Case study

#4 Pike-perch in south-east Europe

#5 Mussels in the North Sea

#6 Oysters in the North Sea

Species background and economics

The Danube Delta Biosphere Reserve (DDBR) was established to harmonise sustainable development with biodiversity conservation.

Within the DDBR, Razim Lake supports a multi-species fishery targeting more than a dozen freshwater fish species.

Four species provide up to 80% of commercial catches: pike-perch (*Sander lucioperca*), bream (*Abramis brama*), gibel carp (*Carassius gibelio*) and roach (*Rutilus rutilus*) (Figure 2).

These four Eurasian freshwater fish species also tolerate brackish water and have been widely introduced in temperate waters in western Europe as commercial and recreational targets.

The market price of pike-perch is twice to three times higher than the other three species.

From 1961 to 2017, the average annual catch in Razim Lake was 1400 tonnes with contributions from pike-perch, bream, roach, and gibel carp equal to 16%, 30%, 15% and 19%, respectively.

The large annual catch in 1994 (3000 tonnes) was followed by a sharp decline to an average of ~500 tonnes in the last two decades. These fisheries supported about 500 fishermen in the past but only half this number are active now. Their main gear is large (400 m) seine nets with cod-end mesh sizes of 40-50 mm, fished between October and March.

Additional gear such as fyke nets and trap nets ("talian" – composed of three fyke nets) are used throughout the year.

These fish spawn in April-May, depending on latitude and altitude, after temperatures of 10-14°C (pike-perch) and 15-20°C (cyprinids) are reached.

Spawning occurs on sand, gravel, or among exposed plant roots (pike-perch) or fresh flooded vegetation (cyprinids). During the spawning season, the fishery is closed.

Climate-driven warming of lake Razim is expected to advance the spawning period (up to several months) and more frequent summer heatwaves (when waters exceed 25-28°C) are expected to cause water scarcity, modifying the rates of survival and growth as well as the distribution of fish.

Climate change will interact with additional drivers such as habitat degradation (changes in hydrology and sediment and nutrient loads) and overexploitation to potential decline the productivity of these freshwater fisheries.

Expected projections under climate change

The E-HYPE hydrological model (Kay, 2017, Donnelly et al, 29116, https://hypeweb.smhi.se/explore-water/climate-impacts/europe-climate-impacts/) provides projections of physical and chemical variables for the catchment area feeding of Razim Lake, from 1971 to 2100 (RCP4.5 and RCP8.5) with daily resolution.

According to this model, river water temperature will increase up to 4°C by the end of the 21st century under the business-as-usual (RCP 8.5) scenario (Figure 2a). Projections for the moderate-emissions (RCP 4.5) suggest a similar warming for the first half of the century, but then a levelling off at a 2°C increase.

River discharge rates are projected to be similar to the present day but with increased variability under RCP 8.5 (Figure 2b).

Nitrate and phosphate levels show no trend under a business-as-usual (RCP 8.5) scenario, but river nutrient loads depend strongly on patterns of land use in the catchment area, and this was not part of the modelling study.

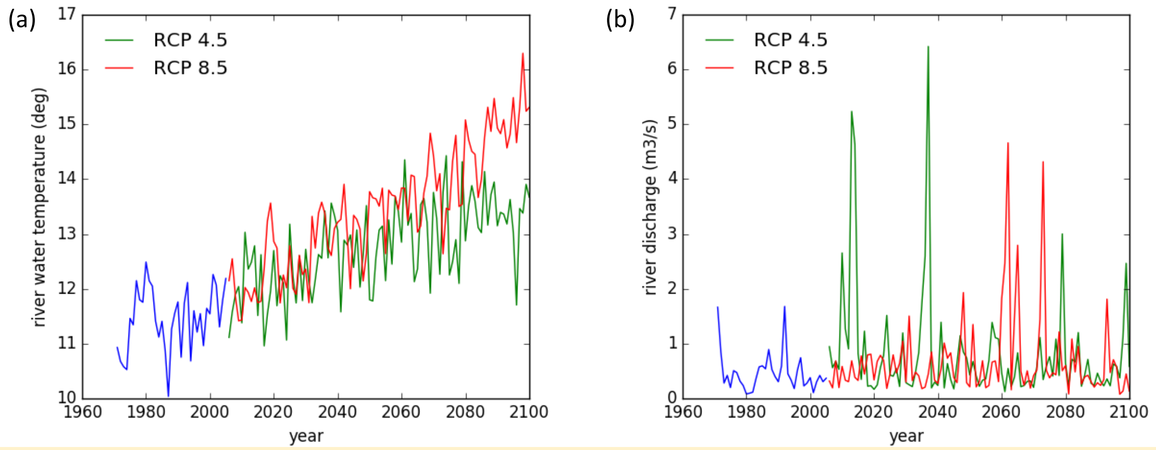


Figure 1 Annual mean (a) water temperature (b) river discharge rate for the catchment feeding Razim Lake, as projected by the E-HYPE model.

