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CERES storyline - inland fisheries

Will inland fishery be effected from climate change?

Over the past 40 years biodiversity has declined faster in inland waters than in marine or terrestrial ecosystems. This is caused by multiple anthropogenic pressures such as agriculture, damming, channelisation, deforestation, navigation, wetland reclamation, urbanisation, hydropower generation, water abstraction and transfer, and waste disposal. For inland waters these pressures are exacerbated by climate change impacts, which are elicited as changes in water temperature and rainfall patterns that modify the volume of water entering rivers or lakes and will therefore affect the hydrological and limnological regimes. Collectively, anthropogenic pressures and climate change have resulted in a shift in the ecological status of inland fisheries and a general decline in productivity and ultimately yield.

In Europe, commercial inland fisheries exploit a wide range of species and most fish are supplied to regional or national markets through local dealers and wholesalers. There are considerable differences in the fish species caught by commercial (or professional) fishers across Europe.

Fish	commercially used in
salmonids	northern western countries
eel (*Anguilla anguilla*)	all countries
whitefish (coregonids)	Baltic & Scandinavian countries, Austria, France, Germany and Poland
carp *Cyprinus carpio*	Eastern European countries and Germany,
cyprinids e.g. :	all countries except for Sweden and UK
pike *Esox luscious*	Austria, the Netherlands, Sweden, most Eastern European countries
perch *Perca fluviatis*	
zander *Sander lucioperca*	

Therefore it is important to understand the impacts of climate change on commercial fisheries and tease out them out from other anthropogenic stressors. Inland waters are also heavily exploited by recreational fisheries, and target a wide variety of freshwater fish species, from salmonids to cyprinids. Tourism within the fishing industry is a large driver of income and can put a high value on species such as salmon and sturgeon. It is important that climate change does not result in a reduction in these species.

How vulnerable is inland fishery to climate change?

Temperature, flow and lunar cycle are controlling factors in the distribution of organisms and timing of spawning. It is likely that climate change will disrupt the spawning regime of fish and encourage them to spawn earlier in the year subsequently allowing juveniles a longer growth period before winter or causing premature hatching and low survival.

Furthermore, higher temperatures will result in higher productivity and therefore increase fish growth and over-winter survival. Inhabitants of large temperate lakes that are intolerant to high temperatures, such as whitefish, will be particularly vulnerable if temperatures were to increase as their "thermal refuge" will be reduced. Longer warming periods and higher temperatures are likely to increase the stratification of lakes thus reducing the amount of oxygen exchange to the hypolimnion from the oxygen rich epilimnion.

Cold water stenotherms such as the Artic charr, Salvelinus alpinus L., use the hypolimnion (deep stable 4°C layers of a lake) as a thermal refuge and the species composition could therefore be negatively affected by rise in water temperature.

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Overall, on a local scale lacustrian species may be forced in to deeper water by rising temperatures while riverine species may have to migrate to higher, cooler stretches of river. On a larger scale, species may be entirely eradicated from a river or lake system, possibly contracting the species' range to a few isolated high altitude pockets, e.g. arctic char in the Cumbrian lakes.

Furthermore, an increase in parasite survival is an indirect effect of climate change and is likely to increase the virulence of certain fish pathogens and the transmission of some parasites. Higher winter temperatures may increase parasite survival resulting in year round infection and multiple generations of parasites in a single year. In addition, non-native species that have higher tolerances to warmer more stressful conditions will likely proliferate and displace endemic fish species homogenise fish communities.

Several studies have shown that drought and flooding have a noticeable effect on community composition, diversity, size structure of populations, spawning and recruitment of inland fish. Droughts may disconnect fish from floodplains and reduce the availably of habitat for spawning, feeding and refuge. Whilst unpredictable flooding due to climate change will change the regularity, amplitude, frequency and duration of annual flooding and could therefore cause changes in fish productivity. For example, migratory fish such as Atlantic salmon, *Salmo salar* L., are especially affected by high and low flows to complete their migration upstream to spawn. Low flows will make barriers difficult to pass, whilst high flows may allow migratory fish to pass barriers and enable wider access to spawning and nursery habitat.

