# Chapter 32
# Current Status of Eurasian Percid Fishes Aquaculture

**Svend Steenfeldt, Pascal Fontaine, Julia Lynne Overton, Tomáš Policar, Damien Toner, Bahram Falahatkar, Ákos Horváth, Ines Ben Khemis, Neila Hamza, and Mohammed Mhetli**

**Abstract** This chapter presents the actual status and the perspectives of development for Eurasian perch and pikeperch in different countries, mainly in Europe (Denmark, Finland, Sweden, Ireland, The Netherlands, France, Czech Republic and Hungary) but also in Iran and Tunisia. For each country, main culture techniques are summarized and production types are specified, according to the local or international markets.

**Keywords** Eurasian perch • Pikeperch • Production • Culture techniques • Market

## 32.1 Introduction

World percid culture is limited in comparison with more prevalent species e.g. salmonids, bass and bream. In 2009, only Denmark, The Netherlands, Tunisia and Ukraine recorded an annual aquaculture production of pikeperch exceeding 100 tons

S. Steenfeldt (✉)
BioMar A/S, The North Sea Science Park, Willemoesvej 2, 9850 Hirtshals, Denmark
e-mail: sjs@biomar.dk

P. Fontaine
Unité de Recherche Animal et Fonctionnalités des Produits Animaux, Université de Lorraine, USC INRA 340, Vandoeuvre-lès-Nancy F-54505, France
e-mail: p.fontaine@univ-lorraine.fr

J.L. Overton
Aquapri innovation, Lergaardvej 2, 6040 Egtved, Denmark
e-mail: julia.overton@aquapri.dk

T. Policar
Faculty of Fisheries and Protection of Waters, Institute of Fish Culture and Hydrobiology, South Bohemian Research Center of Aquaculture and Biodiversity of Hydrocenoses, University of South Bohemia in České Budějovice, Zátiší 728/II., 389 25 Vodňany, Czech Republic
e-mail: kristj01@frov.jcu.cz



P. Kestemont et al. (eds.), *Biology and Culture of Percid Fishes*,
DOI 10.1007/978-94-017-7227-3_32

**Table 32.1** Pikeperch production in European countries from 2002 to 2011 (Tons) (FAO 2012)

| | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|
| Croatia | 8 | 7 | 7 | 8 | 13 | 16 | 7 | 6 | 6 | 6 |
| Czech Republic | 42 | 55 | 48 | 50 | 50 | 48 | 58 | 58 | 48 | 55 |
| Denmark | 0 | 6 | 10 | 49 | 36 | 47 | 55 | 106 | 105 | 105 |
| Hungary | 81 | 80 | 80 | 80 | 80 | 32 | 32 | 40 | 38 | 40 |
| Netherlands | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 115 | 100 | 120 |
| Total | 231 | 248 | 245 | 287 | 279 | 243 | 252 | 325 | 297 | 329 |

**Table 32.2** European perch production in European countries from 2002 to 2011 (tons) (FEAP 2011; FAO 2012)

| Year | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|
| FAO | 72 | 138 | 152 | 318 | 219 | 311 | 265 | 237 | 280 | 182 |
| FEAP | 24 | 22 | 14 | 75 | 90 | 17 | 26 | 45 | 45 | NA |

*NA* not available

(FAO 2011). Total pikeperch production in aquaculture in 2009 equaled 653 tons and is dwarfed by the natural fishery of 14,739 tons. EU production of pikeperch was in 2011 dominated by The Netherlands and Denmark (Table 32.1).

Culture of Eurasian perch is of the same magnitude with a maximum of 318 tons being produced in 2005 according to FAO (Table 32.2). FEAP though estimates the production of perch as lower, probably as a consequence of differing differentiation between extensive production and captive fisheries.

## 32.2 Denmark

Eurasian perch is an endemic species in Danish fresh- and brackish water systems. It is a popular game fish and probably the "first fish caught" by many young Danes.

D. Toner
Aquaculture Initiative EEIG, 14-15 Grays Lane, Park St, Dundalk, Co. Louth, Ireland
e-mail: toner@aquacultureinitiative.eu

B. Falahatkar
Fisheries Department, Faculty of Natural Resources, University of Guilan, Guilan, Iran
e-mail: falahatkar@guilan.ac.ir

Á. Horváth
Department of Aquaculture, Szent István University, Gödöllő, Hungary
e-mail: Horvath.Akos@mkk.szie.hu

I.B. Khemis • M. Mhetli
Institut des Sciences et Technologies de la Mer, Salambo, Tunisia
e-mail: hamza.neila@gmail.com

N. Hamza
Institut National des Sciences et Technologies de la Mer,
28 rue du 2 mars 1934, Salammbô 2025, Tunisie
e-mail: hamza.neila@gmail.com

Pikeperch on the other hand was introduced to Danish waters more than 200 years ago (Dahl 1982). Through repeated stockings with fish from German waters up until the First World War, the species was released to many Danish water systems. Success was limited though, possibly due to lack of knowledge in transport and stocking of fish. From the first to the Second World War multiple introductions of pikeperch fry from Sweden were carried out with better success, and today pikeperch are found in 70 Danish freshwater and brackish water areas. Records show that 51 of these areas are the result of direct stocking and the remaining 15 have been invaded from stocked populations in connected water systems (Dahl 1982).

Eurasian perch and pikeperch fall into the category of "new species" in Danish aquaculture. As the name implies they have not contributed significantly to Danish aquaculture as yet. Diversification has been on the private sector's agenda for decades and in recent years Eurasian perch and especially pikeperch have been identified as the most promising new fish species to Danish aquaculture. This has led to a number of governmental and EU sponsored R&D projects facilitating the development of intensive rearing methods for Eurasian perch and pikeperch in Denmark. Projects focusing on Eurasian perch fry production technology in RAS systems provided the private sector access to fry for pilot scale grow out trials in both existing pond based trout farms and RAS systems (Overton and Paulsen 2005a, b; Paulsen et al. 2005a, b). These trials were well received by the trout producers and were technically successful. They were not able though to convince the private sector of the economic sustainability of Eurasian perch culture and therefore no farmers continued to produce Eurasian perch after the end of the pilot phase. The knowledge on intensive fry production of Eurasian perch was assimilated by one governmental station that produce salmon fry for national salmon restocking programs. Today this producer is rearing Eurasian perch fry as a secondary production. The annual production is around 350,000 fry (fry size 2 g). The fry are produced twice a year with the aim to increase the production to 500,000 fry annually. Presently all fry are exported to Switzerland and Ireland.

Government and EU sponsored R&D projects on pikeperch were carried out as well. One commercial farm was in operation before the trials commenced. This farm was based on a former eel farm and produced pikeperch for ongrowing. It is not in operation at present time. This to some extent supports the fact that pikeperch culture at one point was considered a potential alternative to eel production in facilities, suffering from restrictions on elver fishery. The concept of substituting eel with pikeperch is now considered less likely to be implemented. Requirements of modern RAS systems performance makes modification of existing eel facilities to pikeperch farming resource demanding, at a scale that is outperformed by erection of new species specific facilities.

In 2005 two Danish fish farming companies ventured into commercial scale production of pikeperch. One took on fry and grow-out production of pikeperch, whereas the other focused on smaller scale production primarily for restocking. Both producers based their production solely on RAS systems. RAS systems provide optimal temperature regimes throughout the year. The considerable investment- and running costs of RAS systems is a constraint though to development of the sector.

**Fig. 32.1** Pikeperch broodstock holding facility. Private sector Denmark

Leading the development in all production phases from broodstock to ongrowing adds to the burden since systems for broodstock including out of season spawning batches as well as incubators, larval rearing facilities, live feed production systems, weaning and fry holding systems, plus ongrowing systems are needed. All these facilities must be constructed and managed as well as support equipment such as fish sorting machinery, workshops, logistics and product marketing and sale.

A number of consecutive development projects in cooperation with private companies and research institutions (Figs. 32.1, 32.2, and 32.3) led to the development of a pikeperch production for one company of one million fry produced annually and a production of pikeperch consumption size fish of 250 tons (Steenfeldt et al. 2010, 2011).

Despite these considerable challenges, one dominating Danish producer of pikeperch will in 2015 increase its annual production capacity of pikeperch to 500 tons. This considerable expansion will take place in a newly erected RAS facility in Denmark, specially designed and optimized for pikeperch production.