Socio-economic developments

Based on the responses received from the stakeholder regarding the four scenarios of climate change developed by CERES, most of them consider extremely important 2 of them: Local Government with local solutions for economic, social and environmental sustainability and Global Sustainability, which will be essential for future developments, with changes in economic structures, the development of clean technologies, and global solutions for sustainability.

All stakeholders surveyed have already observed signs that can be attributed to climate change, the most important being extreme weather conditions, water quality, sea level rise and water temperature increase.

They have mentioned that the impact on fisheries due to climate change has an impact on the biological productivity of aquatic ecosystems with effects on the biological characteristics of each species, producing socio-economic consequences to wat they should to adapt.

Key research needs

It is important to understand how projected warming will influence the productivity and distribution of the four most commercially important fisheries targets to provide science-based advice for sustainable management of these freshwater stocks.

A second, related challenge for sustainability of the inland fishery is to develop mitigation or climate adaptation tools and strategies in order to guides climate-ready, suitable management tools for regulation and sustainable fishing.

Scenarios describing future society and economy

CERES uses models to estimate economic developments in Europe's fishery and aquaculture based on select, pre-defined physical and socio-economical future scenarios.

These future scenarios were specified by industry partners and stakeholders in the first year of CERES (e.g. fish prices, fuel prices, technological advancements, regional policy issues, etc.).

'World Markets'	**'National enterprise'**
• Personal independence, high mobility and consumerism • Reduced taxes, stripped-away regulations • Privatised public services • High fossil fuel dependency • Highly engineered infrastructure and ecosystems	• National isolation and independence • Protection of national industry • High resource intensity and fossil fuel dependency • Low investment in technological development and education • Low priority for environmental protection
'Global sustainability'	*'Local stewardship'*
• High priority for welfare and environmental protection • Cooperative local society • Intense international cooperation • Increased income equality • Low resource intensity and fossil fuel dependency	• Promotion of small scale and regional economy • Less attention for global (environmental) problems • Moderate population growth • Income of industrialised and developing countries converge • No overarching strategy to manage ecosystems

Table 1 Outline of the four social-political scenarios developed by CERES partners and stakeholders

CERES research

For Razim Lake pike-perch and cyprinids storyline was performed following activities:

- reviewed the literature on direct and indirect effect of CC on the physiology, productivity and distribution of Razim Lake fish
- compiled historical data on fish catches (1961-2017) and environmental factors
- performed statistical analysis to discriminate historical shifts and trends in fishers catches
- utilised e-HYPE model results (1971-2100) results to run an environmentally sensitive virtual population analysis (VPA) model for MSY predictions (and fish productivity estimates) under two IPCC scenarios (4.5 and 8.5). Natural fish productivity (kg/ha*year) estimated by the Léger-Huet method is an alternate model used to predict trend of global natural fish productivity of Razim Lake, under pressure of increase of water temperature.
- engaged stakeholders using questionnaires and round table discussions
- Performed a Bow-Tie analysis to summarise stakeholder viewpoints.

