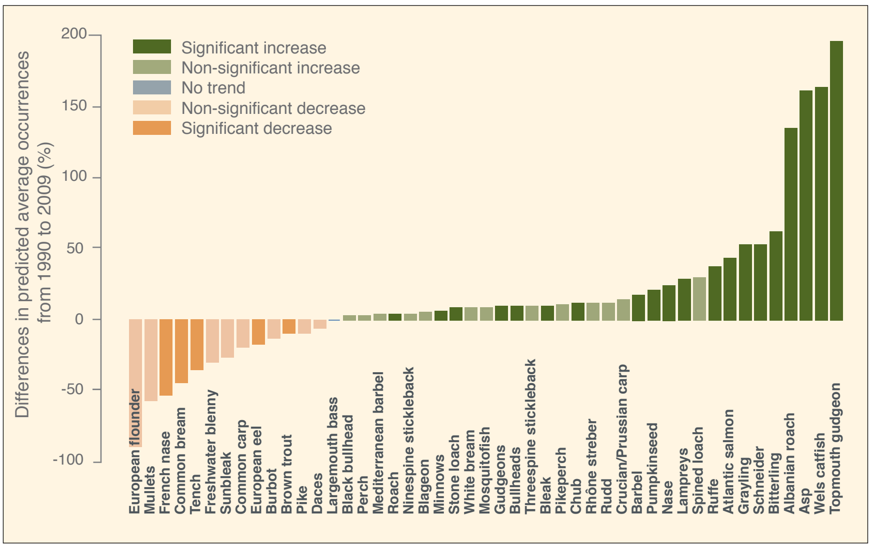


Divergent trends in occurrence and density of different species

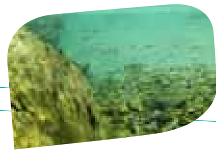
The increase in the number of species is due to a significant rise in occurrences, i.e. numerous species were detected at sampling sites where they were previously absent. Their ranges have therefore increased, as has the number of species per sampling site. A full 42% of the species exhibited a significant upward trend and only 11% a significant downward trend, with 47% showing no significant trend.

Occurrence of species from 1990 to 2009

Source : BDMAP (Onema) – May 2011



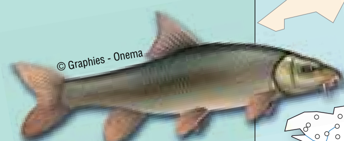
[13] The term «significant» means that the observed result has less than a 5% chance of being a fluke.



Exotic species represent the greatest increases, e.g. Wels catfish (*Silurus glanis*), asp, topmouth gudgeon (*Pseudorasbora parva*) and the Albanian roach. This is because the exotic species, most of which arrived fairly recently in France (less than 50 years ago, except for the Wels catfish), have much greater potential for progression, once they have become accustomed to the new environment, than the existing native species. The «older» exotic species, such as carp and pikeperch (*Sander lucioperca*), exhibit lower growth rates in their populations. That being said, certain native species, such as schneider, have progressed significantly. That is also the case for native species that were already widely present on the national level, e.g. barbel (*Barbus barbus*), gudgeons and chub. Species affected by downward trends include brown trout (*Salmo trutta*), common bream (*Abramis brama*), eels, tench and French nase (*Parachondrostoma toxostoma*).

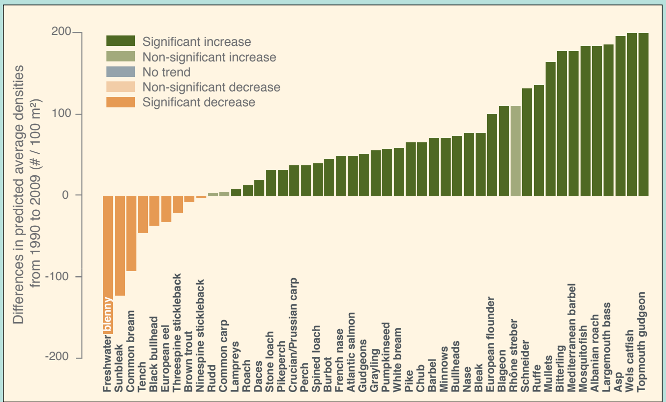
Concerning densities (the number of individuals per unit of surface area), most species exhibit an upward trend with 74% showing a significant increase and 17% a significant decrease, with 9% showing no significant trend. Once again, the exotic species exhibit the greatest increases, generally because few individuals arrive initially, but then reproduce rapidly if the environmental conditions are favourable. However, many native species, e.g. schneider, Mediterranean barbel (*Barbus meridionalis*), barbel and chub, also exhibit considerable increases in their numbers. The numbers have dropped for some species, e.g. black bullhead, brown trout, common bream, tench, freshwater blenny and sunbleak (*Leucaspius delineatus*).