## 32.3 Finland

Finland's aquaculture sector produced 11,000 tons in 2011. The main production was trout and whitefish amounting to 9900 and 1200 tons respectively.

**Fig. 32.2** Upwelling system for incubation of pikeperch eggs. DTU-Aqua, Denmark

Eurasian perch is widespread in Finland's many waters. Low prices seems to have prevented Eurasian perch from being a candidate for culture or export and the recreational fishery for Eurasian perch is not demanding fish for restocking, as is the case for pikeperch.

On the contrary, pikeperch is a highly valued fish species in Finland. Capture fisheries have exceeded 3000 tons with more than half being caught in the coastal waters of the Baltic region. During the last decade catches have decreased to around 2000 tons annually. Pikeperch wild stocks experienced a decline during the 1960- and 1970s and disappeared from many lake systems. A combination of intensive restocking programs and warm summers manifested the value of restocking, and in 2003 more than nine million fry were released to Finland's lakes. Recreational fisheries contribute significantly and represent 70–90 % of the catch with the largest catch in the summer season. The commercial catch is based on gillnets during autumn, winter and spring.

Pikeperch fry is produced in most regions of Finland excluding a few regions in the northern and eastern part. The fry is almost exclusively produced for restocking purposes. Annual production of pikeperch has since 2002 been 8–11.9 million and with a production in 2011 of 8.6 million fry there is no trend towards a change in future production. The value of the pikeperch fry production in 2011 was estimated to 1.6 million euros.

**Fig. 32.3** Laboratory scale intensive hatchery for development of larval rearing methodology for pikeperch at DTU-Aqua Denmark

The production methods are based on extensive pond rearing techniques which reduce the production costs to a minimum. Pikeperch thrives in warm water (Hilge and Steffens 1996; Deelder and Willemsen 1964; Frisk et al. 2012). Ongrowing is not carried out as an aquaculture production and to bridge this gap the need for recirculation technology is acknowledged. Lack of experience and high investment costs seems to limit development of this segment of aquaculture in Finland at the present.

## 32.4 Sweden

Both Eurasian perch and pikeperch are widespread in Sweden. Aquaculture is limited though. A concept of production of Eurasian perch in floating cages in the Swedish archipelago is being tested (Öberg 2008).

Pikeperch on the other hand have been produced in aquaculture for decades in Sweden. Three producers are producing totally approximately one million fry annually. All three producers rely on extensive methodology for production. Most fish are restocked. The majority 90 % are restocked with the purpose of biomanipulation of lakes. The remaining 100,000 are exported for grow out in RAS systems.

At present the production is estimated to equal the market demand. Only the demand for fry for grow out is assumed to change in the future, but as intensive pikeperch fry production is developed in other countries, it is not envisaged that the present level of export is likely to expand.

## 32.5 Ireland

In the 1990s a renewed interest in the cultivation of perch emerged. Ireland's aquaculture industry is predominately marine based, focusing on species such as salmon, oysters, and mussels. The development of freshwater aquaculture centered largely on traditional flow through units growing trout (*Oncorhynchus mykiss*) and salmon (*Salmo salar*) smolts. Production units were mainly situated on larger river catchments and were often situated at the sites of old grain mills where artificial heads had been created using dams. It is not documented when the Eurasian perch (*Perca fluviatilis*) was first introduced into Ireland, however it is most likely that it was introduced from elsewhere in the British isles. Eurasian perch is indigenous to south-eastern England and has been widely redistributed "for their food value and ease of catch" (Maitland and Campbell 1992).

Eurasian perch is found throughout Ireland and has proliferated in certain catchments. This has inevitably led to some management issues particularly in salmonid rivers and lakes. In some areas, control of perch populations has been embarked on by Fisheries staff. Removal of Eurasian perch egg strings during spawning season and netting of stock is common in designated salmon and trout fisheries (Leggett 1966). Such control measures have by and large been unsuccessful given Eurasian perch's adaptability and suitability to the environment. In certain areas where Eurasian perch proliferated, Eurasian perch fisheries developed. Lough Corrib in Co. Galway and Lough Neagh in Northern Ireland were two such commercial fisheries. Whilst commercial fishing for Eurasian perch ended in Lough Corrib in the 1990s, it still continues in Lough Neagh where other coarse fish such as pollen *Coregonus autumnalis*, bream *Abramis brama* and European eel *Anguilla anguilla* are also fished (Wood et al. 1993).

Eurasian perch aquaculture was identified as having potential in Ireland in a review of the options for non salmonid aquaculture carried out in 1995 and subsequently in BIM's Aquaculture Explained manual, Cultivating Perch (Ashe 1997). Bord Iascaigh Mhara (BIM) is the state agency with the responsibility for development of Irelands fishing and aquaculture sectors. The agency gives producers technical and business advice and has been intrinsically involved in the development of

Irelands fledgling perch sector. As part of the review, BIM staff visited pond production systems for yellow perch *Perca flavescens* in North America. Such pond systems in Indiana and Wisconsin also produce bait fish and predominately sell their yellow perch on local markets. The pond systems are in general earthen based, utilising both surface water and groundwater sources.

The strategy at the time was to identify suitable areas in Ireland on marginal agricultural land and investigate whether such pond based systems would work for producing Eurasian perch. In 2000 PDS Irish Waters Perch established Ireland's first pond based perch farm. The farm situated in Gowna, Co. Cavan was based on marginal land in an area renowned for its waterways and angling lakes. The farm was based on 1.2 ha and utilized water from a nearby stream. The presence on the land of grey clay which has excellent water retention properties was a key factor in site selection. The farm initially began production of both Eurasian perch and Northern pike (*Esox lucius*). However in 2002 it stopped pike production to concentrate on juvenile perch production for emerging farms.

The initial production method for Eurasian perch was entirely pond based. Adult fish were allowed spawning naturally in the earthen ponds and their ribbons collected and placed in separate ponds. The resultant larvae were allowed to hatch naturally and proceeded to feed on zooplankton present. The development of zooplankton populations and the intensification of pond management were carried out with the assistance of the Institute of Vodnany in the Czech Republic. The institute had extensive experience of freshwater fish production in ponds and similar management protocols were put in place at the PDS site. Addition of natural fertilizers, timing of water fills for proper zooplankton succession and drying out of ponds for sterilization were some of the procedures which improved juvenile production at the PDS site. Whilst the farm was initially developed to grow Eurasian perch to market size, the demand for juveniles from other farms being established at the time changed the focus at PDS to one of being a hatchery.

In the mid 2000s significant interest was being expressed in Ireland in Eurasian perch aquaculture. The economy in general was prosperous and promoters were looking at new forms of aquaculture as a means of investing. In tandem with this the availability of grant aid through various EU programmes provided an incentive for farms to be developed. Keywater Fisheries Ltd (2002) based in Co. Sligo and Emlagh Fisheries Ltd (2003) based in Co. Roscommon soon followed PDS and developed Eurasian perch farms at new sites. The emphasis was still on the potential of pond production systems but interest was growing in RAS throughout Europe. In 2004, Emlagh converted much of its site to RAS through the addition of covered and insulated polytunnels, drumfilters, ultraviolet lights and a biofilter. Such additions were seen as the best way to improve growth rate, survivability and ultimately increase stocking density and production. In 2007, Clune Fisheries, Co. Tipperary established the first full RAS in Ireland for perch production and this was followed by the development of Ballybay Perch Ltd RAS in Co. Monaghan in 2008.

The development of these ongrowing farms created the impetus to improve and substantially increase juvenile production in Ireland and indeed in Europe. A European CRAFT project, PERCATECH was funded involving partners from across Europe.

The research and development on issues such as out of season spawning and improved feeding strategies allowed significant improvements to be made in hatchery production at PDS and Keywater. The importation of Eurasian perch eggs from Denmark and New Zealand from 2006 onwards enabled the hatcheries to produce the quantities of juveniles required.