A

B

C

D

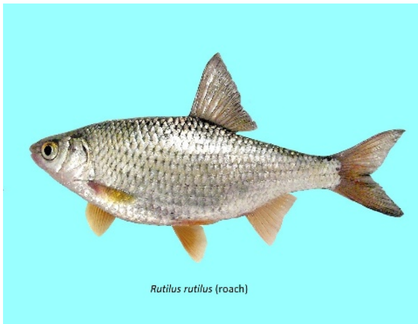
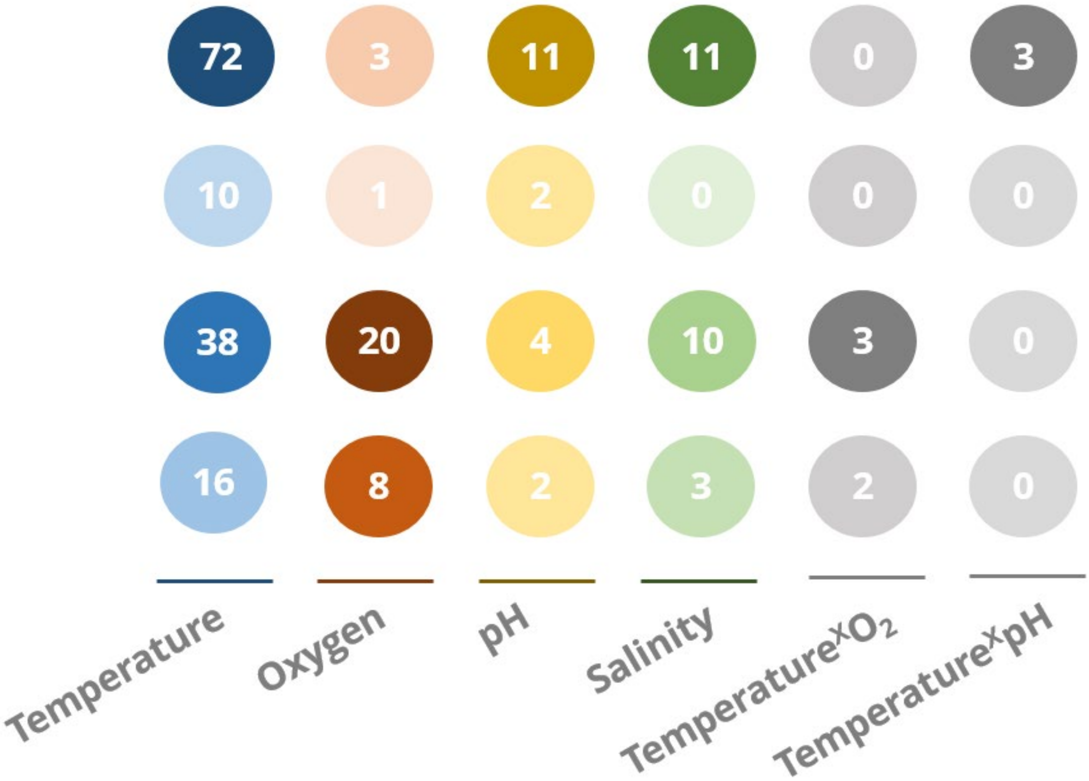


Table 1 A) Pike-perch (Sander lucioperca) B) bream (Abramis brama) C) gibel carp (Carassius gibelio) D) roach (Rutiluds rutilus). *Ownership Otel 2017*

Biological consequences

Research published on finfish in European seas



- Pike-perch consists of 6 genera ranked from 9 to 22 out of 28 European fish and shellfish genera reviewed here. In total SL 4 comprises 22 studies. Few studies were found outside Europe.
- Most studies on perch were from Scandinavia (11).
- Well studied were especially embryos but all other life stages are well covered, as well.
- Most studies were conducted on the effect of temperature on growth and mortality

Although no studies have studied the direct effects of CC on fish from the region, studies conducted on pikeperch from Dutch and Finnish lakes suggest a positive relationship between recruitment (0+ Year-Class Strength) and warming (sum of degree-days at temperatures above 14°C in spring and summer.

The gap analysis (D2.1) indicated that for inland fishes, including NE Europe cyprinids, the most responses on direct effects of CC of temperature are for growth and physiology, and less for abundance, recruitment, mortalities, reproduction range and temperature tolerance.

These effects are most forceful on early life stage (juveniles and embryo) rather on older life stages (adults).

The seasonality is an important factor on effect of temperature on growth and mortality, increasing in temperature have positive effects of growth, but an increase the mortalities when thermal effect occurs in summer, however, less clear on freshwater fishes.

Few or none research approached to CC effects on inland fish ecological responses on productivity, population dynamics, community structure, distribution shifts, ecosystem function, mainly due to change or loss of habitats.

From 1961 to 2017, landings of pike-perch markedly declined after 1987 while declines in other fish species occurred somewhat earlier. For example, landings of perch considerably decreased after 1983.

Landings for gibel carp which were first reported in the 1970's, peaked in the 1980's and remained high until recent years. This species may have better tolerated eutrophication which started in the 1970s (Figure 3). During this 56-year period, fisheries landings were not related to temperature.

Landings may have declined due to poor water quality (low dissolved oxygen levels) associated with increased nutrient loading after 1980.

Eutrophication caused a well-documented regime shift from clear water to turbid waters dominated by macrophytes and algae leading to a decrease in the diversity of benthic organisms).

Under several assumption and scenarios, the Virtual Population Analysis (VPA) model predicted that increasing water temperature will increase the natural mortality in both RCPs with decreased productivity for RCP8.5.

A subtle decrease in fish abundance occurred along with a slow increase in stock biomass. For sustainable exploitation, however, fishing effort on pike-perch should be decreased while that for the smaller cyprinids species can increase. Reaching MSY for all species at the same time will not be possible since F_{SMY} is different for the different stocks.

Knowing that fishery management in the lake is based on quota levels and not fishing effort, the quota should be constrained for pike-perch as it is the most threated stock from the Razim Lake multi-species fisheries.

The natural productivity of Razim Lake fishes displays no significant increase (1%-3%) from actual (2000-2020) to mid-century (2040-2060) in both climate scenarios (RCP4.5 and RCP8.5). By the end of the century (2080-2100) a doubling of natural fish productivity is expected under RCP8.5. This is due to a significant increase in air and water temperatures from a temperate to a warmer (nearly subtropical) climate associated with RCP8.5.