Whereas the analysis on the national level shows a significant upward trend, the situation for barbel populations differs depending on the local geographic area. Numbers have increased in the Rhine, Meuse and upper Seine river basins, but numerous populations have dropped in the Loire, Garonne and Mediterranean coastal basins. The barbel is a case in point illustrating the need for spatial analysis of population trends.



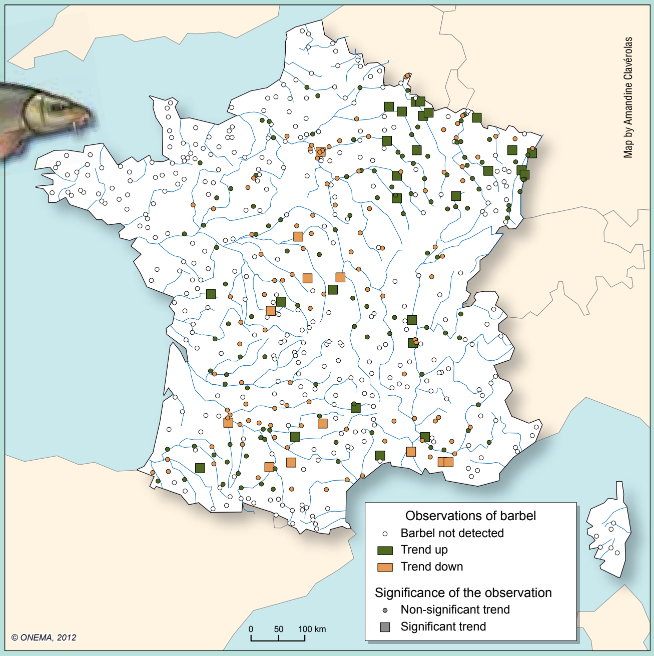
Density of species from 1990 to 2009

Source : BDMAP (Onema) – May 2011



Trend in densities of barbel from 1990 to 2009

Source : BDMAP (Onema) – May 2011



Diverse causes of trends

The factors behind these trends are most likely highly varied. Though this aspect has not been specifically analysed, a number of hypotheses may be put forward. First, climate change is thought to favour warm-water species, e.g. Wels catfish, topmouth gudgeon, bitterling and bleak (*Alburnus alburnus*), to the detriment of cold-water species such as brown trout. However, this observation does not apply systematically because certain species that reproduce at low temperatures (less than 10°C) have also tended to increase, e.g. stone loach and grayling (*Thymallus thymallus*), whereas others that reproduce at higher temperatures have decreased, such as common bream and tench. Considerable research has demonstrated that climate change tends to favour the expansion of numerous species, but the mechanisms involved are highly complex and the means to analyse them are limited. This is because the in-depth knowledge on the temperature ranges required for the complete biological cycle of a species (best thermal conditions) is generally available only for commercial or flag species, notably salmonids (trout and salmon). This makes it very difficult to determine the effects of global warming on the life cycle of most freshwater fish.

In addition to climate change, one reason for the upward trends for most species could be an improvement in water quality. The analysed data series begin in 1990, when rivers had already been subjected to major pressures caused by the industrial and agricultural revolutions, including pollution, fragmentation, habitat destruction, etc. At that time, the populations of many species were far from their «natural state» that would exist if no anthropogenic disturbances existed. Consequently, there was considerable margin for progress.

