Vulnerability assessment of ecosystem services for climate change impacts and adaptation (VACCIA)

Action 10: Assessment of impacts and adaptation of fisheries production and wash off effects in Lake Päijänne

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Report 3

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VACCIA

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1. Introduction

Lake Päijänne is one of the three lakes having a surface area larger than 1000 km^2 in Finland. It is also the deepest lake in Finland, maximum depth is 94 m. The lake water level was artificially lowered in 1832-1837 and it has been regulated since 1964 (Järvinen and Marttunen 1998). Currently it is recovering from pulp and paper mill wastewater loading. Lake water is used for source of tap water in Helsinki metropolitan area. Lake Päijänne is one site in the Finnish Long Term Socio-Ecological Research Network.

In reports 1 the present situation of fish stocks and fisheries in L. Päijänne as well as lake and drainage area characteristics were described. In paper 2 some results of climate change on L. Päijänne were presented based on modeling. In this paper, report 3, we present more modeling results and also speculate the needs of adaptation and how this will be possible.

2. Lake Päijänne and drainage area

According to Carter (2007) the most pronounced effects of the climate change in Finnish inland aquatic systems seem to be linked to the change in annual rhythm of runoff, discharge and water level fluctuations. These changes are due to increase in mean air temperature and increase in precipitation and evaporation. Winter runoff is predicted to increase due to rainfall and freeze-thaw cycles in a warmer season. Spring floods will diminish at least in southern and central Finland because of lack of snow melt.

Due to warmer season and increased evaporation, summer runoff is likely to decrease in these areas, and episodes of long dryness and occasional heavy rainstorms are becoming more common. As the winter runoff, also autumnal runoff is likely to increase in all regions in Finland. Transportation of substances to water systems depends on runoff and land use. Climate change is about to change the temporal distribution of runoff as well as affecting the agriculture and forestry and therefore it has impacts on the quality of the water and the recreational use of inland waters (Silander et al. 2006). To form a more local view, changes and adaptation measures regarding Central Finland and the lake Päijänne drainage area are presented based on watershed load simulations and workshop discussion.

2.1. Methods

Simulations

WSFS-VEMALA-model (Finnish Environment Institute, FEI) calculates the development and progression of watershed load from drainage area in one day steps. The model uses daily rainfall and air temperature data to calculate the amount of snow, soil humidity, ground water level, runoff and discharge as well as water levels in lakes and in rivers. In load simulations the runoff concentrations depend on daily runoff, season and land use. The model calculates the total phosphorus, total nitrogen and suspended solids (filtered with polycarbonate filter) load. In Asikkalanselkä case the model has description of lakes with surface area of 1 ha and larger than that, and land use information from each drainage area. The model calculated the loading from drainage basin area and its proceeding in the watershed with one day time steps.

Workshop discussion on climate change in Lake Päijänne area

Päijänne Vaccia-project organised a workshop for stakeholders, administrators and other interest groups on March 29, 2011. The objective was to raise discussion and ideas about the future changes and adaptation measures. The participants were:

Juha Karjalainen, University of Jyväskylä, Department of Biological and Environmental science
Tapio Keskinen, University of Jyväskylä, Department of Biological and Environmental science
Mari Nykänen, Centre for Economic Development, Transport and the Environment, Jyväskylä
Tanja Oksa, City of Jyväskylä
Arja Palomäki, University of Jyväskylä, Institute for Environmental Research
Merja Pulkkanen, University of Jyväskylä, Department of Biological and Environmental science
Pentti Valkeajärvi, Game and Fisheries Research Institut
Reima Välivaara, Regional Council of Central Finland

The theme B discussion was roughly based on simulated results on temperature, oxygen concentration and loading changes in Lake Päijänne
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2.2. Results

Simulations

FEI assessed the potential change in annual P-load development in river Kymijoki catchment area. According the WSFS-model calculations based on scenario A1B, the winter and autumnal load seem to be increasing but summer load is decreasing in future (Fig. 1).The total volume of annual discharge in Asikkalanselkä increases from 211 m^3s^{-1} in present situation to 231 m^3s^{-1} in 2070-2099 according to scenario A1B (Fig. 2). The main difference is that the current peak in spring discharge is changing to a large, continuous discharge during winter.

Also with P-, N- and suspended solids loading the future situation seems to turn from maximum peak during spring to more continuous loading in winter and decrease during summer (Figs 3-5). If the land use does not change dramatically, the P-load is increasing only slightly from 228 to 230 kgd^{-1} and the N-load from 9400 to 9500 kgd^{-1} in 2070-99 (A1B). The amount of annual suspended solids load is to increase from 740 in current situation to 920 kgd^{-1} in 2070-99 (A1B).

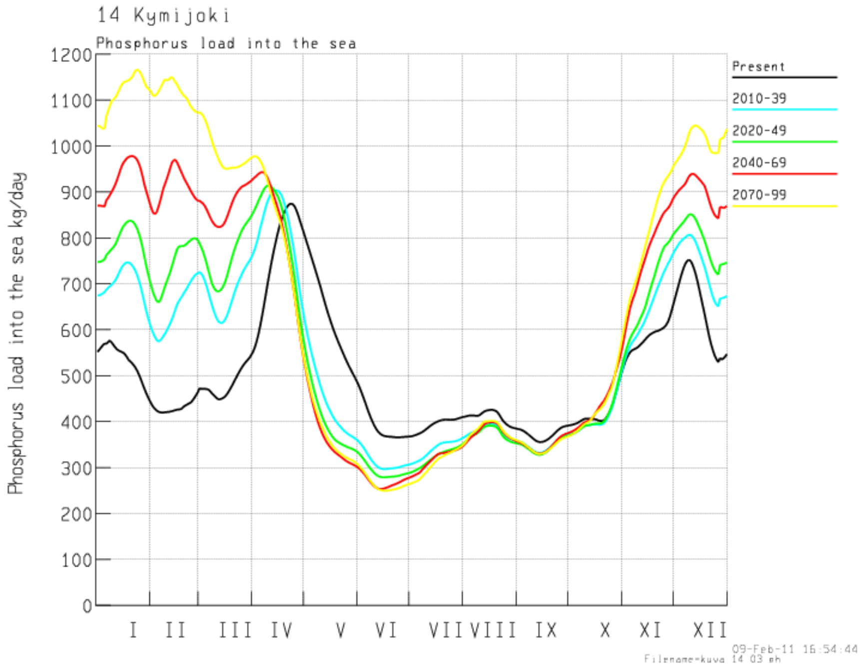

Fig. 1. Phosphorus load into the sea from river Kymijoki catchment.

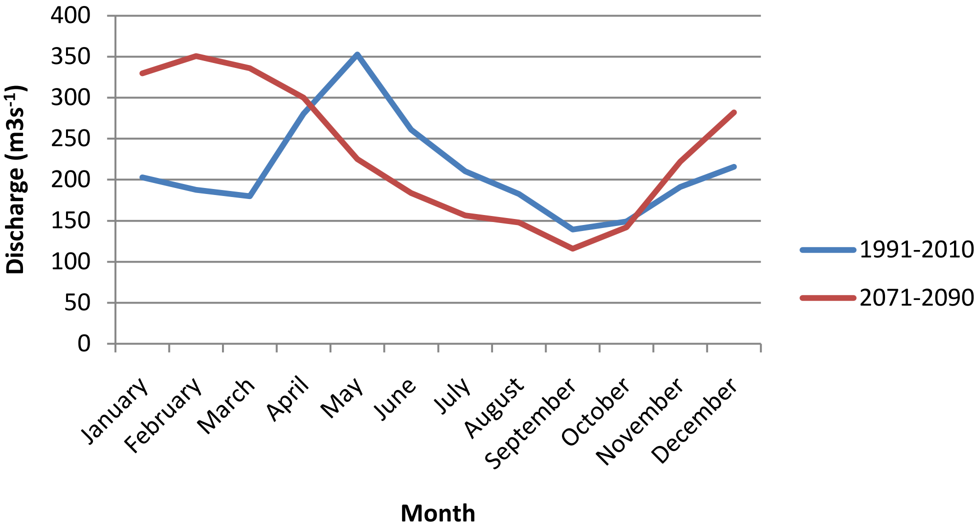

Fig. 2. Discharge in Asikkalanselkä.