These estimates need to be viewed with caution since some model parameters were not well estimated and, in future projections, they were assumed to be constant.

Figure 3 Catch landings from Razim Lake. *Ownership I. Năvodaru*

Climate-ready solutions

For bottom-up - mitigation measures

The main control measures that can be taken to limit the effects of climate change on the fishery are: introduce conservation and restoration techniques to improve missing habitats, extend closed seasons, area, moratorium, decrease fishing effort & quota and change recreational fishing to catch and release.

The main mitigation measures that can be taken is to encourage alternative tourism to compensate for loss of banned fisheries, because tourism activity represents an emerging market that has developed in recent years and retains a majority of local labour force in the Danube Delta.

The developments of various tourism forms such as eco-tourism and rural tourism that capitalize on the specific of this traditional community's fishery-dependant represent an alternative for decreasing the pressure on fishery resources.

Other mitigation measures identified were: increase gear/net selectivity, develop aquaculture based on native species, introduce restoration techniques to improve missing habitats (e.g. reduce siltation and increase connectivity), extend closed seasons, area, moratorium, decrease fishing effort & quota, change recreational fishing to catch and release, restocking threatened and in decline species alternative species, increase enforcement for fish stock (e.g. of traceability from fishing to retail markets) conservation local and European.

Policy recommendations

Political managers must allow funding through government incentives or subsidies to help fishermen adopt new technologies to overcome droughts and floods.

It is necessary to take measures at political level, such as:

- establishing a national system for monitoring threatened species,

- expanding the use of the data obtained from the monitoring process by adapting the results obtained using mathematical modelling,

- reducing pressures affecting vulnerable species.

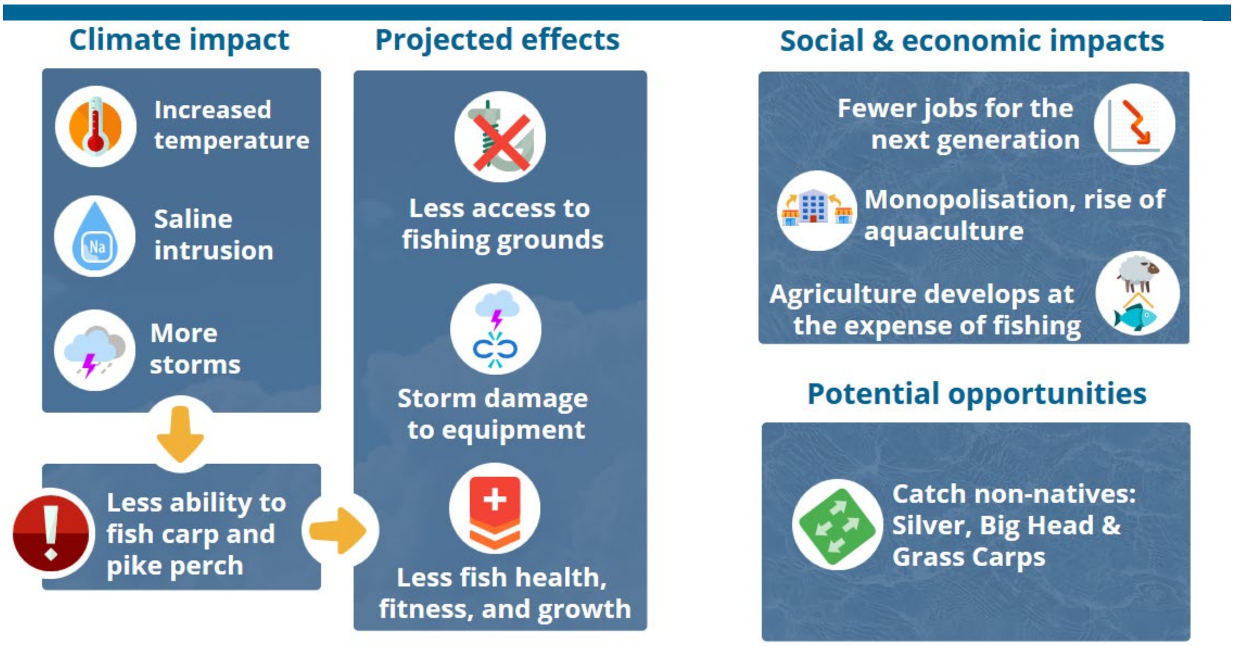


Figure 1 BowTie analysis based on stakeholder feedback. Full bowtie available http://bit.ly/CERESbowtieRazim

Further reading

CERES publications

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Danube Delta and the Razim - Sinoie complex). IN: Analele Ştiinţifice ale Institutului Delta Dunării - 1993, pp. 139 - 144.

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