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EIFAC SYMPOSIUM ON INTERACTIONS BETWEEN SOCIAL, ECONOMIC AND ECOLOGICAL OBJECTIVES OF INLAND COMMERCIAL AND RECREATIONAL FISHERIES AND AQUACULTURE

Antalya, Turkey, 21-24 May 2008

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EUROPEAN INLAND FISHERIES ADVISORY COMMISSION

PROCEEDINGS OF THE EIFAC SYMPOSIUM ON INTERACTIONS BETWEEN SOCIAL, ECONOMIC AND ECOLOGICAL OBJECTIVES OF INLAND COMMERCIAL AND RECREATIONAL FISHERIES AND AQUACULTURE

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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PREPARATION OF THIS DOCUMENT

A symposium on "Interactions between social, economic and ecological objectives of inland commercial and recreational fisheries and aquaculture", was organized in conjunction with the twenty-fifth session of the European Inland Fisheries Advisory Commission (EIFAC) in Antalya, Turkey, from 21 to 24 May 2008.

This Occasional Paper contains the conclusions and recommendations of the symposium to the subsequent EIFAC session and papers presented at the symposium that are additional to those published in a special issue of Fisheries Management and Ecology. The Report of the symposium on "Interactions between social, economic and ecological objectives of inland commercial and recreational fisheries and aquaculture, Antalya, Turkey, 21-24 May 2008 was published in 2008 as EIFAC FAO Fisheries and Aquaculture Report No. 871[1]. That report contains next to the symposium report also the agenda and list of participants.

This document was prepared by Mr Ian Cowx, Mr Ryan Taylor, Mrs Sam Walton, Ms Natalie Angelopoulos, Ms Michelle Smith, Ms Karen Twine and Ms Chloe Davies (Hull University, UK) and Mr Raymon van Anrooy of the FAO Subregional Office for Central Asia (SEC). All papers were lightly edited and were not necessarily fully checked for accuracy of the information. All views and opinions expressed are the views of the authors of the paper and not of EIFAC or the editors. It was agreed that bibliographic citations would be presented according to Fisheries Management and Ecology style. The authors of the report would like to thank Mr Ramazan Celebi and Mr Erkan Gozgozoglu (Ministry of Agriculture and Rural Affairs – MARA, Turkey) and their staff, Mr Yilmaz Emre **(**Mediterranean Fisheries Research, Production and Training Institute – AKSAM, Turkey) and his staff, Mr Ibrahim Okumus (Rize University, Turkey) Mr Robert Arlinghaus (Leibniz-Institute of Freshwater Ecology and Inland Fisheries, Germany), Mr Phil Hickley and Mr Miran Aprahamian (Environment Agency, UK), Mr Eric Hudson (Centre for Environment Fisheries and Aquaculture Science, UK), Mr Laszlo Varadi (Research Institute for Fisheries, Aquaculture and Irrigation, HAKI, Hungary), Mr Arjo Rothuis (Ministry of Agriculture, Nature and Food Quality, the Netherlands), Mr Sedat Yerli (Hacateppe University, Turkey), Mr Andy Thorpe (University of Portsmouth, UK), Mr Atilla Ozdemir (Central Fisheries Research Institute, Turkey), Ms Annarita Colagrossi, Ms Dila Altin, Ms Deniz Ozkan, Ms Aysegul Omur, Mr Gerd Marmulla and Mr Thomas Moth Poulsen (FAO), and many other assistants provided by the local hosts, for their collaboration in the preparation and organization of the symposium and in making it the success it became. General thanks for their important contributions to the presentations and discussions are due to all who attended the symposium.

Distribution:

All EIFAC Members
Participants at the Symposium
Other interested nations and national and international organizations
FAO Fisheries and Aquaculture Department

[1] ftp://ftp.fao.org/docrep/fao/011/i0423e/i0423e.pdf

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ABSTRACT

The symposium on Interactions between Social, Economic and Ecological Objectives of Inland Commercial and Recreational Fisheries and Aquaculture, was organized in conjunction with the Twenty-Fifth Session of the European Inland Fisheries Advisory Commission (EIFAC) in Antalya, Turkey, from 21 to 24 May 2008.

The symposium objectives were:

1) To review the wide range of socio-economic and ecological interactions between fisheries and aquaculture and the roles of various stakeholders with respect to these interactions.
2) To identify where future research should focus and propose measures to decrease interactions that compromise sustainable development and management, and promote interactions that contribute to sustainability.
3) To provide information to policy and decision makers to contribute to the general awareness of trends in socio-economic and ecological interactions within and between the sector and other rural sectors.
4) To facilitate dialogue between scientists, researchers, fisherfolk, aquaculturists and policy and decision makers on the motives, interactions and interests of stakeholders.
5) To advise EIFAC on appropriate management and development measures and tools for inland fisheries and aquaculture in Europe.

This Occasional Paper in conjunction with a special issue of *Fisheries Management and Ecology* represents the proceedings of the symposium. The symposium made considerable progress towards understanding the interactions between ecological/environmental and socio-economic/governance objectives for fisheries and aquaculture. There was a broad recognition that inland fisheries and aquaculture need to shift from a sectoral view where they are treated in isolation to an integrated, multi-disciplinary systems view.

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Obituary

Professor Ibrahim OKUMUŞ

Pioneer of Turkish Aquaculture

Professor İbrahim OKUMUŞ was the Chairperson of the International Symposium on "Interactions between social, economic and ecological objectives of inland commercial and recreational fisheries and aquaculture", Antalya, Turkey, 21-24 May 2008, held in conjunction with the 25th Session of the European Inland Fisheries Advisory Commission (EIFAC). He was one of the scientific pioneers of Turkish aquaculture and worked tirelessly to promote its sustainable development at a national level and especially internationally. One of his great projects was the development of a Roadmap for Turkish Marine Aquaculture Site Selection and Zoning Using an Ecosystem Approach to Management.

Professor Okumuş was educated at Çukurova University where he completed his Masters degree in 1986 in the field of animal husbandry. Three years later he went to The Humberside College of Higher Education in Grimsby, UK and graduated with a Diploma in Fisheries Management in 1990. Between 1990 – 1993 he studied at the University of Stirling in Scotland earning his PhD. He spent much of his career at the Karadeniz Technical University researching, teaching and supervising students, as well as carrying out his administrative responsibilities in the fisheries department.

During his career he supervised eleven M.Sc and eleven Ph.D students and worked on more than 18 aquaculture projects, many of which related to local trout species. He was acutely aware of the environmental aspects of aquaculture and strove to reduce the impact of aquaculture on the environment. At the same time he saw the potential of fish farming and knew the importance of maintaining good relationships between all the stakeholders. He was also the coordinator of the Socrates/Erasmus programme in Turkey, an European student exchange facility, from 2004 to 2007. Professor Okumuş was appointed to Rize University, as Dean of the Faculty of Fisheries and Pro-Rector in 2007.

Professor Okumuş passed away on 5 December 2008; just a few months after the Symposium he chaired for EIFAC. His death can be regarded a great loss for the Turkish and European aquaculture industry. Professor Okumuş is survived by his wife Leyla OKUMUS and three daughters, Gülşah, Bilgen and Bengisu.

Social, economic and ecological objectives of inland commercial and recreational fisheries and aquaculture

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Background and objectives

Sustainability is at the core of efforts to develop and manage inland fisheries (i.e. commercial and recreational) and aquaculture in Europe. Sustainability in this context includes social, economic and ecological (or more broadly environmental) aspects, which are shaped by functioning governance structures and management institutions. Previous EIFAC symposia have shown that in many cases sustainability is not viewed from all these three aspects in an integrated manner.

The FAO Code of Conduct for Responsible Fisheries and the EU strategy for sustainable development of European aquaculture recognize that the sector should take an approach where farming and fisheries technologies, social and economic issues, natural resource use, biodiversity conservation and governance are integrated to enhance sustainable management.

Interactions between social, economic and ecological objectives of inland fisheries and aquaculture are numerous, and include amongst others:

- Improvement in ecological status of rivers, lakes and other water bodies
- (Re-)stocking for commercial and recreational fisheries
- Recovery and conservation of depleted/threatened stocks
- Collection of fish from the wild for aquaculture
- Harvesting by commercial and recreational fisheries for human consumption
- Catch-and-release recreational fishing
- Employment and income generation by capture fisheries and aquaculture
- Pollution of inland water bodies by aquaculture
- Escapes of fish from farms and introduction of alien species
- Increase of eutrophication through water discharge from farms or other sources
- Harvesting of protected species
- Conflicts between resource users, non-users and interest groups, and competitiveness of the sector compared to other sectors
- The role of fisheries within society and in cultural and religious traditions, and
- Enactment of new and enforcement of current policies, and decisions on water use.

Interactions between social, economic and ecological objectives are particularly relevant considering the ongoing shift from a dominance of commercial towards recreational fisheries. This raises issues of economic rent, angling tourism, ethics of exploitation and competing objectives between biodiversity conservation and expansion of recreational fishing opportunities. A Seminar organized by the European Association of Agricultural

Economists (EAAE) on the "Economics of aquaculture with respect to fisheries[2]" (Civitavecchia, Italy, December 2005) identified there is a great need to explore these interactions further to identify appropriate solutions that balance private and public use of goods now and in the future.

Similarly, the General Fisheries Commission for the Mediterranean/ADRIAMED organized an Expert Consultation in Rome, Italy (November 2003) on "Interactions between aquaculture and capture fisheries[3]". That consultation highlighted the importance of interactions between capture fisheries and aquaculture in terms of impact on biodiversity, restocking of depleted stocks, space and water competition, marketing and the livelihoods in fishing communities with particular emphasis on the Mediterranean area. Unfortunately, discussions on this subject have mainly focused on the marine environment and inland fisheries have received little attention. The EIFAC symposium aimed to address this gap.

This issue is particularly relevant in inland waters in Europe because of obligations under the EU Water Framework, Bird and Habitats Directives. Conflicts could potentially arise within the fisheries and aquaculture sectors because of needs to protect biodiversity and improve the ecological status of waters. Resolution of such conflicts was discussed at the symposium.

The principal aim of the symposium was to provide a forum for those working on specific socio-economic and ecological aspects of inland fisheries and aquaculture in Europe (including researchers, natural and social scientists, environmental scientists, fisherfolk, aquaculturists, economists, planners, government officials, NGO representatives, and other stakeholders), to review the interactions between socio-economic and ecological objectives in fisheries and aquaculture, exchange experiences and discuss solutions to imbalances in sustainable development and management of the sector.

The specific objectives of the symposium were:

- To review the wide range of socio-economic and ecological interactions between fisheries and aquaculture and the roles of various stakeholders with respect to these interactions.
- To identify where future research should focus and propose measures to decrease interactions that compromise sustainable development and management, and promote interactions that contribute to sustainability.
- To provide information to policy and decision makers to contribute to the general awareness of trends in socio-economic and ecological interactions within and between the sector and other rural sectors.
- To facilitate dialogue between scientists, researchers, fisherfolk, aquaculturists and policy and decision makers on the motives, interactions and interests of stakeholders.

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[2] "The Economics of aquaculture with respect to fisheries" Proceedings of the 95th EAAE Seminar, Civitavecchia (Rome), Italy, 9-11 December 2005. K.J. Thomson and L. Venzi (eds), November 2006.
[3] "Interactions between aquaculture and capture fisheries: a methodological perspective". *Studies and Reviews. General Fisheries Commission for the Mediterranean.* No. 78. Rome, FAO. 2005. 229p Cataudella, S.; Massa, F.; Crosetti, D. (eds.) http://www.fao.org/docrep/009/a0141e/A0141E00.htm#TOC

The symposium examined interactions, in accordance with the following four thematic areas:

1) *Ecological interactions* (including among others, rehabilitation of aquatic systems, pollution, global warming overexploitation, species introductions, restocking of inland water bodies for fisheries and extensive culture, use of natural stocks for aquaculture production, organic and inorganic waste, organic aquaculture, use of fish to feed fish, aquatic animal health issues, utilization of chemicals, therapeutants and hormones). Competition for resources between commercial fisheries, recreational fisheries and aquaculture and with other resource users was one of the key issues under this theme.
2) *Economic interactions* (issues might include among others markets and market opportunities, equity issues, income issues, recreational fisheries evaluation, opportunity costs of resource use, value of natural common property resources)
3) *Social interactions* (employment and gender issues, alternative uses of resources, cultural aspects of resource harvesting and consumption, stakeholder participation in integrated planning)
4) *Governance interactions* (including latest developments with regards to the EU Water Framework and Habitats Directives, forthcoming policy regulations, directives and management plans, codes of practices and guidelines, competition between stakeholders for allocation of public and common-property-goods, legislation and zoning, conservation areas)

Conclusions and recommendations

The symposium made considerable progress towards understanding and resolving the interactions between ecological/environmental and socio-economic/governance objectives for fisheries and aquaculture. There was a broad recognition that inland fisheries and aquaculture need to shift from a sectoral view where they are treated in isolation to an integrated, multi-disciplinary systems view.

The conclusions of the symposium can be summarized as:

- There are a considerable number and range of inter- and intra-sectoral users. It also recognised the management conflicts and synergies that exist between recreational and commercial fisheries and aquaculture and other aquatic resource users. These arise, for example, from stocking and introductions to meet angler demand versus protection of biodiversity or development of hydropower production versus fisheries interests. As a consequence, there is a need to balance promotion of aquaculture and inland fisheries with biodiversity protection.
- One of the inherent problems recognised throughout the inland fisheries and aquaculture sectors in Europe was the lack of basic socio-economic data, and an understanding of socio-economic concepts on which to support promotion of the sectors. Economic research tends to be too narrowly focussed on the economic aspects and is poorly linked to social interactions and environmental issues.
- This problem is exacerbated by weak political, and often institutional, support (i.e. operational resources and finance) to help resolve conflicting

ecological/environmental and socio-economic objectives arising from user interactions.

- The EU Water Framework Directive is a major driver of the inland fisheries sector management and development. As a consequence, the intrinsic ‘value’ of water and water bodies, is likely to increase, which will exacerbate competition over the resource and its environs.
- Aquaculture – like farming – is not immune to the growing trend towards intensification of resource use (e.g. water use limitation through recirculation, automatic systems, increasing productivity). This driver could help ameliorate conflicts over resources, but could also have adverse ecological consequences.
- There is a worrying increase in tensions arising from sectors of society that consider exploitation of fisheries to be unacceptable.
- For a variety of reasons, the preference of policy makers seems to be moving from supporting commercial fisheries towards promotion of recreational fisheries. This has not necessarily been reflected in the co-opting of recreational fishers (or recreational fishers associations) into formal management structures.
- While there is a recognized growing demand for fish for consumption, it was also acknowledged that this trend might develop with respect to aquaculture for restocking purposes; this is in view of the common need to restore fish populations and improve the quality of aquatic ecosystems in many EIFAC member countries (under the EU WFD).
- River governance, particularly in terms of trans-boundary management of water resources that are used for fisheries purposes, is inadequate in large parts of the EIFAC region. In this respect, the construction of dams – and water retention and abstraction policies – may have severe consequences downstream, potentially causing conflicts and socio-economic and ecological hardships to the sector.
- The wider society has generally only limited understanding of inland fisheries issues, and particularly of how the inland fisheries sector is contributing to ecological and socio-economic objectives of society; this calls for an increase in efforts to raise awareness and education on inland fisheries.
- Management of inland fisheries continues to have problems being recognized as an equal partner by other users who fail to take full account of multiple user needs and objectives. Many of these problems arise from poor communication and dialogue between user groups and fisheries interests, lack of empathy of the needs and aspirations of each other, lack of finance and knowledge on integrated management of inland fisheries and aquaculture that melds economics, social issues and biology.

It was recommended that the appropriate responsible bodies take the following actions:

- Develop toolboxes, quantitative models and indicators for high quality socio-economic assessment of inland fisheries and aquaculture in data-poor situations. This should include best practice examples and case studies that are sufficiently robust to account for regional variability in ecological, social and economic conditions.

- Promote development of interdisciplinary fisheries research and management methods, approaches and decision-making that link economic, sociological and psychological expertise (coined socio-economics) with the traditional fisheries biological approach.
- Improve communication, information transfer and public outreach of inland fisheries and aquaculture issues to non-fishery stakeholders and to those charged with taking decisions on the development and management of the aquatic environment.
- Develop and promote a more structured approach to recreational fisheries management to take due account of the importance of the activity to local and regional economies.
- Develop and promote alternative employment opportunities for those currently engaged in commercial fisheries to maintain and enhance livelihoods and revenue opportunities. Also, due consideration should be given to gender equity.
- Carry out forward-looking research to examine the ecological and socio-economic implications for inland fisheries/aquaculture of attaining the 2015 targets from the EU WFD – at the national and local level – so as to support managerial decision-making in an *ex-ante* manner.
- Assess the future direction of European inland aquaculture to ameliorate any likely ecological costs whilst maximizing the various (alternative) opportunities that aquatic ecosystems might generate.
- Generate and communicate research on the economic value of recreational fishing as a lever to promote the evolution of managerial decision-making in a manner that equates to stakeholder prevalence in the sector.
- Ascertain the nature of the interaction between commercial and recreational fishing in terms of participation in governance, management of the fisheries resource, and IUU fishing.
- Assess the demand on aquaculture for fish for stocking and adjust the range of products, species and sizes to address the needs of conservation, rehabilitation and (recreational) fisheries that apply stocking.
- Establish a European-wide mechanism for examining, preventing and mitigating of transboundary water resource access and availability issues and problems, which pays proper attention to fisheries sector needs and requirements.
- Address emerging issues via a project management type approach so as to better facilitate the availability of financial and other critical resources.
- Develop (technical) guidelines on recreational fisheries and inland capture fisheries related sectors, to contribute to responsible development and management of these sub-sectors.

Effluent treatment concepts for trout aquaculture in dependence on production intensity

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Abstract In- and outflow nutrient concentrations from 13 German trout farms were monitored. The farms had a significant effect on the effluent quality and the macro-invertebrate fauna. Inflow nutrient concentration, type of rearing units, feeding intensity and the effluent treatment method were the factors predicting effluent nutrient concentration by 50 to 88 % for most nutrient fractions except total suspended solids (TSS) where these factors lead to a predictability of only 13 %.

Based on these results, different treatment options were monitored for their treatment performance. Sedimentation basins for the total farm effluent had no or minor treatment effects. The examined micro-screen was quite effective on particulate nutrient treatment, measured as total phosphorous (TP), biological oxygen demand (BOD_5), chemical oxygen demand (COD) and total suspended solids (TSS), resulting in treatment efficiencies of 29 – 53 %, which was less than expected from literature data. Finally a constructed wetland showed the highest treatment efficiency compared to the other treatment options with nutrient reduction rates of > 35 % for TP, COD, BOD_5, TSS and total ammonia nitrogen (TAN). Additionally, different processing methods for the treatment of micro-screen backwash sludge, such as sedimentation and further treatment in constructed wetlands were discussed. From these results and data from literature, treatment strategies for trout farms in dependence on rearing system and feeding level were developed.

Introduction

The demand on aquaculture products worldwide is constantly increasing (FAO 2006). In the European Union's aquaculture, rainbow trout (*Oncorhynchus mykiss* (Walbaum) is the most important finfish species cultured, with a total production of 215,207 t in 2003 (European Commission 2006). More than 90 % of European aquaculture farms are small and geographically dispersed (Varadi *et al.* 2001) and in particular the trout production sector is mainly characterized by regionally rooted enterprises with an average annual production of 100 t or less (MacAlister Elliott 1999).

Trout production as with any other animal production produces wastes. Aquaculture waste, by definition, includes all materials that are not removed through harvesting. The principal wastes are uneaten feed, excreta, chemicals and therapeutics (Bergheim & Asgard 1996). The aquaculture wastes were discharged through the farm effluent, if not extracted through effluent treatment.

The effect of trout farm effluents on adjacent ecosystems is a function of the amount and type of pollutants and the assimilative capacity of the receiving system (Rosenthal 1994; Piedrahita 2003; O'Bryen & Lee 2003). Potential environmental problems that can arise from aquaculture effluents are (reviewed in Sindilariu 2007):

1. Reaction on nutrient enrichment

2. Effect of suspended solids (TSS)
3. Oxygen depletion in the effluent
4. Direct toxic effects
5. Impact on wildlife

To prevent the potentially negative effects of nutrient rich trout farm effluents, and potential conflicts with other users, effluent nutrient management is required. Removal through "end of pipe" cleaning facilities is needed (Cripps & Bergheim 2000).

In this contribution, the factors influencing effluent nutrient concentration were identified through the survey of the in- and outflow data from 13 trout farms in Southern Germany. In addition, the effect of the farm effluent on the macro-invertebrate fauna was examined at six of these farms. Subsequently different effluent treatment methods were scrutinized and an effluent treatment concept in dependence of production intensity is developed.

Material and methods

Monitored trout farms

Thirteen trout farms were examined for their inflow and outflow water quality. All farms were situated in Southern Bavaria (Germany). Six farms take their inflow water from brooks, inflow amount 100 – 800 Ls^{-1}, while seven farms were fed by spring water, inflow amount 25 – 120 Ls^{-1}. On 163 days between end of 2005 and end of 2007 farm in- and outflow water was sampled. The following factors with a potential impact on effluent nutrient concentration were recorded and scaled to be integrated in a multifactor regression model.

Rearing units

The rearing units used for fish production have to be classified in self-cleaning units, or non self-cleaning units (Willoughby 1999). Self cleaning units are characterized by a fast export of suspended particles out of the system, like concrete raceways or circular tanks (Milden & Redding 1998; Wheaton & Singh 1999). In this study, six farms used earthen ponds only as rearing units; three farms used concrete raceways only. The other four farms used a mix of concrete and earthen ponds and raceways. The amount of concrete raceways per farm was scaled from 1.0 for earthen ponds exclusively to 2.0 for concrete raceways exclusively. For the other farms the amount of raceways compared to ponds was scaled as fraction and added to 1.0.

Amount of feed applied / production intensity

For each farm, the fish farmer noted the amount of feed applied per day. Additionally the amount of inflow water was measured. Flow measurement was performed with a flow meter (model HFA, Höntsch inc.), measuring the mean flow velocity. Through multiple measurements, the total water could be calculated.

Consequently the production intensity per year (Pi) was calculated as the amount of feed applied per day (f), in dependence on the amount of inflow water (Q, Ls^{-1}) on a yearly base ($Pi = (f \cdot 365) / Q$). The production intensity of the trout farms ranged from 200 to 3,370 kg $(Ls^{-1})^{-1}year^{-1}$. All farms applied energy rich extruded feed.

Effluent treatment device of the farm effluent

Six farms used no effluent treatment scaled as treatment option 1.0. Four farms used sedimentation basins, with a certain fish stock, scaled as treatment option 2.0. One of these farms used a constructed wetland, described below, for the treatment of about 20 % of the total effluent. This treatment option was scaled with 2.2. Sedimentation basins without fish were scaled as treatment option 3.0. The fifth farm used a micro-screen as effluent treatment, option 4.0 and the sixth farm used two consecutive micro-screens, a coarser one in the farm (as intermediate treatment) and a fine one as 'end of pipe' treatment, scaled as option 5.0.

Macro invertebrate fauna

At six farms the macro invertebrate fauna up- and downstream the fish farm was sampled. The sampling stations for a farm were selected to have high habitat similarity (structure, insulation, current) and for the downstream station mixing between river water and the trout farm effluent and no self-purification should occur (Boaventura *et al.* 1997). At each sampling station, the macro invertebrates were collected by "kick sampling and collection" (DIN 2006), twice per station with a clearance time of at least one month. Samples were then identified and compared to the German standard methods for the examination water, wastewater and sludge (DIN 2006), and after von Tümpling & Friedrich (1999). For each sampling station a saprobic index with confidence interval was calculated from the collected species and their abundance confirmed (DIN 2006. The index can range between 1.0 for unaffected brook water to 4.0 for highly polluted water.

