

Management of lake fish populations and lake fisheries in Denmark: history and current status

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Abstract The development of lake fisheries in Denmark is described and the various management measures applied to lake fish populations reviewed. Over the last 100 years catch records revealed a peak in annual yield in the 1950s and 1960s, with a subsequent decrease in catches thereafter coinciding with increasing eutrophication of Danish lakes. In particular, catches of the most valuable fish, the eel, *Anguilla anguilla* (L.), have diminished. Lake fisheries are regulated by legislation to protect populations of lake fish of commercial and recreational interest and prevent overfishing. Management of lake fisheries includes stocking of, for example eel, trout, *Salmo trutta* L., and pike, *Esox lucius* L., and, previously, introduction of new species. Lately, management of the aquatic environment has favoured the desirable fish species, which are hampered in eutrophic lakes, with the exception of pikeperch, *Sander lucioperca* (L.), introduced in a number of Danish lakes. Biomanipulation has been carried out during the last decade to help rehabilitate lakes by either stocking of piscivorous fish or removing planktivorous fish.

KEYWORDS: biomanipulation, catch records, lake fisheries, legislation, management, stocking.

Introduction

Lake fish populations and lake fisheries in Denmark have been managed for centuries. Traditionally, lake fish have been managed to optimise fisheries yield, irrespective of consequences for nature or the environment. However, as environmental consciousness emerged in the 1980s, goals for lake fish management now target management of the aquatic environment as a whole, underlining the role of fish in the ecosystem.

Most Danish freshwater lakes are small (98% <1 ha) and shallow (50% <1.6 m average depth). The five most common fish species are roach, *Rutilus rutilus* (L.), bream, *Abramis brama* (L.), perch, *Perca fluviatilis* L., pike, *Esox lucius* L., and eel, *Anguilla anguilla* (L.) (Jensen, Søndergaard, Jeppesen, Lauridsen & Sortkjær 1997). Increased eutrophication of Danish lakes during the last century has shifted the fish community composition towards a dominance of coarse fish like roach and bream. Together with a decrease in eel stocks during the last 20–30 years (Moriarty & Dekker 1997), this changed the basis for commercial lake fisheries, which in particular target eel, pike, pikeperch and perch.

Whereas in the past lake fisheries supported many small-scale fishermen, today the situation has changed

and fishing in lakes is mainly carried out for recreational purposes. Nevertheless, as a result of eutrophication, the recreational value of the lakes has declined, as the target species for Danish lake anglers are primarily pike, perch and pikeperch, *Sander lucioperca* (L.). There is very little demand for coarse fish like bream and roach. Hence, as management of the aquatic environment generally enhances target fish species, inland fisheries and the environment can often be co-managed (see Mehner, Arlinghaus, Berg, Dörner, Jacobsen, Kasprzak, Koschel, Schulze, Skov, Wolter & Wysujack 2004).

This paper describes the development and history of lake fisheries in Denmark over the past 100 years and reviews the history and current status of the various management measures applied to lake fish populations in Denmark.

Development in commercial lake fisheries in Denmark over the last 100 years

Traditionally, each large lake was commercially fished by a few or even only a single fisherman, using small boats. Fishing was, and is, still carried out mainly by passive gear like fykes, pound nets and gill nets. As the yield of many lake fisheries has decreased significantly,

especially during the last decades, today in Denmark < 10 commercial fishermen earn a major part of their income from lake-fishing.

At present, commercial fishing is done on both private and state-owned lakes. In Denmark the state owns the fishing rights in 25% of the total national lake area, the rest belongs to private owners. Fisheries can be leased for limited time periods, up to a maximum of 25 years.

The development in lake fisheries was followed over the last 100 years by compiling catch records from 1903, when the registration of freshwater catches was initiated, until 2000. The mean (\pm SE) for every 10-year period was calculated to show the general trend in catches. The catch records are not complete, but they cover all major lake fisheries as well as some riverine fisheries and eel traps. Catches by anglers and recreational fishermen are included to a minor degree.