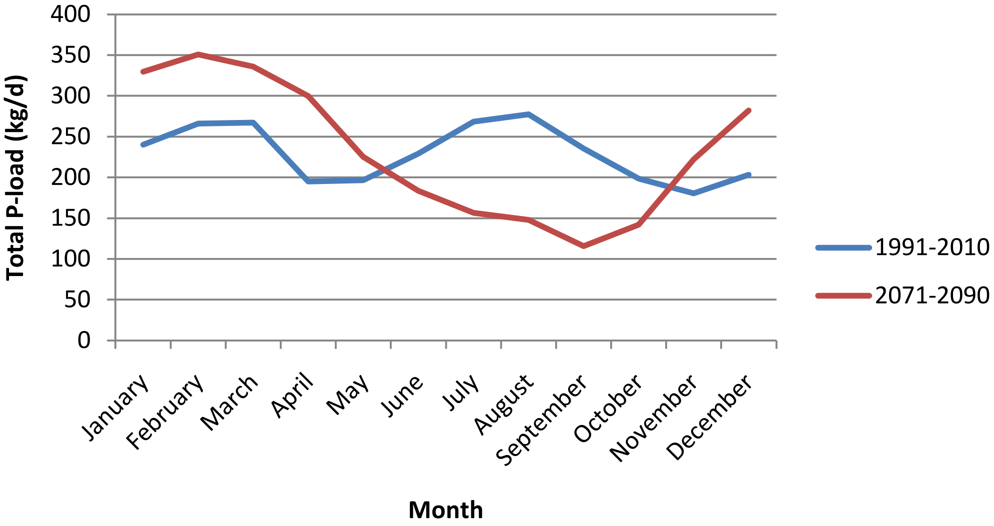

Fig. 3. Phosphorus load in Asikkalanselkä.

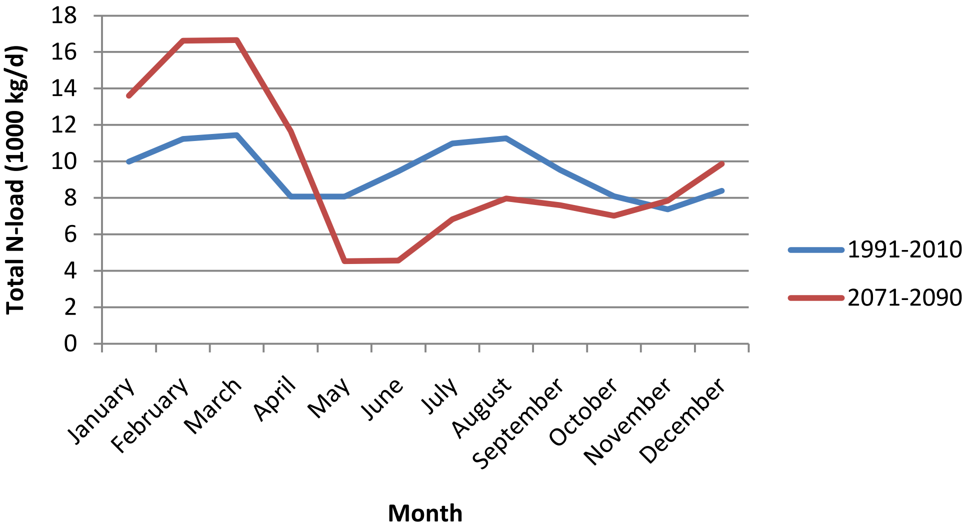

Fig. 4. Nitrogen load in Asikkalanselkä.

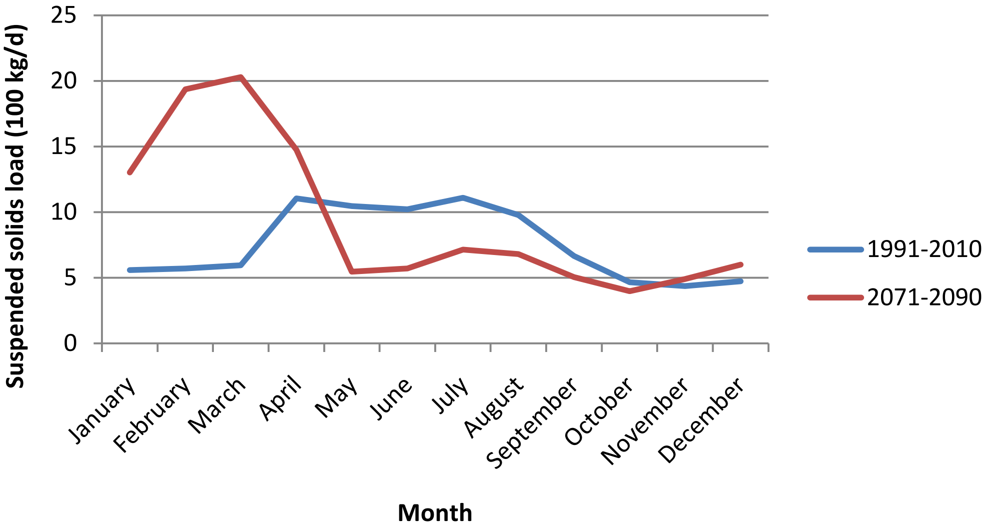

Fig. 5. Suspended solids load in Asikkalanselkä.

Workshop discussion on climate change in Lake Päijänne area

Changes in loading take place since the winter precipitation is increasing and especially the leaching of humus may become a problem. Growth season of algae is longer in the future, but on the other hand, the light climate in lakes may change. During summer the leaching may decrease. Therefore also summer nutrient limitation may be more common in lakes. Cyanobacteria may thrive in lakes with N-limitation because of their ability to use directly the atmospheric N_2.

The Water Framework Directive was launched to prevent the deterioration of marine and inland waters. The main objectives are the conservation and improvement of water ecosystems. In addition the Directive aims to enhance sustainable water use (surface and ground waters) and to minimize the impacts of floods and drought periods. One of the questions in future adaptation is the determination of the natural state to which the water ecosystem should be restored e.g. after extreme weather events. Climate change can also affect to the ability to the ecosystem to recover from drastic events. Flood and water system control measures (minimum levels and draining) should be fitted to these changes, which is one of the major challenges of water administration. In water research the effects of temporal change of N and P-loading to water ecosystem should be the main task in near future. There is abundance of long-term phytoplankton data available from lake Päijänne, which could be reviewed closely with weather observations to predict future changes in phytoplankton dynamics.

The main non-point loading sources in Central Finland are agriculture and peat production. The volume of peat production is predicted to double from present state. The production may become more effective because of more dry summers in future. The colour of water and the amount of suspended solids will increase in lakes near peat production areas, but on the other hand, the functioning of drainage fields (or river fields) during winter will be enhanced. Heavy rainfall may increase loading substantially after a long dry period in summer.

In agriculture the expanding of exclusion areas and precise timing of fertilization are the first measures to meet future needs in water protection. Also changes in cultivation techniques (e.g. no autumnal ploughing) may take place. In any case, agricultural production is predicted to benefit from climate change in Finland. As an example of a point load source, waste water treatment plants may occasionally have difficulties in sustaining the treatment processes due to dilution caused by increased precipitation and urban runoff.

As a main conclusion, the changes in land use and temporal change of loading and the occurrence of extreme events are the major factors determining the scale of future changes and adaptation measures.

3.Fish stocks and fisheries

3.1. Fish stocks

Climate change can modify fish stocks in different ways. Geographic distribution or occupied habitat of single species can change (Shuter et al. 1998). Also reproduction success and recruitment can change (Casselman 2002). Changes in temperature can affect to food consumption and predation pressure to prey species which can change production and biodiversity of fish stocks (e.g. Jackson & Mandrak 2002, Brandt et al. 2002). Changes in abundance of individual species affect to interactions and whole lake ecosystem. Thus, the changes induced by climate change are complex and predictions include uncertainty.