Effluent treatment devices examined

The following effluent treatment devices applied in the monitored trout farms, were closer examined.

SEDIMENTATION BASIN WITH FISH: The sedimentation basin consists of two chambers, separated by a wooden wall. In the basin the whole effluent (90 – 100 Ls^{-1}) of a farm consisting exclusively of earthen fish ponds was treated. The production intensity (amount of feed applied) is about 280 kg $(Ls^{-1})^{-1}yr^{-1}$. The in- and outflow of the sedimentation basin was sampled on 12 days between July and November 2006. In the basin a small stock of large rainbow trout existed which were irregularly fed.

SEDIMENTATION BASIN WITHOUT FISH This basin contains a baffle at the inflow to lower the flow velocity. On the bottom of the basin sedimentation cones were implemented. The settled sludge was extracted daily from the basin, by opening the bottom drain of the sedimentation cones. In the basin 30 - 40 Ls^{-1} outflow from several raceways used for trout production were treated. The basin was fish-free. Nine samples were taken between July and September 2007. In the sampling period, the production intensity in the raceways was between 1000 and 1260 kg $(Ls^{-1})^{-1}yr^{-1}$.

MICRO-SCREEN AS 'END OF PIPE' TREATMENT The examined micro-screen is a drum filter with a mesh size of 63 µm (FAIVRE Sarl 120-16). It is situated at the outflow of a farm operating exclusively with raceways. After the drum filter 40 L/s (50 %) of the water is discharged, the rest is recirculated. In the sampling period from April until October 2007, 15 samples from the drum filter in- and outflow were taken. During the sampling period the production intensity in the farm was about 1700 – 3000 kg $(L/s)^{-1}yr^{-1}$.

CONSTRUCTED WETLAND In one of the monitored fish farms, a constructed wetland was used to treat a part (20 %) of the total farm effluent, about 23 Ls^{-1}. The constructed wetland consisted of a pre-sedimentation basin, a surface flow (SF) wetland and a sub surface flow (SSF) wetland. For wetland construction, spare fish ponds were used. The SSF wetland had a gravel root zone consisting of 18 – 32 mm gravel. During the sampling period from November 2005 until February 2007, 11 samples from wetland in- and outflow were taken.

Water sampling and analysis

Sampling of water probes was conducted by automated water samplers. They were positioned at the in- and outflow of the device to be examined. The samplers run for 24 hours. Every 10 minutes a sub sample was collected. The sub samples were mixed to 24 hour pooled samples and transported to the lab for analysis.

The water samples were analysed for the following parameters measured in mgL^{-1}: total nitrogen (TN), total ammonia nitrogen (TAN), nitrite nitrogen (NO_2-N), nitrate nitrogen (NO_3-N), total phosphorous (TP), phosphate phosphorous (PO_4-P), biological oxygen demand in 5 days (BOD_5), chemical oxygen demand (COD), and total suspended solids (TSS). The physicochemical properties of the water samples were determined following German standard methods for the examination of water, wastewater and sludge (DIN 2006). For BOD_5 the total oxygen consumption of the original probe was assessed, including nitrification and the particulate matter in the sample was not destroyed prior to measurement.

Data analysis

To identify the main effects on the effluent nutrient concentration, a multivariate regression model was calculated. The following model assumption was used: $Y_{ijkl} = \mu + \alpha_i + \beta_j + \gamma_k + \delta_l + \varepsilon_{ijkl}$, where Y_{ijkl} is the relevant effluent nutrient concentration, μ is the overall effluent nutrient concentration, α_i is the inflow nutrient concentration, β_j rearing unit, γ_k used effluent treatment device, δ_l feeding amount in $kg(L/s)^{-1}year^{-1}$ and ε_{ijkl} is the random residual error. The factors were identified as relevant at a probability level of $\alpha < 0.05$. The residuals were tested for homogeneity and normal distribution. All statistical calculations were performed with SAS 8e.

For the examined treatment methods, differences (Δp) between inflow and outflow concentrations were calculated for each parameter as well as each pair of simultaneously taken samples. The relative treatment efficiency ($\%\Delta$) was calculated for each parameter as $\%\Delta = (\Delta p \ / \ c_{in}) \bullet 100\ \%$, with Δp = inflow-outflow concentration in mgL^{-1} and c_{in} = inflow concentration in mgL^{-1}.

For the Δp data of each parameter a Shapiro-Wilk test for normality was performed, with a significance level of $\alpha < 0.05$. When the Δp data where normally distributed, then the one sample students t-test was performed, in order to evaluate if Δp is significantly different from 0. When normality for the Δp data was rejected, then the Wilcoxon-Test (signed rank test) was used to test whether Δp is significantly different from 0.

Results

Monitoring of farm effluents

EFFECT OF FISH FARMS: For all measured nutrients fish farming showed a significant increase in effluent nutrient concentration, compared to inflow concentration. Except for

NO_3-N, where a significant decrease in the effluent concentration was measured (Table 1).

Table 1: Mean in- and outflow concentrations with standard deviations, and differences (Δp) from all monitored trout farms, with the indication of significance of Δp.

Water parameter (mgL^{-1})	Average inflow (SD)	Average outflow (SD)	Difference Δp (SD)	Significance of Δp
TN	5.35 (1.37)	5.79 (1.55)	0.44 (0.85)	0.0001
TAN	0.038 (0.030)	0.467 (0.402)	0.429 (0.408)	0.0001
NO_2-N	0.031 (0.048)	0.081 (0.061)	0.049 (0.049)	0.0001
NO_3-N	5.28 (1.23)	5.09 (1.25)	-0.18 (0.54)	0.0001
TP	0.038 (0.034)	0.132 (0.100)	0.095 (0.106)	0.0001
PO_4-P	0.015 (0.024)	0.055 (0.051)	0.038 (0.050)	0.0001
BOD_5	1.57 (0.07)	3.73 (1.90)	2.13 (1.74)	0.0001
COD	5.89 (4.42)	8.95 (3.69)	3.06 (3.35)	0.0001
TSS	6.70 (14.69)	6.73 (4.47)	0.03 (14.51)	0.0001

EFFECT ON MACRO INVERTEBRATE FAUNA: The saprobic index increases in the trout farm effluent, compared with the inflow index. However for the farms operating with a low production intensity of 280 and 300 kg $(Ls^{-1})^{-1}year^{-1}$, the shift in the saprobic index between up- and downstream sampling station was not significant. At higher production intensities the difference between up- and downstream macro invertebrate fauna is more pronounced, as well as for the farm operating at 200 kg $(Ls^{-1})^{-1}year^{-1}$.

Modelling of effluent nutrient concentration

The effluent nutrient concentration can be predicted by 50 – 88 % through four main factors: feed amount applied, inflow nutrient concentration, rearing unit used and effluent treatment device. Solely for TSS the predictability is about 13 % (Table 2).

An increase in the amount of feed applied in the fish farm, resulted in a significant increase in the effluent nutrient concentration for all measured nutrients. The inflow nutrient concentration had a direct effect on all nutrients except TAN. Self cleaning farms released more TN, NO_3-N and BOD_5, while less NO_2-N and TSS were discharged. The effluent treatment units, showed a significant effect in reducing TP, BOD_5 and COD. For PO_4-P they led to a slight increase in the effluent concentration.

Effluent treatment devices

In- and outflow nutrient concentrations of the examined effluent treatment devices are summarized in Table 3.

Table 2. Estimates for the regression model on effluent nutrient concentration, in dependence on relevant trout farm factors (* indicate significant estimates p = probability value for each factor and the whole model, R^2 predictability of the whole model).

Water parameter mgl^{-1}	μ Estimate	P	Inflow concentration Estimate	P	Rearing unit Estimate	P	Effluent treatment Estimate	P	Feeding 100 $kg(Ls^{-1})^{-1}yr^{-1}$ Estimate	P	R^2	P
TN	-0.237	0.364	0.906*	0.001	0.487*	0.011	-0.084	0.204	0.075*	0.001	0.88	0.001
TAN	0.053	0.405	0.370	0.445	0.016	0.790	-0.023	0.248	0.049*	0.001	0.82	0.001
NO_2-N	0.112*	0.001	0.709*	0.001	-0.035*	0.022	-0.010	0.056	0.002*	0.001	0.50	0.001
NO_3-N	-0.498*	0.048	0.914*	0.001	0.492*	0.004	-0.031	0.599	0.013*	0.0378	0.86	0.001
TP	0.020	0.349	0.333*	0.038	0.025	0.248	-0.014*	0.044	0.011*	0.001	0.63	0.001
PO_4-P	-0.006	0.494	0.658*	0.001	-0.007	0.465	0.008*	0.012	0.005*	0.001	0.74	0.001
BOD_5	0.329	0.421	0.912*	0.001	0.785*	0.038	-0.347*	0.005	0.184*	0.001	0.68	0.001
COD	2.461*	0.002	0.686*	0.001	1.417	0.080	-0.636*	0.022	0.210*	0.001	0.61	0.001
TSS	8.118*	0.001	0.728*	0.001	-4.384*	0.015	0.516	0.346	0.156*	0.022	0.13	0.001

SEDIMENTATION BASIN WITH FISH: The examined sedimentation basin showed no treatment effect on any of the measured nutrient parameters. The theoretical overflow rate in the basin was 0.0012 ms^{-1}.

SEDIMENTATION BASIN WITHOUT FISH: The sedimentation basin without fish, showed significant treatment effects for TP and COD of 32 and 26 %, respectively. For all other nutrient parameters no significant treatment effect was measured. The theoretical overflow rate in the basin was 0.0022 ms^{-1}.

MICRO-SCREEN: The micro-screen had a significant treatment effect on TP, BOD_5, COD and TSS of 25 – 41 %, respectively. For the other nutrient fractions no effect was found.

CONSTRUCTED WETLAND: The wetland had a high treatment effect on TAN, TSS and BOD_5 of 82, 64 and 59 %, respectively. TN, TP and COD showed lower treatment efficiencies of 6, 37 and 40 %, respectively. The dissolved nutrients NO_2-N, NO_3-N and PO_4-P increased significantly in the wetland outflow by 140, 12 and 42 %, respectively.

Discussion

The results from in-and outflow monitoring indicate that the production intensity is the main factor influencing effluent nutrient concentration and the biological quality of the effluent. On the other side, effluent treatment is the only factor positively influencing the effluent nutrient concentration. The rearing unit plays a certain role in the distinct nutrient distribution. From these findings and the results of the examined effluent treatment devices, an effluent treatment concept in dependence on production intensity can be developed.

Table 3. Inflow and outflow nutrient concentrations of the monitored effluent treatment devices (* indicate that the difference (Δp) between inflow and outflow is significant $P < 0.05$).

Water parameter (mgL^{-1})	Sedimentation with fish n = 12 inflow (SD)	outflow (SD)	Sedimentation without fish n = 9 inflow (SD)	outflow (SD)	Micro-screen n = 15 inflow (SD)	outflow (SD)	Constructed wetland n = 11 inflow (SD)	outflow (SD)
TN	6.03 (1.31)	5.60 (0.879)	7.53 (0.579)	7.45 (0.714)	7.74 (0.637)	7.91 (0.710)	6.23* (1.04)	5.88* (0.983)
TAN	0.182 (0.044)	0.183 (0.034)	0.890 (0.194)	0.883 (0.176)	1.19 (0.440)	1.23 (0.236)	0.706* (0.286)	0.124* (0.098)
NO_2-N	0.062 (0.014)	0.060 (0.016)	0.017 (0.012)	0.015 (0.003)	0.041 (0.010)	0.042 (0.011)	0.023* (0.003)	0.050* (0.041)
NO_3-N	5.40 (0.885)	5.04 (0.491)	6.51 (0.419)	6.34 (0.301)	6.20 (0.358)	6.16 (0.306)	5.03* (0.641)	5.43* (0.607)
TP	0.073 (0.033)	0.072 (0.036)	0.305* (0.162)	0.206* (0.078)	0.299* (0.146)	0.201* (0.044)	0.165* (0.087)	0.103* (0.026)
PO_4-P	0.068 (0.037)	0.072 (0.040)	0.087 (0.026)	0.094 (0.025)	0.120 (0.051)	0.113 (0.040)	0.054* (0.038)	0.077* (0.040)
BOD_5	2.63 (0.433)	2.97 (1.05)	5.17 (0.870)	5.09 (2.24)	7.98* (3.52)	5.92* (3.28)	4.84* (1.86)	2.00* (0.720)
COD	10.86 (3.42)	11.66 (4.40)	9.44* (3.44)	6.97* (2.65)	14.39* (7.84)	10.20* (3.90)	8.80* (5.51)	5.29* (3.91)
TSS	9.10 (3.51)	10.22 (4.92)	5.63 (4.88)	3.76 (1.69)	6.31* (3.93)	3.73* (2.52)	4.88* (2.11)	1.74* (0.538)

Monitoring of farm effluents

Trout farming, and the rearing of fish with energy rich extruded feed, has a significant effect on the effluent water quality. This is not surprising, as other studies already found significant nutrient increases in trout farm effluents, at least for some of the measured nutrient parameters (Boaventura *et al.* 1997; True *et al.* 2004; Viadero *et al.* 2005; Maillard *et al.* 2005). Also the macro-invertebrate fauna shows a specific shift in individuals and species distribution (Camargo 1994, Doughty & Mc.Phail 1995, Loch *et al.* 1996, Selong & Helferich 1998). This shift is more pronounced with increased production intensity (feed applied) (Selong & Helferich 1998). However, the actual production intensity is not always represented through the biological macro-invertebrate assessment, as production intensity is a short term figure, while the macro-invertebrates integrate disturbance is over a long period of time (at least one year). Consequently, a higher impact on the aquatic fauna is found than the actual production intensity might predict (Camargo 1994), as found for farm 1 with the lowest feeding amount and a relative high impact on the invertebrate community. This high impact might date from earlier or very short time disturbances not detected in the sampling period.

The new result of this study is the statistical proof, that there are only three factors mainly influencing the effect of trout farming on the effluent nutrient concentration: the amount of feed applied, the rearing unit used and the effluent treatment.

INFLOW NUTRIENT CONCENTRATION: Farm inflow nutrient concentration has a high impact on the effluent concentration for most nutrient fractions. This reveals the crucial importance of simultaneously sampling of inflow and outflow, in order to assess the effect of trout farming (Foy & Rossel 1991; Rennert 1994).

FISH FEEDING: Fish feeding is the only factor with an effect on all nutrient fractions. With increased production intensity the effluent nutrient concentration increases. Fish feed is the only nutrient source added to the fish farming system (Bergheim & Asgard 1996). From the introduced feed a part remains uneaten (feed wastes). From the ingested nutrients, the undigested part is excreted as particulate faeces (Cho *et al*. 1994; Piedrahita 1994; Bergheim & Asgard 1996; Cho & Bureau 1997; Green *et al*. 2002), containing mainly organic carbon and phosphorus (Cripps 1994; Kelly *et al*. 1997, Cripps & Bergheim 2000). The digested nutrients are partially retained in fish body mass (Schreckenbach *et al*. 2001). The rest is excreted as dissolved nutrients through the gills, mainly as ammonia and via urine as phosphate and ammonium (Steffens 1985; Cho *et al*. 1994; Cho & Bureau 1997; Bureau & Cho 1999; Green *et al*. 2002; Roy & Lall 2004).

From trout aquaculture two waste streams were emitted, the particulate nutrients from uneaten feed and faecal excretion and the dissolved nutrients from gills and urea excretion. The final distribution in the effluent between the two streams depends on the local physical, chemical and biological conditions (Brinker 2005).

REARING UNITS: These conditions are influenced by the kind of the rearing units used. They have a significant effect on some nutrient fractions. For example, the lower release of NO_3-N and TN from ponds is due to denitrification occurring in the pond sediments. Here oxygen free areas occur, with sufficient carbon sources from settled faeces, enhancing denitrification (Tchobanoglous *et al.* 2003) of the naturally nitrate rich inflow water. Partial denitrification leads to the increased NO_2-N release from ponds. Additionally less BOD_5 is exported from ponds, compared to raceways, as heterotrophic digestion is one of the first processes occurring in oxygen rich environments (Tchobanoglous *et al.* 2003). The reason for the higher release of TSS from ponds, compared to raceways is not clear. The most reasonable cause is the occurrence of flooding events prior to sampling. Through the long water retention time in ponds, a generally higher TSS outflow from ponds can be expected. However, also other studies had major problems in predicting TSS outflow from trout aquaculture (Roque d'Orbcastel *et al.* 2008).

EFFLUENT CLEANING DEVICES: The effluent treatment devices have a positive effect on the nutrient concentration of the fractions containing also particulate matter as TP, BOD_5 and COD (Cripps & Bergheim 2000). With increased efficiency and technical improvement of the treatment unit, the effluent nutrient concentration decreased. Only for TSS, where the main effect from mechanical treatment should be supposed (Cripps & Bergheim 2000), no effect was found. Probable over- and underestimation of TSS in water sampling due to insufficient mixing of the effluent (Brinker *et al.* 2005 a) and the occurrence of flooding events have a high impact on the general predictability of TSS export from aquaculture farms.

For phosphate (PO_4-P) the treatment devices had a negative impact. The leaching of PO_4-P from particulate phosphorous in trout faces is very high especially during the first 24 hours (Stewart *et al.* 2006). Thus, especially sedimentation basins (Cripps & Bergheim 2000) and constructed wetlands lead to increased PO_4-P leaching (Sindilariu *et al.* 2007).

Ttreatment devices examined

The treatment efficiency increased from the sedimentation basin with fish, to the sedimentation basin without fish, to the micro-screen and the constructed wetland.

SEDIMENTATION BASINS: Sedimentation relies upon the density differences between particulate waste and the surrounding water (Cripps & Kelly 1996). The settlement velocity of suspended solids depends on the particle surface and dimension, its specific weight and the flow velocity of the surrounding water (Tchobanoglous *et al*. 2003). Baffles are often incorporated to promote quiescent conditions (Cripps & Bergheim 2000).

The sedimentation basin with fish was well designed, the incorporation of a baffle, promoting quiescent zones and a low overflow rate of 0.0012 ms^{-1}, much less than the recommended flow velocities of 0.017 ms^{-1} (Henderson & Bromage 1988) should lead to an effective particle retainment. Only the presence of fish, especially when fed, lead to high re-suspension rates of already settled particles and additional nutrient leaching (Stewart *et al*. 2006). Thus, no treatment effect of the basin could be measured. Nevertheless in four of the 13 monitored fish farms sedimentation basins with fish were used.

The sedimentation basin without fish, had a higher overflow rate of 0.0022 ms^{-1}. However, here significant treatment effects for TP and COD were measured. Additionally, for this basin a fast separation and removal of settled sludge from the primary flow was realized through regular flushing of the sedimentation cones. Thus, high re-suspension and leaching rates of the settled nutrients (Lefebvre *et al*. 2001; Stewart *et al*. 2006) were avoided. The use of sedimentation is not inherently wrong, highly effective separators were successfully applied (Lawson 1995), but sometimes the application is inadequate (Henderson & Bromage 1988; Cripps & Bergheim 2000).

MICRO-SCREEN: The examined micro-screen had higher treatment effects than the sedimentation basins. Here an additional significant effect on BOD_5 and TSS was measured. The screen treatment effect was much below the expected treatment efficiency. Normally drum filter with a mesh size below 80 µm have suspended solids removal efficiencies ranging from 10 % (Wedekind 1996) over 19 % (Bergheim *et al*. 1993) to 65 % (Brinker & Rösch 2005), 70 % and 90 % (Bergheim *et al*. 1998) as lower treatment efficiencies and 75 % (Bergheim *et al*. 1998) to 87 % (Brinker & Rösch 2005), 91 % (Bergheim *et al*. 1993), 99 % (Bergheim *et al*. 1998) and more than 99 % (Wedekind 1996) as upper treatment efficiency. The examined screen with a TSS efficiency of 41 % is at the lower margin of the expected treatment range. This can be explained by regular occurring leakages on the filter gauze and a slightly too small dimensioning of the drum filter compared to the treated water volume.

CONSTRUCTED WETLAND: The constructed wetland had the highest treatment efficiency compared to the other treatment units. The wetland provided in addition to the mechanical sedimentation and filtration, a highly effective biological treatment of TAN and BOD_5 (Schulz *et al.* 2003; Sindilariu *et al.* 2007). Only for TP the treatment efficiency is in the range of the examined sedimentation basin without fish and the micro-screen. TP is only retained in the wetland, and no effective extraction of phosphorous from the wetland occurs, as extraction through plant growth is of minor importance in highly loaded wetlands (Tanner & Sukias 1995; Brix 1997; Stottmeister *et al.* 2003; Vymazal 2005). Thus, high leaching rates of PO_4-P from the trapped particulate phosphorous occur in the wetland, as the precipitation potential of the filter matrix is limited and fast saturated (Arias *et al.* 2001; Del Bubba *et al.* 2003; Seo *et al.* 2005). The significant increase of NO_2-N and NO_3-N is mainly due to partial nitrification, as it is one of the most important treatment effects of constructed wetlands (Platzer 1999; Stottmeister *et al.* 2003). A potential problem of SSF constructed wetlands are short service lifetimes of the root zone filter, especially when used for the treatment of high hydraulic loads of particle rich farm effluents with no mechanical pre-treatment (Sindilariu *et al.* 2008)

Strategies for effluent nutrient treatment

With increasing production intensity, nutrient concentration and the effect on the aquatic biology increases in the farm effluent. Improved effluent treatment is the only way to balance this increase. Thus, with increasing production intensity the effluent treatment efficiency has to increase, in order to undercut potential pollution thresholds and remain below critical concentrations, which produce sever impacts on the effluent ecosystem. The kind of effluent treatment device is dependent on the effluent characteristics (influenced by the production intensity and the type of rearing units used) and the treatment efficiency of the particular effluent treatment device.

Consequently, for low production intensities, no effluent treatment is affordable (Schobert *et al.* 2001). At a low to medium production level (about 350 – 700 kg $(Ls^{-1})^{-1}year^{-1}$, for self cleaning units) sedimentation should be sufficient as effluent treatment device (Sindilariu 2007). Maximum treatment efficiencies of up to 60 % of TSS can be reached (Sindilariu 2007). With a daily or twice a day extraction of the settled solids, re-suspension and leaching of dissolved nutrients can be avoided (Steward *et al.* 2006). Fish should be anyway totally excluded from the basins as they prevent successful sedimentation.

At an higher annual production, (about 700 – 1,150 kg $(Ls^{-1})^{-1}year^{-1}$, for self cleaning units) micro-screens should be effective enough for successful treatment (Sindilariu 2007). Efficiency can be improved through the application of special binder added feed, leading to a significant improve on screen treatment efficiency up to 88 % for TSS (Brinker *et al.* 2005 b, c). The micro-screen backwash sludge has to be further processed. In a first step sedimentation is the most successful alternative (Sindilariu *et al.* unpublished). Alternatively a second micro-screening step (Bergheim *et al.* 1998) or the application of a flocculation chemical and subsequent belt filtration (Ebeling *et al.* 2006) can be applied. The settled sludge can be applied as agricultural manure (Donaldson & Chadwick 2006). The overflow of the second dewatering step can get a successful final treatment in a constructed wetland (Sindilariu *et al.* unpublished).

Depending on the self cleaning ability of the rearing units, the application of a biological effluent treatment device, like constructed wetlands is needed. Biological treatment shows reduced efficiency at high TSS loads (Eding *et al.* 2006). Sub surface flow constructed wetlands are most efficiently combined with prior TSS treatment. As standalone treatment unit, constructed wetlands are only successful at low production intensities (Sindilariu *et al.* 2007). At high intensities the combination with a sedimentation basin and a surface flow constructed wetland, has a high treatment effect, especially for farms using ponds as rearing system, as shown above. At an intensive production level (higher than 1,200 kg $(Ls^{-1})^{-1}year^{-1}$ for self cleaning units) dissolved nutrient concentrations exceed the set pollution margins (Sindilariu 2007). The combination of constructed wetlands with prior micro-screening is a solution for high production intensity (Sindilariu 2007).