Catch records should be interpreted with care due to varying fishing effort. The rather low catches in the years 1904–1930 are partly because of the initial low numbers of incoming reports, increasing to about 120 catch reports in 1925. Catches in the subsequent 10-year periods 1930–1980 are more comparable, based on catch reports of approximately 200 fisheries. The number of fisheries reports has decreased during the last 20 years, in line with the decreasing number of lake fishermen. This has a self-reinforcing effect on statistics, as the total fishing effort is lower when commercial fisheries are reduced.

Total reported catches (Fig. 1) were highest in the late 1950s and 1960s peaking in 1957 with an annual yield of about 1000 t, but have decreased subsequently, with a severe decline over the last 20–30 years.

One of the reasons for the reduced income from lake fisheries is that the most valuable fish, the eel, has drastically declined during the past 20–30 years (Moriarty & Dekker 1997). The mean annual eel catches in the 1990s was only 23% of that in the 1960s (Fig. 2a). Catches of eel did show some oscillations earlier (e.g. a

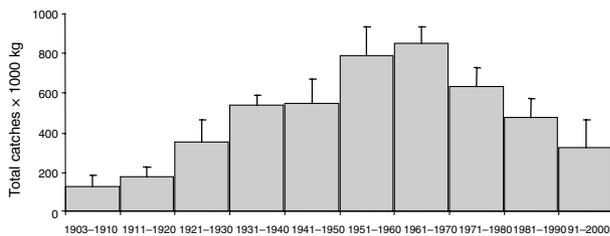


Figure 1. Total annual fisheries yield in Danish freshwater lakes, including some stream fisheries and eel traps. Ten-year means + SD (vertical lines).

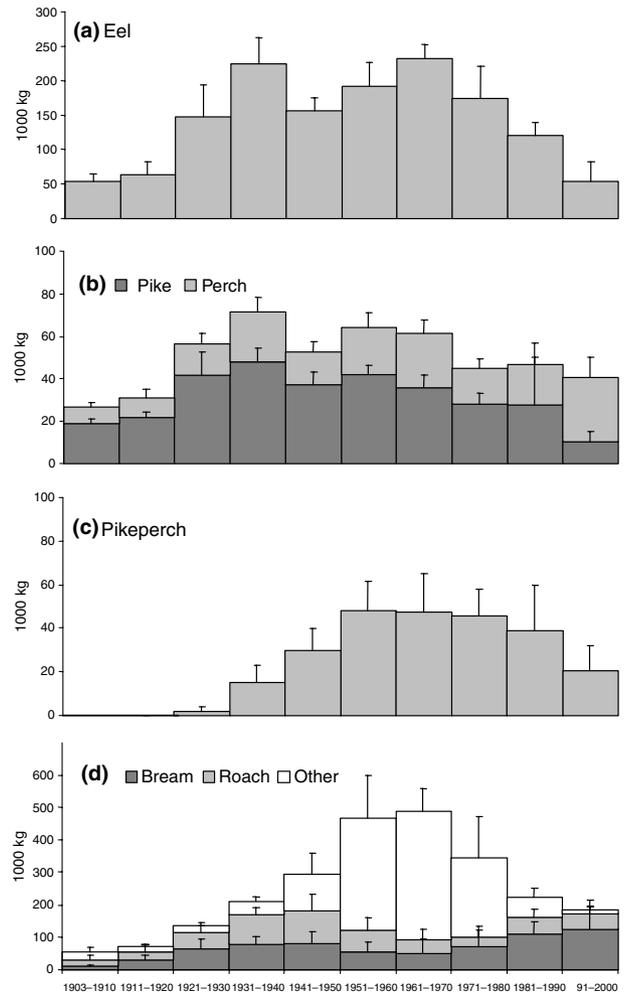


Figure 2. Fisheries yield in Danish freshwater lakes, including some stream fisheries and eel traps. Ten-year means + SD (vertical lines). Note the different scaling on the y-axis.

decline in the 1940s), but have never been as low as today.