The development at this time was not without serious hurdles. Inconsistent quality of juveniles became a major issue and resulted in some ongrowers developing their own hatcheries. Issues during ongrowing with disease, system failures and financial issues resulted in some farms closing with a resultant knock on effect on the sector. Such issues mirror that experienced by every other part of the aquaculture industry at some stage of their development. However the scale of the perch sector has inhibited its ability to deal with such issues. The emergence of an economic recession in Ireland from 2008 onwards has severely impacted on the sectors success in drawing in fresh investment and expanding to a fully commercial entity. Issues such as out of season spawning, juvenile quality and growth have largely been overcome, however the residual effect of these issues continues to be felt by remaining operators. Significant restructuring of Irelands perch sector is likely to take place in the short term and this should allow the companies involved to expand and grow the sector as initially envisaged.

Irelands perch sector is still at a fragile stage of development. The majority of R&D work has been carried out on semi commercial farms and predictably it has been a steep learning curve with many mistakes and failures along the way as well as significant success's. Early development of the sector was hampered by inconsistent and infrequent juvenile production. The refinement of out of season spawning strategies was a major step forward for the sector bringing with it predictable and cost efficient juvenile production. At the same time, development of skills and systems for ongrowing Eurasian perch has tended to focus on use of RAS technology. RAS is by its nature is costly to construct and implement as well as to operate. High operating costs have hampered production such that annual production has still not reached licence capacity. The development of markets, processing capability and logistics has also been a difficult path for Irish perch growers given their distance from the market. The success of the perch sector in Ireland will depend on further expansion and growth of the sector whilst at the same time, reducing production costs and further market development. Preliminary work has also begun on further development of pond systems which may be suitable for large area of cutaway peatland situated in the midlands of Ireland. Such pond production systems would tie in with Ireland's significant organic production of seafood and may lead to a premium in the environmentally conscious marketplace.

There is no market in Ireland for Eurasian perch at present and all fish produced is exported to markets in alpine countries such as Switzerland, Germany, France and Italy. In 2012, some 1500 kg of Eurasian perch was produced per week by Irish growers and this is expected to grow to 2000 kg per week by 2013. The majority of Eurasian perch produced in Ireland is in the form of skinless and skin on fillets. Whilst whole fish is sold directly to wholesalers in Europe, this invariably entails higher transport costs and curtails value addition. Whole fish are generally either filleted by the producers themselves in approved processing facilities or by third party processors on behalf of the producers. Generally speaking, Irish perch farmers produce whole fish in the 100–200 g size range. The preference in some markets for small size fillets (10–20 g) equating to whole fish of 80–100 g is generally not a market sought by growers. Harvesting fish less than 100 g is not seen at present as economical in RAS, given the high juvenile costs. Improvement of growth rate and survival may in future lead to market development of fish greater than 200 g. Whilst such a market exists in Nordic countries, it is generally small in comparison to the main market in Switzerland.

The future of percid aquaculture would seem to depend on a number of factors. Existing wild production of perch from lakes in Estonia, Poland and Russia continues to provide the large bulk of product available on the market. Aquaculture producers have tended to concentrate on the development of niche markets. Such a strategy makes sense given the price variability in wild production. Seasonality, quality, availability and market demand all feed in to market price. The success of other aquaculture sectors such as salmon, oysters, mussels and sea bass has been in having the quantity to dictate a response to such variable factors. It is likely that whilst there is still a significant wild catch of perch, aquaculture producers must concentrate their marketing efforts on building niche, high quality markets. The market ultimately dictates the success or otherwise of production strategies. Whether future expansion of the Eurasian perch sector in Ireland is based on RAS or pond systems is still very much debatable. Ultimately however SME's in any agrifood sector control their own density and must embark on a path which they believe will be successful.

## 32.6 Western Europe, France and The Netherlands

In Western Europe, the initial intentions to promote the production of percid fish date from the end of the 1980s and the beginning of the 1990s over last century, especially in France. Actually, percid fish were the freshwater species the most appreciated by French consumers and anglers for their flesh quality. For example, after salmonids (trout, salmon), pikeperch is the freshwater fish species the most frequent on fishmonger's stall and restaurant menu (supply only by fisheries captures). At that period, due to the stagnation and/or progressive decrease of restocking markets, pond fish farmers, especially in the North-East of France, were interested to diversify their production. Some surveys have demonstrated that important markets existed for percid fish (Tamazouzt et al. 1993). Eurasian perch was perceived as a species related to important niche markets, mainly located in Alpine areas (Switzerland, North-Italy, South-East of France) while pikeperch was considered for larger markets. For pond farmers, the development of Eurasian perch culture was welcomed due to the poor control of this production in ponds. In fact, these farmers had a high demand of large perch (>150–200 g) for restocking markets; however in ponds few individuals achieve this weight and the large majority of a cohort doesn't grow and remains at a small size (stunting). In some French regions (Sologne, Dombes), small perch were considered as undesirable fish for pond production. Consequently, the intensification of the Eurasian perch culture was not considered as competing with the production in ponds and was supported by fish farmers, whereas it was not the case with pikeperch. However, due to its high level of consumption in France, pikeperch was also considered a potential candidate species for inland aquaculture diversification and a French farm (SEPIA) in South-West of France initiated a project to promote an intensive production of pikeperch juveniles, based on the research conducted by CEMAGREF (now IRSTEA) (Schlumberger and Proteau 1991). This farm stopped its activities after few years. The first rearing trials, mainly for Eurasian perch, tested the feasibility of different rearing systems (ponds, floating cages or RAS). The on-growing of Eurasian perch was evaluated in a large eutrophic pond (Etang de Lindre, Moselle, France) and Lake reservoirs (Feronval and Plate-Taille Reservoirs, Wallonia, Belgium) (Fontaine et al. 1996; Tamazouzt et al. 1996; Kestemont et al. 1998). These comparative studies have clearly shown that floating cage or pond systems were limited by low growth rates, high mortality due to pathology (external parasites) and precocious sexual maturity, especially in males, comparing to the performances observed in RAS. Later the constraints identified with floating cages were confirmed by the results of the project Perlac developed over Neuchâtel Lake in Switzerland during the early 2000s. About 15 years ago RAS system was selected to support percid culture in Western Europe.

After this initial prospecting period, an intensive research activity was conducted during the 1990s and 2000s to develop knowledge on percid biology and promote their culture. In the framework of national or European projects, theses researches concerned initially the Eurasian perch and more recently pikeperch and were focused on the control of the reproductive cycles and gamete quality, larval rearing, nutritional requirements, on-growing, genetic improvement and flesh quality (Kestemont et al. 2000; Fontaine et al. 2001; Fontaine and Thomas 2004; Kamstra et al. 2001; Teletchea et al. 2006; Wang et al. 2008). All these researches targeted to develop intensive culture of percid in RAS.

Based on this knowledge which has been highly disseminated using scientific (Kestemont and Dabrowski 1996; Kestemont and Melard 2000) and technical documents (Kucharczyk et al. 2008; Torner and Rougeot 2008) or the organization of a percid culture workshop (Fontaine et al. 2008), completed by other activities (first rearing trials at pilot scale), several farms have been built to produce percids mainly in France (SARL Lucas Perches, SARL Asialor, EI Bresse Aquaculture), Switzerland (Percitech SA, Valperca SA), The Netherlands (Excellence fish farm B.V., HESY Aquaculture B.V., SEA FRESH B.V.). In some cases, percid production was initiated to diversify the production in farms already existing like FLAMICELL VERD S.L. in Spain. Over the last 5 years, numerous projects were studied in Western Europe (Belgium, France, North-Italy, Portugal …). Generally, these farms are compounded by building with isotherm walls for internal and thermoregulation energy economy and used drinkable water (tapwater or ground water pumping by a bore-hole). Using optimal temperature (20–22 °C for Eurasian perch and 24–26 °C for pikeperch), they produce fish at high density (on-growing phase with 60–100 kg. $m^{-3}$). The environmental management of the reproductive cycle in cooling chambers ensures several reproductions per year, all the year round, between 3 and 12 times per year according to SME.

In terms of markets, Eurasian perch is mainly sold as fillet (15–40 g) or sometime as whole fish (from 40 to 150 g) addressed to Swiss markets. However, in North-East of France, a local commercialization is progressively organized in order to supply restaurants; this market is promising but somewhere difficult to structure because it needs a specific logistic. The price vary between 5–8 euros/kg and 22–30 euros/kg for whole fish and filet respectively, according to season and fish or fillet size. For pikeperch, the market concerns mainly whole fish (0.8–1.2 kg) and fish are sold to wholesalers. The current prices are between 8 and 13 euros/kg. In Western Europe, percid production appears more and more as the major way to diversify and develop inland aquaculture in a sustainable way e.g. production of local species, economy of water and use of high water quality.