Conclusions & recommendations

1. Trout aquaculture has an impact on the effluent nutrient concentration and biological status of the receiving effluent. The strength of the effect is dependent on the amount of feed applied, the type of rearing units used in the farm and the kind and efficiency of the effluent treatment used.
2. Effluent treatment efficiency increases from sedimentation basins with fish, showing no treatment effect over sedimentation basins without fish, to micro-screens and constructed wetlands, showing an effect on all nutrient fractions.
3. The specific effluent treatment concept is dependent on the production intensity and the effluent nutrient thresholds. However, with increasing production intensity a development of the treatment system from sedimentation, over micro-screening, to the combination of sedimentation or screening with biological effluent treatment in constructed wetlands, can be recommended.
4. A detailed cost calculation for the different treatment possibilities is needed in order to facilitate the decision of trout producers to effectively apply effluent treatment.

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Management strategies to protect and restore sturgeon biodiversity in Bulgaria

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Abstract Sturgeons are among the most endangered fish species worldwide. Six sturgeon species are native to the Black Sea and the Danube River: beluga (*Huso huso*), Russian sturgeon (*Acipenser guldenstaedti*), stellate sturgeon (*A. stellatus*), sterlet (*A. ruthenus*), ship sturgeon (*A. nudiventris*) and Atlantic sturgeon (*A. sturio*). Nowadays only four reproduce in the Lower Danube River; Atlantic sturgeon is extinct from the region and fishermen occasionally report catching ship sturgeon, but this needs confirmation. This is the result of degradation of the environment over the past 60 years by intense anthropogenic activities coupled with commercial exploitation of the high value sturgeon products, caviar in particular, and considerable poaching and illegal trade in the products. Recent observations in the Lower Danube have indicated that all sturgeon populations are close to extinction. In this paper national and international attempts to protect the sturgeons in Bulgaria are summarized. The system of measures for sustainable management and protection, which have been applied in the last 10 years in Bulgaria and the critical evaluation of their efficiency are outlined.

Introduction

The order Acipenseriformes includes approximately 25 species divided into two families Acipenseridae and Polyodontidae (Birstein 1993). The Danube River and the Black Sea region are inhabited by six sturgeon species: Russian sturgeon (*Acipenser gueldenstaedti* Brandt & Ratzeberg), ship sturgeon (*Acipenser nudiventris* Lovetsky), stellate sturgeon (*Acipenser stellatus* Pallas), sterlet (*Acipenser ruthenus* L.), Atlantic sturgeon (*Acipenser sturio* L.) and beluga (*Huso huso* L.).

Sturgeon species of the Black Sea basin are of high economic importance to the people living along the Danube River and other rivers of the Black Sea Basin. Since the mid-20th century, the annual catches of sturgeons in the Lower Danube River has steadily decreased, signalling the unfavourable status of these populations (Bacalbasa-Dobrovici 1997; Bacalbasa-Dobrovici & Patriche 1999; Reinartz 2002; Paraschiv & Sucio 2006). Nowadays all sturgeon species in Bulgarian waters are present in critically low numbers (Vassilev & Pehlivanov 2003; Bloesch *et al.* 2006), and two, *A. sturio* and *A. nudiventris*, seem to be extinct (Bacalbaşa-Dobrovici & Holčik 2000). The reasons for this situation are: the sturgeon's life history is characterized by a long-live span, late maturity, intermittent spawning frequencies and long migratory movements (Ambroz 1964; Bemis *et al.* 1997). Negative human impacts such as over-fishing, increased fishing pressure (a result of increased number of fishermen and more effective fishery equipment), barriers to migration and water pollution have reduced the number of sturgeon. For example, the construction of the Iron Gate I dam (1972) and Iron Gate II dam (1984) have prevented spawning migrations of sturgeon into the Upper and Middle Danube, the Lower Danube remains the only river in the Black Sea basin where sturgeon are present. Their main spawning grounds used to be located near Beluga, between river km 1866 and 1766 in the contemporary Slovak-Hungarian stretch (Hensel & Holcik 1997). Currently, the main spawning grounds are located approximately 1000 km downstream of Beluga under the Iron Gate II dam, between river km 863 and 755 (Vassilev 2003).

Several studies have shown depletion in the population structure of the Danube sturgeons, leading to their endangered species status (Ceapa, Williot & Bacalbasa-Dobrovici 2002; Vasilev & Pehlivanov 2003; Lenhartdt *et al*. 2006). They are now the focus of a variety of nature-protection organizations. For example, in 1996 all sturgeon species were included in the Red Book (IUCN, Red List of Threatened Animals). Since 1 April 1998, all species of the order *Acipenseriformes* were in the list of species under the Convention of International Trade in Endangered Species of Wild Flora and Fauna (CITES Appendix II). In the Bulgarian Red Book of endangered species *A. nudiventris* is included, as rare and *A. sturio* is considered extinct.

At the end of the 1990s, the countries of the Lower Danube began to implement different programmes for investigation, conservation and restoration of the sturgeon stocks (Navodaru & Staras 2002; Raikova *et al.* 2004; Lenhardt, Hegedis & Jaric 2005; Reinartz 2006). The Sturgeon Action Plan was accepted in December 2006 and aimed to co-ordinate activities on conservation and restoration of the Danube sturgeons (Bloesch *et al*. 2006).

The aim of this study is to outline the current status of the wild sturgeon populations in the Bulgarian part of the Danube River and the Black Sea, and management practices applied in Bulgaria, to protect and restore the sturgeon populations.

Materials and methods

The National Agency of Fisheries and Aquaculture at the Ministry of Agriculture and Food Supply provided statistical data about sturgeon catches, aquaculture production and restocking activities over the last 20 years. A total of 31 published sources, personal communications, and author observations were used in this study. The taxonomy of fishes was based on the review of Eschmeyer (2006).

Results

State of natural sturgeon stocks in the Bulgarian part of the Danube River and the Black Sea

Sturgeons have been the object of commercial fishing activities in Bulgaria for centuries, mainly in the Danube River (about 90% of the total catch) and less in the Black Sea (remaining 10% mainly along the Northern coast near Romania and to the South of Sozopol). Sturgeon catch data have been kept in Bulgaria since the 1920s

(Drenski 1928). During the period 1920-1926 catches in the Bulgarian sector of the Danube River varied from 30 to 72 t yr^{-1}, with an average of 51 t yr^{-1} (Fig. 1).

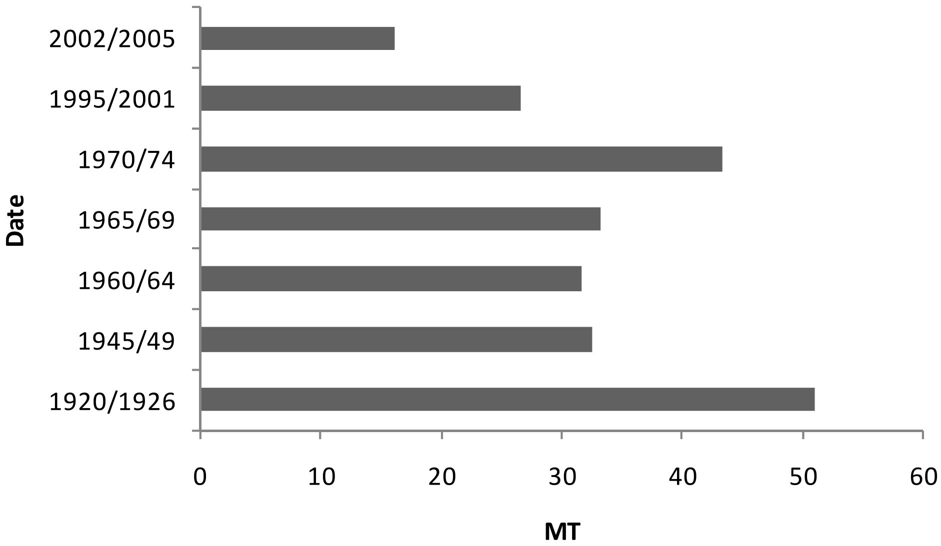

Figure 1. Sturgeon catches in Bulgaria since 1920s.

In 1942, approximately 64 t of sturgeons were caught. During 1945-1949 the average catch of sturgeons was 32.5 t yr^{-1}. The most fishes caught were *A. gueldenstaedti* and *A. stellatus* (Table 1), which comprised respectively 50.8 and 43.4% of the total catches. *Huso huso* was only 5.8%. In the period 1960-1974 catches increased and the average total catch for each 5-year period varied from 150.5 to 196.5 t (31.5 to 43.3 t yr^{-1}), i.e. no significant change was observed in the total quantity of the catch.

Table 1. Catch per year for 3 species of sturgeon, *H. huso, A. gueldenstaedti* and *A. stellatus.*

Year	*Huso huso*	*A. gueldenstaedti*	*A. stellatus*	Total
1996	5.3	0.7	-	6
1997	11.5	1.8	-	13.3
1998	12.3	2.2	-	14.5
1999	10	2	-	12
2000	0.9	-	0.3	1.2
2001	0.3	-	-	0.3
2002	3.5	2	3	8.5
2003	0.6	-	0.3	0.9
2004	2.5	0.5	1	4
2005	0.6	-	-	0.6
Total	47.5	9.2	4.6	61.3
Average	4.75	0.92	0.46	6.13

Changes occurred in the species caught (Fig. 2). The considerable changes in the structure of catches were one of the first signals of disturbance of sturgeons stocks. *A. ruthenus* dominated the catch in the 1960s and comprised 58.3% of the whole catch, followed by *A. gueldenstaedti* (28.7%), *A. stellatus* (8.5%) and *H. huso* (4.6%). The total fish catch from the Danube River was about 600 t yr^{-1} during the 1980s (according to the official statistics data of the state companies), or which sturgeons contributed about 80 t yr^{-1}, 80% were *H. huso*.

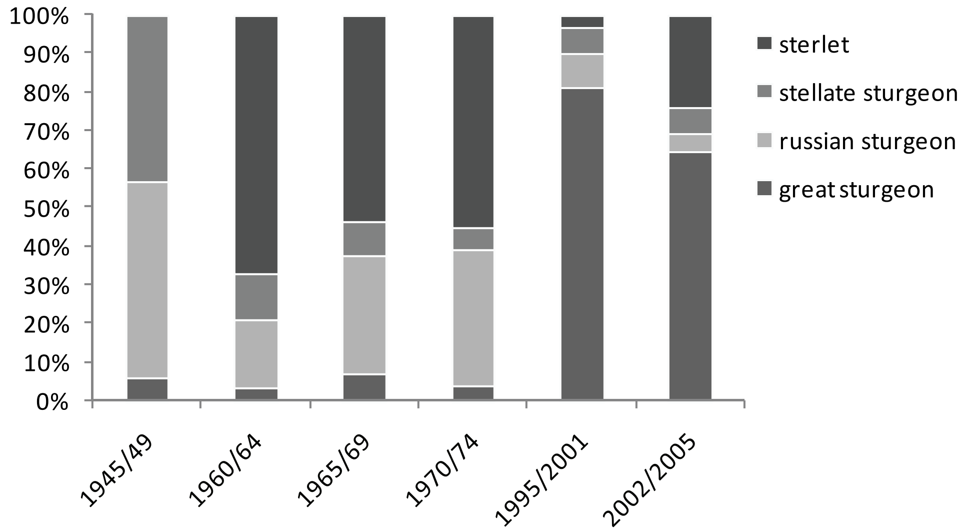

Figure 2. Percentage catches of sturgeon from 1945 to 2005.

Since 1995, sturgeon catches have drastically decreased to 26 t yr^{-1} for the period 1995-2001 and 26 t yr^{-1} for the period 2002-2005 (Table 2, Fig. 1). However, *H. Huso* was still the dominant species in the last 10 years and for the period 1995-2001 it represented 81.12% of the total sturgeon catch, followed by *A. gueldenstaedti* (8.91%), *A. stellatus* (6.39%) and *A. ruthenus* (3.57%) (Fig. 2).

Table 2. Sturgeon catches from 1995-2005.

Year	Beluga (t)	Russian sturgeon (t)	Stellate sturgeon (t)	Sterlet (t)	Total (t)
1995	13.6	0.9	0.1	0.1	14.7
1996	23.5	1.7	0.5	0.8	26.5
1997	30.7	3.6	0.2	0.8	35.3
1998	31.2	5.3	3.7	1.2	41.4
1999	27	4	6	1.5	38.5
2000	18.4	0.9	1.4	1.6	22.3
2001	6.6	0.16	0.03	0.66	9.1
2002	9.9	1.2	1.7	2.8	15.6
2003	8.21	1	1.3	4.5	14.1
2004	9.9	0.5	0.5	3.4	14.3
2005	13.2	0.3	0.7	4.8	18.9
Total	192.21	19.56	16.13	22.16	250.7

Between 2002 and 2005, *H. huso* was the dominant species caught contributing 64.5% of the total catch (average catch 16 t yr^{-1}) (Fig.2), followed by *A. ruthenus* (24.3%), *A. stellatus* (6.6%) and *A. gueldenstaedti* (4.7%), an increase of approximately 6.8 times the previous period. In total, about 80% of all sturgeon species were caught in the Lom and Vidin region (river km 570-850).

Based on published data and sturgeon catches in the Danube River the following trends were identified. During 1945-2005 *A. gueldenstaeti* and *A. stellatus* lost their dominant role (respectively 50% and 43% of the total sturgeons catch, Fig. 2); currently they contribute <7% of catches (Fig.3). *A. ruthenus* showed the strongest change dropping from 58% of the total sturgeon catch between 1960 and 1975) (Fig.2) to less than 5% in the following period, although there has been an increase during the last 2-3 years up to 20% (Fig.3). Beluga catches fluctuated widely. Prior to the 1980s, *H. huso* catches were insignificant (< 5%) of the total catches (Fig. 2) but during the last 20 years have contributed approximately 80% of total catches (Fig. 3). Consequently, Russian sturgeon and the stellate sturgeon are not important for the black caviar yield, produced mainly from Beluga because of its higher quality and market price.

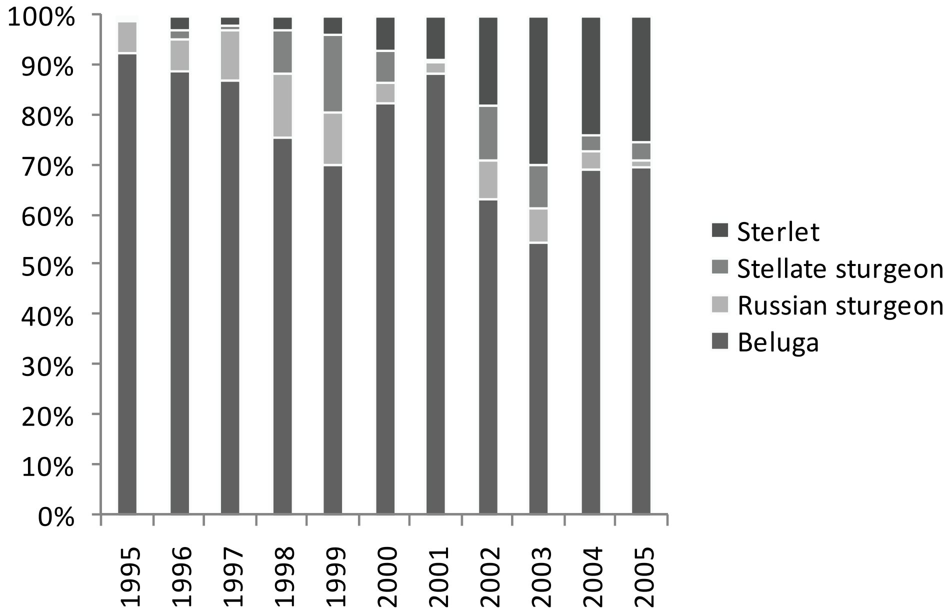

Figure 3. Percentage catches of sturgeon from 1995 to 2005.

In total, Black Sea catches of sturgeon species were 3-4 times lower than the Danube River, but in some years (2003-2001) it was 15-30 times lower (Fig. 4). Currently, sturgeon catches in the Black Sea do not exceed 15 t annually (Table 1). The catches of *H. huso* contribute 77% (Table 2), *A. gueldenstaedti* 15%, and *A. stellatus* only 7.5%. *Huso huso* is usually caught in the south – in the region of Ahtopol -Tzarevo - Rezovo by baited hooks. In the north (near to the Romanian border) the usual catch is Russian sturgeon and rarely *A. stellatus*. There are several cases when sturgeon species were caught in fixed trap nets, but this happens occasionally. The female sturgeons caught in the Black Sea are mostly at an early stage of maturity and consequently of no commercial value.

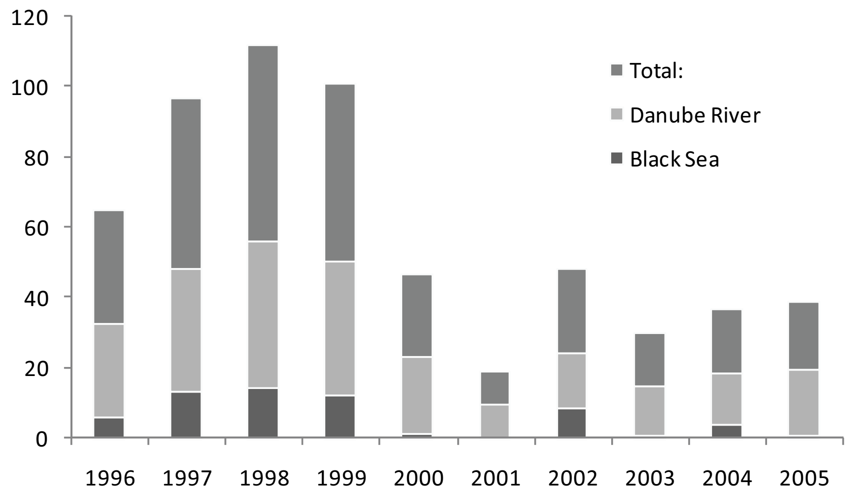

Figure 4. Comparison of sturgeon catches between the Danube River and the Black Sea.

Management strategies concerning the endangered Sturgeons in Bulgarian Waters

Restocking activities

Restocking of the River Danube is an alternative to mitigate the negative impacts on the sturgeon populations in the region. By the end of the 1990s, in conjunction with different conservation projects and to fulfil CITES recommendations concerning the protection of sturgeon stocks, attempts were being made in Bulgaria for artificial propagation and production of restocking material from sturgeons. In 1998, juvenile *A. gueldenstaedti* produced in the Perpen Chobanov fish farm (in the village of Boljartsi) were released into the river near Rousse (river km 493) (Zlatanova 2000; Vassilev 2005).

Since 2003, restocking has been done according to an Order of the Minister of Agriculture and Forestry and the Minister of the Environmental protection and Waters. It obliges the people who receive black caviar export quotas, to restock the Danube River according to their own choice, which is usually *H. huso* and/or Russian sturgeon, based on the rule that a minimum 30 fish and a maximum of 120 fish must be restocked for every 1 kg of caviar exported.

In the period 1998-2005, more than 711 000 sturgeons were released into the Danube River: approximately 670 000 were Russian sturgeon, weighing between 10 And 1 000 g, 37 000 beluga, weighing from 20 to 500 g and 2125 serlets, weighing 15 to 100 g (Table 3). Russian sturgeon contributed 94.5% of all fish released into the river, the Beluga was 5% and the sterlet was 0.3%.

During the period 2006 and 2007, caviar export quotas for Bulgaria were not released by CITES because the export companies were not obliged to restock the Danube River. For that period only 2000 Russian sturgeon with an average weight of 5 g were released.

Since 2007, restocking of the Danube River has been the main task within the framework of the National Program for Support of the Stable Growth of Fish Resources, which was accepted by the Minister of Agriculture and Food Supply in 2008. Accordingly, in 2008 the Danube River was restocked with 30 000 Russian sturgeon and 20 000 Beluga. Financial support was from IARA. An important requirement of this programme is the restocking is of juvenile fish of

Table 3. Number of sturgeon released into the Danube River.

Year		Release site on Danube River	
		Vidin rkm 790	Svishtov rkm 570
1998-2001	Russian sturgeon	0	200,000
2002	Russian sturgeon	42300	20230
	Sterlet	1000	1125
2003	Beluga	5300	0
	Russian sturgeon	115500	45817
2004	Russian sturgeon	67000	144126
2005	Beluga	31950	0
	Russian sturgeon	0	35000
2006	Russian sturgeon	2000	0

Danube origin. This has not always been taken into consideration in recent restocking events where both native and hybrid species were used. For example, Siberian sturgeons (*A. baeri*), Adriatic sturgeons (*A. naccarii*) and hybrids grown in fish farms were previously released into the Danube (Reinarz 2002 & Vasilev 2005). Considerable attention has to be paid to the restocking of two extinct species, Ship and Atlantic sturgeon. The results from the implementation of the Ministry of Environment and Water restocking project in the Danube River have to date been unsatisfactory.

Aquaculture development

The significant decrease of sturgeon catches and the implementation of different restrictions for their catch promoted a serious interest in artificial rearing of sturgeons for the production of both meat and caviar. The beginning of sturgeon aquaculture in Bulgaria was in 1995, when the first sturgeon fish farm was built. The farm is situated in the Southern part of Bulgaria near the city of Plovdiv at a distance of more than 300 km from the Danube River. In 2001 a second sturgeon fish farm was established - Beluga located directly on the banks of the Danube River near the town of Vidin, at river km 790. Sturgeons are also reared in other places in the country, but on a smaller scale. By 2005, there were 5 officially registered sturgeon fish farms, but more are planned, mainly net cage farms. Formerly, Esetra Commerce Ltd., Beluga Ltd. и Aquamash Ltd. was the main producer of restocking material, fish for consumption and caviar.

In the past, producers relied mainly on imported fertilized eggs, mainly from Russia, Krasnodar and Astrakhan, for stocking material. Presently it is from sexually mature specimens, grown on the fish farms.

The main object of rearing has been for the Russian sturgeon (Tables 4 and 5). Beluga, stellate sturgeon and sterlet have been reared in smaller quantities. The production of stocking material is in tanks until the fish weigh 5-20 g. Thereafter, they are moved into nets cages and during the first year the juveniles usually reach 300-500 g.

Table 4. Production (number specimens) of sturgeon stocking material from aquaculture (Source: NAFA)

Species	2002	2003	2004	2005	2006	2007
Beluga	0	21380	7,230	112,960	0	0
Sterlet	0	0	6,100	155,550	0	0
Russian sturgeon	65,000	205,606	108,440	49,550	64320	24897
Stellate sturgeon	0	0	0	385	0	839
Paddlefish	0	0	32,500	445	0	0
(Russian x Siberian)	0	0	0	55,000	0	0
Total:	65,000	226,980	154,270	373,890	64,320	25,736

Table 5. Production (t) of market-size sturgeons from aquaculture (Source: NAFA).

Species	2002	2003	2004	2005	2006	2007
Beluga	0	3.4	3.7	21.5	27.66	46.16
Sterlet	0	0.3	0.1	2.2	2.5	4.58
Russian sturgeon	80	144	6.7	281	113.5	142.8
Stellate sturgeon	0	0	0	0	15.11	2.1
Paddlefish	0	0	2.3	0.05	0.005	0.007
Total:	80	147.7	12.8	304.75	158.7	195.6

Fish for consumption are mainly reared in cage farms. The biggest cage farm in the country is located at the Kardzhali dam, where water temperature throughout the greater part of the year is 20-23 ^{o}C and the oxygen concentrations about 6 mg.L^{-1}. During the second year of rearing, the Russian sturgeon reaches an average weight of 2-3 kg. During the third year, the males and the females are separated using ultrasound, when at an average weight of 4-5 kg. Sex determination without using ultrasound can be done during the fourth year, at a weight of 6-7 kg; when a white coating on the heads of maturing male fish is used as an indicator of sex dimorphism. The males are mostly used for consumption on the home market; the total quantity of fish from all sturgeon fish farms in the country sold was about 80 t. The females are reared to Sexual maturity in females occurs from 6 years old fish, but caviar is only produced from 9 year old fish. About 2-2.5 t of caviar is produced from beluga grown in aquaculture.