During the same period, catches of other commercial fish species, pike and pikeperch, have also declined (Fig. 2b, c). Ever since pikeperch was introduced and established self-reproducing populations in the 1930s (Dahl 1984), it has added significantly to the fisheries, but mean catches in the 1990s were only 43% of those in the 1950s (Fig. 2c). In some places this decrease is believed to be a result of overfishing. Whereas present pike catches are only 22% of catches in the 1930s, perch catches are more stable or have increased over the last decade (Fig. 2b).

Roach catches have increased during the last two decades (Fig. 2d), which is in line with environmental changes in most Danish lakes. Roach, bream and other

non-marketable fish (Fig. 2d) constantly represent 40–60% of the total catches, although they did peak in the 1950s and 1960s. In these years a high proportion of mostly non-marketable fish was recorded as other fish or trash fish, but these catches mainly comprised cyprinids. As there is no market for bream and roach in Denmark, these fish were either caught as by-catch or were intentionally removed from the lake ecosystem to reduce food competition between bream and eel. The catch of bream and roach was sold as industrial fish for animal feeds or was destroyed.

Management of lake fisheries by legislation

The Fisheries Act sets the rules for lake fisheries to ensure sustainability by recruitment to spawning stocks of game fish (Table 1). Legal minimum sizes and closed seasons have been established for eight species found in lakes (Table 1). For the same reason, gill nets are prohibited during April and May and the minimum mesh size in gill nets is 60 mm (bar mesh size).

The number of fishing gear (gill nets, fykes, etc) as well as their size (including seine nets) are regulated. To allow fish migration, the gear must not exceed a total of one third of the width of the lake; protected zones are declared around inlets and outlets in all lakes with an area of 10 ha or more. Trawling is not allowed in lakes. Quotas, such as found in marine fisheries, do not exist.

Management of lake fish populations

Lake fish populations are managed: (i) to enhance commercial and recreational fisheries; and (ii) to improve the environmental state of lakes by changing fish composition by biomanipulation (Shapiro,

Lamarra & Lynch 1975). Both objectives are closely related and can usually be pursued together, as in both cases most of the coveted fish species are the same (Mehner *et al.* 2003). Lake fish populations are managed in various ways:

Enhancement of commercial and recreational fishing by fish stocking

Stocking has been carried out since the Middle Ages. In those days, the main purpose was to establish self-reproducing populations by stocking a relatively small number of large fish. Species involved were mainly tench, *Tinca tinca* (L.), and crucian carp, *Carassius carassius* (L.), and later also carp, *Cyprinus carpio* L., and whitefish, *Coregonus lavaretus* (L.). Around 1860 the first hatcheries were established and stocking became more widespread and included more species (Otterstrøm 1925). It was now possible to stock large quantities of fry or fingerlings. Today, stocking is still an important measure in Danish lake fishery management, focusing on eels, trout, perch, pike and pikeperch.

Stocking of eels has been carried out at least since the beginning of the last century, either stocking with juveniles (15–20 cm) or with elvers. These were traditionally caught in traps in river inlets and transplanted to lakes as much as available. Since the 1960s, eel stocks in Denmark, as all over Europe, have declined for still unknown reasons (Pedersen 2000). The immigration of elvers in spring has also fallen (Moriarty 1990). Consequently, transplantation of juveniles and elvers ceased and has been prohibited since the late 1980s because of the decrease in availability and to avoid the spread of the parasitic nematode *Anguillicola crassa* (Pedersen 2000). Since 1990 elvers for stocking and for raising in eel farms have been imported from Southern Europe.