The common trend is that cyprinids and percids are benefit of changes having high optimum temperature (Graham & Harrod 2009). Species suffering of changes are mainly salmonids with low optimum temperatures. Important fish species in L. Päijänne benefiting of predicted changes in the future according to optimum temperatures presented by Lehtonen (1996) are pike, roach, rudd, perch and pikeperch. Respectively species which will suffer based on predicted changes in distribution area are vendace, whitefish, smelt and brown trout (Lehtonen 1996).

One important question is the ability of fish to adapt to changes. Most fish are very flexible in relation to temperature requirements and can survive in large scale of temperatures. In boreal region the difference between lowest and highest temperature within a year is high and also differences between years are high. This gives good possibilities to adapt slow changes in temperature. Thus, the predicted changes in water temperature are not physiologically significant. Besides water temperature are indirect effects modifying fish stocks, e.g. eutrophication, interactions and changes in vegetation which can have significant effects on whole lake ecosystem and its function.

3.2. Vendace and whitefish

In whitefish fertilization temperatures over 7 °C has been reported causing decreasing fertilization and increased abnormalities for embryos (Cingi et al. 2010). Also high incubation temperature caused abnormalities and increased mortality. These studied temperatures (over 7 °C) are however above the predictions by MyLake simulations of future incubation temperatures in L. Päijänne.

In one part of VACCIA during autumn and winter 2009/2010 development of vendace and whitefish eggs were studied in Konnevesi research station in respect to different climate change scenarios. First scenario was the predicted temperature 2070-2099, second 2040-2069 and third was natural temperature in Lake Konnevesi 2010.

There were no differences in survival of eggs between temperature treatments (Fig 6). In general, the survival of whitefish was higher than vendace. The quality of hatched larvae (length, energy content) will be analysed later to find out if there are differences between temperatures.

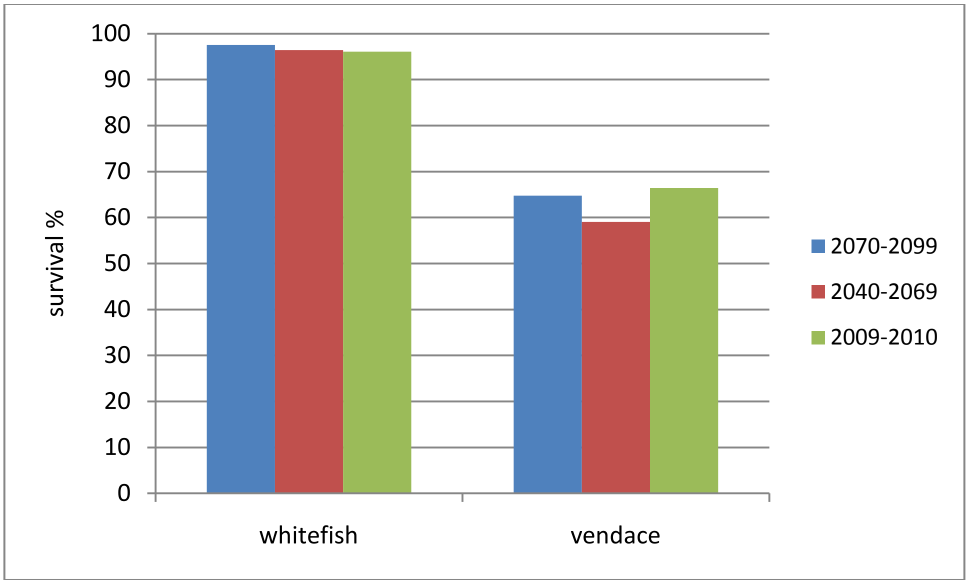

Figure 6. The survival of whitefish and vendace eggs in different water temperatures based on MyLake simulations for different time periods and temperature in L. Konnevesi 2009-2010.

Hatched larvae from scenario 1 and L. Konnevesi temperature were cultured to find out the differences in their survival ability after hatching. We used three different feeding levels (0, 10 and 100% of fish weight day^{-1}). The used temperatures were predicted temperatures in scenario 1 and observed in L. Konnevesi after hatching.

The ability of larvae to survive without food was higher in the second experiment than in the first experiment. The time of 50 % mortality in the first experiment was 12 days and 19 in the second one for vendace and 15 and 22 days for whitefish, respectively.

The main reason to differences was temperature. In the first experiment temperature was selected according to scenarios for 2070-2099 and in the second experiment it was the same than that in L. Konnevesi after hatching. The results indicate that in the future scenario larvae have to find suitable food in shorter time than in present water temperatures to avoid starvation. In contrast, in warmer environment the production of zooplankton is also higher.

According to bioenergetics modeling, predicted changes in water temperature during summer increase the growth rate of vendace (Keskinen et al. 2010). These calculations include the assumption that the amount of suitable food is not limiting the growth. The increasing temperature can change interactions (competition, predation) between species and affect on growth of vendace.

3.3. Smelt

The observed exceptional years can be used as estimator what will happen in the future. Summer 2002 was extremely warm in Finland. This probably caused in a small lake collapse of smelt stock (Keskinen et al. 2011) when low oxygen concentration in metalimnion forced smelt staying in epilimnion where temperature was too high for this species. In that case, the smelt stock recovered in two years because young-of-the-year smelts tolerate higher temperatures and survived. However, if few following years are exceptional warm this can mean local extinction of smelt stock in a small lake.

3.4. Pikeperch

Pikeperch is among those species which are expected to benefit of climate change (Lehtonen 1996). It is a predatory percid fish which main prey species in L. Päijänne are smelt and perch (Keskinen & Marjomäki 2004). Pikeperch have optimum temperature for growth 22-25 °C (Hokanson 1977) and has been observed in lake selecting usually the warmest available temperature (Keskinen 2008). In this manner the selected temperature of pikeperch in L. Päijänne will increase few decrease compared to present (Fig. 7). Bioenergetics modeling shows that after 6 years growth the final weight of pikeperch is 50 % higher (Fig. 8). Also the food consumption is higher in the future (Fig. 9). These calculations include assumption that the food resource is not limiting the growth of pikeperch.

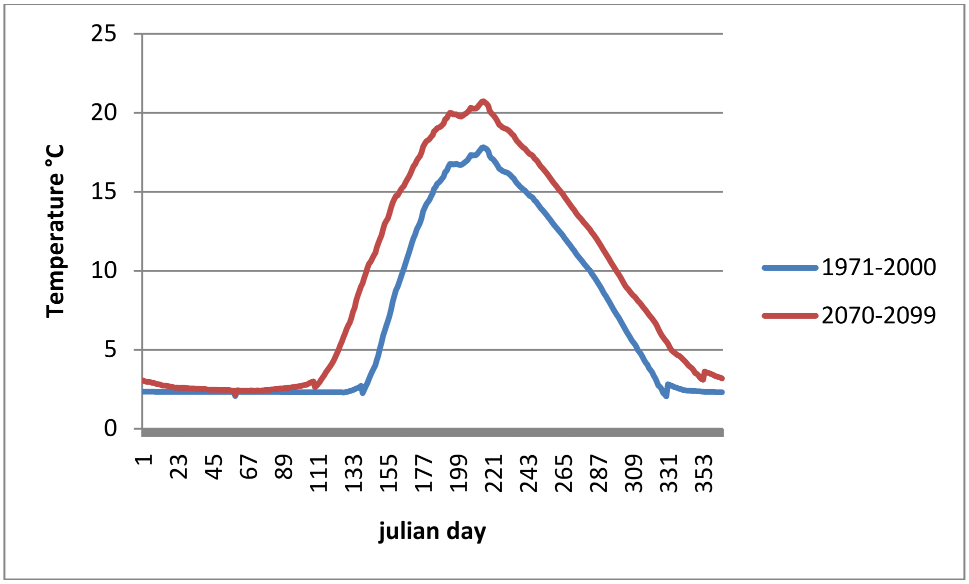

Figure 7. The estimated average temperature of pikeperch in L. Päijänne in two time periods.