In 2003, the paddlefish (*Polyodon spathula*, Walbaum) was introduced into Bulgaria (Hubenov *et al*. 2004) because of its faster growth and high commercial value. It is mainly for rearing in the inland water bodies, mostly in reservoirs. During the first year it can reach an average weight of 150-200 g, during the second, when reared in ponds or reservoirs it can reach more than 2 kg (Hubenova *et al.* 2007).

Legislative framework

Active procedures on a legislation level concerning sturgeon species in Bulgaria were undertaken at the end of 1995, when the following laws, acts and orders came into force:

- Order by the Minister of Agriculture and Forestry and by the Minister of Environmental Protection and Waters from 2003, which binds the right for caviar export with the obligation to restock the Danube River with 30-120 sturgeon fingerlings against the export of one kg of caviar.
- The "Action Plan for Sturgeons in the Bulgarian Parts of the Danube River and the Black Sea" (Raikova *et al.* 2004), which was elaborated in 2004.
- The Law of Fisheries and Aquaculture (State Gazette, No. 94/11.2005). According to the Article 35, Paragraph 6 of this Law the catches by using bottom hooks from 01.12.2007 was forbidden.
- The Biodiversity Act (State Gazette from 10.2005), Appendix 2 and 3 have included the ship sturgeon and the Atlantic sturgeon as endangered species and their catches have been forbidden.
- Order by the Minister of Agriculture and Forestry and by the Minister of Environmental Protection and Waters from 2006, which disallows sturgeon catches in the Bulgarian Black Sea.
- Order by the Minister of Agriculture and Food Supply and by the Minister of Environmental protection and Waters for moratorium of sturgeon catches for a period of 8 years in the Bulgarian section of the Danube River implemented since May 2008.

From an international aspect the following events and acts have been carried out:

- Meeting of the Black Sea countries on protection and sustainable management of the sturgeons populations in the Black Sea Basin organized by CITES Secretariat and the Ministry of Environmental Protection and Waters in Bulgaria, in 2001;
- Regional Strategy for sturgeon management developed by Bulgaria, Romania, Serbia & Montenegro and the Ukraine in 2003;
- In November 2005 the Government of the USA banned import of beluga caviar from the countries of the Danube, the Black Sea, and the Caspian Sea regions (Bulgaria, Georgia, Rumania, the Russian Federation, Serbia & Montenegro, Turkey and the Ukraine);
- National Action Plan for sturgeon management in fishing waters by Serbia & Montenegro (Lenhardt, Hegedis & Jaric (2005);
- 10-year catch moratorium implemented since May 2006 by the Romanian Government;
- Action Plan for Conservation of Sturgeons in the Danube River Basin 2006.

The unfavourable status of sturgeon populations in the Danube River and the Black Sea was a result of a combined effect, including: over-exploitation, poaching, habitat loss and disruption of spawning migration (Bloesch *et al*. 2006). First data about the declining catches were reported at the beginning of the 20th century. One century later, catches have continued to decline because of increased fishing pressure resulting from improved fishing equipment and the increased number of fishermen. There are several reasons for the long-term delay of adequate measures and implementation for the protection and restoration of sturgeon stocks in that region: 1) the high economic value of sturgeon caviar and meat, and the great demand for them on the world market; 2) the policy of respective authorities in Bulgaria to protect the socio-economic status of sturgeon fishermen, but later analysis showed that despite the high profitability of this activity, only a small percentage of the people make their living from sturgeon.

We should also report that official statistics of catches are inaccurate. The Danube fishery statistics in Bulgaria, as well as the fisheries statistics as a whole, were destroyed for about 10 years during the transition period. There is also lack of data about poaching and these catches can exceed legal ones many times (Bacalbasa-Dobrovici & Patriche 1999; Vassilev & Pehlivanov 2003).

In the 10 years since the first activities to protect and conserve sturgeon populations were implemented there has been little positive effect on the status of sturgeon populations. The different instruments used by the Bulgarian authorities to regulate catches during the breeding season, such as gear restriction, minimum size requirements, restrictions imposed by CITES (such as the quotas for caviar) have not lead achieved the effect desired. One of the main reasons for this has been the considerable delay in the implementation of these measures. The former State Fisheries Inspectorate (now the Agency for Fisheries and Aquaculture) only managed to implement the Fishing Licensing System and to re-establish collection of data for the Danube River and the Black Sea fisheries in 1995. Now this process has been placed under the regulation of the Fisheries and Aquaculture Act (2005), and should be implemented more efficiently.

Serious attempts have been made to ban fishing by all Danube countries. A moratorium has been implemented since May 2006 by the Romanian Government and since May 2008 by the Bulgarian Government, under the Action Plan for the Conservation of Sturgeons in the Danube River Basin (2006). This might be the only means to avoid the complete extinction of sturgeons in the Danube River (Bloesch *et al*. 2006).

The results expected will not be seen quickly and the moratorium will only be effective if the poaching is terminated. However, there are some complications that remain, including insufficient staff and financial resources to control the ban on fishing and the prerequisite for export quotas for caviar from sturgeon aquaculture. This conceals the selling of caviar from wild fish populations on the market under the banner of farm production. Biochemical studies (gene markers) and adequate labelling and control of products will hopefully overcome these problems.

Sturgeon restocking activities in Bulgaria, during the last few years has not been systematic and the quantity of the released fish has not been enough. The estimated quantity of restocked juveniles has varied, but it has decreased during the last two years because of the zero-trade quotas for caviar export from wild populations. Insufficient wild bred stock at existing hatcheries in the country has prevent the production of enough fingerlings for stocking and the production of stocking material is relatively expensive and requires financial support from the Government that is not forthcoming.

Sturgeon aquaculture has the capacity to solve this problem and an increase of sturgeon farming is the way to restore natural population coupled with reduction in fishing pressure. Also captive rearing of sturgeons is an alternative source of caviar for the market (Pikitch *et al*. 2005). However, considerable capital investment in research programmes directed towards increasing the efficiency of sturgeon production, enhancing the survivability of released individuals, tracing of survivability and migration of tagged specimens is also necessary.

In conclusion, this study shows the need for adequate measures to protect the stocks including: increasing the control on sturgeon protection on behalf of the authorized bodies IARA and the National Forestry Management, to stop poaching; increasing the quantities of restocking material mainly from beluga; tagging and estimating survival to different ages; increase production capacity and efficiency of farms; development of programme to support fish farms in the country to produce stocking material, for example through financial support by the Government, low-interest credits, structural funds financial support by the EC; protection of the regions where sturgeon spawn; investigations about sturgeon population status (age-and size structure); use of genetic tools to support identification of poached fish from aquaculture production. The strengthening and harmonization of the national legislation and the implementation of the Action Plan for Conservation of Sturgeons in the Danube River Basin should be directed towards achieving sustainable management and restoration of the natural habitats and migratory movements of the sturgeons. In conjunction with the existing national and international instruments, the action plan might provide important instruments and mechanisms to avoid the extinction of the sturgeons in the Danube River and the Black Sea.

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Ecological status of inland waters of Muğla

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Abstract Muğla is located in the basins of Büyük Menderes, Dalaman and Eşen rivers and surrounded by the Mediterranean Sea in the South and the Aegean Sea in the West. Major water sources in the province are; Eşençay, Dalaman, Tersakan, Yuvarlak, Namnam, Dipsiz-Çine, Sarıçay streams and rivers, Kocagöl and Köyceğiz lakes, and Bereket and Mumcular dam lakes. In this study, water quality features (physicochemical and biological) and fish fauna of these water sources were investigated and most of the sampling sites on these water sources were found in good status. 32 fish taxa (26 species and 6 subspecies) belonging to 15 families were found to be living in the region. Tourism activities, tourist-boat traffic, trout farms and gravel pits are threatening these sources. The sampling points with "good" status should be protected. Water management based on river basins should be developed and monitoring programmes for surface and ground waters must be achieved.

Introduction

Water sources are among the most threatened habitat types. Urbanization, agricultural run off, greenhouse farming, untreated urban effluent, shipping and gravel pits have altered the landscape of Turkey for years resulting in a substantial loss of habitats and biodiversity. Recognizing that biodiversity as well as the functions and services provided by aquatic ecosystems have changed markedly, limnological studies now receive greater attention throughout Turkey. In Muğla province, lakes, especially Köyceğiz Lake, received more attention than running waters from limnologists (Yerli 1989; Özdemir *et al*. 1995; Buhan 1998). Köycegiz Lake is influenced by several external factors such as sulfuric springs, Mediterranean seawater and a relatively strong and changing wind. The water body is divided in two layers of differing hydrology so the lake can be classified as meromictic (Kazancı *et al*.1992). Besides natural lakes, dam lakes were also studied in the area (Yılmaz 2004; Özdemir *et al*. 2007).

Stressed systems by anthropogenic factors often show a reduction in species richness, with a change in the number of individuals within a species and a predominance of stress-tolerant species (Johnson *et al*. 2006). This change was used early in the 1900s by Kolkwitz and Marsson (1902) in the development of the Saprobien system to assess the effects of organic pollution on stream systems. A number of approaches have been developed to evaluate the ecological effects of stress on stream ecosystems, epecially in the last two to three decades, (Metcalfe 1989; Woodiwiss 1964; Chandler 1970; Lorenz *et al*. 2004). Ecosystem analysis using benthic environment and physical and chemical features together has recently been conducted on running waters in the study area (Kazancı & Dügel 2000; Barlas *et al*. 2001a; Barlas *et al*. 2002; Yorulmaz *et al*. 2003; Balık *et al*. 2005).

Also, detailed studies on freshwater fishes in the study area were carried out (Balık 1975; Balık 1995; Bogustkaya 1996; Bogustkaya 1997). Recent studies the fish fauna of inland waters of Muğla were examined (Barlas *et al*. 2000; Özdemir *et al*. 2003; Dirican & Barlas 2004; Onaran *et al*. 2006). Yılmaz *et al*. (2000) and Yılmaz and Öğretmen (2001) studied the *Ladigesocypris ghigii*, an endemic species in Muğla area.

There are many legal instruments that relate to nature conservation in general. The Environment Law in 1983 and the related Decree-Law concerning the establishment and functions of the Ministry of Environment in 1991 are the major legal instruments regulating environmental conservation of Turkey. Instruction for Water Pollution Management (SKKY) was issued by the Council of Environment as a book in 1988 (Resmi Gazete 1998).

The EU recently passed legislation, the Water Framework Directive (WFD), focused on improving the ecological quality of inland and coastal waters (Water Framework Directive, 2000). The main objectives of the EU Water Framework Directive are protecting all waters, covering all impacts on waters, achieving good quality (good status) classes for all water bodies and water quality definitions in terms of biology, chemistry, hydrology and morphology (Hering *et al.* 2006). It is aimed to identify the quality classes and to determine ecological status of major water sources in Muğla province in this case study.

Materials and methods

Muğla, located between 36^o 17`and $37^o$ 33` Northern latitude and 27^o 13`and $29^o$ 46` Eastern longitude, has 13 328 km^2 surface area and a very rough terrain. The province is located in the basins of Büyük Menderes, Dalaman and Eşen rivers and surrounded by the Mediterranean Sea in the South and the Aegean Sea in the West. Muğla province is rich in terms of freshwater sources with major water sources in the province being the Eşençay and Dalaman rivers and Köyceğiz Lake (Anonymous, 1998). In this study, ecological statuses of major water sources of the area were evaluated and the data used were obtained at certain intervals in the period between 1997 and 2007.

Physical-chemical metrics, representative of nutrient status (nitrogen and phosphorus fractions) and acidity (pH) status as well as oxygen conditions (dissolved oxygen and BOD_5) and water hardness were measured for each site for all water bodies. Benthic macroinvertebrates were collected with a hand net (50X30cm; 500 m mesh size) by sweeping the sampling site 100 m in length (Plafkin *et al*. 1989). On running waters, the number of sampling sites was chosen according to the size of the water body. Biological water quality classes were determined according to LAWA (1980). The fish samples were caught mainly by electro-fishing in the area of research; cast-nets and fishing lines were also used when required. The fish samples collected were fixed by 4% formaldehyde solution in the field.

In total, 58 sites were sampled on major waters sources in the study area at certain intervals in a ten year period (Fig. 1). The streams used in this study were classified into three groups; small sized streams (0-49 km long), middle sized streams (50-99 km long) and large sized streams (100-150 km long). Lakes were classified into three groups according to their surface area; small sized lakes (0-150 ha), medium sized lakes (150-250 ha) and large sized lakes (≤250 ha) (Tables 1 & 2).

The ecological quality of each sampling site was pre-classified based on physical, chemical and biological data, expert judgment of the field researchers having sampled the water sources and the additional knowledge derived from previous studies on these water sources.

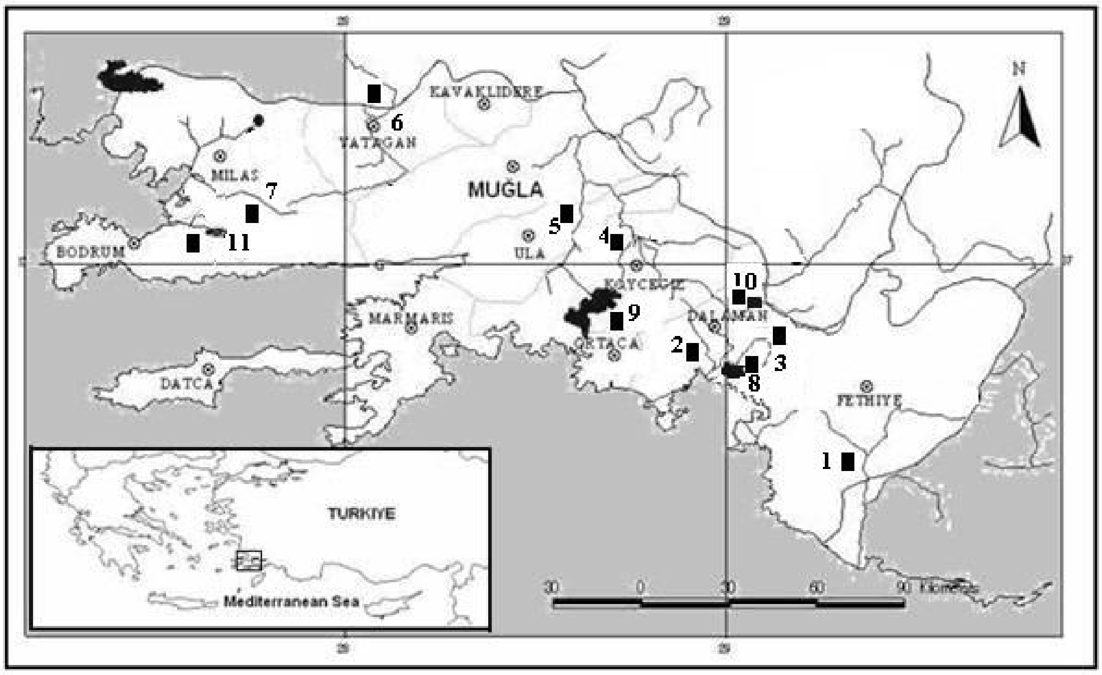

Figure 1. Study Area and Stations; 1-Eşençay River 2-Dalaman River 3- Tersakan Stream 4- Yuvarlakçay Stream 5- Namnam Stream 6- Dipsiz-Çine River 7- Sarıçay Stream 8- Kocagöl Lake 9- Köyceğiz Lake 10- Bereket Dam Lake 11- Mumcular Dam Lake

Table 1. Overview of sites on running waters

Stream name	Length (km)	Stream type	Location	Number of sites
Eşençay River	146	Large sized stream, flows up to Mediterranean sea	Fethiye	7
Dalaman River	120	Large sized stream, flows up to Mediterranean-Aegean sea (border line)	Gölhisar-Dalaman	7
Tersakan River	30	Small sized stream, flows up to Mediterranean sea	Dalaman	4
Yuvarlakçay Stream	14	Small sized stream, flows up to Köyceğiz Lake	Köyceğiz	4
Namnam Stream	30	Small sized stream, flows up to Köyceğiz Lake	Ula-Köyceğiz	3
Dipsiz-Çine River	88	Medium sized stream, flows up to Büyük Menderes stream	Yatağan-Aydın	7
Sarıçay Stream	50	Medium sized stream, flows up to Güllük Bay-Aegean sea	Milas	3

Table 2. Overview of sites on lakes

Lake name	Surface area(ha)	Lake type	Location	Number of sites
Kocagöl	249	Medium sized oligotrophic natural lake flows up to Mediterranean sea	Dalaman	3
Köyceğiz	5400	Large sized natural lake flows up to Aegean sea by a 8 km channel	Köyceğiz	7
Bereket	120	Small sized dam lake for energy production on Dalaman river	Dalaman	4
Mumcular	143	Small sized dam lake for water supply both drinking and agricultural	Bodrum	5

Each site was assigned to one of the five quality classes (high, good, moderate, poor and bad) referring to the physical-chemical and biological water quality methods and expert judgments. On running waters Sabrobien system (LAWA 1980) was used to evaluate the biological water quality and The Book of Instruction for Water Pollution Management issued by the Council of Environment (SKKY) was used for physical and chemical water quality. On lakes, only physical and chemical water quality was determined according to The Book of Instruction for Water Pollution Management (1988).

Fish Farming on Inland Waters of Muğla

Inland waters of Muğla have an important potential in terms of fish farming of trout. This also helps to show the ecological water quality of water sources, but all these fish farms are located in upper parts of inland waters. On Eşençay River there are 38 medium sized fish farms with a capacity of 5546 $^{t\ yr-1}$ achieved. On Dalaman River there are two fish farms with the capacity of 125 $^{t\ yr-1}$. On Yuvarlakçay stream there is a fish farm with a capacity of 900 $^{t\ yr-1}$. On Namnam stream there is one fish farm with a capacity of 150 t yr^{-1} and on Sarıçay stream there is a fish farm with a capacity of 100 t yr^{-1}. In three farms around Milas fish farming on ground water is operated on ground ponds for culturing of sea origin species; Gilt-head bream and Sea bass with a capacity of 55 t yr^{-1} (Table 3). In this study marine fish farms were not evaluated.

Results

Most of the sites on water sources were of ‘good’ status. Biological water quality classification results were parallel to physical and chemical water quality classification (Table 4).

On the Eşençay River, six of seven sampling points along the stream were in high quality status, only the sixth site was found to be good quality status according to Instruction for Water Pollution Management (SKKY). According to biological water quality, the fifth site was in high status, the sixth site in moderate status and others were in good status. On the Dalaman River, according to both Sabrobien system and SKKY the third and seventh stations were found in moderate status while the others were all classed as good status. All three stations on Tersakan Stream were found in good status according to both classification systems. The first station on Yuvarlakçay stream was labelled high status and the second station good status according to both systems. The third station was deemed to be of moderate status according to SKKY while it was found poor status according to Sabrobien system. The last station was labelled as moderate status according to both classifications systems.

Table 3. Fish Farming on inland waters of Muğla

Locality	Number of farms	Annual Capacity ($^{T\ yr-1}$)
Eşen River	38	5546
Dalaman River	2	125
Yuvarlakçay Stream	1	900
Namnam Stream	1	150
Sarıçay Stream	1	100
Ground ponds	3	55
Total	46	6876

Table 4. Ecological status of stations on inland waters of Muğla

Water source	Method	1 st.	2 st.	3 st.	4 st.	5 st.	6 st.	7 st.
Eşençay R.	Saprobien	Good	good	good	good	high	moderate	good
	SKKY	High	high	high	high	high	good	high
Dalaman R..	Saprobien	Good	good	moderate	good	good	good	moderate
	SKKY	Good	good	moderate	good	good	good	moderate
Tersakan S.	Saprobien	Good	good	good				
	SKKY	Good	good	good				
Yuvarlakçay S.	Saprobien	High	good	moderate	moderate			
	SKKY	High	good	poor	moderate			
Namnam S.	Saprobien	Good	good	moderate				
	SKKY	Good	good	moderate				
Dipsiz-Çine R.	Saprobien	moderate	good	moderate	good	good	high	good
	SKKY	good	good	good	good	good	good	moderate
Sarıçay S.	Saprobien	moderate	moderate	Poor				
	SKKY	good	moderate	poor				
KocagölL.	SKKY	moderate	moderate	poor				
Köyceğiz L.	SKKY	moderate	moderate	poor	moderate	poor	moderate	moderate
Bereket D. L.	SKKY	good	good	good	good			
MumcularD.L.	SKKY	good	good	good	good	good		

According to both systems the first and second stations on the Namnam stream were found as good status where as the third was found to be of moderate status. The first and third stations on the Dipsiz-Çine River were found in moderate status, the sixth station was found in high status and the others were found to be of good status according to Sabrobien system. According to SKKY only the last station was found in moderate status while the others were found in good status. According to the Sabrobien system the first and second stations were found in moderate status and the last was found to be of poor status on the Sarıçay stream. According to the SKKY classification system used on the lakes; two of the three stations on Kocagöl Lake were deemed moderate status where the remaining site was classified as poor status. On Köyceğiz Lake five of the stations were classified to be of moderate status and two of the stations were classified as poor. All the stations on Bereket and Mumcular Dam lakes were classified as having a good status.

Freshwater fishes of inland waters of Muğla

According to the results of the studies, 26 species and 6 subspecies belonging to 15 families are present in the research area. In terms of distribution of the fish species, it was found that 20 species live in Köyceğiz Lake, 14 species live in Dipsiz-Çine River and 12 species in Eşen River, 11 species in the rivers Tersakan and Yuvarlakçay, 10 species in Sarıçay River and less than 10 species, usually 6-7, are found living in the other rivers and 3-4 species in dam lakes. 13 species of the Cyprinidae family were determined in the region and 6 species of the Mugilidae family were found intensively in Köyceğiz-Dalyan area. *Salmo trutta macrostigma* (Duméril 1858), a natural trout, was observed at the upper zones of Eşen River. An endemic species, *Ladigesocypris ghigii* (Gianferrari 1927) was found living in Dalaman and Marmaris area. Exotic species like *Tilapia zilli* (Gervais 1848), *Carassius carassius* (Linnaeus 1758) and *Lepomis gibbosus* (Linnaeus 1758) were also found to be living in the Muğla province (Table 5).

Discussion

Assessing the ecological quality classes of water sources is a fundamental objective of Water Framework Directive (European Commission,2000). It is therefore important to identify the ecological status of water sources in Turkey. Some of the stations are identified in different quality classes according to the classification methods used. Biological water quality classification systems (Sabrobien system was used in this study) evaluate the presence of the organisms that reflects the ecological status but traditional systems only evaluate the physical-chemical features (SKKY was used in this study). The presence of organisms also depends on the benthic structure and morphology of the water bodies.

Gravel pits are one of the major impacts affecting running waters. On the sixth station of the Esen River there is a gravel pit and the stream body is damaged by this. The third station on the Dalaman River is moderately polluted by fish farming, but after the third station the situation has improved by the fast flow caused by the nature of the river bed. There is no pollution source on the Tersakan Stream. The high capacity trout farm (900 ^{t} $^{yr-1}$) on the Yuvarlakçay stream affects the third and fourth stations; Dügel (1995) and Barlas et al. (2000), reported that the highest BOD_5 and nutrient levels, which reflects the organic pollution, among all the stations on the Yuvarlakçay was found on the station that was affected by the trout farm. The third station on the Namnam stream was affected by the gravel pit and the first station along the Dipsiz-Çine River was polluted by a restaurant and the small trout pond of the restaurant located near the station. The third station is polluted with the agricultural activity on the Dipsiz-Çine River. The Sarıçay stream is one of the most endangered water sources around Muğla, with its main problem resulting from the waste discharge of Milas.