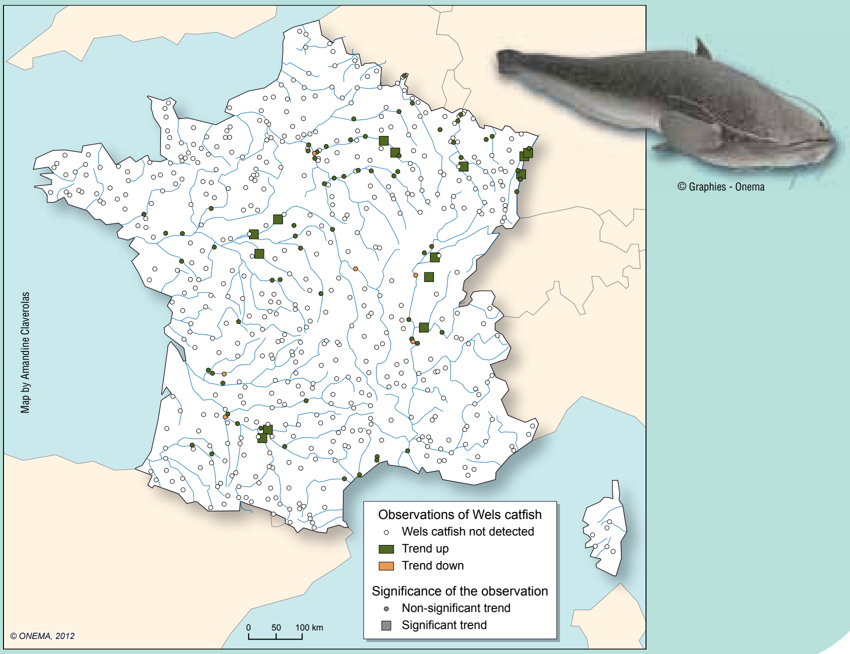
Efforts to treat wastewater over the past decades have reduced organic pollution and the level of phosphates in many rivers, and may have contributed to the upward trends of most species. However, these trends must not be understood to mean that all species have achieved a satisfactory conservation status. For example, the increase in Atlantic salmon[14] (*Salmo salar*) stocks is far from compensating the dramatic decline since the end of the 1800s following the construction of many large dams. Similarly, the upward trend in burbot populations must be considered in light of the severe regression of the species prior to the start of the study period[15].

The upward trend for many species must not mask the fact that some species have significantly declined and even virtually disappeared, an example being the European sturgeon (*Acipenser sturio*) which is not included in this study. The study confirms the general decline in European eel stocks that began in the 1980s. The many causes include overfishing, habitat destruction, pollution and mortality in hydroelectric turbines. Unfortunately, the relative importance of each pressure remains unknown. A European eel-management plan[16] has been established to restore eel stocks.

Density of Wels catfish from 1990 to 2009

Source : BDMAP (Onema) – May 2011

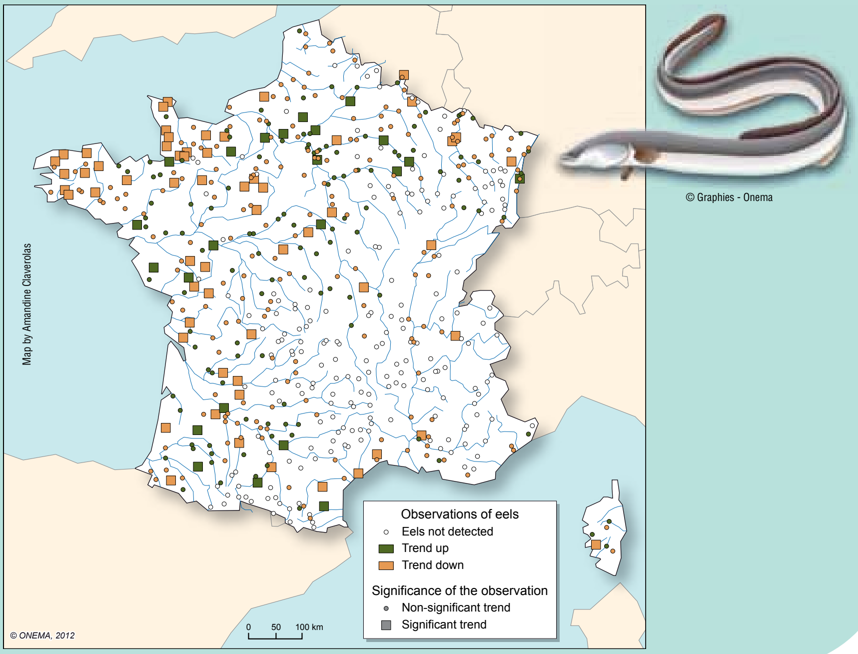
All significant trends for this species point clearly upward. Population numbers have increased on a vast majority of the sampling sites where it has been caught. The main sectors showing increases are the intermediate sections in large river basins, namely the Rhine, Seine, Loire, Rhône and Garonne.