What is the economic value of this fishery?

In Europe, most inland waters support commercial and recreational fisheries and therefore climate change has the potential to affect the societies and their economies that rely on them by altering fish production and potential yields. Commercially, fish are produced for sale to consumers or managers of recreational fisheries for stocking. For example, in the UK, brown trout *Salmo trutta* L., farming industry produces several hundred million pounds of marketable product annually and supports other livelihood activities related to the recreational fishing industry.

Recreational fishing in fresh waters produces far more revenue in the industrialised world than commercial capture industries. It is difficult to attach a true monetary value to the recreational fisheries of the world because participation is voluntary and not regulated. However, the money spent by recreational anglers on fishing equipment is quantifiable and indicates that the activity is a multibillion dollar industry and an integral component of local economies. Recreational fisheries is estimated to be 555 million EUR, of which 121 million EUR is spent by out-of-state anglers. When indirect impacts are factored in then the overall economic impact is estimated to be approximately 750 million EUR. Furthermore, they estimate that recreational angling can support 10,000 job. The most prized fish to anglers are generally cold water fish species such as salmonids and centrachids. These are the species that are most at risk from warming as their thermal habitat will be reduced. Subsequently, the recreational fisheries dependant on such species will decline, decreasing their contribution to the economy. The economic problems associated with a decrease in fish yields include a reduction in employment in the fish capture and fish culture sectors and a reduction in income from these activities.

Furthermore, loss of biodiversity is a major social issue as it is considered part of our heritage that must be available for future generations to enjoy and utilise. A species may have a direct use value, an indirect use value, an ecological value and/or a cultural and spiritual value . Atlantic salmon, for example are valuable in many as they are an important and desirable source of food and they have an important ecological value. If a flagship species such as this were to be extirpatedt, obligations to preserve biodiversity foregone. Many countries (e.g. Denmark, the

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Netherlands) also consider that the most valuable fishes in commercial fisheries are in decline, and, with increasing costs, their exploitation becomes less and less profitable, especially due to imports of cheap fish from Eastern European (post-Soviet Union) countries. Nevertheless, the productivity of some fresh waters is expected to increase as a result of climate change resulting in potentially greater yields and economic benefits. Pedictions indicate that the production of zander will increase in northern Europe through a strengthening of year classes and an enhancement of growth due to climate warming.

What are the challenges?

Climate change could cause a loss of, or reduction in abundance of inland waters species affecting both recreational and commercial fisheries. The challenge is to identify the risk and uncertainty associated with climate change, its effect on freshwater species and how this will consequently affect inland fisheries and the resilience of communities to respond to these changes. This will lead to the development of guidance and tools for suitable mitigation (e.g. catch limits, closed periods, legal size limits and type of gear) options to alleviate any negative effects of climate change, or adaptation strategies to the alleviate the problems encountered. It is also important to identify possible opportunities to overcome uncertainty for inland fisheries, both commercial and recreational, so they become resilient to climate change and develop adaptive management and governance techniques to support sustainability. For this it will be useful to not only produce an up-to-date literature review, but to also cross compare the socio-economic importance of fisheries, between inland and the marine sector.

What is the working program in CERES?

- Time series of precipitation (for meteorological droughts), river flows (for average flows), extreme high and low flows (for floods and droughts, respectively), and river and lake temperatures (for water quality), fisheries data. These time series can be observed or simulated for historical time periods and can be projected for future time windows, taking into account climate change and potentially also other drivers of change, such as land use changes.
- Identify if a climatic driven regime shift has occurs and which environmental factor was the driver through application of:
  - » Principle component analysis (PCA)
  - » Chronological clustering (CC)
  - » Sequential Regime Shift Detector (STARS)
  - » Non-linear Threshold Generalized additive Models

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