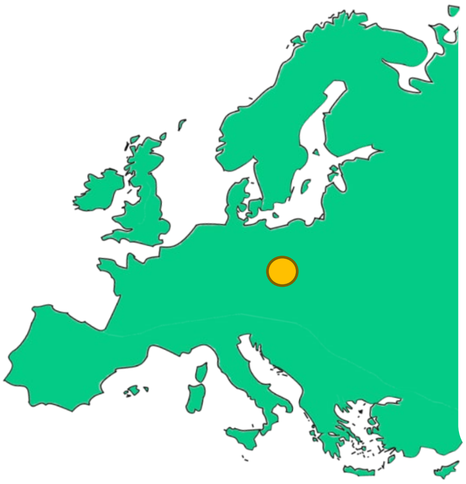
Case study



#3 Carp in north-east Europe

#4 Pike-perch in south-east Europe

#5 Mussels in the North Sea

Species background and economics

The traditional production of carp in the earthen ponds is well described and recognised. The practice developed from the Middle Ages to the monks established the first large carp farms in eastern Europe. Today, after the recent significant innovations at the turn of the 19th and 20th centuries by Tomass Dubiss, the European system of carp production in ponds has been stabilised.

However, depending on the development of the carp market, new challenges may emerge.

The most relevant barriers and challenges affecting the growth of this sector are:

1. Increased competition from another species in aquaculture.
2. Climate change direct and indirect effect on the production (growth, new diseases)
3. Increased cost of water using (but it is too chance when we take in account eco service from earthen pond)
4. Diseases management especially problem with Viral diseases as KHV (Cy-HV3)
5. Predators under government parasol (for example otter, beaver, cormorants)
6. Unregulated supply and demand causing imbalance in the market and reduced profitability
7. Predominance of big-scale farmers but with low capacity of production from one hectares of pond and for one employment people.
8. Lack of co-operation amongst local and international producers, and between government and industry on R&D.
9. Lack of product differentiation and development – special traditional market with live fish versus processed fish suitable for selling in discount, super and hypermarket.
10. Lack of coordinated national strategic plan for aquaculture and poor industry administration
11. Lack of strategy of development new methods of production of carp (for example aquaponics systems etc.)

Most carp are produced by aquaculture. The EU is very small producer worldwide (only 1,38 % of world production), Trade between the EU and third countries is very limited. In UE main producer are (fig 1) Poland, Czechia and Hungary. Total production of carp was in 2014 only 57,291 ton compared to 4,159,117 ton (fao.org) in the world. Climate related change is expected to affect production yields. This change can provide two shorter cycle of production and moving production to north of Europe, but because of tradition not out of typical 'carp countries'.

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

Expected projections under climate change

Common carp (Cyprinus carpio) is broadly reared species in Europe. Traditional place is area of Middle and East Europe. Traditional production of carp is conducted in earthen pond.

Depend on thermal condition it takes from 2 to 3 years. Depending on local tradition, fish of different market sise from 600 g (Ukraine, part of Poland) to over 3 kg (Czech Republic, Bavaria) are produced.

As production takes place in naturally-occurring earthen ponds, and fish are predominantly fed with cereal feed, with a significant share of natural food, carp production is highly dependent on climatic conditions. Carp as a warm-blooded fish grows well in water temperatures above 20 ° C.

However, further increase in water temperature (for commercial fish over 28 ° C) leads to inhibit the growth of fish.

Therefore, any climate change that are the results of the increase in average water temperatures affects the conditions of production.

Our aim in CERES is determine the potential impact of Climate change on environmental condition and potential of growth carp production in European countries.

Key research needs

Further development on carp aquaculture in Europe requires that knowledge gaps are covered in the future:

a) Projecting the impact of climate change on carp production based on current data is expected to be accompanied with a great uncertainty, thus higher data collection is needed to assess the direct and indirect effects of climate changes on common carp.

b) Overcoming the barrier of demand, intensive methods of breeding this species. The prospect is to link RAS systems using agricultural post-production water (eg. Aquaponic).

c) Traditional farming technology is limited by the lack of new places to build ponds. At present legal regulations are unfavorable for the development of traditional carp breading farm, and it largely corresponds to the so-called small water retention in significant areas of Eastern Europe.

d) It is necessary to develop new innovative carp products that can increase the demand for this species.

e) Significant threats to virological diseases in traditional breeding methods require the development of new, effective ways of combating viral diseases, eg. by introducing genetically resistant carp lines to specific viruses.