Density of eels from 1990 to 2009

Source : BDMAP (Onema) – May 2011

The eel is in decline throughout its entire range. However, increases have been noted on some sampling sites, essentially in the Garonne, Adour and lower Seine river basins. On the other hand, populations known for their considerable size have undergone significant declines, notably in Brittany.



[14] This observation remains hypothetical in as much as it has not been possible to take into account the effects of restocking efforts.
[15] The results presented here must analysed in light of events preceding the study period.
[16] Regulation 1100/2007/EC (18 Sept. 2007) setting up measures for the recovery of the eel stock.

More surprisingly, common bream and tench are also in decline. This may be due to flood-control efforts including limiting discharges and the construction of dikes, thus inhibiting the flow of water to side channels which are transition zones between the terrestrial and aquatic environments. These zones can then no longer serve for spawning and growth of these species, notably tench. The reduction in eutrophication (a phenomenon that occurs when an environment receives excessive quantities of nutrients, e.g. phosphorous or nitrogen, and algae proliferate as a result) in large rivers due to water-treatment efforts may have contributed to the reduction in bream which develop particularly well in high-nutrient environments. The study results also suggest a slight, but real decline in brown trout, a species whose ecological requirements make it particularly sensitive to anthropogenic pressures causing temperature rise in water, reduction in the dissolved oxygen, silting of the riverbed and fragmentation of the environment.

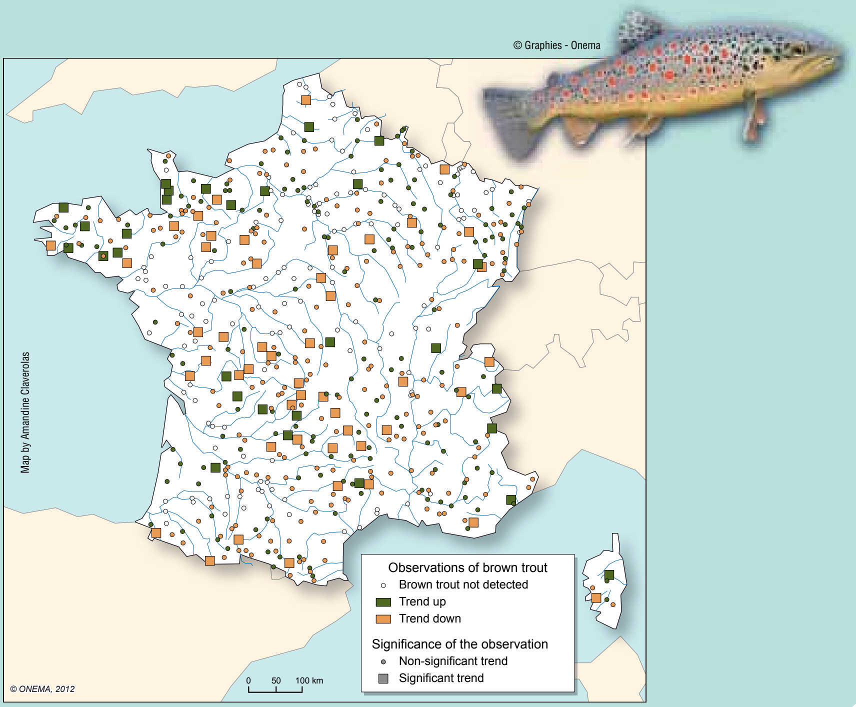
It should also be noted that many species are restocked for recreational fishing, e.g. brown trout, pike, roach (*Rutilus rutilus*), carp, pikeperch, gudgeons, etc. Unfortunately, the data on these restocking efforts are not available, thus making it difficult to determine the natural evolution of populations. For example, the trend for pike is positive, even though the IUCN experts have classified it as vulnerable[17].

Density of brown trout from 1990 to 2009

Source : BDMAP (Onema) – May 2011

The results for brown trout are generally in line with the overall situation on the national level, i.e. a general decline in the monitored populations in all river basins except in Brittany and coastal rivers in Western Normandy.