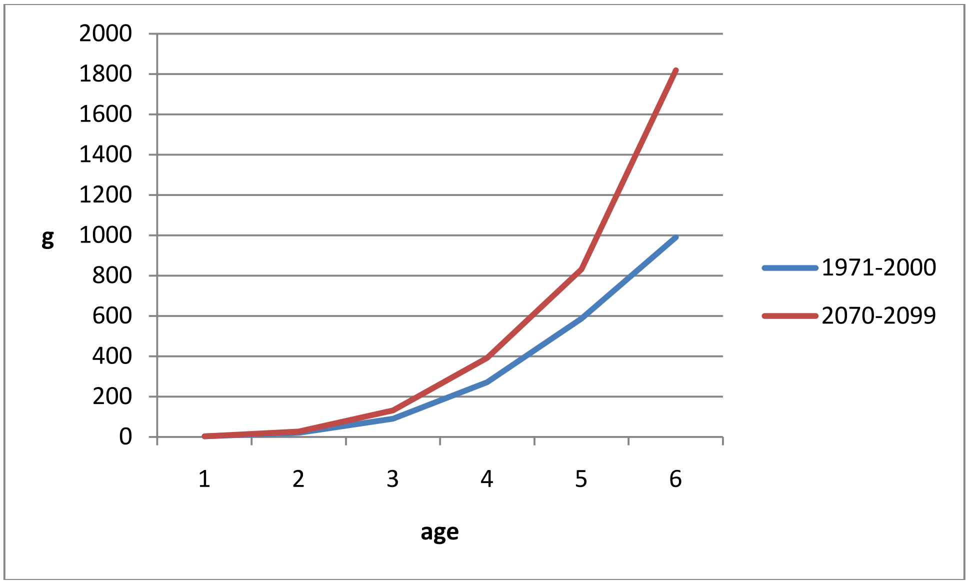

Figure 8. Estimated average mass of pikeperch in L. Päijänne in two time periods in age 1-6 years.

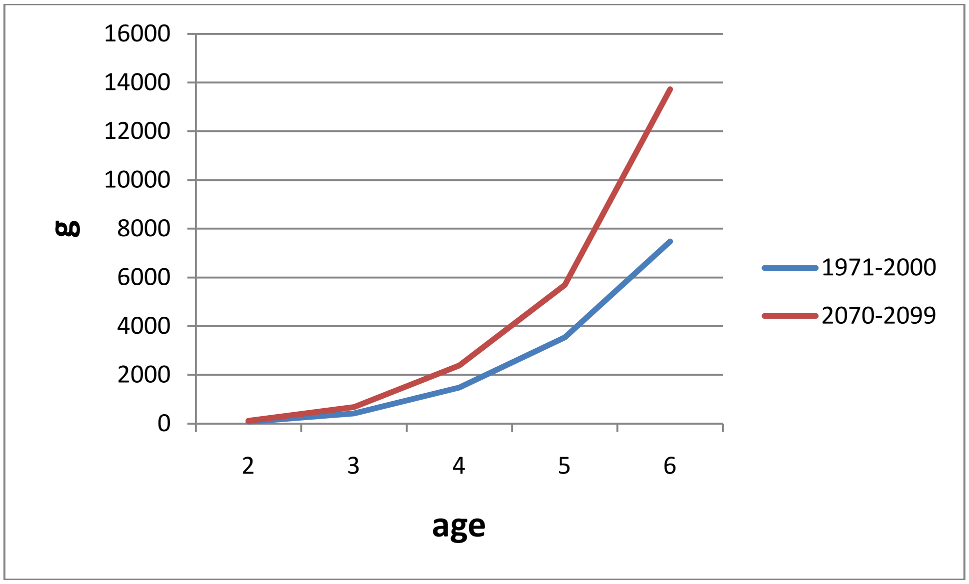

Figure 9. Estimated average food consumption of pikeperch in L. Päijänne in two time periods in age 1-6 years.

Pikeperch is a predatory percid fish which main prey species in L. Päijänne are smelt and perch (Keskinen & Marjomäki 2004). The estimated stock size of pikeperch in L. Päijänne will be equal or increase compared to present because warm summers produce strong year-classes of pikeperch (Lappalainen 2001). Thus, the stocks of prey species will face stronger predation pressure than present. Smelt is expected suffering of climate change and perch will benefit. Also large perch use smelt as food resource. Thus, together with increasing predation pressure by pikeperch and perch and increasing water temperature smelt stocks are suffering of climate change.

3.5. Brown trout

Brown trout in L. Päijänne is an endangered species (Syrjänen & Valkeajärvi 2010). The main threat of natural reproduction is water temperature in small streams during summer (Keskinen et al. 2010). With bioenergetics modeling it has been estimated that temperature can be too high for trout to survive in some years. Also the increased probability of floods and increased wash off of suspended solids can be harmful for brown trout stocks in the future during their life stages in small streams. These factors together with the present status can increase the probability to extinction of natural brown trout stock in L. Päijänne.

The bioenergetics calculations are mainly based on average values of predicted water temperature. However, the extreme years are often more important for lake ecosystem than an average values. If harmful extreme conditions occur few years after each other it can affect an extinction of certain species.

3.6. Signal crayfish

Signal crayfish is introduced species in L. Päijänne and has dense stocks especially in southern parts of L. Päijänne. This species will benefit especially on predicted warm and long autumns. Thus, the distribution of signal crayfish will enlarge through natural ways and stockings.

The invasion of signal crayfish has both economical and ecological consequences in L. Päijänne. It is valuable resource for recreational and professional fishery. In some parts of L. Päijänne local fishery associations get more incomes from crayfish licenses than traditional fish licenses. Dense crayfish stocks can also be harmful for traditional gillnet fishing and decrease the fishing effort by this method. The invasion of signal crayfish has been observed causing changes in benthos in L. Päijänne (Ruokonen et al. unpubl.). These changes indicate also potential effects on whole ecosystem.

3.7. Adaptation of fisheries

The ways of adaptation are based mainly on workshop organized in March 2011 (see 2.1. and Appendix 1, in Finnish) and additional interviews of some stakeholders. The adaptation was mainly evaluated through workings in years with exceptional weather conditions resembling predicted future climate.

The effects of extreme warm summers on professional fisheries depend on how deep is thermocline. For example, in 2010 water surface temperature in Tehinselkä was over 25 °C but because thermocline was relative near the surface, it does not affect to distribution of vendace and whitefish. Thus, the harmful effects on professional fisheries were small. Opposite of that, years with thermocline relatively deep causes problems because fish stay in deep water and fishing is difficult. Warm air temperature requires more capacity for chilling the catch and this increase the cost of fishing operations.

In the future winters are predicted to be warmer and permanent ice cover is not composed in every year. This makes winter seining almost impossible. Respectively trawling season will be longer and in some mild winters it has continued to January. However, because it is not regular there have been difficulties in marketing the catch in this time of year. In the situation that trawling would be possible regular during winter the marketing would be easier. Traditional winter seining has been timed to late winter when marketing has been easier. On the other hand, earlier ice break would longer trawl season in the beginning of the season. Usually trawling will be started when surface temperature is about 10 °C. This point will be in average in May 18 on period 2070-2099 and about 20 days earlier compared to period 1971-2000 (June 10). Replacement of winter seining by trawling decreases investments to fishing gears and could make fishing more profitable assuming that vendace and whitefish stocks are at present or higher level.

Changes in fish stocks alter the economical value of fisheries. Marketing price of vendace and whitefish is higher than small perch and cyprinids. At the present, these fish are used as animal food. Smelt is frozen and export to Estonian or central Europe. The predicted changes require that there will also be markets to these fish species to keep professional fishery profitable. There are at the moment some professional crayfish fisheries but marketing is difficult due to great supply. Thus, the increasing signal crayfish stock is not a potential for professional fishery.

Recreational fishery is mainly focusing to pike, perch and pikeperch. These all species are estimated to benefit of climate change. Thus, the potential catch for these fishermen is increasing. Also the increasing stocks of signal crayfish offer a new potential for recreational fishery.