## 32.7 The Czech Republic

The Czech Republic produces both Eurasian perch and pikeperch. Production is based on commercial aquaculture and recreational fisheries (angling). According to statistics from FAO, the Czech Republic was the world's 6th biggest aquaculture producer and the 18th largest captive producer of Eurasian perch during the decade from 2000 to 2010. Regarding pikeperch the Czech aquaculture production was the 5th largest while captive production was the 11th largest (FAO 2011).

Czech annual capture production was between 14 and 37 tons of Eurasian perch and between 106 and 147 tons of pikeperch in the period 1996–2010 (Table 32.3). Aquaculture production was between 14 and 27 tons and between 31 and 58 tons in the same period respectively. The resulting total Czech production was between 32 and 61 tons of Eurasian perch and between 154 and 213 tons of pikeperch (Brožová 2005; Ženíšková and Gall 2011). Commercially this production was reported by 59 fishery companies associated to the Czech Fish Farmers Association (Kratochvíl 2012). Classical average body weight of produced marketable fish was 150–300 g for Eurasian perch and 1.3–3.5 kg for pikeperch. Cultured fish were 3, 4 or 5 years old. More than half of the Eurasian perch total production was carried out by six farms (Adámek and Kouřil 2000; Adámek et al. 2012; Policar et al. 2009, 2011b). Seventy five percent of the pikeperch were cultured by six farms.

Production of 6–12 months old juvenile pikeperch (TL = 120–180 mm) for stocking purposes has received much attention lately and one company is currently producing 100,000 fry annually for stocking only.

Generally, aquaculture production in the Czech Republic is characterized by extensive and semi-intensive fish farming in ponds. Common carp (*Cyprinus carpio* L.) is the dominant fish species produced in these systems and amounts to 87 % of total Czech fish production (Adámek et al. 2012). However, polyculture productions

**Table 32.3** Czech Eurasian perch and pikeperch production by commercial aquaculture and by recreational fisheries (angling) and summarized total production during 1996–2010 periods (Brožová 2005; Ženíšková and Gall 2011)

| Year | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Production by commercial aquaculture | | | | | | | | | | | | | | | |
| Perch | 15 | 27 | 17 | 21 | 24 | 18 | 24 | 22 | 14 | 18 | 18 | 13 | 17 | 18 | 18 |
| Pike-perch | 32 | 35 | 40 | 41 | 40 | 31 | 42 | 55 | 48 | 47 | 47 | 48 | 58 | 58 | 48 |
| Production by recreational fisheries (angling) | | | | | | | | | | | | | | | |
| Perch | 33 | 34 | 36 | 37 | 34 | 34 | 30 | 30 | 30 | 26 | 24 | 20 | 17 | 18 | 14 |
| Pike-perch | 130 | 157 | 125 | 130 | 134 | 139 | 144 | 133 | 165 | 145 | 147 | 121 | 106 | 107 | 106 |
| Summarized total production | | | | | | | | | | | | | | | |
| Perch | 48 | 61 | 53 | 58 | 58 | 52 | 54 | 52 | 44 | 44 | 42 | 33 | 34 | 36 | 32 |
| Pikeperch | 162 | 192 | 165 | 171 | 174 | 170 | 186 | 188 | 213 | 192 | 194 | 169 | 164 | 165 | 154 |

are very important. Eurasian perch, pikeperch and European catfish are useful predatory species which play important roles in the control and regulation of the overpopulated and less valued small cyprinids such as: roach (*Rutilus rutilus*), bleak (*Alburnus alburnus*), bream (*Abramis brama*), topmouth gudgeon (*Pseudorasbora parva*) and Eurasian ruffe, *Gymnocephalus cernua*) (Adámek et al. 2012).

Broodstock of both Eurasian perch and pikeperch are held in production ponds with areas of 5–400 ha. Small cyprinids are used as natural food (Křišťan et al. 2012a; Policar et al. 2011b). The diet close to natural conditions results in broodstock with very well-developed gonads and high-quality gametes (Křišťan et al. 2012a). Broodstock are transported to hatcheries before the final oocyte maturation (Křišťan et al. 2012b). Out of season spawning broodstock are stocked in cooling rooms (6–9 °C) with controlled light regime (10 L:14 D, 300–400 lux) and fed small cyprinids. One spawning term in April is routinely used though (Policar et al. 2013).

Hatched larvae are stocked in small ponds with littoral macrophyte vegetation at densities of 100,000–120,000 larvae $ha^{-1}$. Well-timed harvesting of advanced juveniles is important to avoid cannibalism. Common average survival of advanced juveniles (TL = 30–40 mm and W = 0.35–0.8 g) is about 22 ± 8.9 % (with minimum 10.0 and maximum 33.0 %). Produced juveniles are without deformations (Policar et al. 2011b). Harvested fry are used for several purposes: (1) adaptation in RAS for intensive culture (Stejskal et al. 2010; Policar et al. 2013), (2) stocking into dams, lakes and ponds for angling and (3) stocking into production ponds such as supplementary fish within polyculture stocks.

Marketable fish have a weight of 1.3–3.5 kg which is reached within 3–5 years in pond polyculture (Policar et al. 2011b; Adámek et al. 2012).

Of the 46 % of percids marketed in the Czech Republic most are sold live. A little less i.e. 44 % are exported mainly into Germany, Austria, France and Switzerland. The price per kg is 3–5 € for Eurasian perch and 10–15 € for pikeperch at the farm gate. Wholesale prices are around 3 € for Eurasian perch and 10 € for pikeperch (Kratochvíl 2012).

Pikeperch culture is a relatively new production the Czech Republic. New methodologies are continuously being developed e.g. the use of ponds for fry production in combination with RAS for ongrowing. University of South Bohemia, Faculty Fisheries and Protection of Water has led this development.

During 2009–2011, three pilot projects were conducted at three Czech farms and supported by the European Fisheries Fund. The projects focused on: (1) optimization of hormonally induced mass spawning in pikeperch inclusive optimal methods of artificial egg fertilization and incubation, (2) optimization of mass juvenile production under pond conditions including successful weaning and (3) adaptation of juveniles to artificial food and induction of two out-of-season spawning terms in pond-cultured broodstock. One new Czech pikeperch RAS farm was established in 2011. Its planned pikeperch production is 100 tons of marketable fish in 2013 (Policar et al. 2011a, b, 2012).

## 32.8 Hungary

Hungary is home to eight species of the family Percidae: *Gymnocephalus cernua*, *G. baloni*, *G. schraetser*, *Zingel zingel*, *Zinger streber*, *Perca fluviatilis*, *Sander lucioperca and S. volgensis*. Of these, only *S. lucioperca* is cultured commercially at fish farms. Trials have been carried out to develop aquaculture of Eurasian perch as well as the hybrids of *S. lucioperca* and *S. volgensis*, however these remained experimental. Eurasian perch is occasionally marketed as a by-product of pond fish farming collected during fall harvest. The species is seldom stocked to ponds intentionally.

The culture of pikeperch *S. lucioperca* in Hungary is characterized by long-standing traditions of low intensity pond farming of the species. At the moment, pikeperch is farmed only in ponds, in spite of successful experimental trials to culture it in more intensive conditions.

Predator species (wels catfish, pike and pikeperch) occupy a special role in pond polyculture in Central Europe, including Hungary. They are stocked into ponds to control the populations of smaller wild fish that penetrate into the ponds during their flooding in the spring. These nuisance species would act as food competitors for the cultured cyprinids, thus, stocking of predators represents a means of biological protection against them. Each predator species has its own specific target prey species. For the pikeperch in pond aquaculture the primary prey species include the perch and the exotic topmouth gudgeon or stone moroko (*Pseudorasbora parva*). Obviously, beyond its role of controlling nuisance species, pikeperch is valued for its premium quality meat and has good market potentials. Typically the ratio of predator species (including all three) in the polyculture ponds does not exceed 3–5 %.

Generally, the culture of pikeperch in Hungary is divided into four technological steps: spawning, fry rearing, fingerling rearing and rearing of market-size fish.