Table 5. Fish taxa inhabiting inland waters of Muğla

Stations Fish species	Esen R.	Tersakan R.	Yuvarlakcay	Namnam R.	Sarıçay R.	Dipsiz-Cine R.	Dalaman R.	Köyceğiz L.	Kocagöl L.	Mumcular D. L.	Bereket D. L.	Other Sources
Anguilla anguilla	+	+	+	+	+	+	+	+	+		+	
Salmo trutta macrostigma	+											
Leuciscus cephalus	+	+	+	+	+	+				+	+	
Leuciscus smyrnaeus				+	+	+						
Barbus plebejus escherichi	+	+	+	+	+	+		+				
Barbus capito pectoralis						+						
Capoeta capoeta bergamae	+	+	+	+		+		+				
Ladigesocypris ghigii ghigii		+	+	+				+				
Cyprinus carpio					+			+		+		+
Carassius carassius	+									+		+
Pseudorasbora parva					+	+						
Alburnus orontis						+						
Alburnoides bipunctatus						+						
Vimba vimba tenella						+						
Cobitis taenia			+		+			+				
Cobitis simplicispina		+				+		+				
Orthrias angorae					+	+		+				
Aphanius fasciatus								+				
Siluris glanis								+				
Mugil cephalus	+	+					+	+	+		+	
Liza ramada	+	+	+					+				
Liza labeo	+							+				
Liza aurata								+	+			
Liza saliens	+							+				
Chelon labrosus							+	+			+	
Tilapia zilli			+					+				
Blennius fluviatilis	+	+	+									
Gobius ophicephalus		+	+									
Gambusia affinis		+	+		+	+		+				
Lepomis gibbosus					+	+						+
Morone labrax								+				
Atherina boyeri	+							+				
Total	12	11	11	6	10	14	3	20	3	3	4	3

Kocagöl Lake has an oligotrophic character because of its geological structure. The mixture of sea water and the presence of H_2S were detected on the deepest station on Kocagöl Lake. Köyceğiz Lake is the most important water body of the inland waters of Muğla. The main causes of ecological problems include; tourism activities, tourist-boat traffic and agricultural activities. The trout farm on the Yuvarlakçay stream also affects Köyceğiz Lake because this stream is the principle water source that feeds the lake. Because of its importance to tourism, 491 tourist boats belonging to 6 agents were licensed here and another 100 tourist boat are on duty without license. There is intensive agricultural activity (green housing and citrus fruits) around Köyceğiz Lake with most of the farmers using significant amounts of chemicals (mainly pesticides and fertilizers) to earn more.

All stations on Bereket and Mumcular Dam Lakes were in good status and their status should be kept. We can conclude that Muğla area can be regarded rich in terms of fresh water fish fauna. However, gravel pits, agricultural, tourist and urban activities have negative impacts on the habitat of the species.

As a result, gravel pits on inland waters must be controlled and this control should be maintained. Fish farms must be allowed for extensive farming. The discharge on Sarıçay stream must be prevented. The tourist-boat traffic and agricultural activities on Köyceğiz Lake should be controlled and monitored and tourist boats working by solar energy must be supported. Use of chemicals in agriculture must be under a strict control and monitoring programmes need to be developed for inland waters of Muğla. Governmental and non-governmental foundations must work together to protect inland waters, covering all impacts on waters to achieve good quality ('good status') classes and apply water quality definitions in terms of biology, chemistry, hydrology and morphology.

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Preliminary study on the status of sturgeon populations (*Acipenser* sp) in the South Eastern Black Sea Coast (Kızılırmak-Yeşilırmak Basin) in the early 21st century

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Abstract The Kızılırmak and Yeşilırmak regions were the most important spawning areas of anadromous sturgeons in the Black Sea coast of Turkey until the end of 1980s. Since then, four hydroelectric and irrigation dams were built on these rivers and they blocked spawning migrations and destroyed spawning habitat of sturgeons. However, overfishing of sturgeon for caviar production at the river mouth caused a dramatic decline of stocks in the second half of the 20th century. Nowadays, sturgeon are extremely rare in the South Eastern Black Sea and they are listed under CITES as an endangered species. This study gives information about the current status of sturgeon populations (*A. stellatus, A. gueldenstaedti, Huso huso*) around the Black Sea coast of Turkey between 2004 and 2008 based on accidentally captures in different fishing nets and from illegal marketing in the early 21st century. It is recommended a management strategy is implemented for the Yeşilırmak Basin to protect and recover the sturgeon populations.

Introduction

Sturgeons were fished intensively in the Yeşilırmak-Kızılırmak basin (Samsun) between 1940 and 1970 with catches up to 150 t in some years, but these have declined gradually due to the overfishing, pollution and the construction of two dams on these rivers since the 1980s (Çelikkale *et al*. 2004; Ustaoğlu and Okumuş 2004) and today they are near extinction. As a result, a legal arrangement was put into place in 1973 to ban sturgeon fishing in mouths of rivers flowing into the Black Sea (Anon 1975). As from 1977, catches of all sturgeon species bigger than 140 cm except *Huso huso* were banned (Anon 1977). This status was kept until 1997. After 1997, all the species were protect (Anon 1997). Since the beginning of the 1990s sturgeon populations have become critically endangered but they are still being fished. In the Yeşilırmak-Kızılırmak basin they are captured as a bycatch in bottom trawls and the individuals > 1.5-2 kg are marketed illegally. This study examines habitat-population interactions and fishing of sturgeon in the Yeşilırmak-Kızılırmak basin which is an important spawning and feeding area for the Turkish Black Sea basin.

Materials and methods

This study was conducted in the Samsun fishing area, in the middle of the Black Sea, between 2004 and 2007. This area is located along the middle of the Black Sea coast of Turkey; between 37°47^{1} L,41°09^{1}N east and 35°57^{1}E,41°47^{1}N west (Fig. 1). The continental shelf into which the Yeşilırmak and Kızılırmak rivers discharge is situated between Ünye and Bulancak in the east, Sinop and Gerze in the west and the river areas in which the sturgeons historically migrate most frequently for spawning are along the southern cost of the Black Sea. The Yeşilırmak and Kızılırmak rivers have been heavily degraded by human activities since 1980. The region is an important trawl fishing ground and the other fishing occurs (Zengin 2006). Despite the area being an important fishery, it is more productive than other regions with regard to benthic macro fauna. This is because the continental shelf of the Southern Black Sea coast is generally very narrow and around Samsun, deposits from the rivers Kızılırmak and Yeşilırmak have created extensive shallow grounds. These shallow grounds support productive benthic macro fauna which support the fish stocks. There is reason to believe, however, that intensive trawling in this region has a negative effect upon spawning grounds and regeneration of a range of species (Knudsen & Zengin 2006).

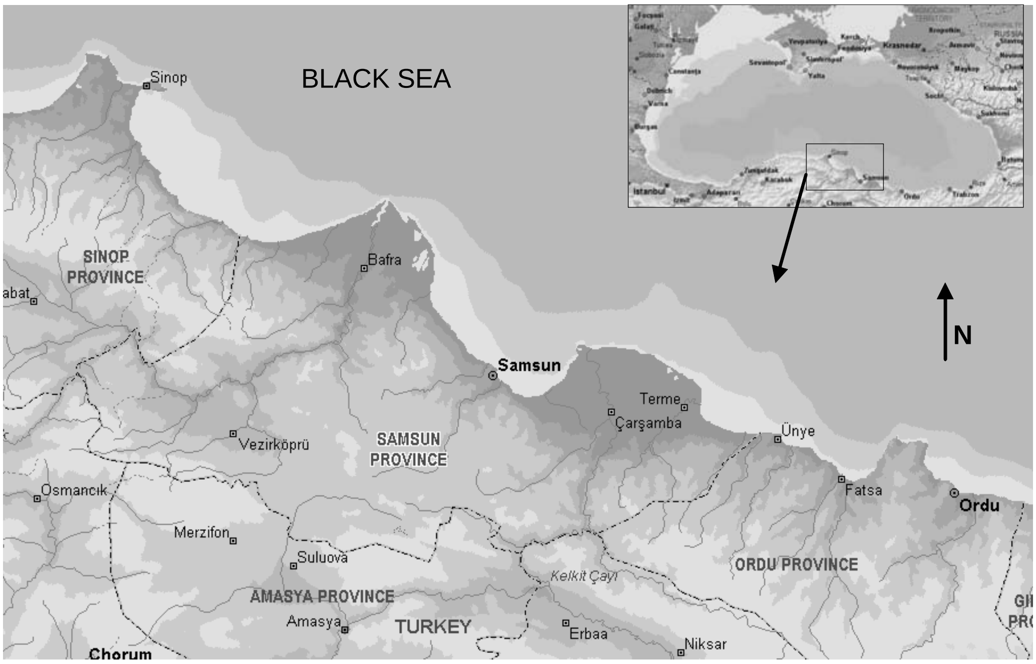

Figure 1. Study area.

Data were provided from different sources; mostly by indirect ways since sturgeon fishing is forbidden by Turkish authority. A strong cooperation and communication network (fax, telephone, website, email) was set up between fisheries cooperatives, fishermen and researchers to report accidental catches of alive or dead fish. "*Local contact persons*" in Provincial and District Directorates of MARA Samsun, Ordu, Sinop cities were appointed. Direct observation was carried out monthly around feeding habitats and spawning migrations in the Yeşilırmak and Kızılırmak rivers.

Some live sturgeons were tagged and released at different locations (Hopa-Trabzon-Ordu-Samsun-Kızılırmak&Yeşilırmak basin-Sinop-Sakarya). The tags used were plastic with special marks on (*number and address*). The tags were placed on the end of the dorsal fin. In order to ease collection of samples, small rewards such as t-shirts, caps, some fishing equipment and posters were offered. A total of 40 individuals were tagged between 2007 and 2008. The mean length and weight of tagged sturgeons released were 58.1 (37-91) cm and 895.9 (168-2900) g, respectively.

The reported and directly measured data were recorded on standard Survey- Information Registration forms. This form held information on; (1) date, (2) fishing zone (sea, river, fish market, store, and restaurant), (3) the fish sample (dead-alive), (4) fishing gear / fishing method, (5) the distance from coast, (6) fishing depth, (7) the fish species (morphological features were taken into consideration for identification of the fish species (Holcik 1989)), (8) total length, (9) body weight ,(10) sex (M/F), (11) gonad weight, (12) gonad maturation stages, (13) stomach content, (14) market price of the fish.

Results

Species and seasonal distributions

Three species were caught around the Yeşilırmak-Kızılırmak basins; *Huso huso* (44.3%), *Acipencer stellatus* (35%), and *Acipencer gueldenstaedti* (20.8%). In the early 1980s five species *H. huso*, *A. gueldenstaedti*, *A. stellatus*, *A. sturio* and *A. nudiventris*. (Geldiay & Balık 1988; Edwards & Doroshov 1989) were reported around the Turkish Black Sea coast. *Acipencer sturio* was considered very vulnerable to fishing in the Kızılırmak-Yeşirmak basin by Edwards and Doroshov (1989).

Bycatch of sturgeon species was higher in autumn, winter and spring than in summer (Table 1). This trend was mainly associated with intensive trawling, especially in Samsun during all seasons except the summer, and spawning and feeding migrations of the sturgeon towards the Southern Black Sea coast occur during the autumn, winter and spring periods.

Table 1. Seasonal distribution of the sturgeon species between 2004 and 2008 in the Kızılırmak-Yeşilırmak basin

Seasons	*A.gueldenstaedti*	*Huso huso*	*A. stellatus*	Total
Spring	8	20	24	52
Summer	7	6	5	18
Autumn	11	11	10	32
Winter	5	29	13	47
General (%)	31 (20.8)	66 (44.3)	52 (35)	149

Illegal fishing and bycatch rates

Fifty-five percent of the bycatch of sturgeon species was in commercial bottom trawl nets in Samsun. This was followed by gill-nets (35%) (bottom and pelagic). A small number were caught by encircling nets (5.4%), dredge nets (2%) and line and hook (2.6%). The trawl fishery operates along the Black Sea coast of Turkey and targets other fish species. (Knudsen & Zengin 2006). Gill-nets operate in the waters the near the coast; note bottom gill-nets (demersal-benthic) are more destructive at catching sturgeon than surface gill-nets. Fishing with encircling nets for bonito and Pacific mullet operate between September and December, and May and June, respectively. Almost all of the captured individuals in the river were caught by traps and heavy hook and line gear.

Sturgeons are mostly caught illegally or accidentally between October and April when commercial trawl fishing intensifies in the fishing grounds beyond 3 miles from the shoreline in the province of Samsun (Anon 2006). Most beluga (*H. huso*) are caught by bottom trawl nets (54.7%).

The majority of the accidentally caught sturgeons (65.4%) were sold illegally on local or public markets (Fig. 2). Although the sturgeons are caught accidentally, the high value of the flesh in large cities encourages the illegal sale of individuals larger 1.5-2 kg; the majority of fish released after capture were <2 kg, mainly *A. gueldenstaedti* and *A. stellatus*. Forty of the 62 individuals released to the sea were done so to determine bio-ecological characteristics of the species.

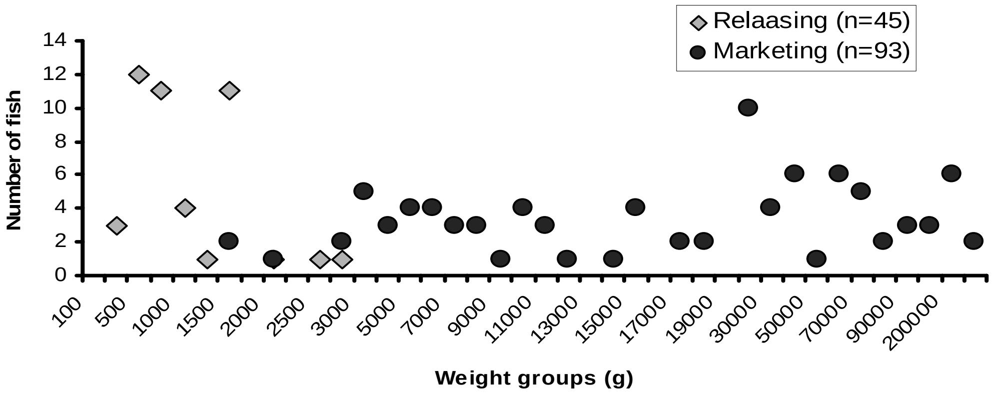

Figure 2. Distribution of the released and tagged sturgeons that were caught accidentally, in terms of weight s (pooled data; 2004-2008).

The price of sturgeon in local stores and luxury restaurants' counters is 40-45 Turkish new liras (TRY)/ kg. The market is mainly *Huso huso* because the growth characteristics of the species (due to its larger size) and spawning and feeding migration behaviour from the northern Black Sea towards the south during the autumn–winter period mean it is caught and retained in the trawl fishery. Beluga sturgeons reaching weights of 250-300 kg are highly sought after and encourage sales.

Migrations: sea and river

In the southern Black Sea, sturgeons are found as deep as 120 m with an average depth of 50.2 (2-123.3) m, but there is no evidence of seasonal variation in depth distribution (Fig. 3). All three species were mainly found between October and May. This may be related to fishing being banned in the region during the summer period. Adult populations move towards the river mouth during the spring period (April- May) as they migrate into the fresh water (river). Nine individuals were reported from the Yeşilırmak River in the studies on Yeşilırmak-Kızıırmak Rivers between the 2004-2008 years, but none was reported from the Kızılırmak River; four individuals were *A. gueldenstaedti* and five *Huso huso* (Fig. 4). The fish were sexually mature, except for two *A. Gueldenstaedti,* observed in August some 55-56 km upstream near the Hasan Uğurlu Dam and Hydroelectric Power Station.

Length-weight relation

The length weight relation parameters for the sturgeon species are given (Table 2). The majority of fish caught were in the range of 30-80 cm, but with an average length of 60.1 cm for *A. stellatus,* 78.0 cm for *Huso huso* and 78.7 cm as for *A. gueldenstaedti,* equivalent to 1967.6, 52752.1 and 7569.9 g, respectively. The maximum size of *H. huso* was 395 cm (353 kg) compared with 100 (10 kg) and 200 cm (60 kg), respectively for *A. stellatus* and *A. gueldenstaedti* (Fig. 5). The differences in the length and weight parameters of these species, were due to differences in growth characteristics; the length weight coefficient *b* was higher than 3 for *H. huso* indicating allometric growth, suggesting this species increases proportionally more in weight more than length as it gets larger. Length and weight composition for each species in the Southern Black Sea are similar to the Northwest Black Sea-Danube delta at 100-120 cm (6-8 kg), 150-200 cm (40-70 kg) and 200-256 cm (145-400 kg) respectively for *A. stellatus, A. gueldenstaedti* and *H. Huso* (Vassilev & Pehlivanov 2003; Ciolac & Patriche 2005).

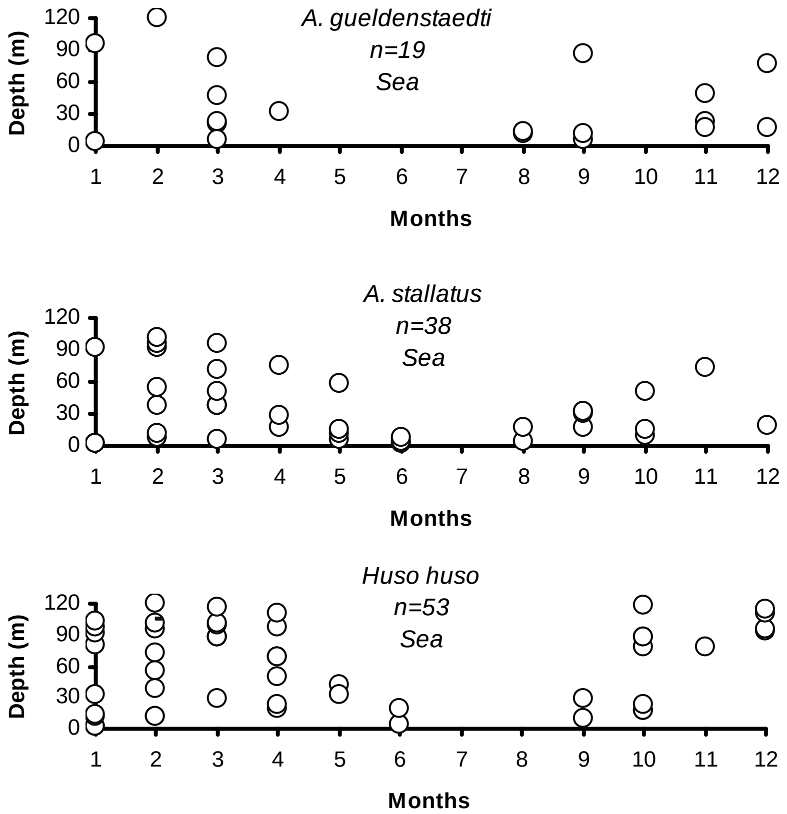

Figure 3. Monthly vertical distributions of the sturgeon's populations in the Kızılırmak-Yeşilırmak littoral.

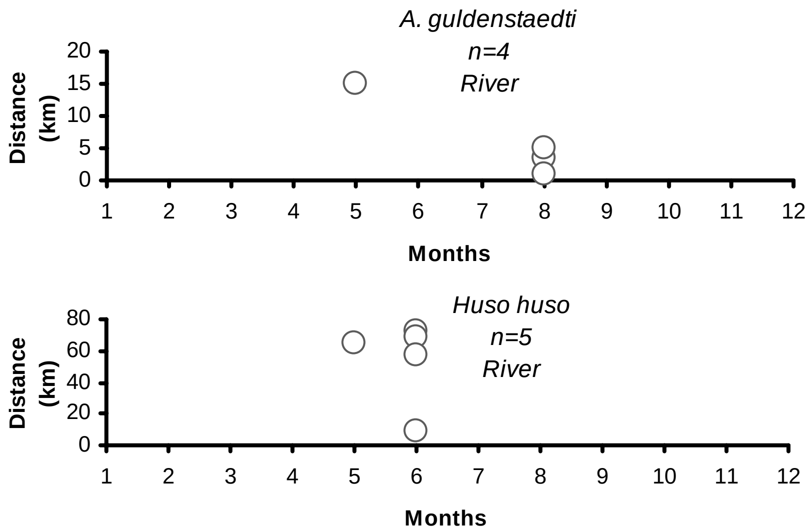

Figure 4. Monthly migration of the sturgeon's population in the Yeşilırmak river (distance is from river mouth to sampled localities).

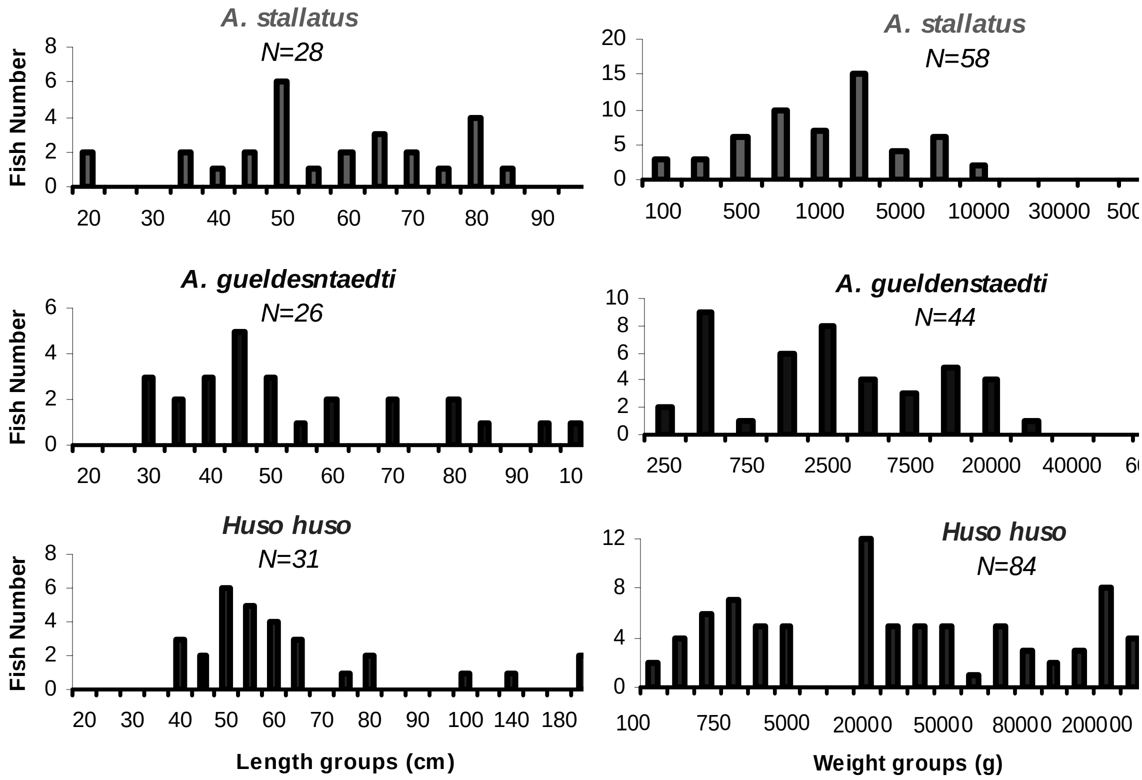

Figure 5. Length and weight compositions of sturgeon in the Kızılırmak-Yeşilırmak basin (2004-2008 period; pooled data).