Professional fishery has been adapted to changes in fish stocks and temperature between years. Thus, the changes in climate and predicted changes in lake ecosystem are so slow that this livelihood could adapt to changes and maybe even benefit of changes.

In aquaculture the main problems are with water quality and temperature. Possible adaptation ways are new species, for example pikeperch (Jokelainen et al. 2009) and move in recirculation fish farms. One risk is also the increasing problems caused by fish diseases (Karvonen et al. 2010).

4. References

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Appendix 1.

Ilmastonmuutos ja kalat

Mitä tapahtuu?
Miten sopeutua?

VACCIA 29.3. 2011

Vaikutustapoja

- Lajien levinneisyys
- Kannan runsaus
- Kasvunopeus
- Esiintymisalueet
- Kalastus
- Predaatio

Mahdollisesti hyötyvät lajit

	Optimilämpötila
Särki	30
Sorva	28
Salakka	20
Pasuri	?
Ahven	28
Kuha	31
Täplärapu	25

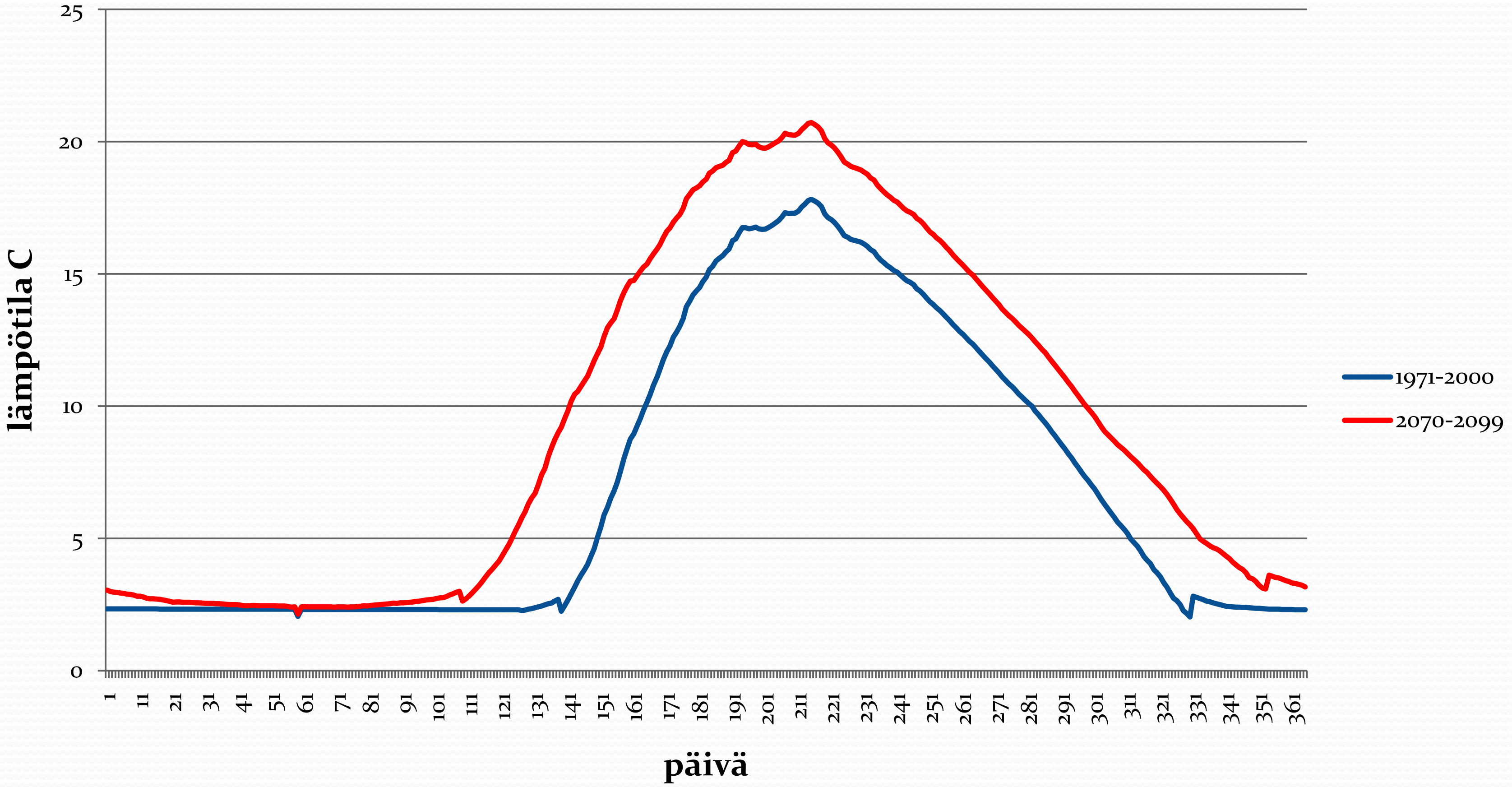
Lehtonen 1996

Mahdollisesti kärsivät lajit

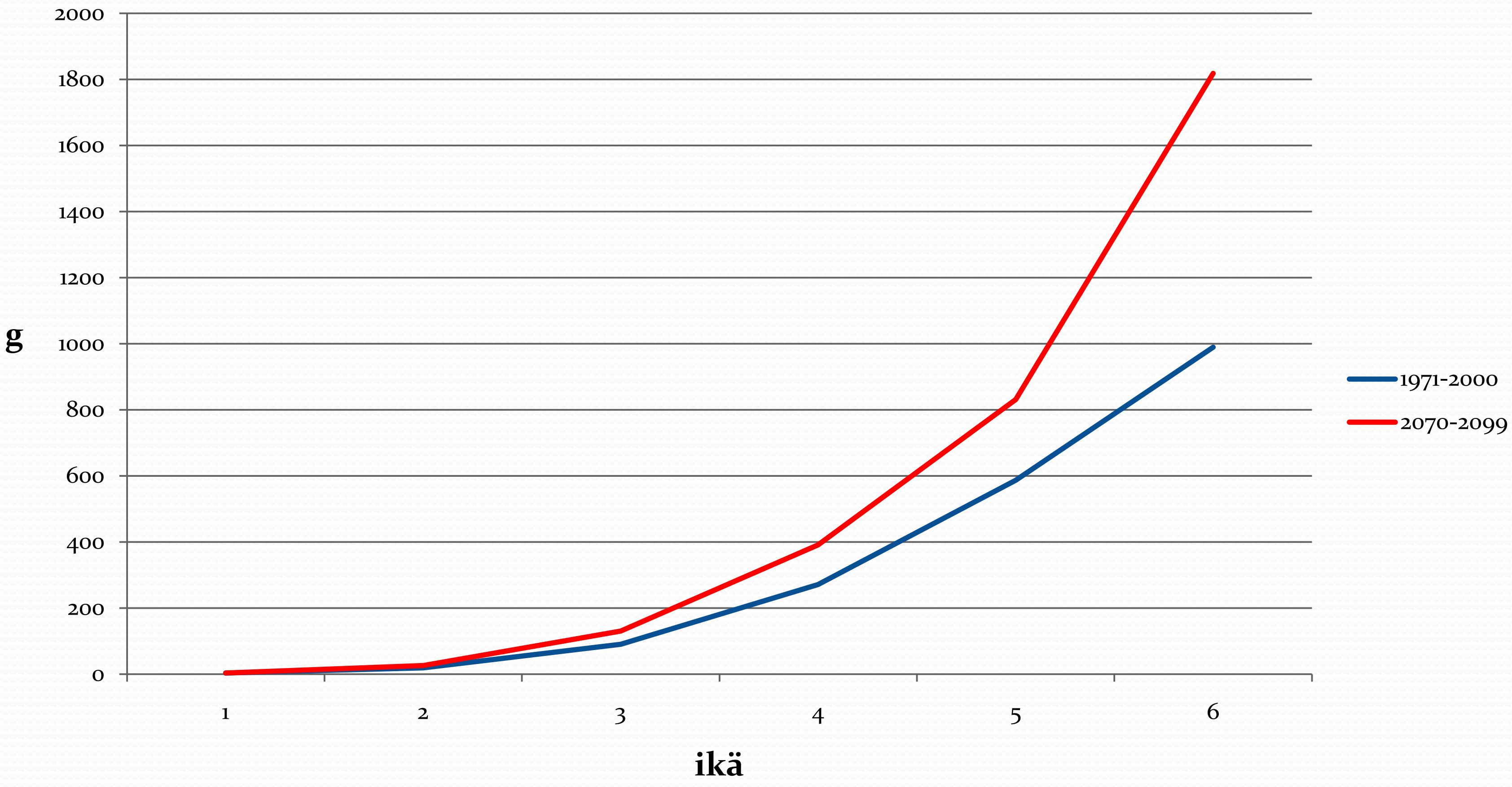
	Optimilämpötila
Muikku	13
Siika	18
Kuore	12
Taimen	17