Fingerling rearing starts in April-May (following fry rearing) and lasts until the end of the production season. This phase of pikeperch rearing is already done in polyculture with other fish species. Pikeperch is a fast-growing species, typically by the end of fingerling rearing they reach the individual size of 150–200 g. Typically 1000–1500 fingerlings are stocked per hectare and 20–25 % survival can be expected. At the end of the production season (October–November), the fish are harvested and stocked into wintering ponds.

Market-size rearing can last one or two additional production seasons, depending on the desired size of marketable fish. At the end of the second production season they can reach the size of 300–500 g while a further year of culture results in 1–1.5-kg fish. Survival rates are good and depend primarily on the presence of adequate prey fish. The typical yield of market-size pikeperch is 25–40 kg $ha^{-1}$, although, occasionally yields of 50–70 kg $ha^{-1}$ can be achieved. As pond harvest is a seasonal activity, pikeperch is also marketed during the late fall-early winter period. Yields of pikeperch vary each year, however; generally 70–110 tons of this species are produced in Hungary each year (Table 32.4).

**Table 32.4** Pond surface and volume of pikeperch produced in Hungary in the period between 2001 and 2011

| Year | Pond surface (ha) | Volume of pikeperch (kg) |
|---|---|---|
| 2001 | 22,462 | 67,093 |
| 2002 | 21,090 | 81,099 |
| 2003 | 22,839 | 67,323 |
| 2004 | 22,850 | 72,598 |
| 2005 | 23,078 | 119,821 |
| 2006 | 23,878 | 79,525 |
| 2007 | 24,302 | 82,785 |
| 2008 | 24,248 | 91,762 |
| 2009 | 23,967 | 89,098 |
| 2010 | 23,639 | 86,757 |
| 2011 | 24,364 | 101,255 |

Source: Statistics Department, Research Institute of Agricultural Economics, Budapest, Hungary

## 32.9 Iran

Among four main species of the percidae family which are highly valued for aquaculture (Kestemont and Mélard 2000), two of them are found in Iran; the Eurasian perch and the pikeperch. Between these two species, pikeperch consistently has been high in market demand. The mean weight and age caught fish from the Caspian Sea estimated to 332.7 g and 3.5 years, respectively (Abdolmaleki 2005).

However, commercial fishing of Eurasian perch is limited to some protected areas in north of Iran such as the Amirkalayeh and Anzali lagoons. The two main habitats of pikeperch in Iran i.e. the Caspian Sea and the Lake behind the Aras dam support a limited fishery of pikeperch, representing 0.2 % of the landings dominated by cyprinids and mullets. Historically though, pikeperch fishery has been considerable, representing 30 % of the landings during the period from 1927 to 1936 (Abdolmaleki and Psuty 2007).

The collapse of the pikeperch fishery from over 3000 tons in the early 1930s to less than 5 tons for the last six decades (Fig. 32.4) led to a decision in 1989 by the Iranian Fisheries Organization (Shilat) to seriously supplement natural populations by establishing a hatchery for this species. Since then the hatchery has steadily increased its production to a level where 1.6 million fry was produced in 2012 (Fig. 32.5).

Aquaculturists rearing Chinese carp in ponds are also interested in using pikeperch for biological control of fish in their ponds, with the added benefit of a pikeperch production supplementing the carps (Fig. 32.6).

There is a high demand for pikeperch in Iran. Consequently pikeperch receive 6–10 USD per kg at the farm gate which is a high price compared to other traditional fish species on the market in the northern part of Iran.

The reproductive cycle of pikeperch has not been fully investigated in Iran. The results of Rahimibashar et al. (2008) showed the highest GSI in Lake Aras (the main

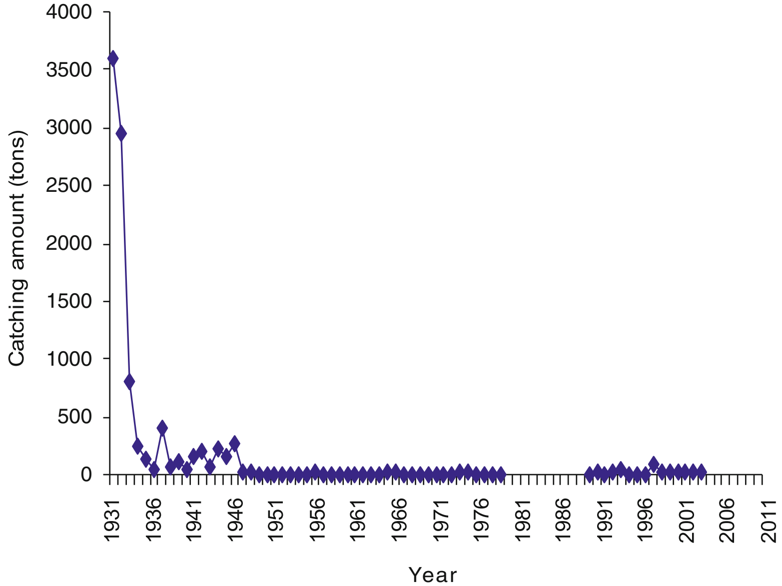


**Fig. 32.4** Landing of pikeperch in Iranian coastline of the Caspian Sea

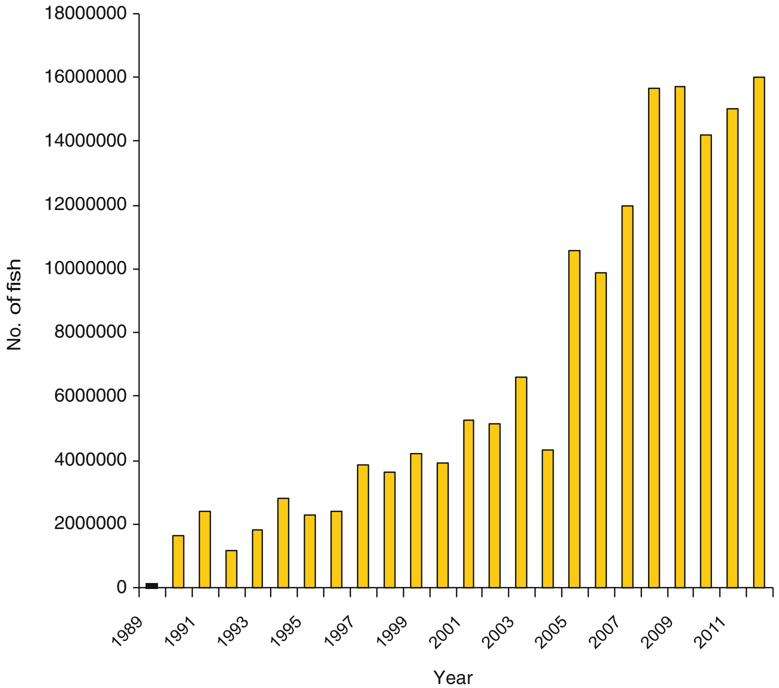


**Fig. 32.5** Pikeperch juvenile production by Iranian hatcheries for stock rehabilitation

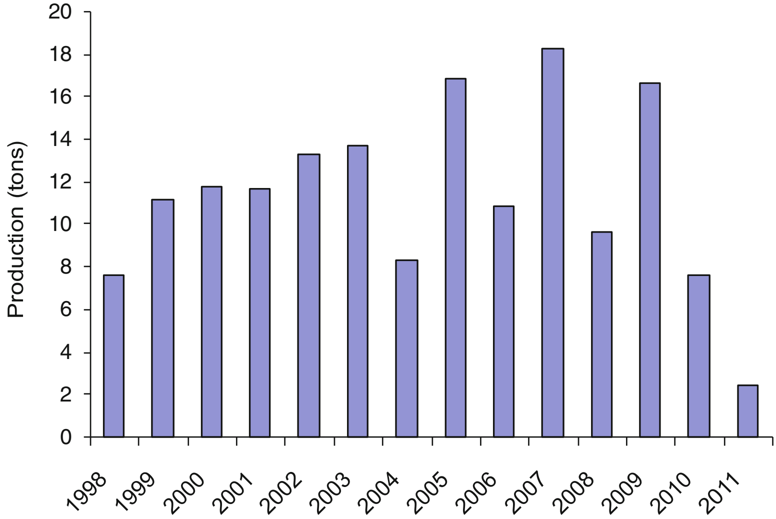


**Fig. 32.6** Iranian aquaculture production of pikeperch in earthen ponds

habitat of pikeperch) during March–April. Spawning usually occurs from March to May at a water temperature of 10–16 °C. Reproductive control experiments revealed only minor effects of short term photoperiod changes. Forty days of exposure to darkness up to spawning only delayed spawning by 24 h. Changes in hematological and stress indicators were observed and were possibly related to the treatments (Pourhosein Sarameh et al. 2012, 2013).