CERES research

Effect of temperature on growth, survival and stress biomarkers of farmed carp in different rearing condition.

We monitor water and air temperature and every 3ºC increase of water temperature in pond. 5 fish from each pond and cage (30 fish per sampling) are weighted, measured, blood collected for cortisol level assessment and body indices calculated (VSI, HSI, etc).

The individual growth model (*AquaFish*™) for common carp was developed based on the net energy balance approach. The equations were taken or adapted from the literature and were parameterised and calibrated against different locations.

The individual growth models were then integrated into the FARM population model for simulation of farm-scale production and environmental effects.

The culture practice for the typical carp (*Cyprinus carpio*) farm in earthern ponds (Table 1) and the environmental drivers for current conditions were collected for a farming site in Maliniec (Poland).

The individual growth model (WinFish) and the FARM production model were calibrated and validated against Maliniec current production.

Table 1. Culture practice data for a typical common carp farm in Maliniec (Poland) used to validate the individual and production models under current conditions and to assess the effects of different climate change projections.

Descriptor	Detail
Species	*Cyprinus carpio*
Location	53° 42' N, 15° 21' E
Sise and layout	Cultivated area: length: 337 m; width: 188 m; 25 cages of 2-m cage depth
	Earthern ponds
Culture structure	Starting day: end October; Harvest: end October-beginning November
	Culture cycle: 365-395 (380) days
Culture practice	Stocking density: 0.1 ind. m^{-2}
	Juvenile weight: 200-300 g live weight
	Harvestable weight: >1200 g live weight
Mortality	10% over cycle
Finance	Juvenile cost: 872 € per thousand fish
	Feed cost: 0.5 € kg^{-1}
	Farmgate sale price: 2.1 € kg^{-1}

The common carp individual model (Figure 1) and the FARM model (Figure 2) were validated against reported growth and production values for Maliniec ponds using environmental drivers for current conditions (years 2017 and 2018). Modelled end-point live weight for carp after 380 days of culture was 1166 and 1160 g for 2017 and 2018, respectively, only 3% below the minimum reported harvest weight (1200 gLW). FARM production outputs also matched the current production (5.62 and 5.51 tons $farm^{-1}$ for 2017 and 2018, respectively), that is only a 0.3 and a 1.7% lower than the reported production (5.52 tons $farm^{-1}$). The modelled Feed Conversion Ratio was 2.6 and 2.7 for 2017 and 2018, respectively, which is more optimistic than the observed range (3–4).