Lehtonen 1996

Kuhan oleskelulämpötila



Kuhan kasvu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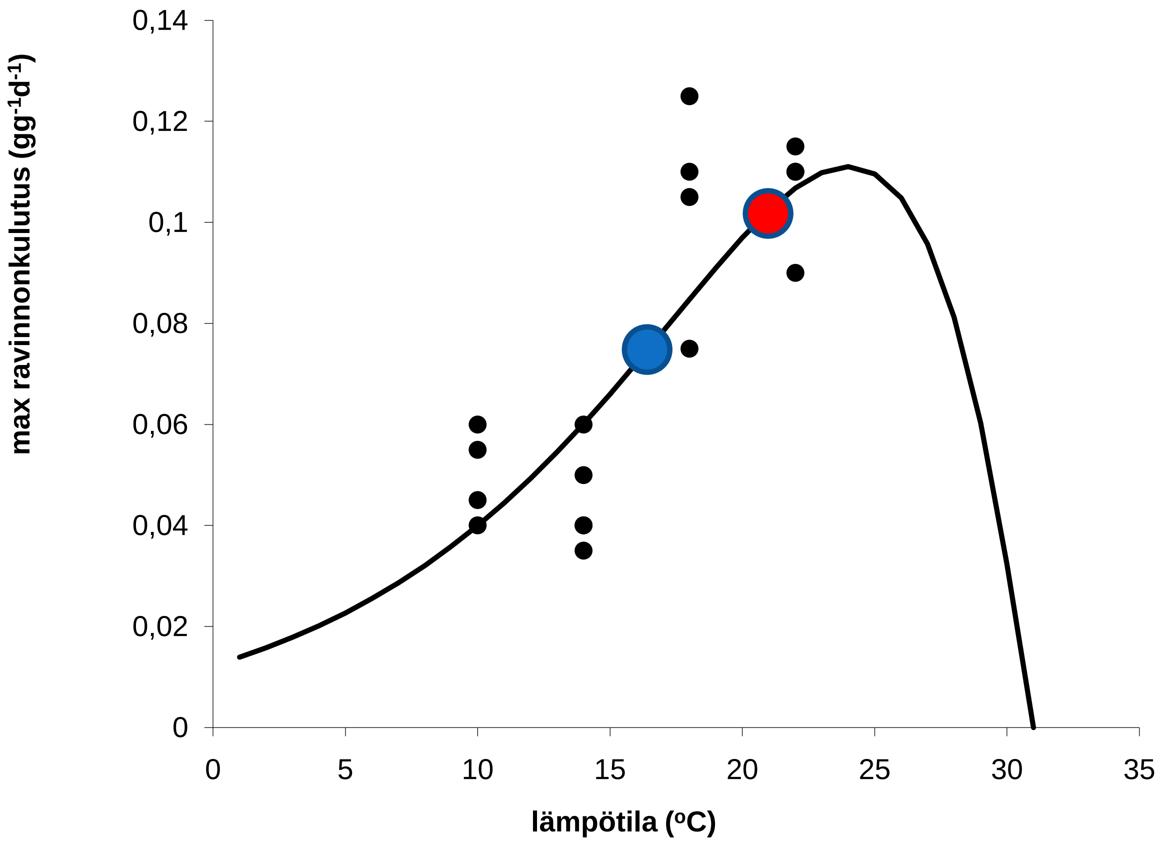
Kuhan ravinnonkulutus