Wild broodstock is captured by beach seine net from the lake behind the Aras dam in the northwestern part of Iran during the late fall and winter. The fish are transferred to the Dr. Yousefpour Fish Hatchery Center in Siahkal 800 km from the lake by truck . At the hatchery center fish are held in earthen ponds and fed baitfish (carp fry) till spawning. Prior to expected spawning in March, fish are introduced to large 600 $m^3$ concrete or small circular 1 $m^3$ concrete ponds, or to 2–4 ha earthen ponds. Nests made by willow branches (53 × 53 × 5 cm), are placed in the tanks or ponds (Fig. 32.7).

Recently, hormonal treatments have been implemented with success. Females are injected with 200 and 400 IU hCG $kg^{-1}$ for the priming and resolving doses and males receive 200 IU $kg^{-1}$. After 28–34 h, most fish will spawn on the nests (Falahatkar et al. 2009; Golmoradizadeh et al. 2010).

Although the main propagation methods for pikeperch include the capture of wild broodstock in the autumn before spawning, reared broodstock can be used as well (Falahatkar and Poursaeid 2012).

Stripping and fertilizing of pikeperch eggs using more intensive methodology are carried out, i.e. the dry method where 2 mL of semen is added to 100 g of eggs followed by addition of a fertilization solution (4‰ Carbamide, salt and 3‰ urea) to prevent sticking of the eggs. Eggs are washed with water and transferred to upwelling jars till hatching.

**Fig. 32.7** Spawning nests in the rectangular concrete ponds at Dr. Yousefpour Fish Hatchery Center in Siahkal

Larvae hatched from the upwelling systems and from the nests in the concrete systems are returned to the pond systems 4–6 days after hatching. They feed on the natural live food, mainly rotifers. Ponds are conditioned with cow (organic) and chemical (inorganic) fertilizers before and during larval rearing. Stocking densities vary from 300 to $400 \times 10^3$ larvae $ha^{-1}$ in the earthen ponds. Yields after 50 days are 300–440 kg $ha^{-1}$ of 1–1.1 g Survival in fertilized ponds is highly variable, but in good cases near 50 % after 5–7 weeks or rearing. High rates of cannibalism are observed and seem related to high water temperatures (up to 30 °C) during the summer months.

Currently, many carp farmers have shown interest in culture of pikeperch. One aim is to control undesirable fish species in ponds and lakes, although a production of market size pikeperch also seems to be interesting to the sector. Present limiting factors seem to be repeated failures in rearing of the species and the lack of specific formulated diets.

The average harvest size after 232 days rearing in earthen ponds together with Chinese carps was 235 g the 1 year, but growth performance and production outputs seems highly fluctuating and unpredictable (Tamazouzt et al. 1993).

Survival rates were 18 % in some water reservoirs and 41 % in earthen ponds. The main reason for the low survival rates seems related to lack of adequate adaptation with pond condition but more importantly seems the sensitivity of this species to transport (Falahatkar et al. 2012).

As mentioned previously, the main purpose of pikeperch production in Iran is wild stock rehabilitation.

## 32.10 Tunisia

In the geoclimatic context of Tunisia, the satisfaction of water needs for the population and the economic sectors necessitated the mobilization of renewable hydric resources by building a large number of dams and reservoirs. Even though these mobilized water resources are first destined to drinkable water, irrigation and industrial needs, they also may be object of an additional valorization through the production of freshwater fishes under extensive conditions without any alteration of water quality or perturbation of the ecosystems (Mhetli et al. 2012). Tunisian government worked in this sense since the 1960s. Knowing that native freshwater fish species are either scarce or not exploited because they are not considered economically valuable (Mhetli et al. 2011), several species have been introduced in Tunisia, including pikeperch which appeared of particular interest. Pikeperch was also introduced in Algeria in 1985 (Meddour et al. 2005). In North Africa, pikeperch populations inhabit the most southern regions of the species' geographical distribution (Mhetli et al. 2011).

This carnivorous species allow the transformation of small invaluable fishes (*Phoxinella*, *Gambusia*, young cyprinids) into exploitable biomass, of excellent nutritional quality and commercial value. Generally, fishermen are pleased with its introduction because it augments their income by increasing substantially the economic value of their catches (Lammens 2001). The species was introduced for the first time in Tunisia in 1968 by the importation of a batch of 30,000 eggs placed in incubating boxes in the lake of Nebhana dam by the National Office of Fisheries (Zaouali 1981). At the beginning of the 1990s, translocations of few adult specimens were done within the framework of a development program having as objective the utilization of the dams for the production of freshwater fish in the North of the country (Losse et al. 1991). Since 2004, a multitude of seeding has been operated based on the reproduction of wild caught pikeperch broodstocks in hatchery and the larval rearing in intensive conditions (Hamza et al. 2007, 2008, 2010, 2012). More recently, researches performed at the INSTM (Institut National des Sciences et Technologies de la Mer) allowed acclimating wild broodstocks to captivity, warranting regular collections of spawns for seeding operations (Ben Khemis et al. 2014). Nowadays, according to recent compilation of data, the species has been introduced into a total of 49 spots: 16 dams, 12 reservoirs and 21 hill lakes. Among these lakes, 18 are exploited (Table 32.5) by licensed fishermen who are mostly young people (under 30 year old) with high school graduation level (Mtimet 2010). Thus, this activity contributes to employment and creation of economic resources in the lakes surrounding regions, where opportunities are generally scarce.

Global pikeperch production increased during last decade to overpass 200 tons/year (Fig. 32.8), placing the country among the main producers with Ukraine, Netherlands and Denmark. At the national level, the production ranges between 18 % and 20 % of freshwater fish production but it contributes to more than 25 % of its value on local market. In terms of valorization, Tunisia is among the countries in which unitary value is the weakest in the world (FAO). Indeed, the prices are around

**Table 32.5** Production and productivity of exploited Tunisian lakes (2004–2013)

| | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|---|---|---|---|---|
| Production (mt) | 58.9 | 89.5 | 192.4 | 196.2 | 198 | 227 | 190 | 172.4 | 211.8 | 210.9 |
| Weighted mean productivity (kg/ha) | 6.8 | 7.8 | 17.2 | 16.6 | 15.7 | 14.9 | 10.9 | 11.4 | 13.5 | 13.5 |
| Minimum (kg/ha) | 0.5 | 0.4 | 0.9 | 0.3 | 1.8 | 1.1 | 0.5 | 0.4 | 0.3 | 0.4 |
| Maximum (kg/ha) | 13.2 | 24.0 | 24.8 | 26.3 | 40.0 | 60.0 | 25.0 | 27.2 | 32.0 | 36.0 |
| Number of exploited lakes | 8 | 10 | 8 | 9 | 9 | 12 | 17 | 14 | 17 | 18 |
| Cumulated surface (ha) | 8600 | 11,554 | 11,234 | 11,854 | 12,604 | 14,664 | 17,434 | 15,126 | 15,721 | 15,576 |

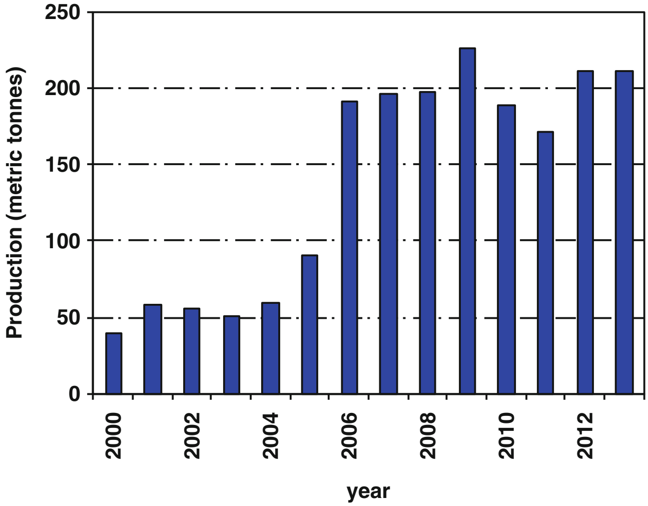


**Fig. 32.8** Pikeperch production in Tunisian lakes and reservoirs from 2000 to 2013 (Statistics DGPA)

2.2 $ US/Kg. The pikeperch is exclusively produced by fishermen and license holders of reservoirs which correspond to small economical units of limited power. To allow a better valorization of the production, some of the stakeholders would like to export part of the production towards European countries where there is a strong demand for the species. The access to these markets may allow a valorization at prices six to sevenfold higher comparatively to local Tunisian market. In this way, researchers from INSTM are studying the nutritional quality and safety of pikeperch captured in Sidi Salem lake (largest dam in Tunisia) in the frame of a survey performed during 2014 (BioVecq). This survey was carried out with the aim of certification of this fish for export.