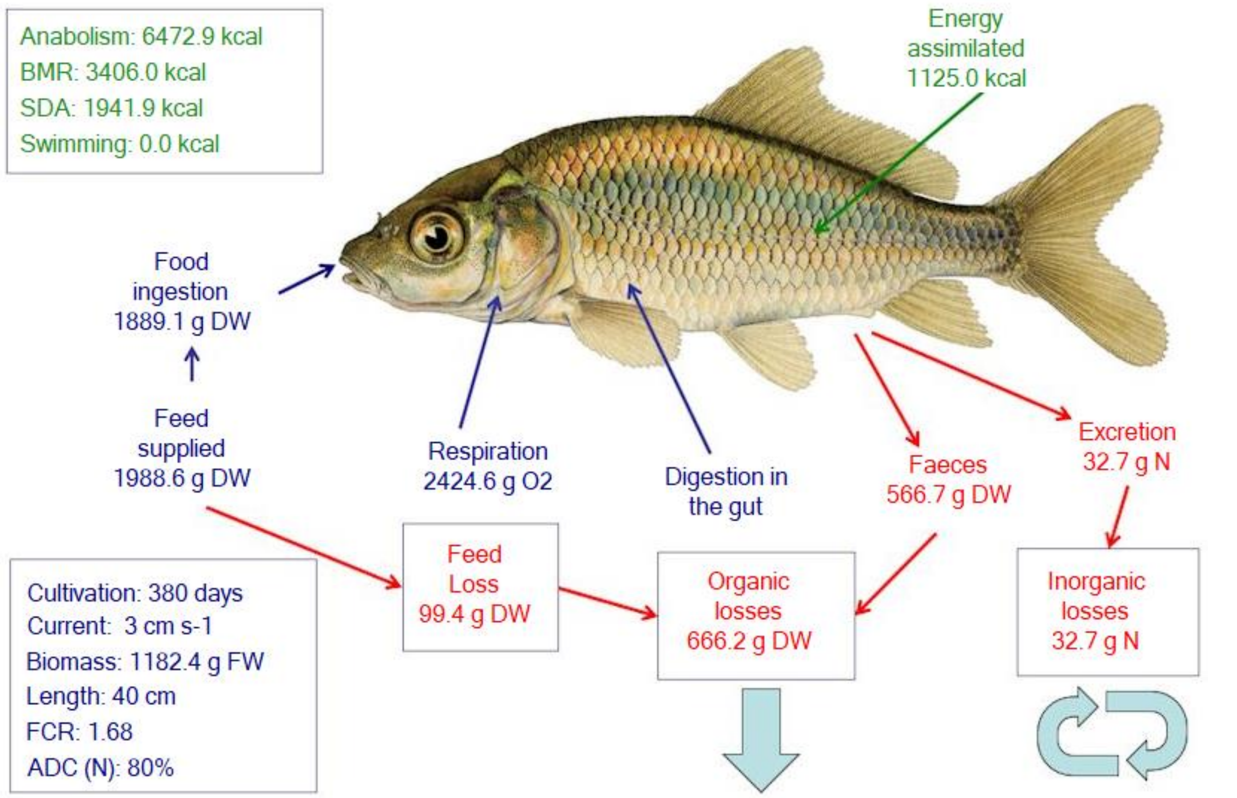


Figure 1 WinFish mass balance results for an individual common carp over a full growth cycle at Maliniec farm. DW (FW): dry (fresh) weight; BMR: basal metabolic rate; SDA: specific dynamic action; FCR: feed conversion rate.

For each time slice (2000-2019, 2040-2059, and 2080-2099) and emission scenario (RCP 4.5 and 8.5) we used water temperature to establish the boundaries of the variance in environmental drivers.

We have calculated the percentile 10 and Percentile 90 for the range of temperatures within each time slice and emission scenario (i.e. the value below which only 10% of the temperatures are lower and the value above which only 10% of the values are warmer, respectively) and counted the number of days above and below these percentiles.

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We chose two boundary years: the year with greater number of days above the day's P90 and the year with greater number of days below the day's P10.

By definition, P90 is the year with a greater number of days above the P90 for temperature, i.e. the year with more extreme warm events, but P90 is not necessarily warmer on average than P10. The results for P10 and P90 years give the spread of statistical forcing and need to be seen as the range of possible values within each emission scenario