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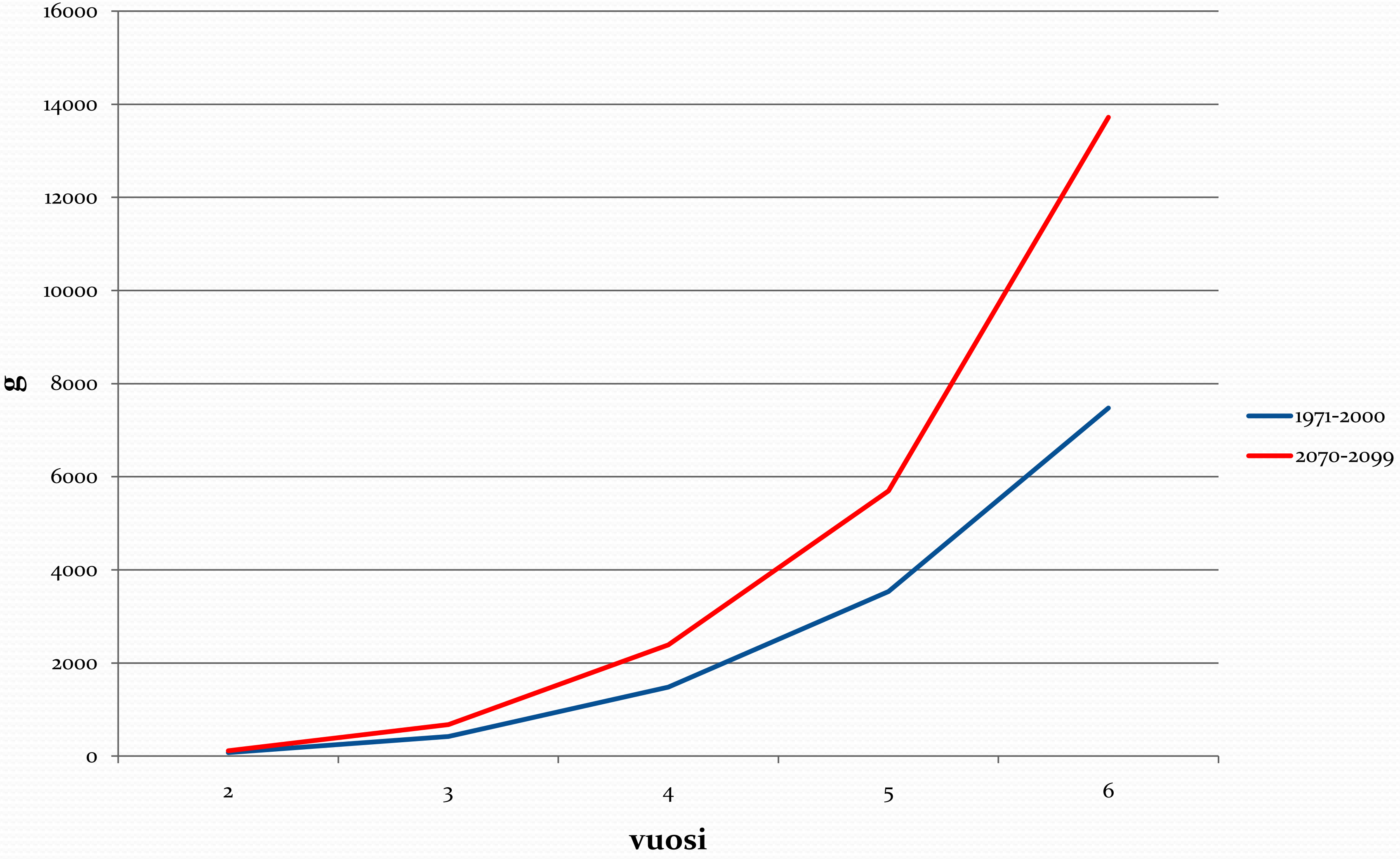
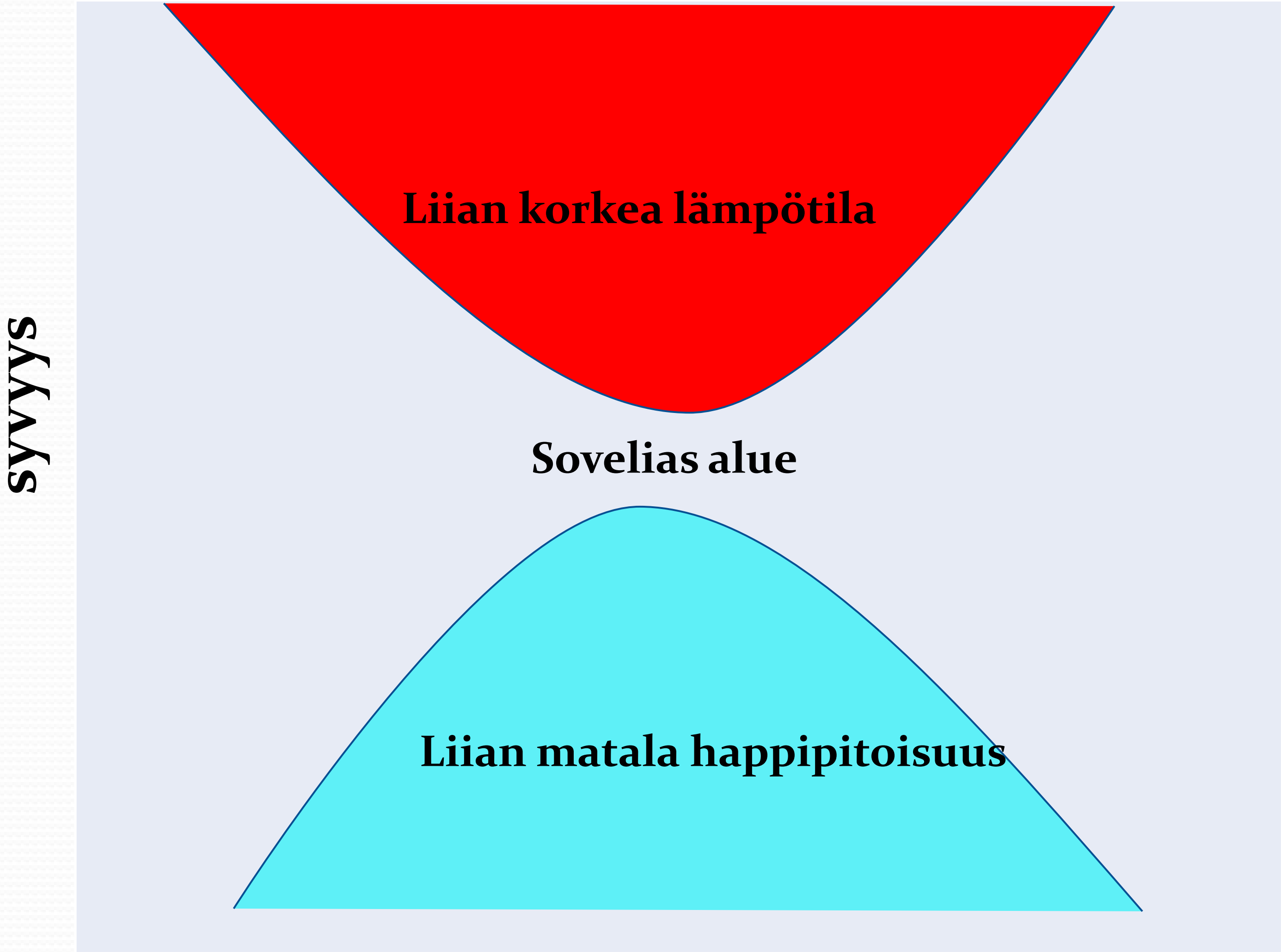