## References

Abdolmaleki S (2005) Stock assessment of the Pike perch (*Stizostedion lucioperca*) in the southern coastal waters of the Caspian Sea. Iran Sci Fish J 13:95–110

Abdolmalaki S, Psuty I (2007) The effects of stock enhancement of pikeperch (Sander lucioperca) in Iranian coastal waters of the Caspian Sea. ICES J Mar Sci 64:973–980

Adámek Z, Kouřil J (2000) A long aquaculture tradition in the Czech Republic. Aquacult Eur 25:20–23

Adámek Z, Linhart O, Kratochvíl M, Flajšhans M, Randák T, Policar T, Masojídek J, Kozák P (2012) Aquaculture the Czech Republic in 2012: modern European prosperous sector based on thousand-year history of pond culture. Aquacult Eur 37:5–14

Ashe DA (1997) Cultivating perch. Aquaculture explained, Bord Iascaigh Mhara (Irish Sea fisheries Board) Ed, 20, 47 p

Ben Khemis I, Hamza N, Ben Messaoud N, Ben Rached S, Mhetli M (2014) Comparative study of pikeperch *Sander lucioperca* (Percidae; Linnaeus, 1758) eggs and larvae from wild females or from captive females fed chopped marine fish. Fish Physiol Biochem 40:375–384

Brožová M (2005) Fish – annual report of Ministry of Agriculture. Ministry of Agriculture of the Czech Republic, 40 p – in Czech only

Dahl J (1982) A century of pikeperch in Denmark. FAO EIFAC 42:344–352

Deelder CL, Willemsen J (1964) Synopsis of biological data on pike-perch *Lucioperca lucioperca* (Linneaus) 1758. Anonymous, Rome

Falahatkar B, Poursaeid S (2012) Effects of hormonal manipulation on stress responses in male and female broodstocks of pikeperch (*Sander lucioperca*). Domestication in Finfish Aquaculture, 23–25 Oct, Olsztyn

Falahatkar B, Poursaeid S, Efatpanah I, Ranaye Akhavan S, Meknatkhah B, Arzboo Z (2009) Induction of spawning pikeperch (*Sander lucioperca*) in response to various hormones. Aquaculture Europe 2009, 15–18 Aug, Trondheim

Falahatkar B, Akhavan SR, Efatpanah I, Meknatkhah B (2012) Primary and secondary responses of a teleostean, pikeperch Sander lucioperca, and a chondrostean, Persian sturgeon *Acipenser persicus* juveniles, to handling during transport. N Am J Aquacult 74:241–250

FAO (2011) Fisheries and aquaculture information and statistics service – 8/10/2012. http://www.fao.org/fishery/statistics/global-capture-production/query/en

FAO (2012) The state of world fisheries and aquaculture. Anonymous, Rome

FEAP (2011) Production and price report for fish species produced in European aquaculture. Anonymous, FEAP Secretariate, Liege, Belgium

Fontaine P**,** Thomas M (2004) Mise au point de protocoles de contrôle de la production de larves « hors-saison », d'optimisation de l'alimentation et de caractérisation de la qualité des produits en perciculture. Rapport final du programme d'innovation ANVAR N°A0011134LATEK / Programme franco-espagnol Eurêka ACRAPEP, 21 p. (In French)

Fontaine P, Tamazouzt L, Capdeville B (1996) Growth of the Eurasian perch *Perca fluviatilis* L. reared in floating cages and in water recirculated system: first results. J Appl Ichthyol 12(3–4):181–184

Fontaine P, Kestemont P, Mélard C, Verstraete W (2001) Nouvelles technologies microbiennes appliquées à l'élevage de la perche eurasienne (*Perca fluviatilis*) en circuit fermé. Final report FAIR CT98-9241 (1/1/99-31/12/00), 149 p

Fontaine P, Kestemont P, Teletchea F, Wang N (2008) Percid fish culture: from research to production. Abstracts and short communications, 23–24 Jan 2008, Namur, 148 p

Frisk M, Skov PV, Steffensen JF (2012) Thermal optimum for pikeperch (*Sander lucioperca*) and the use of ventilation frequency as a predictor of metabolic rate. Aquaculture 324–325:151–157

Golmoradizadeh A, Sajjadi MM, Falahatkar B, Efatpanah I (2010) Effect of human chorionic gonadotropin (HCG) and carp pituitary extract (CPE) on induced spawning of Pikeperch (*Sander lucioperca*) and fertilization parameters. J Mar Sci Technol 9:18–27

Hamza N, Mhetli M, Kestemont P (2007) Effects of weaning age and diets on ontogeny of digestive activities and structures of pikeperch (*Sander lucioperca*) larvae. Fish Physiol Biochem 33:121–133

Hamza N, Mhetli M, Ben Khemis I, Cahu C, Kestemont P (2008) Effect of dietary phospholipid levels on performance, enzyme activities and fatty acid composition of pikeperch (*Sander lucioperca*) larvae. Aquaculture 275:274–282

Hamza N, Silvestre F, Mhetli M, Ben Khemis I, Dieu M, Raes M, Cahu C, Kestemont P (2010) Differential protein expression profile in the liver of pikeperch (*Sander lucioperca*) larvae fed with increasing levels of phospholipids. Comp Biochem Physiol D 5:130–137

Hamza N, Kestemont P, Ben Khemis I, Mhetli M, Cahu C (2012) Effect of different sources and levels of dietary phospholipids on performances and fatty acid composition of pikeperch (*Sander lucioperca*) larvae. Aquacult Nutr 18:249–257

Hilge V, Steffens W (1996) Aquaculture of fry and fingerling of pike-perch (*Stizostedion lucioperca* L.) – a short review. J Appl Ichthyol 12:167–170

Kamstra A, Schram E, Span JA (2001) Trials with intensive production of pike-perch fry using dry diets. EAS Publ Ser 29:125–126

Kestemont P, Dabrowski K (1996) Recent advances in the aquaculture of percid fish. J Appl Ichthyol 12(3–4):137–200

Kestemont P, Mélard C (2000) Aquaculture (chapter 11). In: Craig JF (ed) Percid fishes – systematics, ecology and exploitation. Blackwell Science, Oxford, pp 191–224

Kestemont P, Mélard C, Etienne F, Baras E (1998) Bases biologiques de l'élevcage intenif des percidés en cage. Rapport annuel 3. Ministère de la Région Wallonne, Publication code :FP SB61/3, Namur

Kestemont P, Mélard C, Fontaine P, Anthouard M, Boujard T, Kentouri M (2000) An integrated study of interindividual competition and its relationships with feeding physiology and behaviour in cultured predatory fish. Final report FAIR CT96-1572 (1/1/97-31/12/99), 148 p

Kratochvíl M (2012) Harvesting of marketable fish in members of Czech fish farmers association in 2011 and using of fish production in the Czech Republic during 1990–2011. Report of Czech Fish Farmers Association, 31 pp – in Czech only

Křisťan J, Stejskal V, Policar T (2012a) Comparison of reproduction characteristics and broodstock mortality in farmed and wild Eurasian perch (*Perca fluviatilis* L.) females during reproduction under controlled conditions. Turk J Fish Aquat Sci 12:191–197