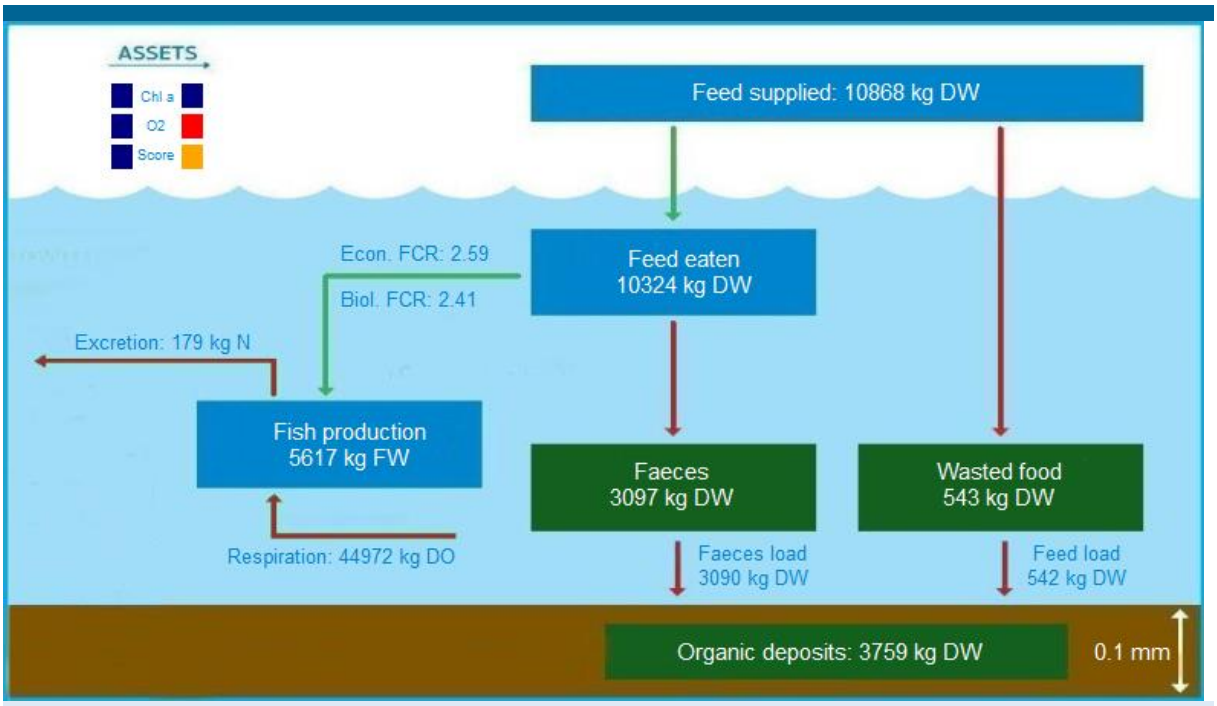
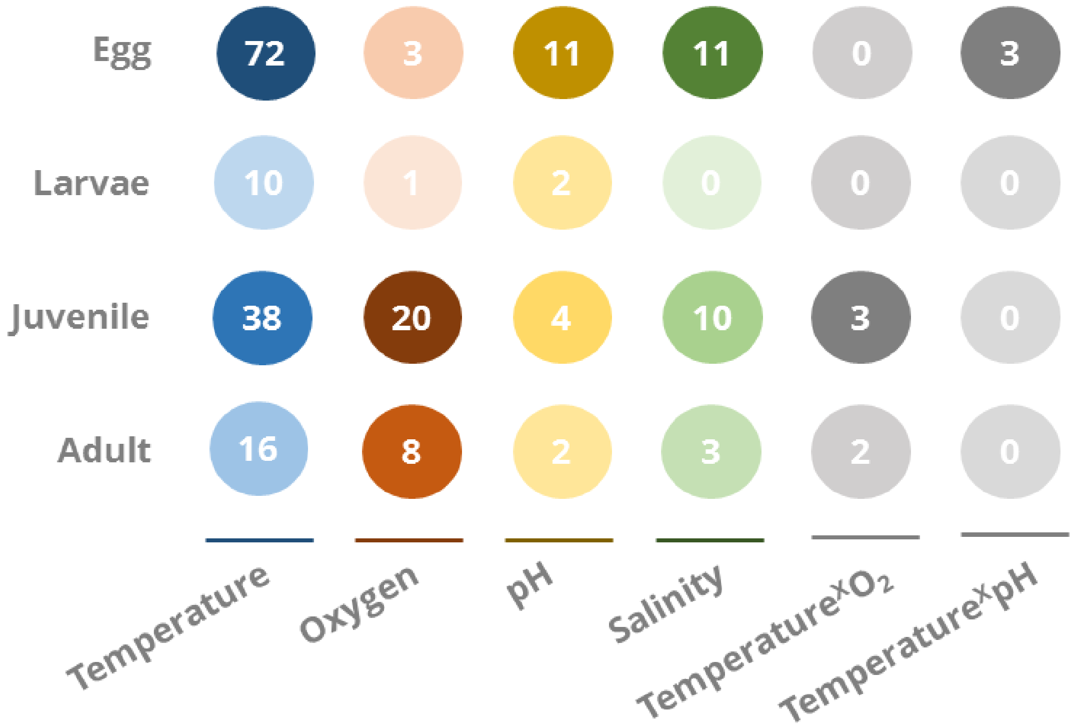


Figure 2 Mass balance for individual growth of a common carp (1160 gFW final weight) cultivated in a typical earth pond in Maliniec (Poland). DO: dissolved oxygen, FCR: feed conversion ratio, DW: dry weight, FW: fresh weight.