Table 2. Length weight relationship parameters for sturgeons (2004-2008 pooled data)

Species	a	b	r^2	*n*	Length range (cm)	Weight range (g)
A. gueldenstaedti	0.0037	3.0609	0.9552	26	78.7 (40-200)	7569.9 (217.7-60000)
A. stellatus	0.0031	3.0081	0.7513	26	60.1 (37-100)	1967.6 (125-10500)
Huso huso	0.0007	3.4665	0.9506	31	78.0 (40-359)	52752.1 (196-353000)

Reproductive behaviour

Observations on spawning migrations were limited (Table 3**:** (1) reproduction migration was observed only in the Yeşilırmak River and its shelf area; (2) adult sturgeons (*Huso huso*, and *Acipenser gueldenstaedtii*) migrate in spring and early summer in this river (similar to the Danube; Ciolac & Patriche 2005); (3) all fish caught had mature gonads - immature and early maturity stages were generally found in the sea. Although adult sturgeons were found in the Yeşilırmak River, no evidence of spawning was found based larvae and juvenile surveys. It is possible mature fish return to the sea without any finding suitable spawning opportunities and suitable habitat. This is because dams on the Yeşiırmak and Kızılırmak rivers now block access to the most important areas for spawning, especially on the Kızılırmak River where three barriers/dikes have been constructed on different sections for flood prevention along the Bafra plain. This situation is less impacting on the Yeşilırmak River with no barriers on the first 65 km stretch from the river mouth. Also the stream bed in the Yeşilırmak, across the Çarşamba flat, is a deeper and larger delta area than in the Kızılırmak. However, increasingly unfavourable environmental conditions and illegal catching on the river prevent fish from spawning.

Table 3. Reproduction parameters for sturgeon populations in the Kızılırmak-Yeşilırmak basin (TL: total length, W: body weight, GW: gonad weight)

Species	Date	Locality	Habitat	Depth (m)	TL-W (cm-kg)	Sex	GW (g)	Gonad maturity stage
A. gueldenstaedti	15.3.05	Yakakent	Sea	21	150-14.5	F	2000	Immature
	15.4.05	Kızılırmak	Sea	18.3	200-30	F	3600	Early mature
	22.8.05	Yeşilırmak	Sea	12	?-10	M	?	?
	1.1.05	Yeşilirmak	Sea	12	?-20	M	?	?
	10.4.07	Kızılırmak	Sea	inshore	?-27	F	5000	Early mature
	9.5.07	Yeşilırmak	River	-	170-60	F	9700	Mature
	14.5.07	Yeşilırmak	River	-	?-70	F	8500	Mature
	24.10.07	Samsun	Sea	-	?-25	F	8000	Early mature
	25.11.07	Samsun	Sea	-	?-25	F	3500	Early mature
	2.12.07	Dereköy	Sea	77.8	107-5.5	F	92	Immature
	27.12.07	Samsun	Sea	-	?-21	F	?	Immature
A. stellatus	25.3.05	Terme	Sea	95.2	80.2-2	F	?	Immature
	26.4.07	Samsun	Sea	inshore	?-6.5	F	2800	Mature
Huso huso	16.4.05	Kızılırmak	Sea	50.3	?-18.7	F	2700	Immature
	2.6.05	Yeşilırmak	River	-	?-77.5	F	16000	Mature
	15.2.06	Yeşilırmak	Sea	73.2	?-150	F	?	Immature
	18.2.06	Terme	Sea	104.3	?-300	M	?	Immature
	10.5.07	Yakakent	Sea	32	?-60	M	?	Immature
	16.5.07	Yeşilırmak	River	-	?-36	F	?	Mature
	16.6.07	Yeşilırmak	River	-	?-42	F	7400	Mature
	3.12.07	Kızılırmak	Sea	93.3	220-90	F	2152	Immature
	26.1.08	Terme	Sea	110	265-152	F	2873	Immature
	24.2.08	Terme	Sea	100.7	359-353	F	18500	Immature

Feeding habits

The stomach contents of sturgeons from throughout the southern Black Sea littoral suggest they feed on benthic and benthopelagic macrofauna (Table 4). A variety of factors such as; feeding ground characteristics, season, water temperature, food availability (Polyaninova 1996) and predator species determine feeding behaviour. While *H. Huso* feeds in the benthopelagic (horse mackerel, whiting, and gobies) and pelagic (anchovy), *A. Gueldenstaedti* feeds on crustaceans and molluscs in the benthic. The diet of beluga was predominantly anchovy (Berg 1948) reinforcing the impression that this species is connected with the anchovy autumn-winter migration along the southern Black Sea. On the contrary, A. *gueldenstaedti* shows a feeding strategy depending on benthic (Table 4) (Berg 1948; Zolotarev *et al*. 1996).

Discussion

Historically, few studies have been performed on the abundance and distribution and bio ecology sturgeon in the southern Black sea coast. There is a study on taxonomic features of the sturgeon species distributed in a region (Geldiay & Balık 1988). Edwards & Doroshov (1989) compared habitat-population-migration and fishing relations of sturgeon populations in the early 1980s with the 1940s. Accordingly, it is possible compare the status in the Kızılırmak-Yeşilırmak basin described in this paper with the period between 1940 and 1980, between 1980 and 2000, a period of transition in the market economy in Turkey. The features that designate the state of sturgeon populations for each period are given in Table 5.

Table 4. Some feeding parameters about on the sturgeon's populations in the Kızılırmak- Yeşilırmak basin (TL: total length, W: body weight)

Species	Date	Locality	Habitat	Depth (m)	TL-W (cm-kg)	Stomach contents	
						Prey name	Number-weight (g)
	8.10.06	Samsun	Sea	7.5	71-1.6	*C. gallina*	1-?
A. gueldenstaedti	2.12.07	Dereköy	Sea	77.8	107-5.5	*C gallina* *A. cornea* *M. galloprovincialis* *C. crangon*	4-? 1-? 1-? 2-?
	12.8.07	Yeşilırmak	River	-	41.7-0.2	*C gallina*	1-?
	3.12.07	Dereköy	Sea	93.3	220-90	*C. gallina* *E. encrasicolus*	1-? 78-741
Huso huso	26.1.08	Terme	Sea	110	265-152	*E. encrasicolus* *T. trachurus*	88-834.6 9-148.5
	24.2.08	Yeşilırmak	Sea	100.7	359-353	*E. encrasicolus* *T. trachurus* *M. m. euxinus* *G. niger*	129-1225 2-33.7 2-31.2 3-29.1

Sturgeon stocks were overexploited in terms of both species number and amount from the early 1940s and stocks along the coast of Turkey are now included in the CITES "Endangered species" list (CITES 2006). Prior to construction of dams on the rivers in the late 1970s, 6 sturgeon species were found; *H. huso, A. gueldenstaedti, A. stellatus, A. sturio, A. nudiventris, A. ruthenus* (Çelikkkale 2004); the number of species decreased to 4 at the end of the 1980s (*H. huso*, *A. gueldenstaedti, A. stellatus, A. sturio* (Edwards & Doroshova 1989)), and 3 at the beginning of the 2000s (*H. huso, A. gueldenstaedti, A. stellatus*). Despite legal protection, sturgeon are still captured as bycatch in the trawl fishery in the Samsun region and sold illegally. In addition, gillnetting in the coastal areas and mollusc dredging increase pressure on the sturgeon stocks along the coast.

Along the southern coast of Turkey the main sturgeon species caught was the beluga in the Yeşiırmak-Kızılırmak littoral; most weighed between 100-350 kg but did not contain caviar. The majority of fish caught now are immature female *H. huso* suggesting that *H. huso* does not migrate for spawning to the rivers in this region. Instead it is likely that *H. huso* and *A. gueldenstaedti* migrate along the southern coast of the Black Sea in the autumn-winter to coincide with the pelagic anchovy migration followed by migration to the rivers for spawning. Further evidence of migration was gained from fish caught that had suture marks that were possibly the result of fish released after aquaculture experiments at Batum Oceanography and Fishery Institute, Georgia, and Kerch YugNiro Research Institute, Ukraine, before and after 2000 (Shlyakhov 2003). These aquaculture studies were performed on the mature individuals caught from the wild. Alternatively, the suture scars could be from fishes harvested for caviar via the surgical operation and returned to the wild.

Another indication in relation to the migration behaviours of the sturgeon species, distributed on the coast of the southern Black Sea is the results, gathered from the marking experiments. Further evidence of migration was gained from a marked individual *A. gueldenstaedti* weighing around 2 kg, caught on the Bulgarian coast at Galata on 10 December 2006; this fish was reared at Sapanca foundation, İstanbul University Faculty of Aquaculture and released at the mouth of the Sakarya River in July 2006. Also *A. gueldenstaedti* caught on the coast of the River Kızılırmak on 8 December 2006, one *A. stellatus* caught in the River Perşembe on 13 February 2007, one *H. Huso* caught at the mouth of the River Sakarya on 4 December 2007. were marked, released and recaptured 275 km west (143 days), 15 km east (9 days) and 4 km-west (2 days) respectively from the localities where they were released. Sturgeon population thus appear to exhibit long distance migration over in short time intervals.

Data on catch, population, habitat and migration characteristics migrate into the Yeşilırmak River to spawning; no data were available for the Kızılırmak River suggesting it is no longer used for spawning. It is crucial to create a conservation area below the first dam in the north of the Kızılırmak Rive and downstream of the Yeşilırmak basin and Çarşamba delta. The Yeşilırmak delta, wetland area in terms of freshwater fishes and bird variety, is under pressure from uncontrolled agriculture and urbanization and has not been conserved adequately, but an administration plan study has been started by the Ministry of Environment and Forestry for this region. Its actions include closing down the gravel extractions from the stream beds, assigning appropriate spawning areas over the river, and immediate rehabilitation of the stream bed.

Despite unfavourable ambient conditions and anthropogenic affects, the region provides valuable opportunities to recover the sturgeon stocks and effort must be put in to conserve these important, critically endangered species.

Table 5. Historically changes in the status of sturgeon populations in the Kızılırmak-Yeşilırmak basin

I. PERIOD (1940-1980)	-No environmental degradations in the Kızılırmak and Yeşilırmak river basins -Low level of urbanization and population growth (Özesmi 1999). -No pollution -Dams not yet constructed - fishing technology not developed -Only 27 trawlers in the late 1970s (Knudsen & Zengin 2006)	-6 species exist and stocks exploited (*H. huso, A. gueldenstaedti, A. stallatus, A. sturio, A. nudiventris, A. ruthenus*) (Çelikkale *et al.* 2004) -Ongoing anadromous migration	-Primitive "*karmak/hook*" estuarine fishing -Fishing mainly between Feb. and Jun. -High price of caviar -Best capture fisheries between 1950s and 1970s (Öker 1956) -A little caviar export to Europe (DPT 1962)	-First expert on caviar processing was invited from Germany (Anonym 1966) -First measures were taken to protect stocks and caviar production in 1960s (Çakıroğlu 1968) - Fishing first prohibited in estuaries in 1973 -Fishing all species except *Huso huso* bigger than 140 cm prohibited in 1977 (Çelikkale *et al.* 2004)
II.. PERIOD (1980-2000)	-Rapid urbanization, industrialisation and population growth -4 dams constructed on Kizilirmak and Yesilirmak -Bafra and Carsamba plains improved for cultivation (Özesmi 1999). -Rivers basin degradations started -High dikes constructed on Kizilirmak -Pollution increased -Fishing technology and effort increased after liberalisation in early 1980s	-Main species are *H. huso, A. sturio, A. stellatus and A. gueldenstaedt* -Few migrate for spawning -Pressure on *A. sturio* -Not many beluga over 250 kg contain caviar (Edwards & Doroshova 1989)	-Illegal fishing and very low caviar production -Low productivity of fishing in estuaries -Spring fishing with so-called *morina nets* -45 fishermen were active at the end of 1980s (Zengin *et al.* 1992) - Fishing effort increased (104 trawlers) -Big pressure on sturgeons due to illegal fishing and trawling (Knudsen & Zengin 2006)	-Fishing banned for all species (Anon 1997) -The first experts invited from FAO to advise on stock enhancement (Edwards & Doroshova 1989) -Insufficient and inefficient control mechanism -Caviar and flesh on black market
III. PERIOD (2000-)	- Serious degradation on rivers and estuaries -Intensive urbanization, industrialization and population growth -A new dam on Yesilirmak -Pollution originated from industrial, domestic and agriculture -Very high fishing effort -Demersal stocks collapsed in littoral zone (Knudsen & Zengin 2006)	-Very few specimens belonging 3 species *(H. huso, A. stellatus and A. gueldenstaedt*) -Reproduction migration only in Yeşilırmak river (This study) -Large beluga migrate for feeding depending on anchovy (This study)	-Some catch occurs mainly in trawl fishing and gillnets as by-catch (This study) -123 trawlers (Knudsen & Zengin 2006) -Ongoing black market for flesh from fish > 1.5-2 kg	-Under protection in CITES as endangered stocks (CITES 2006) -Insufficient protection and control measures -Little awareness in fishermen community for protection -Some civil initiative-MERKODER- and nationwide research projects-CFRI-started in early 2000s

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Ameiurus melas (Rafinesque) – pest or possibility

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Abstract Since the nineteenth century, numerous importations of North America catfishes for aquaculture have resulted in the spread of these species in European inland waters. After more than one hundred years, the negative impact of their introduction on natural ecosystems is evident. However, ictalurid catfishes are still reared in aquaculture, so the aim of this paper was to investigate the condition of reared and wild black bullhead. A total number of 296 specimens were collected from three different sites along the Tisza River, during October and November in 2005. In May 2006, 150 specimens were obtained from an aquaculture facility near Sombor, Serbia. Reared black bullhead specimens were 2+ year old, whilst wild specimens ranged in age from 1+ to 4+. Fulton's condition factor and length-weight relationships were compared. In addition, given that wild specimens were collected with different fishing gears (nets, electro-fishing, fishing rods and traps), the potential of different gears for efficient exploitation of these resources was investigated.

Introduction

Biological invasions are common-place in nature (Lodge 1993), facilitated by climatic, geotectonic or other natural events. Nevertheless, human impacts on biodiversity through the introduction of alien species and eradication of indigenous species, is increasing. Introductions of exotic fish species in Europe were either intentional or unintentional, and motives ranged from aquaculture and improvement of wild stocks, ornamental purposes, for sport, biological control and accidental releases. Analyzing the relative importance of these categories, Welcomme (1988, 1991, 1992) found that introductions made for aquaculture purposes have always comprised a significant part of the total, and have steadily increased in importance. Since the early 1970s they have accounted for well in excess of 50% of all introductions made. Copp *et al.* (2005) defined the so-called "tens rule", which stated that only 10% of all introductions result in the establishment of viable populations, and only 10% of these established populations may be regarded as pests and weeds. However, there is increasing concern over the potential impact (adverse or beneficial) of introduced species on native species, ecosystems, local and national economies, and societies, through either direct or indirect effects (e.g. parasites or pathogens). Forty-four fish species native to the United States, are threatened by non indigenous fish species, with an additional 27 native fish species harmed by introductions (Piemental *et al.* 2000). Even if the economic benefits from the introduction of non indigenous fish through sport fishing for example are accounted for, conservative estimates put the economic loss due to exotic fish at more than $1 billion annually (Piemental *et al*. 2000).

The family Ictaluridae contains five genera and 25 species restricted to North America and north-eastern Central America. They inhabit large rivers and slow flowing streams, lakes and ponds. In the nineteenth century, numerous importations of ictalurid catfishes were made to Europe. According to Wheeler (1978), the first introduction occurred in France in 1871, followed by Belgium (1884), then Germany and England (1885). The introduction of 50 specimens to water bodies in Germany in 1885 was the key event that led to their definitive acclimatization. Borne (1891, *cited in* Sotirov 1968) claimed: "I believe that now, in 1891, bullhead can be regarded as naturalized". Most of these catfish introductions were claimed to be *Ameiurus nebulosus*, but Wheeler (1978) suggested that *Ameiurus melas* is now widespread in Europe. These two species are similar and often confused. Moreover, it is known that *A. melas* can hybridize with *A. nebulosus* (Boschung & Mayden 2004). This can explain the low tDNA divergence between these sister species (Hardman and Page 2003), although naturally occurring hybrids do not appear to be common in collections.

Across Europe, numerous dams were constructed for river regulation and as hydropower plants, which lead to water flow lag. Since black bullhead inhabits soft substrates of sluggish sections of creeks and rivers, as well as backwaters, channels, swamps and impoundments, this was excellent opportunity for further expansion of its range.

Ictalurid catfish were introduced to Serbian waters in two ways: firstly, they were released in Croatian fish-ponds before World War I, and secondly, their range expanded from northern neighboring countries through the rivers Danube, Tisza, Tamis and Begej. Bullhead acclimatization was rapid, with Koca and Protic (Sotirov 1968) indicating high abundances in the Danube-Tisza-Danube (DTD) channel. Karaman (1952 *cited in* Sotirov 1968) reported the presence of bullhead in open waters around Smederevo, while Jankovic (1965 *cit. in* Sotirov 1968) reported the expansion of their population in the Serbian part of the Danube. Finally, Sotirov (1968) concluded that over a 20-30 year period ictalurid catfish had successfully inhabited all lowland rivers in the north – Danube, Sava, Tisza, DTD channel, Begej, and that its expansion had reached relative stability in terms of geography and abundance as early as the 1940s.

Catches of black bullhead in Serbia are not negligible, but adopted commercial catch sorting techniques put them in "Mix I" and "Mix II" along with roach, nase and perch. It is therefore very hard to single out the specific contribution of this species to total catch values. Sotirov (1968) provided catch statistics of the "Šaran" fishing company from Novi Sad over the period 1959 – 1962. This data showed that the proportion of this species in the total catch ranged from 4% to 10%, depending on the year. Catches were highest in spring and autumn, presumably due to low water levels and decreases in water vegetation, which allows for the use of drift nets.

Taking into account everything previously mentioned, there is a rising question about the economic potential of black bullhead in Serbian waters. This species is still produced commercially throughout Europe, indicating a demand. The aim of this paper is to investigate and compare wild populations and reared ones and assess their "accessibility".

Materials and methods

During October and November 2005, 296 black bullhead specimens were caught in the Serbian part of the Tisza River (Fig. 1). A total of 115 specimens were caught on the “Dead Tisza channel” (N 45º28’32.88”, E 20º03’26.45”), on 10 October 2005, near Čurug, with cage traps (90x45x45cm). Despite the large number of traps laid in this area (6-10 traps/ha, as a tool for pest control), these specimens were taken from a single trap. From the “Yellow channel” sampling site (N 46º00’49.02”, E 20º00’26.45”), near Kanjiža, on 23 October 2005, 116 specimens were caught with 3 fishing rods. Professional fishermen caught 65 specimens on “DTD channel” (N 45º32’13.71”, E 20º01’00.45”), near Bačko Gradište using gillnets, during the period between 4 and 6 November 2005.

Reared specimens (n=150) were taken from “Alov” fish farm (N 45º48’17.40”, E 19º11’25.82”), near Sombor, on 26 May 2006.

Figure 1. Map of sampling sites: 1. “Alov” fish farm, Sombor (N 45º48’17.40”, E 19º11’25.82”), 2. “Yellow channel”, Kanjiža (N 46º00’49.02”, E 20º00’26.45”), 3. “DTD channel”, Bačko Gradište (N 45º32’13.71”, E 20º01’00.45”), 4. “Dead Tisza channel”, Čurug (N 45º28’32.88”, E 20º03’26.45”)

The age of black bullhead was determined by otolith examination. Otoliths were prepared according to adapted method of Secor *et al.* (1992), and they were analyzed by two independent researchers. Body mass (M) was measured on electronic weighing scales (± 0.01g). A digital picture of each specimen was taken with Nikon CoolPix 4500 digital camera. Standard length (L_S) was measured in Image Tool 3.00 (± 1mm).

Correlation and regression analysis of body length (L_s - standard length) and body mass, according to Ricker (1975), were performed on log transformed data for every sampling site. Fulton’s condition factor (C) was also estimated, according to the equation:

$C = (M / L_s^3) \times 100$

where M is body mass, and L_s is standard length. Correlation, regression and analysis of Fulton's condition factor were also performed on 90 specimens from the 2+ age class, from Sombor (n = 30), Čurug (n = 30) and Bačko Gradište (n = 30). The sample from Kanjiža was excluded, as it predominantly consisted of 1+ age class.

For testing the hypothesis about the equality of the two population regression coefficients, we used the formula:

$t = (b_1 – b_2) / S_{b1-b2}$

where b_1 and b_2 are regression coefficients of the two populations and S_{b1-b2} is the standard error of the difference between regression coefficients (Zar 1984). The critical value of t for this test has $(n_1$-2) + $(n_2$-2) degrees of freedom.

Results

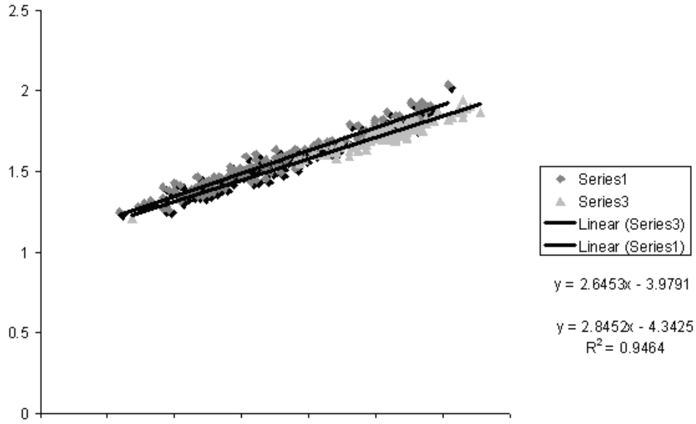

Figure 2. Difference in slope of two regression lines. Series1 (Sombor, n=150); Series3 (Čurug, n = 115)

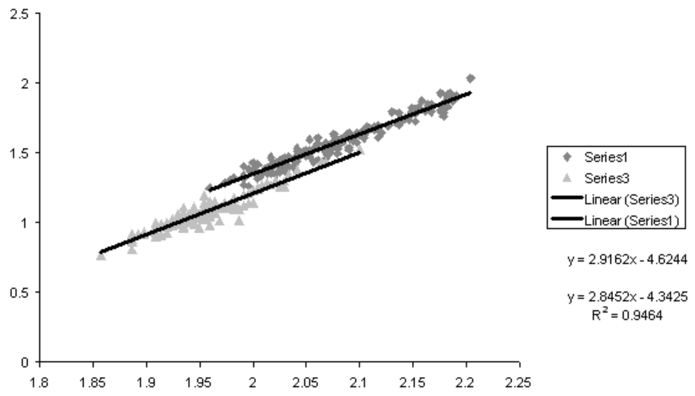

Figure 3. Difference in slope of two regression lines. Series1 (Sombor, n=150); Series3 (Kanjiža, n = 116)

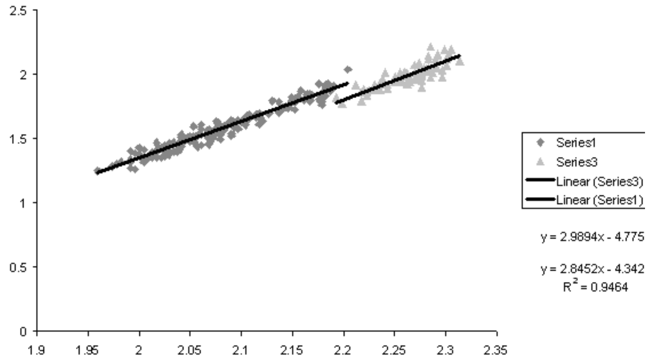

Figure 4. Difference in slope of two regression lines. Series1 (Sombor, n=150); Series3 (Bačko Gradište, *n* = 65)

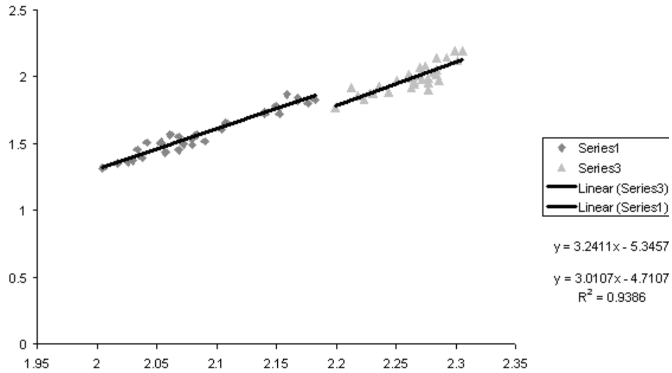

Figure 5. Difference in slope of two regression lines (2+ age class). Series1 (Sombor, n=30); Series3 (Bačko Gradište, *n* = 30)

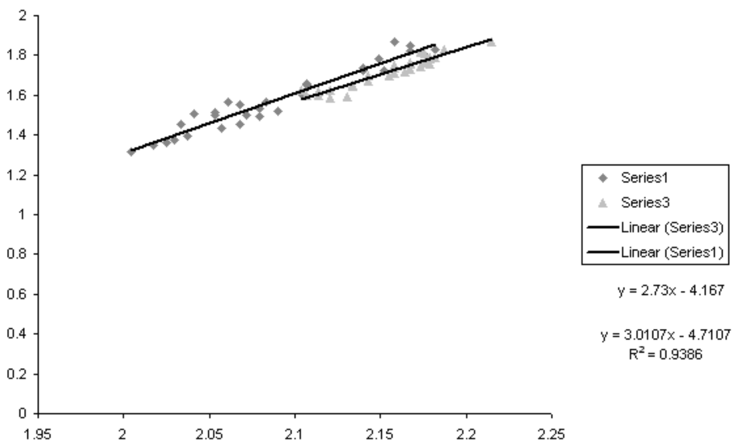

Figure 6. Difference in slope of two regression lines (2+ age class). Series1 (Sombor, n=30); Series3 (Čurug, *n* = 30)

For age determination, otoliths were inspected, except for samples from Sombor fish farm, as they were all known to be in the 2+ age class. Otoliths from 66 Čurug's specimens were inspected and it was concluded that specimens belonged to 1+, 2+, 3+ and 4+ age classes, with an average age value of 2.41. From the sampling site Kanjiža, otoliths from 39 specimens were inspected, and there were two age classes (1+ and 2+), although the average age value was 1.05. Age classes 2+ and 3+ were identified from the otoliths of 52 specimens from Bačko Gradište sampling site, with an average age value of 2.57.