Pike stocking for enhancement has developed since 1897, when pike fry were first raised successfully in hatcheries. In the following years, large numbers of pike fry (up to a total of 3–4 million per year in the 1930s; Fig. 3) were stocked in various lakes, mainly on

Table 1. Legislation on lake fisheries in Denmark

	Minimum size (cm)	Closed season
Pike, <i>Esox lucius</i>	40	1 to 30 April
Pikeperch, <i>Sander lucioperca</i>	50	1 to 31 May
Lake trout, <i>Salmo trutta lacustris</i>	40	16 November to 15 January
Brown trout, <i>Salmo trutta fario</i>	30	16 November to 15 January
Sea trout, <i>Salmo trutta</i>	40	16 November to 15 January
Salmon, <i>Salmo salar</i>	60	16 November to 15 January
Whitefish, <i>Coregonus lavaretus</i>	36	1 November to 31 January
Eel (yellow), <i>Anguilla anguilla</i>	45	–

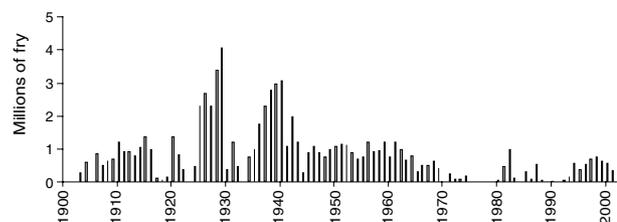


Figure 3. Annual stocking with pike fry in Danish lakes.

Zealand. These massive stockings ceased in the 1970s probably as a response to the decreasing commercial interest in lake fisheries, and only a few sporadic stockings of pike fry took place until the beginning of the 1990s. Today pike is mainly stocked for biomanipulation purposes (see below) with some exceptions, for instance in brackish waters.

Trout, *Salmo trutta* L., is one of the most coveted game fish and has often been stocked in lakes to enhance angling opportunities, but few lakes have water quality suitable for salmonids. Whitefish is stocked successfully, in particular in Western Jutland, its natural distribution area in Denmark.

Perch has been stocked in a few lakes to establish self-reproducing populations, mainly in lakes where the perch population had disappeared or in rehabilitated lakes.

Stocking with alien species In the past, non-native, commercially-important fish species were introduced, but this is no longer considered acceptable. According to the Nature Protection Act, even introductions of native fish species to a watercourse where they did not originally occur, require special permission, acknowledging that new species can have negative impacts on the indigenous species and their ecosystem, and that the zoogeographical diversity is worth preserving.

In Denmark pikeperch was introduced in 1879 (Dahl 1984) and today about 70 lakes hold well-established pikeperch populations. These are from time to time supported by stocking.

Management of the aquatic environment by fish stock manipulations

During the last two decades, focus has increased on the importance of the aquatic environment for fish populations. Improvement of the environmental conditions, e.g. clearer water and submerged vegetation, is essential for a sustainable population of most target lake-fish species, e.g. pike, perch and lake trout. An exception is pikeperch, which thrives in eutrophic lakes.

Many measures have been taken to reduce nutrient loading, the prerequisite for a successful change in state of the lake. However, even after nutrient load reduction, lakes often remain turbid because of the composition of the fish population (Sheffer, Hosper, Meijer, Moss & Jeppesen 1993). Over the last 10 years, biomanipulation has been carried out as a restoration tool in about 40 Danish lakes with intermediate nutrient levels to change the fish composition (Søndergaard, Jeppesen, Jensen & Lauridsen 2000).