Results



- Cyprinus carpio ranked 4 out of 28 European fish and shellfish genera reviewed here (19 studies), Leuciscus spp. ranked 15 (3 studies).
- All studies within SL 3 (10 studies) in NE Europe were done in Germany (5) and Poland (5), but there are numerous studies from other areas inside Europe (12) and outside Europe (21).
- Most studied life stages were embryos (5x). No studies on larvae were found.
- Most studied stressor was temperature (7)
- Physiology (5) and growth (4) are well studied responses.

Biological

FARM leads to greater harvest sise and profits under the RCP 8.5 scenario, although the difference between the low and the high emission scenario diminishes as climate change progresses (Figure 3A and B). Carps are more efficient in leveraging the available feed under the high emission scenario (i.e. lower FCR's), but their feeding efficiency converges over time and the difference is not significant in the far-future scenario (Figure 3C). Under the high-emission scenario, carp growth rate will decrease as climate change progresses and it will take longer to reach harvest sise (Figure 3A). The economic uncertainty will also increase in the high-emission last-century scenario, as farmers would obtain a wider range of harvest sises and economic profits (Figure 3A and B).

In the same line as growth, the feeding efficiency of carps diminishes and fish energy expenditure increases in the high-emission last-century scenario (Figure 3C and D). The metabolic energy expenditure of carps will increase and farmers will need more investment on feed as climate change progresses (Figure 3D and E).