Standard length (L_s) for specimens from Sombor fish farm ranged from 91 to 160 mm, and body mass (*M*) ranged from 17.68 to 108.43 g. The highest values for standard length and body mass belonged to the sample from Bačko Gradište, with 206 mm and 164 g respectively. Minimal values at this sampling site were L_s=156 mm and *M*=58 g. At the sampling site Čurug, L_s ranged from 93 to 169 mm, and *M* ranged from 16.17 to 87.55 g. The Kanjiža sampling site had the lowest values for both body length (L_s) and body mass (*M*). Range for L_s for this site is from 72 mm to 126 mm, and range for *M* is from 5.86 g to 33.48 g.

Log transformed data were used for correlation and regression analyses of body length and body mass. Coefficient of regression (*b*) was highest at sampling site near Bačko Gradište (b=2.9894), followed by the sampling site near Kanjiža (b = 2.9162), Sombor (b = 2.8452) and Čurug (b = 2.6453). A comparison of the differences in slope of the two regression lines showed that there was a significant difference ($P < 0.05$) between Sombor and Čurug (Figure 2), as well as between Sombor and Bačko Gradište (Fig. 4), with *t*-test values of t= 0.42277 and t = 1.01001, respectively. There were no significant differences ($P > 0.05$) between Sombor and Kanjiža sampling sites (t = 2.40247, Figure 3). For the 2+ age class, 30 specimens from each site were compared, except for the sampling site Kanjiža, as they were predominantly 1+ age class. At Sombor, 2+ specimens (n = 30), have a *b* value 3.0107, with *b* equal to 3.2411 and 2.73 for Bačko Gradište and Čurug, respectively. T-test values t=0.54485 (Sombor vs Bačko Gradište) and t = 0.18435 (Sombor vs Čurug) show that there was a difference between these populations (Figs 5 & 6).

Specimens from Sombor fish farm had the highest value of *C* (2.1739), followed by Čurug (C = 1.80571), Kanjiža (C = 1.63593) and Bačko Gradište (C = 1.59863). Furthermore, for the 2+ age class, 30 specimens from each site were compared, except sampling site Kanjiža. The value for *C* was highest at sampling site Sombor (C = 2.05819), followed by Čurug (C = 1.78311) and Bačko Gradište (C = 1.59746).

Discussion

The results obtained by this study suggest that commercial use of black bullhead from the wild could have economic potential. Specimens obtained from Kanjiža, in comparison with specimens from Sombor fish farm, show that there was no significant difference (p>0.05) between the regression coefficients (b = 2.9162 and b = 2.8452, respectively) of these populations. According to Ricker (1975), this *b* value shows that the food obtained by wild specimens was adequately nourishing, and that their increase in body mass was similar to reared specimens. However, these specimens were caught with fishing rods and they were mostly in the 1+ age class, in contrast to the 2+ specimens from Sombor. Nevertheless, this shows the potential for exploitation in this locality.

Specimens from other sampling sites (Čurug and Bačko Gradište), in comparison to specimens from Sombor, showed a significant difference ($p<0.05$) between regression coefficients (b = 2.6453 and b = 2.9894, compared to b = 2.8452, respectively). Furthermore, this shows that the regression coefficient (b) of specimens from Bačko Gradište was higher than that for the fish farm sample (Sombor). Comparison of the 2+ age class from sampling sites Sombor and Čurug, as well as Sombor and Bačko Gradište, showed that there was a significant difference ($p<0.05$) between regression coefficients (b = 3.0107 to b = 2.73 and b = 3.0107 to b = 3.2411, respectively). However, specimens from sampling site "Bačko Gradište" again showed a higher coefficient (b) than the ones from Sombor, which indicates that the increase in body mass is higher in wild specimens than in reared ones. This could also indicate that food composition is, perhaps, better in the wild than in the fish farm, so further investigation into the possibility of exploitation of the Bačko Gradište sampling site is needed.

Values of Fulton's condition factor(C), were higher for specimens from aquaculture (C = 2.1739) than for the rest of sites, Čurug (C = 1.8057), Kanjiža (C = 1.6359) and Bačko Gradište (C = 1.5986). Even for the 2+ age class, Fulton's condition factor (C) was higher for specimens from sampling site Sombor (C = 2.0582), than for Čurug (C = 1.7831) and Bačko Gradište (C = 1.5975).

According to Željko Djanić (*pers. comm.*), working at "Alov" fish farm near Sombor, diseases that reduce number of reared specimens of black bullhead (especially in later age) are *Saprolegnia sp.*(during February), Picornaviruses (during May) and *Columnaris* bacteria (during July). It is very likely that these diseases also influence wild populations (at similar times of the year), as there are few reports of old wild *A. melas* and they mostly belong to 1+, 2+, 3+ and 4+ age classes. These findings could indicate that the best period for harvesting wild black bullhead would be at the end of summer and the beginning of autumn, when water levels are low and fish are generally larger following the summer growth period. Another issue to be addressed is the selection of appropriate and effective fishing gears. Standard gill nets, which were used at sampling site Bačko Gradište by professional fishermen, seem to be efficient in terms of body mass and body length selectivity. However, this catch was made over a period of two days. Fishing rods prove to be efficient, as demonstrated by the fact that authors managed to collect 116 specimens in just 3 hours. One drawback of this method is its selectivity of young age classes (predominantly 1+). Electric fishing proved to be ineffective when it was tested at Sombor (N 45º57'08.53", E 20º04'30.36"). A total of only 10 specimens, with an age range of 0+ to 3+ were caught during a 3 hour period. It was therefore not used in this study. This finding is in accordance with Louette and Declerck (2006) who also suggested that the use of electric fishing and gill nets for mass removal of black bullhead are not appropriate. Perhaps the most efficient tool was fish traps. This type of trap is commonly used for pest control. When checked every 1-2 days, approximately 6-10 traps/ha can catch large numbers of *A. melas* specimens.

With the existence of a market demand for black bullhead, there is a need for further research into wild black bullhead populations. Locations that were assessed in this study should be investigated for population density (kg ha^{-1}), some aspects of the reproductive cycle and the natural diet of this species. The harvest of this "pest" from the wild would not only provide a marketable resource but also facilitate the recovery of indigenous species by alleviating competitive interactions with black bullhead.

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Diet of great cormorant (*Phalacrocorax carbo* L.) in the Special Reserve of Nation ″Stari Begej – Carska bara″, northern Serbia

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Abstract The great cormorant colony located in Special Reserve of Nature “Stari Begej – Carska bara” is the largest colony in the Serbia, approximately 440 nesting pairs, representing more then 1/3 of nesting cormorant population in Serbia. Close to the colony there are two rivers, Tizsa and Begej, as well as fishfarm Ečka – the largest carp fishfarm in Europe. The aim of this work is to analyse diet of cormorants and their negative effects on fish farms. As samples for analyses, we have used fish regurgitated by great cormorants collected in the colony during the nesting season and pellets collected on roosting places during the winter. Fish injuries resulting from unsuccessful cormorant attacks were also analysed. The damage, induced by cormorants in investigated fish ponds, was calculated taking in consideration analysis and results obtained by all three methods mentioned above.

Introduction

The number of cormorants in Europe has been being increasing since 1980’s (Lindell *et al.* 1995). Until 1960s, in Serbia, cormorants nested in six colonies: Obedska bara, Zemun, Kovilj, Carska bara, Apatin i Bački Monoštor (Mikuška 1977). During the second half of the 20th century, large-scale ameliorative and regulatory works in Vojvodina caused sudden ecological disrupt and loss of moor lands, negatively effecting the colonies. In the nesting birds of Vojvodina list, the great cormorant is stated as an endangered species (Ham 1979). In late 1980's and early 1990's cormorant colonies started to re-establish along the great rivers in Vojvodina and in the beginning of this century they re-established populations in southern/south-eastern from Vojvodina, at the Vlasinsko Jezero Lake (Simonov 2001) as well as south-western, in Drina River.

Special Reserve of Nature ”Stari Begej – Carska bara” with the surrounding, rivers Tisza and Begej, as well as Ečka fishpond, present an excellent settlement for numerous bird species, especially swamp birds. Until 1957 the great cormorant nested in the Carska Bara Swamp and at that time there was only one nest with three fledglings (Popović 1960). Human intolerance towards this species was present at that time as well and from 1948 to 1951 there were 35 birds killed (Pekić 1958). The beginning of 20th century was marked with great cormorant re-establishing its presence on the Carska

Bara Swamp. In 1998, this colony was inhabited by 100 or 110 bird couples, while in the previous years this colony consisted of only 2-3 nesting pairs (Puzović 1999). Data from 2007 shows recovery of this colony, with around 440 nesting couples.

Great cormorant, as a fish-eating bird, is in expansion, especially in inland water bodies. Studies of growing cormorants' colonies influence to river and pond fishes have taken place in many countries in Europe (Suter 1997; Veldkamp 1995; Opačak *et al.* 2004; Gwiazda 2004; Adamek *et al.* 2007). Rapidly or moderately growing colonies of cormorants led to fisherman/fish farmers' disaffection and their attempts to limit number of birds in colonies, thus limiting their influence to waters and ponds. Such studies have not been carried out in Serbia.

One of the problems caused by cormorants nesting near the fish ponds Ečka is indirect losses due to unsuccessful attacks on fish, causing wounds and stress. Injured fish, which have escaped from cormorant or if its size was significant enough and the cormorant could not swallow it, suffer from scars or necrosis.

The aim of this study is to assess cormorants' diet analysis during the nesting and the winter period to determine impacts on fish stocks. This study assesses indirect damage to fish, caused by cormorants' unsuccessful attacks. The study area was selected for its importance for swamp birds, this area borders with a large fishing farm system "Ečka" (5 ponds, totalling 2250 acres), thus causing a conflict between, in one hand - species and habitat protection, and fish farming in the other hand.

Materials and methods

The Special Reserve of Nature "Stari Begej – Carska bara" is located in the Central Banat Administrative Region of the Autonomous Province of Vojvodina (45˚16' N, 20˚25' E) and it is regarded as one of the oldest reserves of nature (protected by law) of Serbia (Fig. 1). "Stari Begej – Carska bara" was given protection in 1955, and as of 1994 the reserve gained special status. As Ramsar site, it was declared in 1997, and IBA site from 2000. The reserve is surrounded by the rivers Tisza and Begej, as well as Ečka Fishing Farm (5 ponds, totalling 2250 acres), regarded as the biggest carp pond in Europe. This is also the oldest fish farm in Serbia, established in 1892.

Target species of fish farming include carp (*Cyprinus carpio*) with 80 % of share, grey bighead (*Arystichthys nobilis* L.) with 10 % - share, grass carp (*Ctenopharyngodon idella* L.) with 5 % - share, while the other kinds of fish (European catfish *Silurus glanis* L., pikeperch *Sander lucioperca* L, pike *Esox lucius* L.) totals up to 5 %.

Cormorant` diet analysis was assessed during the spring (breeding season) and winter period. Samples were collected from the colony, during the nesting season, in the period of incubation and of the most intensive feeding of cormorant nestlings period (April – June). Samples consisted of fish vomited by the nestlings or thrown down from nests. Determination of samples was performed in laboratory. In case of fully preserved fish samples, length and weight was recorded.

Cormorant's diet during the winter was studied using pellet analyses. Pellets were collected during the November and February at the cormorants' night roosting location, which has been located at the Stari Begej (Old Begej River) for last few years. Determination was performed according to the fish bone remains found in pellets, primarily parts of head skeleton: otoliths, pharyngeal bones and chewing pads. Determination method included comparative osteology collection IMSI as well as the Remainings Determination Key (Marz 1987).

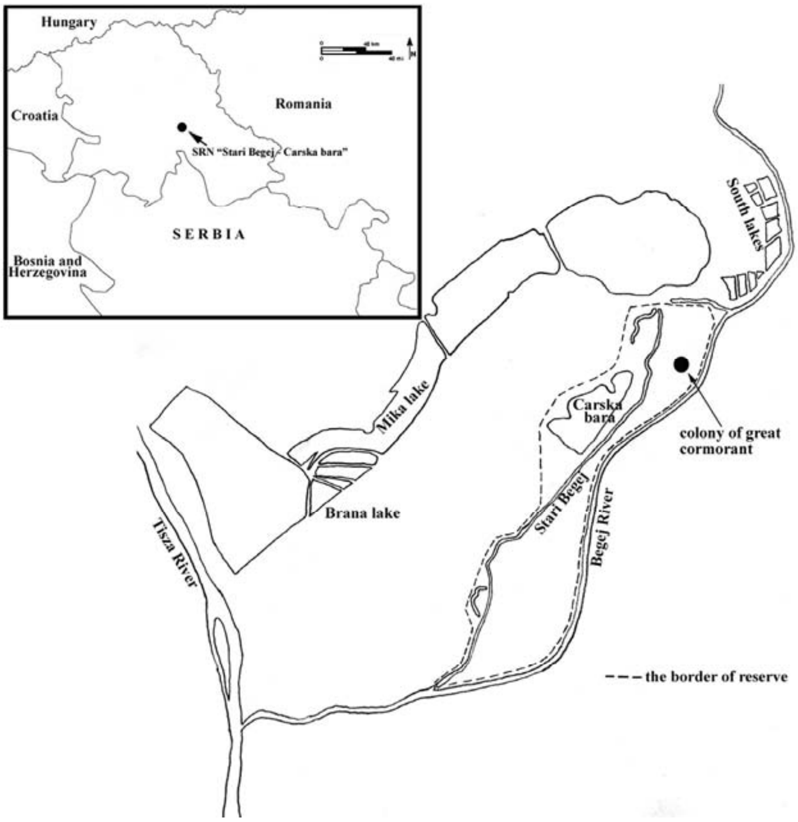

Figure 1. Map of research area

Samples for analyses of fishes' injuries caused by cormorants were collected during the autumn fishery season and fish transfer from one pond to another. One year old injured fish were randomly selected during autumn (November) relocating period from one of the ponds Južno (consist of 5 ponds in the area of 2 ha) to another. Two and three year old wounded fish were collected simultaneously from ponds Brana (29 ha, two-year old) and Mika (188 ha, three-year-old) at the sorting desk in on-growing carp ponds Ečka. Two-year-old carp (common and mirror) were collected just after injuring caused by cormorant attack. Besides carps (common and mirror) five other fish species were examined (pike, European catfish, prussian carp *Carassius gibelio* L., grasscarp, and black bulhead *Ictalurus melas* Le Sueur). According to company documentation, Južno ponds stocked 25000 head/ha of one month-old carps and 633 kg/ha of two-and three year-old carp.

Digital images of injured fish (JPEG format, 1024 X 768 pixel resolutions) were handle with commercial program Motic Images Plus 2.0 using tools for calculates and displays area statistics. In order to show differences between injured and healthy fish a ratio of individual weight (grams) and total length (TL in mm), fish condition coefficient (Fulton's coefficient of condition, $FCC=(W/TL^3) \bullet 100$) was used. Statistical differences between FCC values were evaluated by means of the nonparametric two-tailed Mann-Whitney test.

Samples of carp skin were taken near the wound or the scar, using standard histological technique of paraffin embedding and haematoxylin and eosin staining, HE. For histological analysis and microphotographs, Leica DM LS light microscope equipped with the DC 300 camera was used. Patohistolological analysis of the lesion of carp skin made by cormorant were carried out in order to assess the degree of damages and estimate the potential of regeneration.

Results

During the nesting period, 94 fish caught by cormorants were collected, of which 49 fish were complete and showed no signs of digestion. During this period two kinds of fish dominated the diet, carp with 29.8 % of share and Prussian carp with 60.6 % of share (Table 1). The other species were sporadically included in diet. Standard length of fish included in cormorants' diet was between 7.6 cm and 33cm. The biggest prey was pike with 33cm of length. Average length of the prey was 17.4 cm. The caught fishes were between 13.3 to 347g of weight. Standard length of the two most representative kinds included in diet is 11.9 ± 3.9 cm for Prussian carp and 15.7 ± 3.3 cm for carp. Average weight of Prussian carp was 124.6 ± 70.4 g at the beginning of April and 136.4 ± 16.3 g in May. Economically significant species carp, grass carp and pike represented one third of cormorants diet during the nesting period.

Table 1. Diet composition during breeding season of great cormorant

Species	N	%	Fish length, mm			Fish mass, g		
			Mean	Min.	Max.	Mean	Min.	Max.
Mirror carp (*Cyprinus carpio*)	24	25.5	158	110	200	161.1	51	347
Scaly carp (*Cyprinus carpio*)	4	4.3	156	144	168	118	106	130
Prussian carp (*Carassius gibelio*)	57	60.6	146	76	235	135.56	13.3	276
Pike (*Esox lucius*)	1	1.1	330			225		
Burbot (*Lota lota*)	2	2.1						
Black bulhead (*Ictalurus melas*)	4	4.3			223			216
Bighead goby (*Neogobius kessleri*)	1	1.1	120			33		
Grass carp (*Ctenopharyngodon idella*)	1	1.1	135			40		
Total	94		174.2	76	235	118.7	13.3	347

Seventeen species of fish (211 specimens) were found in 49 cormorants' pellets (Table 2). A cormorant`s pellet contained the remains from 1 to 24 fish specimens (median = 4.3). In qualitative composition there were nine species of Cyprinid which makes 50% of all identified species in diet and they made 50% of quantitative composition. The remains of Prussian carp were found in 28 pellets, being a predominant prey (27.49%) during winter season. It is interesting that in the beginning of winter season dominant food included tri species of the *Gymnocephalus* spp., while, after that, cyprinid species dominated in cormorant's diet. Economically significant fish species, such as carp, European catfish, pike and pikeperch are represented in cormorants' winter diet at around 15 %.

The area of mirror carp body injured by cormorants occupied from 4.53±3.76 % one-old-year, 7.64±7.47 two-old-year, to 2.53±3.33 three-old-year (Table 3, Figure 2). Both types of wounds: the damaged epithelium (scars) and deeper sub-dermal wounds were recorded in all age categories of the mirror carp. The maximal extent of scars (23.15%) in individual mirror carp were recorded in two-year-old and maximal area of deep sub-dermal injure (8.38%) were recorded in same age category. In one two-year-old common carp scars amount 63.05% of body surface. The maximal injured area of body surface in pike was 19.24% in European catfish 4.49% and in 41.7%. The biggest individual fish injured by cormorant were 2700 (mirror carp), 966 (common carp), 1575 (pike), 2300 (European catfish), 631 (grass carp) and 315 (Prussian carp).

Table 2. Diet composition of great cormorant during winter

Species	November 2007		February 2008.		TOTAL	
	N	%	N	%	N	%
Carp (*Cyprinus carpio*)	6	6.82	7	5.69	13	6.16
Prussian carp (*Carasius gibelio*)	12	13.63	46	37.4	58	27.49
Roach (*Rutilus rutilus*)	7	7.95	11	8.94	18	8.53
Bream (*Abramis brama*)	3	3.41	1	0.81	4	1.89
White-eye bream (*Abramis sapa*)			1	0.81	1	0.47
Silver bream (*Bilcca bjoerkna*)			10	8.13	10	4.74
Nase (*Chondrostoma nasus*)			1	0.81	1	0.47
Bighead carp (*Aristichthys nobilis*)			1	0.81	1	0.47
Barbel (*Barbus barbus*)			1	0.81	1	0.47
Pike (*Esox lucius*)	1	1.14			1	0.47
Perch(*Perca fluviatilis*)	3	3.41	10	8.13	13	6.16
Pikeperch (*Sander lucioperca*)	6	6.82	10	8.13	16	7.58
Ruffe (*Gymnocephalus cernuus*)	23	26.14	10	8.13	33	15.64
Balons ruffe (*Gymnocephalus balloni*)	26	29.54	6	4.88	32	15.16
Striped ruffe (*Gymnocephalus shratcery*)	1	1.14	2	1.63	3	1.42
Asp (*Aspius aspius*)			4	3.25	4	1.89
European catfish (*Silurus glanis*)			2	1.63	2	0.95
TOTAL	88		123		211	

Table 3. The area of wound origin by cormorant strikes as percentage (mean± standard deviation) of total body surface.

Species	age	n	TL(mm)	W(g)	scars (%)	deep injures (%)	total (%)	FCC
Cyprinus carpio (mirror)	1	44	219.5±0.9	81.75±51.7	4.5±3.8	0.49±0.8	4.5±3.8	2.1±0.8
Cyprinus carpio (mirror)	3	36	407.5±5.5	1327.8±610.3	2.6±3.4	0.39±0.4	2.5±3.3	1.9±0.3
Cyprinus carpio (common)	3	6	278.3±7.2	338.33±224.7	14.1±7.3	0.33±0.2	14.2±7.2	1.4±0.2
Cyprinus carpio (common)	1	2	198.5±2.1	139.5±50.2	5.5±3.6	0.33	5.6±3.9	1.7±0.1
Silurus glanis	3	2	590±8.55	1660±905.1	3.9±0.8	0	3.9±0.8	0.8±0.1
Esox lucius	3	9	495.3±5.3	977.2±386.3	10.4±5.7	2.07±2.7	11.5±5.1	0.8±0.1
Ctenopharyngodon idella	2	3	333.3	451±272.9	25.1±21.5	0.23	25.1±21.3	1.0
Carassius gibelio	1	7	222.4±1.1	220.86±50.3	18.8±8.8	2.41	19.2±8.0	2.1±0.7
Ameiurus melas	1	1	275	288	6.7	1.37	8.1	1.4
Cyprinus carpio (mirror)	2	42	322.2±45.7	628±348	6.5±6.6	3.45±6.7	7.6±7.5	1.7±0.2
Cyprinus carpio (common)	2	12	310.7±32.1	525.92±174.8	18.4±15.9	0	18.4±15.9	1.7±0.2

The difference between FCC in healthy (Table 4) and wounded (Table 3) one- year- old mirror carp are statistically significant on 0.05 levels (Mann-Whitney U test). There is not any statistically significant difference ($p>0.05$, Mann-Whitney U test) between healthy and injured two- year-old mirror carp in FCC (Table 3.4). Also, no difference ($p>0.05$, Mann-Whitney U test) in FCC were found between mirror carp with deep sub-dermal wound and mirror carp with scars. The statistically significant difference ($p= 0.34$) in FCC not exist between healthy and injured two-year-old scaly carp (Table 3.4).