This downward trend has also been noted in Switzerland. In addition to the causes noted above, PKD (proliferative kidney disease, facilitated by temperature rise in water) and overfishing would seem to be two major factors in the decline. Similar to the studies on the high mortality rates in the Loue and Doubs rivers near Switzerland, more in-depth studies are required to precisely identify and quantify the causes of the decline.



Overall results and future work

Fish-population monitoring efforts using electrofishing techniques from 1990 to 2009 showed that a majority of species increased both their range and numbers. The most spectacular results concern exotic species, e.g. Wels catfish and asp, however trends are also positive for a number of native species such as schneider and barbel. Unfortunately, the situation for other species (European eel, brown trout and French nase) is highly worrisome in that their populations are clearly in decline. Efforts are required to collect data on restocking in order to determine its impact on the dynamics of the natural populations. The many questions raised by this study will require additional work, notably further analysis addressing geographic characteristics because the study revealed that overall trends on the national level are not always mirrored by the results on the river-basin level. The objective of this future work would be to prove or disprove the hypotheses put forward to explain the various trends. It is important that this work be carried out because its results will have a direct influence on the measures implemented to halt the decline of certain species, to slow the invasion of other species and to optimise river-restoration measures.

[17] *The Red List of threatened species in France, in the chapter on freshwater fish in continental France*, IUCN France, MNHN, SFI & ONEMA (2010).

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To observe the evolution of living beings over the time periods required for their management, it is necessary to set up sustainable monitoring programmes:
> carried out in time steps that are biologically relevant;
> implemented according to standardised methods;
> on a set of sites sufficiently numerous to represent most macro-environmental conditions.

Given that monitoring costs are relatively low (less than 1% of the overall costs for WFD management and restoration measures for the period 2007 to 2010[18]), notably compared to the financial gains produced by the improvement in environmental status, monitoring is an eminently worthwhile tool for decision-makers and resource/policy managers in designing, implementing and assessing environmental policies.

[18] *Report on WFD monitoring costs for the years 2007 to 2010*, French Ecology ministry (2011).

Note on methods

The information briefly presented here is drawn from a scientific article that may be consulted on the internet. All numerical data in this document were drawn on 27 May 2011 from the BDMAP databank for aquatic environments and fish, which centralises the data on fishing operations carried out by Onema.

The criteria governing data selection are presented below.
> A total of 590 sampling sites offering at least eight years of data (between 8 and 20 with an average of 12) between 1990 and 2009 were selected for the study, representing a total of 7 746 sampling operations employing the same sampling method over the entire period.
> A total of 48 taxa were selected from the 92 listed in BDMAP. The selected taxa did not include 1) species difficult to catch using electrofishing techniques, 2) species found exclusively in lakes, e.g. whitefish (*Coregonus spp.*), 3) marine species, e.g. European seabass (*Dicentrarchus labrax*), 4) certain diadromous species, e.g. shad (*Alosa spp.*) and 5) certain exotic species that reproduce very little or not at all in France, e.g. rainbow trout (*Oncorhynchus mykiss*). In addition, some taxa were grouped to avoid any confusion, e.g. Crucian carp (*Carassius carassius*) and Prussian carp (*Carassius gibelio*). Finally, recently identified species for which data series are too short for significant analysis were grouped where possible, e.g. daces (*Leuciscus leuciscus and L. burdigalensis*).

The data were analysed using two complementary methods.
> Analysis of all sampling sites to produce a linear trend on the national level for species richness, occurrence and density (general linear model).
> Non-linear analysis of each sampling site to compare the national trend with that specific to each sampling site (Mann-Kendall correlation corrected for autocorrelated data).

For more information…

See the data on fish populations at www.image.eaufrance.fr

Find the article published in the Journal of Fish Biology at http://onlinelibrary.wiley.com/journal/10.1111/%28ISSN%291095-8649

Find this document on the internet at www.eaufrance.fr/IMG/pdf/poissons_19902009_201305_synthese_EN.pdf
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Coordination: Janik Michon and Claire Roussel (Onema)

Authors: Nicolas Poulet (Onema), Laurent Beaulaton (Onema), Samuel Dembski (Onema)

Translation: Bartsch & Cie

Contributors: Amandine Clavérolas (OIEau) and Béatrice Gentil (Onema)

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