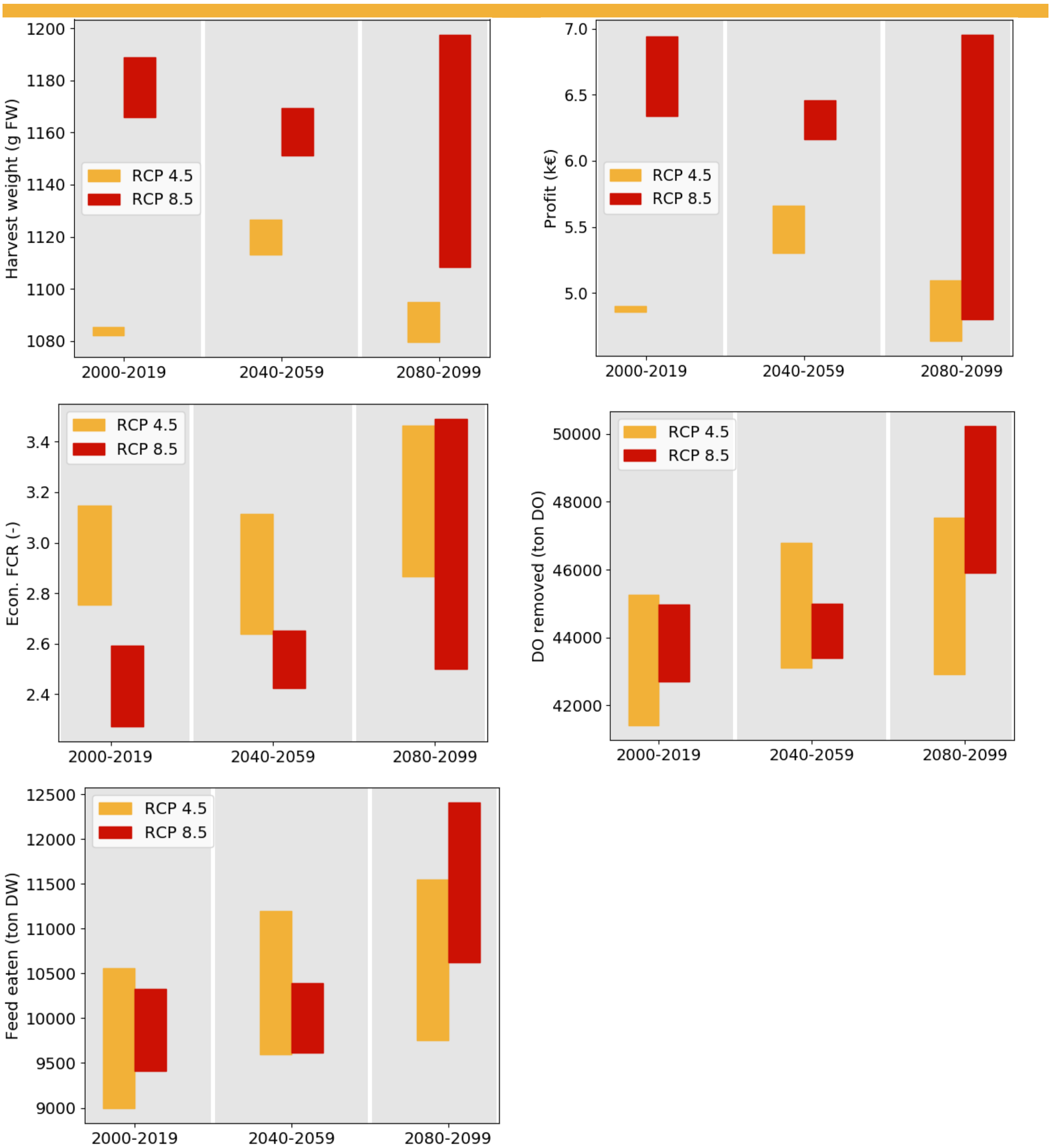


Figure 3 Range of FARM outputs for the typical carp farm in Poland under the different climate change scenarios. Orange and red bars represent the range (spread) of simulation values for the low- and the high- emission scenario, respectively. The drivers for the different climate change scenarios were obtained from the regional climate model as detailed in the text. LW: live weight; DO: dissolved oxygen.

Vulnerability assessment

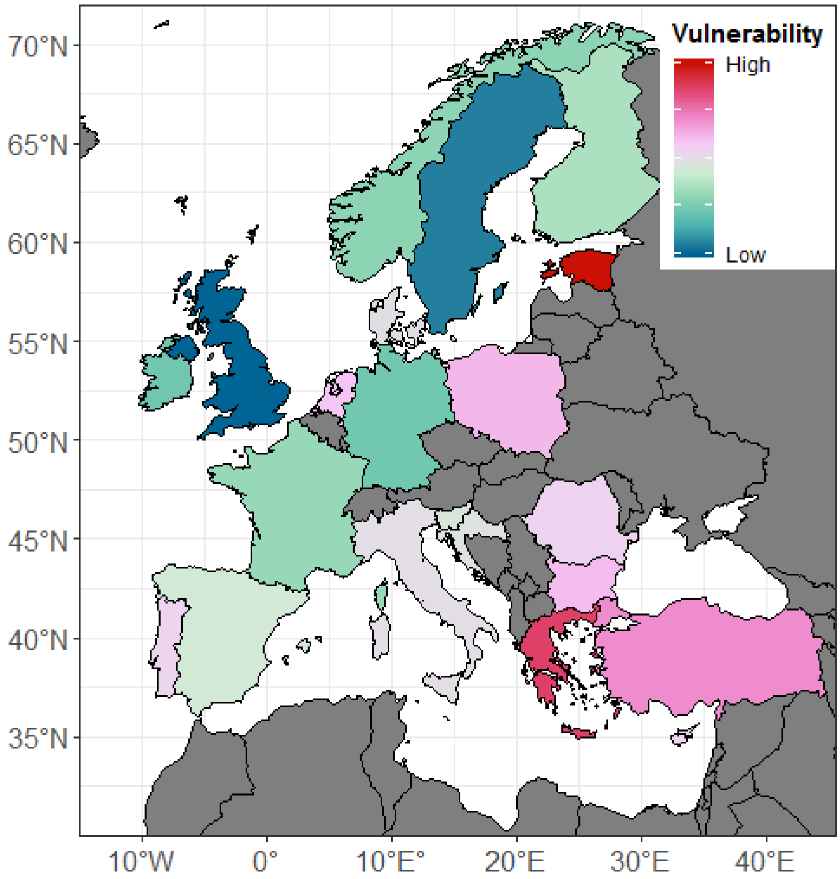


Figure 6 Climate vulnerability assessment for Europe. Colour scale is linear in the value of the corresponding score, but is presented without values, as they have little direct meaning. *Picture credit: Myron Peck*