According to pathohistological analysis on injured carp skin can be notice hyperplastic epidermis and spongiotic infiltrated with lymphocytes. Identified epithelial hyperplasia most probably is a result of wound healing and inflammation. Stratum spongiosum of the dermis and the hypodermis heavily infiltrated with leucocytes indicating inflammation.

Table 4. Healthy mirror carp, basic data. FCC (Fulton's coefficient of condition).

Species	age	n	TL(mm)	W(g)	FCC
Cyprinus carpio (mirror)	2	19	349±64.5	770.3±381.9	1.68±0.3
Cyprinus carpio (mirror)	1	7	135.4±13.5	47.1±14.3	1.85±0.2
Cyprinus carpio (scaly)	2	6	365.8±26.2	901. 7±197.9	1.84±0.28

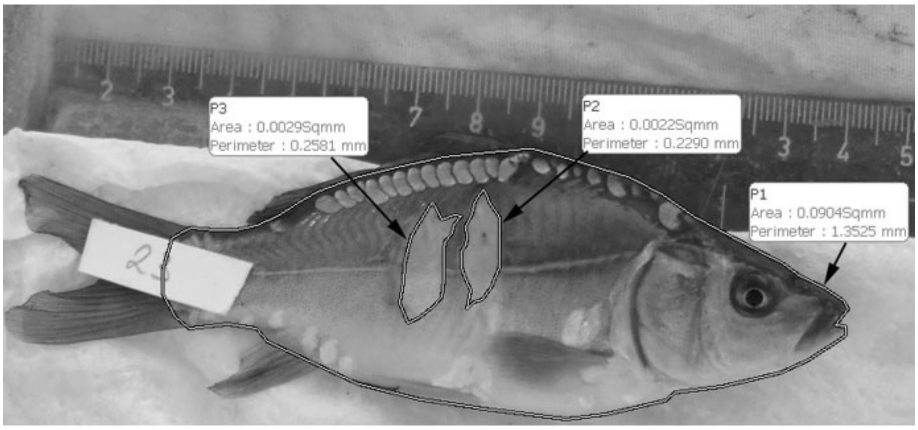

Figure 2. Marked scars area of injured fish

Discussion

Cormorant diet depends on habitat. Roach (*Rutilus rutilus* L.) and perch (*Perca fluviatilis* L.) are the main prey items of cormorants in Switzerland (Suter 1997). Roach, bream (*Abramis brama* L.) and perch are the most significant prey species of cormorants nesting in NW Overijssel, Holland (Veldkamp1995). In France, bream is the most representative diet of cormorants during winter season on rivers, while silver bream (*Blicca bjoerkna* L.), rudd (*Scardinius erythrophthalamus* L.) and roach are also regular prey (Santoul 2004). Analyses of diet of cormorants nested near carp ponds of Donji Miholjec in Croatia as well as in Golysz in Poland, show that carp was dominant in diet at around 70% (Opačak 2004; Gwiazda 2004). Both sites recorded very low presence of Prussian carp: 1.1 % in Croatia, and 4.3 % in Poland. Similarly, Prussian carp was not recorded in diet of cormorants nesting in the Kopački Rit Swamp in Croatia, although being the dominant catch for fishermen of that area (Mikuška 1983). Opposite to the Kopački Rit, this study asserted Prussian carp as dominant prey of cormorants of the Carska Bara – Stari Begej habitat (60.64% - nesting season; 27.49% - winter season; 37.7% - total). Economically significant fish species (carp, grass carp, grey bighead, pikeperch, European catfish and pike) participate in cormorant's diet with about 20%. In Tisza and Begej River, Prussian carp dominates over other cyprinid species, its abundance is associated with a decrease in the number of native autochthones species. Whereas fishpond supply with water from these rivers, contains a significant amount of trash fish entering the fishpond. On the other hand, during traditional fish farm management, when ponds are not emptied entirely during fish harvesting, an opportunity is provided for trash fish to contaminate future farmed stocks. The results of this study indicate that commercially less valuable species may replace commercially important fish species in cormorant's diet in traditional fish farm management (semi-intensive management).

One of the primary concerns for fisheries managers is mortality of fish discards and escapees that is induced by capture and escape. Other problem includes either cormorants which may cause damage to livestock or farm facilities directly, indirectly or both. Direct damage results when the fish is killed or seriously injured by the cormorant and is therefore lost for production. One year old carp is the most endangered age class, because in spring season during the breeding period of great cormorant, these fish specimens contribute about 30% in their diet (mirror carp – 25.5%; common carp – 4.25%). Other age classes of carp were not recorded in cormorant diet in spring season.

Indirect damage is highly variable, and includes non-lethal wounding of fish; chronic stress with a consequent reduction in feeding efficiency or health; transfer of harmful disease-causing organisms, including bacteria, viruses and parasites; and sometimes even physical damage to the animal enclosure system leading to escapement. Scaring of healed wounds reduces the commercial value of afflicted fish.

Often, the indirect damage caused by a cormorant can result in a greater economic loss than that caused by direct damage. Two and tree year old carp specimens are more exposed to indirect damage.

FCC uses for comparison between healthy and wounded fish in the case of two-year-old carp (mirror and common) did not show statistically significant difference, contrasting to study of Adamek *et al.* (2007). The reason of this discrepancy lay in fact that fish from pond Brana were collected shortly after injured. The maximum size of wounded fish (carp 50 cm long ; 2700 g and 8 mirror carp weighting over 2 kg) is in general agreement with Davies *et al.* (1995) who concludes that cormorants can attack fish of over 2 kg in weight. It must be stressed that the size spectrum of wounded fish increases during pond draining at harvesting, including bigger fish that are reported in this case study.

This study indicates cormorants cause damage on economically significant fish species in fishponds, and that future investigation could bring precise and more detailed data about their impact.

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Fishing activities and pollution risk in the Köyceğiz Lagoon System

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Abstract The Köyceğiz Lagoon System is located in south-western Turkey and was declared a Special Protection Area in 1988. The area is composed of terrestrial structures of various qualities around Köyceğiz Subsidence Lake. It is a brackish lake which is fed by springs and several streams. Major commercial fish species are gray mullet (*Mugil cephalus* (L.)), eel (*Anguilla anguilla*(L.)), sea bass (*Dicentrarchus labrax*(L.)), gilt-head bream (*Sparus aurata* (L.)), common carp (*Cyprinus carpio* (L.)) and blue crab (*Callinectes sapidus* (Rathbun)). Fishing activities are carried by DALKO (Dalyan Fisheries Products Cooperation). In the last few decades, the amount of fish caught by DALKO decreased from 440 t to 180 t. The lagoon system and the beach are very important for sea turtles (*Caretta caretta* (L.), *Trionyx triunguis* (Forskal), but they are under pollution pressure from agricultural run-off and untreated urban waste. Heavy boat traffic on the canals between the lake and the sea causes heavy metal pollution, stress on fish and wave-damage to reed beds. In this study, the present situation of the lagoon system and fishing activities are evaluated.

Introduction

Lagoons are coastal bodies of water that can be permanently or temporally connected to the sea. Lagoons are mostly shallow and contain mixohaline or brackish water and are usually quite biologically productive and when compared to the other water sources, they have unstable physical and chemical features. Water depth in these habitats is limited, there is an abundance of organic matter and nutrient content to support the growth of flora and fauna. In the Mediterranean area, lagoons characteristically have mixed populations of brackish or euryhaline fish which enter in the spring and attempt to return to the sea in autumn (Dill, 1990). There have been many studies conducted on the lagoons that cover 75% of the coastal area around the world (UNESCO 1982; Buhan 1998; Marshall & Elliott 1998; Akın *et al.*, 2005). The lagoons in Mediterranean area form 8.5% of surface area and 45% of he number of the approximate 130 lagoons worldwide (Crivelli 1991), illustrating the importance of Mediterranean lagoons.

In Turkey, the number of lagoons in which fishing has been conducted over the years is 36, however only in 12 of them fishing is actively conducted today. The fish catch yield has declined in recent years due to damage of the lagoon structures. Köyceğiz Lagoon System is one of the most important active lagoon systems, it is a sensitive but productive habitat for Turkey and the Mediterranean (Kazancı *et al.* 1992), producing a yield of 32 kg ha^{-1} in 2007. This system covers nearly 15% of the all lagoons along the coast of Turkey. It has been declared as “Special Protected Area” in 1998 by the Turkish Ministry of Environment and Forestry.

Köyceğiz Lake can be divided into Köyceğiz basin and Sultaniye basin, which have physical, chemical and biological differences. Due to the morphological features of the lake, the water body is divided in two layers of differing hydrology therefore the lake is classified as meromictic (Kazancı *et al.* 1992). The farming of citrus fruits and the use of greenhouse farming is intensively carried out in the surrounding land. Honey bee farming and forestry products are other important commercial activities in the area.

There are 491 registered and 100 unregistered boats in the area, of these registered vehicles, 359 work for six agencies, transporting tourists on the lake and into lagoon systems. 265 of these boats belong to Dalyan town and 94 belong to Köyceğiz.

On the Lagoon System, only commercial fishing is practiced, sport fishing is not permitted. Yerli (1989) has conducted a study on the growth parameters of mullet and other commercial fish species, as well as the limnology of the lagoon system. Buhan (1998) obtained detailed data on mullet and described problems occurring within the lagoon fishery. Classifying the mullet according to breeding periods with summer mullets ((*Mugil cephalus* (L.), *Liza saliens* (Risso)) and winter mullets (*Liza ramada* (Risso), *Liza aurata*(Risso), *Chelon labrosus* (Risso)) in two groups.

Study area

Köyceğiz Lake and Lagoon System are located 36^{o} 45" and 37^{o} 15" North latitude and 28^{o} 22' 30" and 28^{o} 52' 30" East longitude in Muğla, the Southwest of Turkey. The lagoon system covers an area of 5400 ha and is connected to the sea by a 10 km long canal (Fig. 1). The width of the canal varies between 5-70 meters and the depth between 1-6 m. Fishing on the lagoon system in Köyceğiz Lagoon System has been practiced since 1971, will 80% of the fish farming is practiced along the canal. The farm is situated in that location because the channel system is a more suitable habitat than the lake, even though the lagoon system is richer in terms of benthic invertebrates and planktons. In addition to the main fish trap in the Dışbükü location, there are 3 more fish traps on Sülüngür Lake.

Figure 1. Köyceğiz Lagoon System.

Results

Köyceğiz Lagoon System contains a rich diversity of fish fauna. There have been detailed studies on the fish fauna of lagoon system and running waters that enter Köyceğiz Lake (Yerli 1989). Bilecik (1993) reported fish species in Köyceğiz Lagoon system and Buhan (1998) studied the commercial fish species in the lagoon. Barlas *et al*. (2000) reported 8 species and 2 subspecies among the fish fauna of Yuvarlakçay stream. Özdemir *et al*. (2003) reported five fish species from Namnam stream. Balık *et al*. (2005) reported 13 fish taxa belong to 9 families from Yuvarlakçay stream. Yılmaz *et al*. (2006) reported 20 fish taxa from Köyceğiz Lake, 6 fish taxa from Namnam stream and 11 fish taxa from Yuvarlakçay stream. In total, these researchers reported 64 fish taxa from Köyceğiz Lagoon System and the running waters that flow into lake (Table 1).

Table 1. Fish species of Köyceğiz Lagoon system and running waters of Köyceğiz Lake Basin

Fish species	References	Fish species	References
Mugil cephalus	a, b, c, f, g, h	*Phycis phycis*	b, h
Liza ramada	a, b, c, d, g, h	*Aphanius fasciatus*	g
Liza saliens	a, b, c, g, h	*Engraulis encrasicolus*	b, h
Liza carinata	b, c, h	*Tilapia sp.*	b, h
Liza aurata	b, g, h	*Tilapia zillii*	d, f, g
Liza labeo	g	*Mullus barbatus*	b, h
Oedalechilus labeo	a, b, h	*Boops boops*	b, h
Chelon labrosus	a, b, c, g, h	*Sarpa salpa*	b, h
Sparus aurata	a, b, h	*Pagellus acarne*	h
Dicentrarchus labrax	a, b, h	*Spicara smaris*	b, h
Anguilla anguilla	a, b, d, e, f, g, h	*Xyrichthys novacula*	b, h
Pagellus mormyrus	a, h	*Sparisoma cretense*	b, h
Diplodus annularis	a, h	*Trachinus araneus*	b, h
Diplodus sargus	b, h	*Uranoscopus scaber*	b, h
Diplodus vulgaris	b, h	*Scomber scombrus*	b, h
Knipowitschia caucasica	f	*Sphyraena sphyraena*	b, h
Epinephelus aeneus	a, b	*Scorpaena scrofa*	b, h
Lichia amia	a, b, h	*Trigla lyra*	b, h
Morone labrax	g	*Bothus podas podas*	b, h
Cyprinus carpio	a, g, h	*Remora remora*	a, b, h
Silurus glanis	a, g	*Capoeta capoeta bergamae*	b, d, g, h
Leuciscus cephalus	a, d, e, f, g	*Capoeta capoeta angorae*	f, g
Leuciscus smyrnaeus	g	*Gobius ophiocephalus*	d, g
Leuciscus borysthenicus	f	*Blennius fluviatilis*	d, f, g
Barbus plebejus escherichi	a, d, e, f, g	*Cobitis taenia*	d, g
Atherina boyeri	f, g	*Cobitis vardarensis kurui*	f
Atherina spp.	h	*Cobitis simplicispina*	g
Gambusia affinis	b, d, f, g	*Ladigesocypris ghigii*	e
Dasyatis pastinaca	b, h	*Orthrias angorae*	e, g
Sardinella aurita	b, h	*Ladigesocypris ghigii ghigii*	f, g
Synodus saurus	b, h		

a: Yerli, 1989; b: Bilecik, 1993; c: Buhan,1998; d: Barlas et al., 2000, e: Özdemir et al., 2003; f: Balık et al., 2005; g: Yılmaz et al., 2006 h: Akın et al., 2005

In addition to the fish fauna, other important organisms in the lagoon system are; *Penaeus kerathurus, Callinectes sapidus, Sepia officinalis, Loligo vulgaris, Octopus* *vulgaris* and *Caretta caretta* in Köyceğiz (Bilecik 1993). In recent years, blue crab, *Callinectes sapidus* (Rathbun 1896) have been consumed by tourists in the area this species is also an important food for Nile soft-shelled turtle, *Trionyx triunguis* and loggerhead turtle, *Caretta caretta*.

Fisheries in Köyceğiz Lagoon system

Fishing activities are carried out by Dalyan Fisheries Products Cooperative (DALKO) in Köyceğiz Lagoon system. The lagoon system belongs to State and is rented by DALKO through two year contracts. DALKO has 691 members and 49 personnel are employed by DALKO, the company gets help from rural policemen and the Environmental Protection Agency. These prevent the poaching of fish and other wildlife species, as well as regulate rules for fishing in the lagoon system.

According to DALKO (Figure 2) during the period between 1972–2006, the commercial catch in Köyceğiz Lagoon varied from the lowest catch of 52.125 t in 1972 to the highest catch of 443 949 t in 1994. Mullet is the main commercial fish on Köyceğiz Lagoon system (Table 2), in 2006 160.386 t mullet were caught. 5 t of Gilt head bream and 5 t of sea bass were also produced from the lagoon. Eel is also an important fish species caught in the lagoon, most of the eels catch is exported because it is not often consumed by Turkish people.

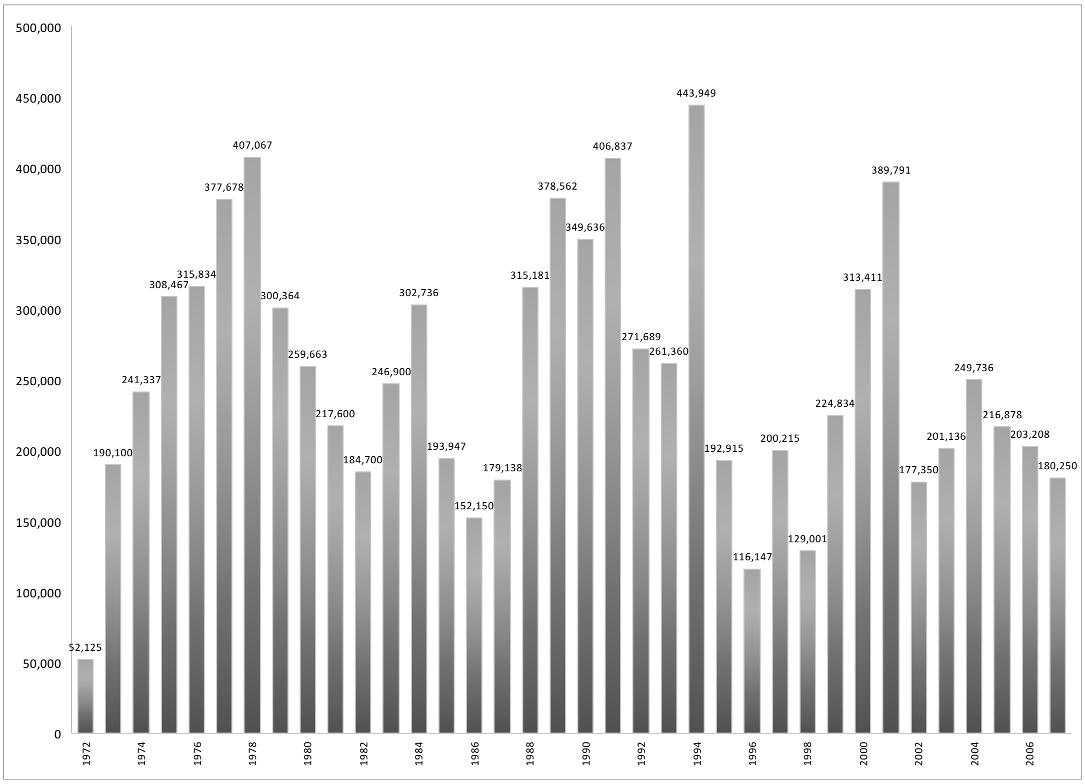

Figure 2. Fish yield (kg) of DALKO between 1972 and 2006 (Data obtained from DALKO)

According to Dill (1990), the average yield for Turkish lagoons is between 36.4 kg ha^{-1} yr^{-1} to 60 kg ha^{-1} yr^{-1} and the average yield from Köyceğiz Lagoon System was 59 kg ha^{-1}. McAllister (1993) reported that the average yield on Köyceğiz Lagoon System was 43 kg ha^{-1}. In 2006 the actual average yield was 33.4 kg ha^{-1}.

Table 2. Fish yield in 2006 by DALKO

Fish	Yield kg
Mullet	160,386
Gilt-head bream	4662
Sea bass	4964
Eel	9438
Grouper	489
others	311
Total	180,250

Fish traps on Köyceğiz Lagoon System are constructed from wooden material and canes (Table2). The fishing activity is practiced throughout the year and is mostly dependent on the mullet fishery. All species caught belong to Mugilidae family, but it was observed that most of the species caught in summer were *Mugil cephalus* and *Liza saliens* while most of the species caught in winter were *Liza ramada*, *Liza aurata* and *Chelon labrosus*. The highest yield of mullet was in February with 32 025 t (Table 3).

Table 3. Fish yield according to monthly records in 2006 (kg).

Fish Period	Mullet	Gilt-head bream	Sea bass	Eel	Grouper	Others	Total
January	10,250	125	84	4229	43	74	14,805
February	32,025	343	413	5209	54	19	38,063
March	27,559	91	735	0	63	0	28,448
April	5934,	153	544	0	48	0	6679
May	2390	317	527	0	39	0	3273
June	1911	297	330	0	46	45	2629
July	9333	701	387	0	63	50	10,534
August	18,716	856	251	0	37	31	19,891
September	19,165	190	521	0	23	0	19,899
October	4835	159	288	0	13	0	5295
November	14,911	803	402	0	22	21	16,159
December	13,357	627	482	0	38	71	14,575
Total	160,386	4662	4964	9438	489	311	180,250

Discussion

According to our observations, and personal conversations with farmers, high amounts of pesticides are applied in the region to help with intensive cultivation. The residues of pesticides accumulate in the soil and can be carried to the lagoon via surface waters and by drainage canals.

There are important citrus fruit farms around Namnam, Yuvarlakçay and Köyceğiz Lake. Due to the use of pesticides, there has been ecosystem destruction and as a result a decrease in fish yield. Farmers are in direct contact with pesticide suppliers. The use of these substances is unregulated and increasing. The use of pesticide must be controlled by organizations such as the Ministry of Agriculture. All farmers must be registered and hold a ration card so that the usage can be monitored. Alternative biological methods should also be recommended to the farmers, organic farming and alternative farming should be supported in the region.

The monitoring of physical and chemical characteristics of the lagoon system is regularly conducted by Environmental Protection Agency for Special Areas, but a detailed monitoring project must be developed for the region. Since 2002, domestic waste has been prevented from entering the lagoon system by the activation of waste water purification in Köyceğiz and Dalyan.

Another issue is the introduction of exotic species such as *Tilapia zillii*. According to the fisheries in the area, after the introduction of this species to the system, many native fish species have been affected, especially common carp, *Cyprinus carpio*. Research into the effects of this species should be undertaken to gain a better understanding of these. This species has a rapid growth rate and reaches sexual maturity rather early. The introduction of such species to both the lake and lagoon must be under control by Governmental organizations.

The cooperative must be supported and use modern techniques for lagoon fishing. Fish caught in the lagoon should be evaluated in terms of their suitability to be marketed. As it is seen in Tables 2 and 3, the fisheries of the region are mainly dependent on the mullet fish that are caught in traps during the spawning migration period. The population should not be dominated by younger age classes that do not have the ability to breed. To prevent this, migration and breeding periods of mullet should be explained by seminars to the fisherfolk. Such seminars could also develop the knowledge of fishermen regarding the fish trap fishery, to understand geological, meteorological, hydrographical and hydrobiological data that affects productivity. This will help fishermen to determine the optimum fishing conditions (Yerli 1989). Scientific solutions must be developed for marketing and selling the fish caught in the lagoon.

Reed fields surrounding the lakes and lagoons provide a convenient habitat for many invertebrate and vertebrate species. These reed fields and the shallow canal bottom are also important resources for fish to feed on and use as a substrate to lay eggs upon. Boat traffic and the noise of boat motors affect fish migrations and damage these reed fields. The tourist-boat traffic on lagoon system must be regulated to reduce disturbances and support should be given to boats powered by solar energy or other sustainable resources. As a note, last year (2007) one boat powered by solar energy took trips in the lagoon. The motors of boats must be assessed, less powerful motors should be allowed in the fishery as powerful motors can damage the bottom of canal. Boats must not discharge their bilge waters into the lagoon.

The local people as well as visitors should be educated regarding the sensitivity of the Köyceğiz Lagoon System. Governmental and Non-Governmental organizations should play an active role in protecting the lagoon system. Ecological trips with educated guides should be arranged to promote the natural and ecological beauty of the region.

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