Changing the fish composition from a dominance of planktivores, like roach and bream, to one controlled by piscivores has been carried out either by removing planktivores or by stocking piscivores or a combination of both:

Removal of planktivorous fish Since 1987 planktivorous fish have been removed in 20–30 Danish lakes (Søndergaard *et al.* 2000). In some lakes the fish composition successfully changed to a higher proportion of piscivores, resulting in clearer water in the following years (Søndergaard *et al.* 2000). It is now understood that as much as 80% of the biomass must be removed during one or two seasons to obtain the required change on the aquatic environment (Hansson, Annadotter, Bergman, Hamrin, Jeppesen, Kairesalo, Loukkanen, Nilsson, Søndergaard & Strand 1998; Søndergaard *et al.* 2000). If less is removed, the growth and reproductive potential among the remaining roach and bream will be high enough to re-establish these populations quickly (Hansson *et al.* 1998). The fish population will return to the previous composition and the lake again becomes eutrophic. Removals are mainly carried out by seining or, in larger lakes, by trawling, often in co-operation with local fishermen or, increasingly, with the help of consultant firms.

Stocking with piscivorous fish Stocking with piscivorous fish is another, less laborious, biomanipulation tool; pike fry being the most frequently used fish (Berg, Jeppesen & Søndergaard 1997; Søndergaard *et al.* 2000). In a few cases, large perch have been stocked (e.g. Skov, Perrow, Berg & Skovgaard 2002) as well as rainbow trout, *Oncorhynchus mykiss* (Walbaum), (Berg 1998).

Stocking pike fry for biomanipulation purposes started in 1990 and since 1993 has been implemented in lake management in Denmark. New pike hatcheries were built, and since the mid-1990s a stable supply of pike fry for stocking is available. Today, more than 30 lakes are stocked annually with 400 000 to 800 000 pike fry of about 2–4 cm length at densities between 1000 and 1500 ha⁻¹ (e.g. Berg *et al.* 1997). As pike fry is considered to be rather stationary, it is recommended to spread the pike fry along the littoral zone of the lake to minimise cannibalism.

Pike fry should be stocked in excess of natural densities as the pike fry is meant to be an effective predation factor at the time when cyprinid fry numbers peak, just after hatching and the following months. Stockings should be repeated over three to five seasons to reduce effectively the reproductive

potential of the cyprinid population (Søndergaard *et al.* 2000). Important criteria for survival of the stocked fish, and hence the success of the stockings, are timing of stocking (Skov 2002) and size-homogenised stocking material to minimise initial cannibalism (Skov, Jacobsen & Berg 2003). These elements have recently been reflected in the stocking guidelines for Danish lake managers.

The biomanipulative impact of the stocked pike on the fish community differed between experiments. In Lake Lyng, stocking of pike was repeated at various densities over a 4-year period (Berg *et al.* 1997), and a negative correlation between stocking density and the numbers of roach fry in the littoral zone was found. At the same time the perch population in the lake benefited and the growth of perch increased, along with an improved Secchi-depth (Søndergaard, Jeppesen & Berg 1997). Conversely, over a 5-year period in Lake Udbyover, pike fry were stocked in sufficient amounts with no subsequent reduction in the density of roach fry (Skov *et al.* 2002). It is not clear what factors regulate whether pike stocking has an effect on the lake environment.

Current status and future management

Commercial fisheries in Danish lakes are not likely to increase in the years to come. On the contrary, during the last decade recreational fishing has developed on rivers and along the coastline, and now 150 000 Danish anglers are registered every year together with 31 000 recreational fishermen (Denmark 2001). Lakes still have an untapped potential for recreational fisheries, especially privately owned lakes, of which only about 50% are accessible to anglers. However, considering the environmental state of Danish lakes, there is a need for management of lake fish communities to enhance target species, in co-operation with stakeholders, i.e. anglers, recreational fishermen and the tourist industry.

In the future, the extent of practical lake management by restoration will be based mainly on two factors: (i) the possibility to reduce nutrient loads in lakes sufficiently; and (ii) the availability of public funding for rehabilitation projects, as private landowners rarely will invest themselves.

The practices in lake management in the future will depend on evaluations of existing measures. Currently, in Danish lakes a thorough evaluation of the use of stocking pike fry as a biomanipulation measure is being carried out, and the long-term stability of biomanipulated lakes has still to be appraised.

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