- A climate vulnerability assessment (CVA) was conducted on the European aquaculture sector using the FAO model of Exposure + Sensitivity + Adaptive Capacity.
- The CVA included the physiological and farming methods of seven species (Atlantic salmon, sea bass, sea bream, trout, carp, mussels, oysters and clams) representing > 95% of the value for the region.
- Based on available economic data, the vulnerability of 22 countries – the top producers in the Europe28 as well as Norway and Turkey – was ranked and relative values are shown (right)
- By 2050 in RCP8.5, warming caused little change in the suitability of culture conditions for most species in most regions, including carp in freshwaters in Eastern and Central Europe. Direct effects of warming were small and, in some cases, positive.
- Many countries growing freshwater fish such as trout and carp, were relatively vulnerable to climate change due to the small size of firms (low adaptive capacity), and the lack of control associated with extensive farming (pond culture).

Policy recommendations

- subsidies paid by government should be available for Polish carp farmers all the time. What is most crucial should be paid only for a small retention of water, because the cost to maintain carp ponds are significantly lower than the cost to construct new retention fields/ponds (impounding reservoirs).
- carp framers have been conservative thus far. They should be more open-minded and willing to cooperate with scientists and government administration.
- the EU should create binding regulations that carp ponds are crucial for the small retention of water.

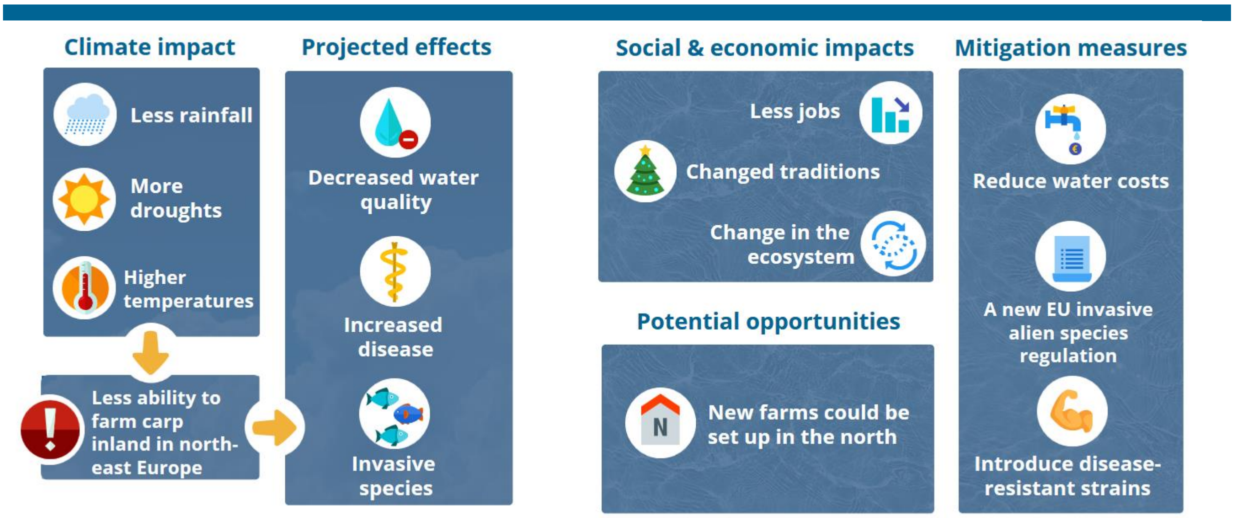


Figure 4 BowTie analysis based on stakeholder feedback. All full BowTies available http://bit.ly/CERESbowties2020 *Credit: Katie Smyth, Hull*