Křisťan J, Alavi SMH, Stejskal V, Policar T (2012b) Hormonal induction of ovulation in pikeperch (*Sander lucioperca* L.) using human chorionic gonadotropin (hCG) and mammalian GnRH analogue. Aquacult Int. doi:10.1007/s10499-012-9572-y

Kucharczyk D, Targońska K, Sosiński M, Kwiatkowski M, Szkudlarek M, Szczerbowski A (2008) Artificial reproduction of pikeperch (Sander lucioperca L.) under controlled conditions. Conference: percid fish culture from research to production, Namur, 23–24 January 2008. In: Fontaine P, Kestemont P, Teletchea F, Wang N (eds) Percid fish culture from research to production, Presses Universitaires de Namur, ISBN: 978-2-87037-582-2

Lammens EHRR (2001) Consequences of biomanipulation for fish and fisheries, FAO, Fisheries circular. No 952, 23 p

Leggett AM (1966) Some aspects of fishing management in the development of inland fisheries in Ireland. Univ Rev 3(10):34–47

Losse GF, Nau W, Winter M (1991) Le développement de la pêche en eau douce dans le nord de la Tunisie. Coopération Technique Tuniso-Allemande. Deutsche Gesellshaft für Technische Zusammenarbeit (GTZ) Eschborn, République Fédérale d'Allemagne, 418 p

Maitland PS, Campbell RN (1992) Freshwater fishes of the British Isles. HarperCollins, Somerset

Meddour A, Rouabah A, Meddour-Bouderda K, Loucif N, Remili A, Khatal Y (2005) Expérimentations sur la reproduction artificielle de *Sander lucioperca*, *Hypophthalmichthys molitrix* et *Aristichthys nobilis* en Algérie. Science et Technologie C 23:63–71

Mhetli M, Ben Khemis I, Hamza N, Turki B, Turki O (2011) Allometric growth and reproductive biology traits of pikeperch, *Sander lucioperca*, at the southern edge of its range. J Fish Biol 78:567–579

Mhetli M, Hamza N, Turki B, Ben Khemis I (2012) Valorisation des plans d'eau en Tunisie par l'introduction de populations ichthyques carnassières. In: 6ème Conférence Internationale: "Ressources en eau dans le bassin méditerranéen", 10–12 Oct 2012, Sousse, Tunisia

Mtimet N (2010) Analyse socioéconomique de la filière de la pisciculture continentale au Nord-Ouest de la Tunisie. Rapport du Groupement Interprofessionnel des produits de la Pêche en collaboration avec la coopération italienne, 150 p

Öberg O (2008) Rearing of perch in recirculating systems in Eastergötlands and Kalmars archipelago. TRITA-LWR.REPORT 3019, ISBN 978-91-7415-023-0 (in Swedish) Stockholm, Sweden

Overton JL, Paulsen H (2005a) First feeding of perch (*Perca fluviatilis*) larvae Bornholms salmon Hatchery Nexo. DFU-report 150-05. DTU-Aqua. Copenhagen, Denmark

Overton JL, Paulsen H (2005b) Ongrowing of perch (*Perca fluvia*tilis) juveniles Bornholms salmon Hatchery Nexo. DFU-report 151-05. DTU-Aqua. Copenhagen, Denmark

Paulsen H, Overton JL, Brünner L (2005a) Development of culture of perch (*Perca fluviatilis*), a potential alternative species for fresh water culture. DFU-report 149-05. ISBN 87-90968-83-2 DTU-Aqua. Copenhagen, Denmark. Hirtshals (in Danish)

Paulsen H, Overton JL, Frandsen D, Larsen MGG, Hansen KB (2005b) Evaluation of state of nutrition for perch. The North Sea Center, Hirtshals, in Danish

Policar T, Stejskal V, Bláha M, Alavi SMH, Kouřil J (2009) Technology of intensive culture of Eurasian perch (*Perca fluviatilis* L.). Practical handbook FFWP USB 89, 51 p – in Czech only

Policar T, Alavi S, Stejskal V, Křišťan J, Kouřil J (2011a) Artificial and semiartificial spawning in Eurasian perch (*Perca fluviatilis* L.) use for mass embryo production. Practical handbook FFWP USB 117, 24 p – in Czech only

Policar T, Bláha M, Křišťan J, Stejskal V (2011b) High quality and stable production of advanced juveniles in pikeperch (Sander lucioperca) under ponds. Practical handbook FFWP USB 110, 33 p – in Czech only

Policar T, Alavi S, Stejskal V, Křišťan J, Kouřil J (2012) Artificial and semiartificial spawning in Eurasian perch (*Perca fluviatilis* L.) use for mass embryo production. Edition of Methods, FFPW USB, Vodňany, No. 117, 24 pp. (in Czech)

Policar T, Stejskal V, Křišťan J, Podhorec P, Švinger V, Bláha M (2013) The effect of fish size and density on the weaning success in pond-cultured pikeperch (*Sander lucioperca* L.) juveniles. Aquacult Int 21:869–882

Pourhosein Sarameh S, Falahatkar B, Azari Takami G, Efatpanah I (2012) Effects of different photoperiods and handling stress on spawning and reproductive performance of pikeperch *Sander lucioperca*. Anim Reprod Sci 132:213–222

Pourhosein Sarameh S, Falahatkar B, Azari Takami G, Efatpanah I (2013) Physiological changes in male and female pikeperch *Sander luciope*rca (Linnaeus, 1758) subjected to different photoperiods and handling stress during the reproductive season. Fish Physiol Biochem 39:1253–1259

Rahimibashar MR, Alipoor V, Danesh M, Alinia MR (2008) Survival of biometrical characteristics, diet, gonad and liver index of (Sander lucioperca) in the lake of Aras Dam. Pajouhesh Sazandegi 79:58–65

Schlumberger O, Proteau J-P (1991) Production de juvéniles de Sandre (*Stizostedion lucioperca*). Aqua-revue 36:25–28 (in French)

Steenfeldt S, Vestergaard M, Overton JL, Paulsen H, Larsen VJ, Henriksen NH (2010) Development of intensive rearing of pikeperch in Denmark. DTU-Aqua report no. 228:2010. (in Danish)

Steenfeldt S, Lund I, Höglund E (2011) Is batch variability in hatching time related to size heterogeneity and cannibalism in pikeperch (*Sander lucioperca*)? Aquacult Res 42:727–732

Stejskal V, Policar T, Bláha M, Křišťan J (2010) Production of marketable Eurasian perch (*Perca fluviatilis*) by the combination of pond and intensive culture. Practical handbook FFWP USB 105, 34 p – in Czech only

Tamazouzt L, Dubois JP, Fontaine P (1993) Production of the perch *Perca fluviatilis* L. and its markets in Europe. La Pisciculture Française 114:4–8 (In French)

Tamazouzt L, Dubois JP, Fontaine P, Capdeville B, Terver D (1996) Zootechnical performances and body composition of *Perca fluviatilis* fed pelleted diet in a floating cage: effect of daily ration. Ann Zool Fennici 33:635–641

Teletchea F, Kestemont P, Mélard C, Schram E, Linhart O, Fontaine P (2006) Securing juveniles production of Eurasian perch by improving reproduction and larval rearing. Final report COOP-CT-2004-512629-PERCATECH, 40 p

Torner D, Rougeot C (2008) Farming of Eurasian perch. Vol. 1 – Juvenile production, Aquaculture explained, special publication. BIM, Ireland, p 24, 78 p

Wang N, Teletchea F, Schram E, Kucharczyk D, Mélard C, Fontaine P, Kestemont P (2008) Improving pikeperch larval quality and production by broodstock management and nutrition, husbandry and sex control. Final report COOP-CT-2005-017646-LUCIOPERCIMPROVE

Wood RB, Smith RV, Neagh L (1993) The ecology of a multipurpose water resource, Kluwer Academic Publ., Dordrecht, The Netherlands. ISBN 0-7923-21 12-X. 529 p

Zaouali J (1981) Problèmes d'aquaculture: eaux saumâtres et potentiel aquacole. Arch Inst Pasteur Tunis 58:93–103

Ženíšková H, Gall V (2011) Fish – annual report of Ministry of Agriculture. Ministry of Agriculture of the Czech Republic, Prague, 45 pp. (in Czech)