Muikulle sovelias elintila nykyään



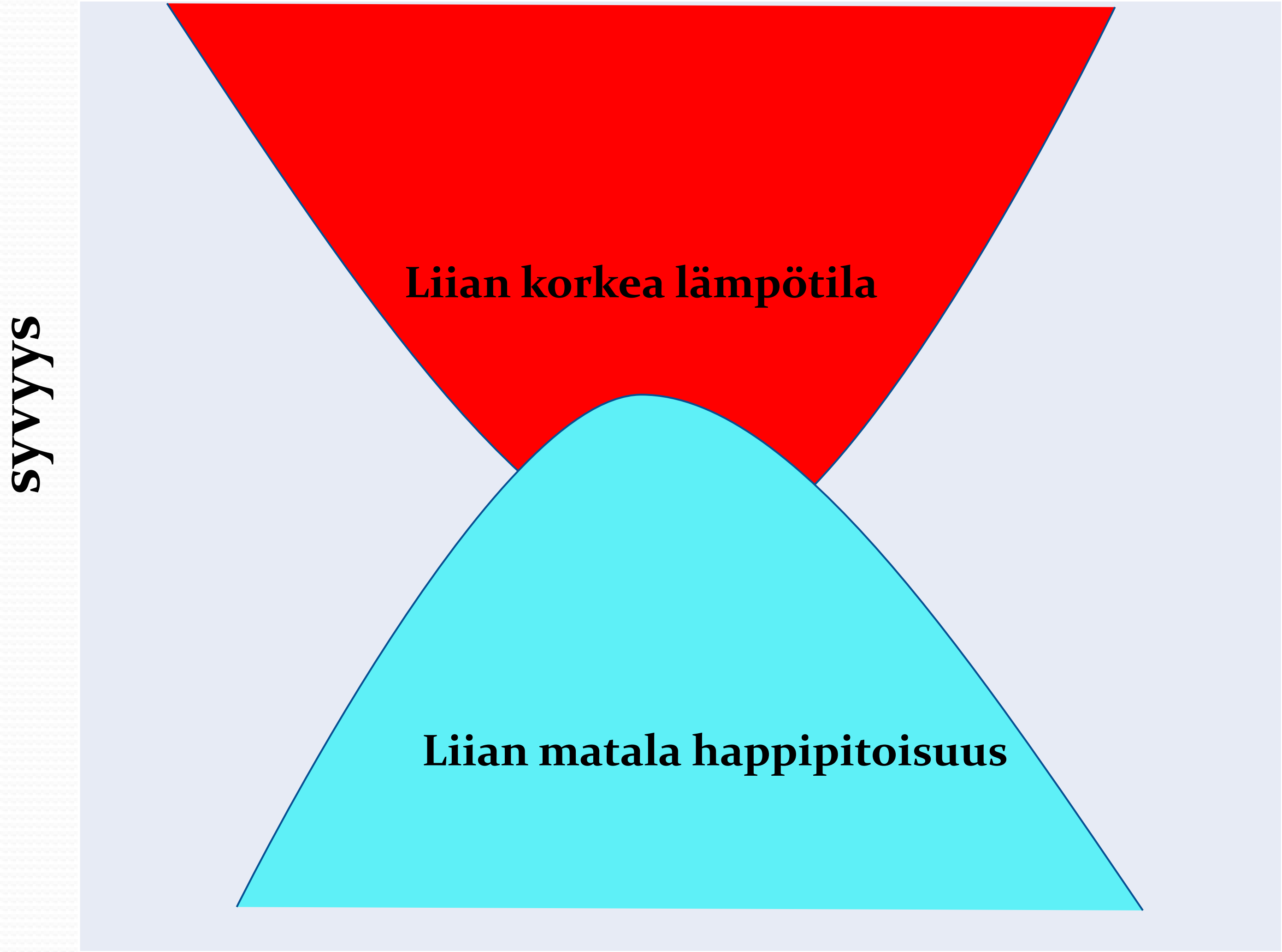
syvyys

Liian korkea lämpötila

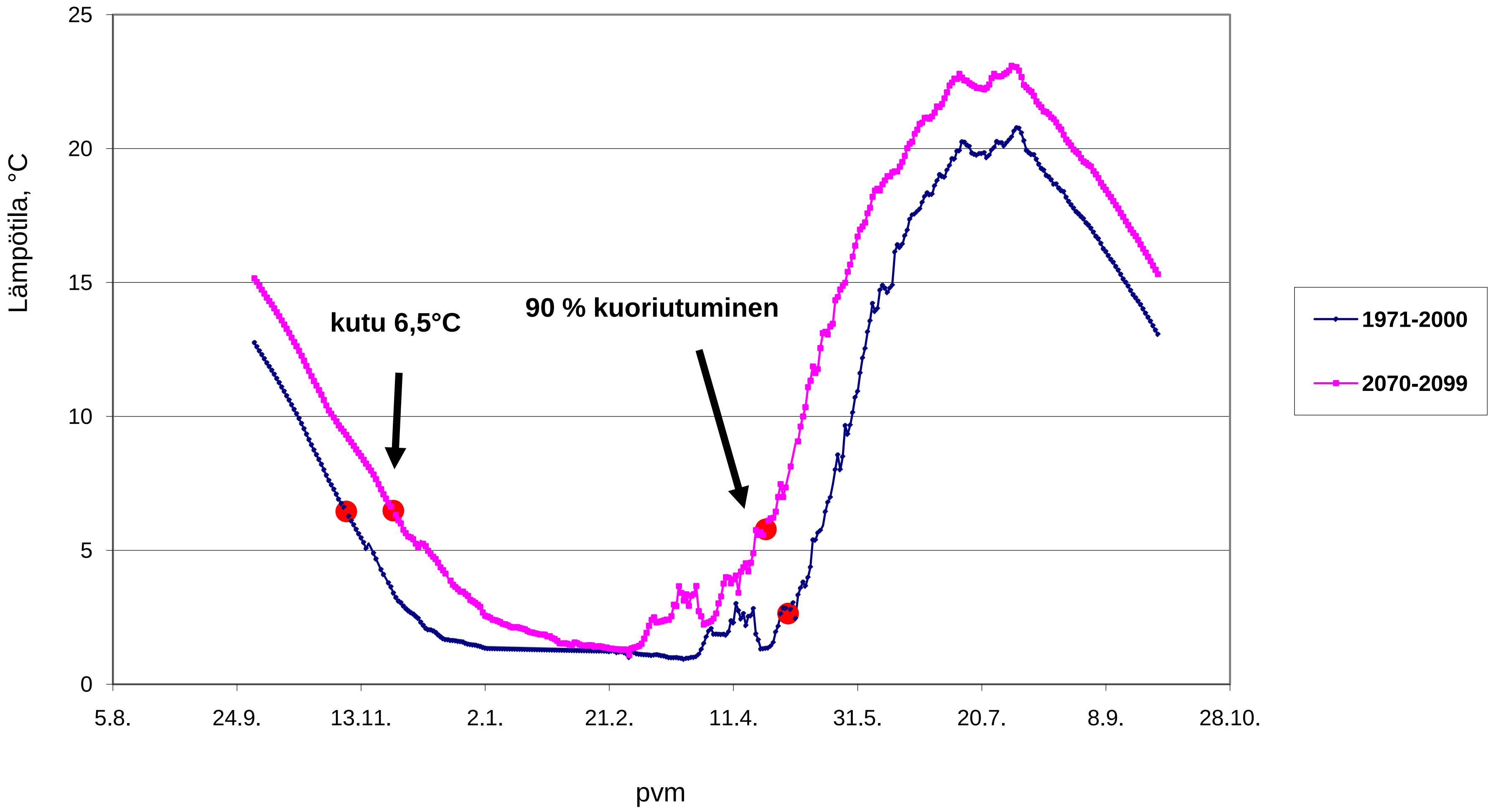
Sovelias alue

Liian matala happipitoisuus

Muikulle sovelias elintila tulevaisuudessa



Muikun lisääntyminen



Ahven avainlaji?

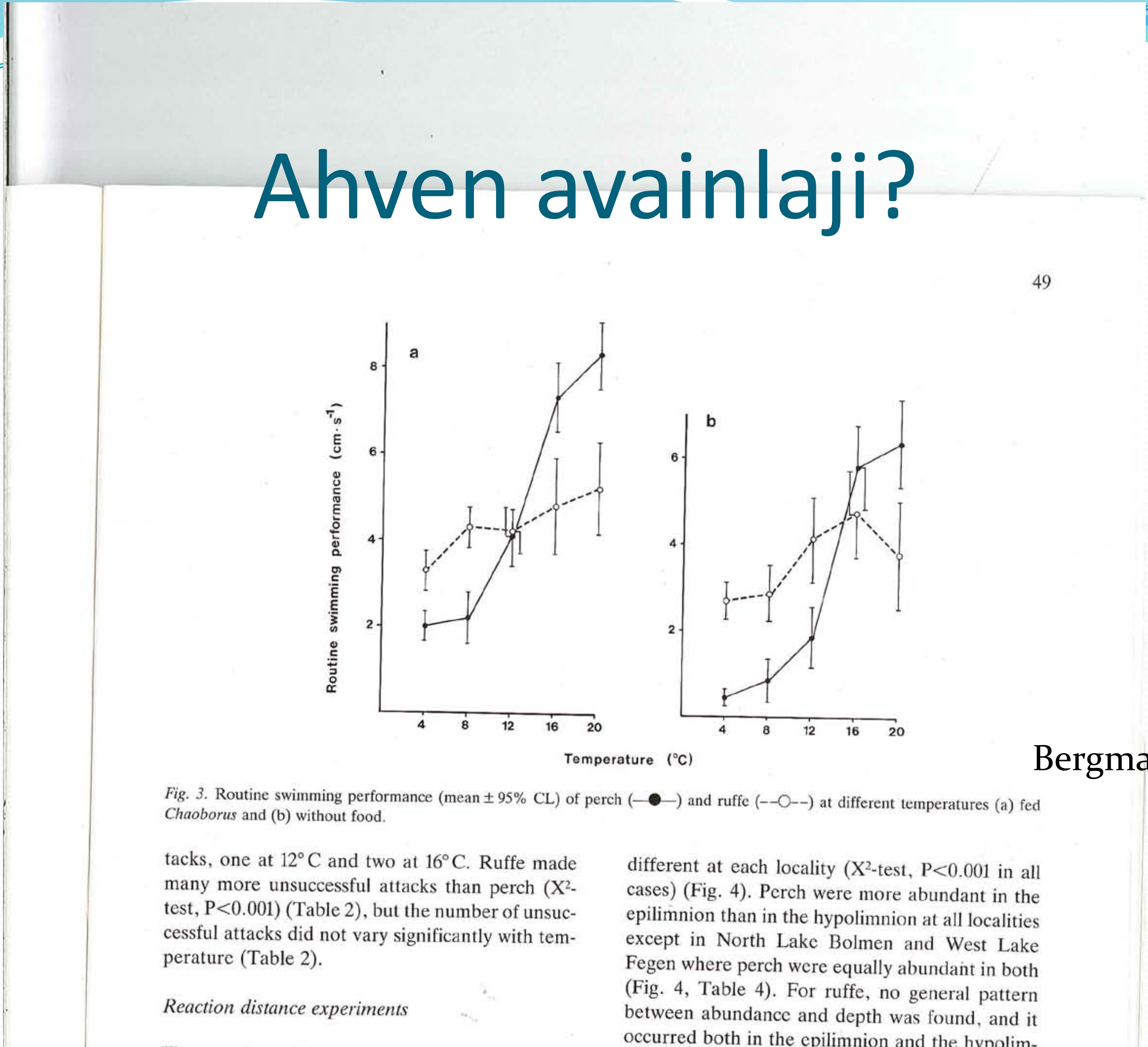


Fig. 3. Routine swimming performance (mean ± 95% CL) of perch (—●—) and ruffe (--○--) at different temperatures (a) fed *Chaoborus* and (b) without food.

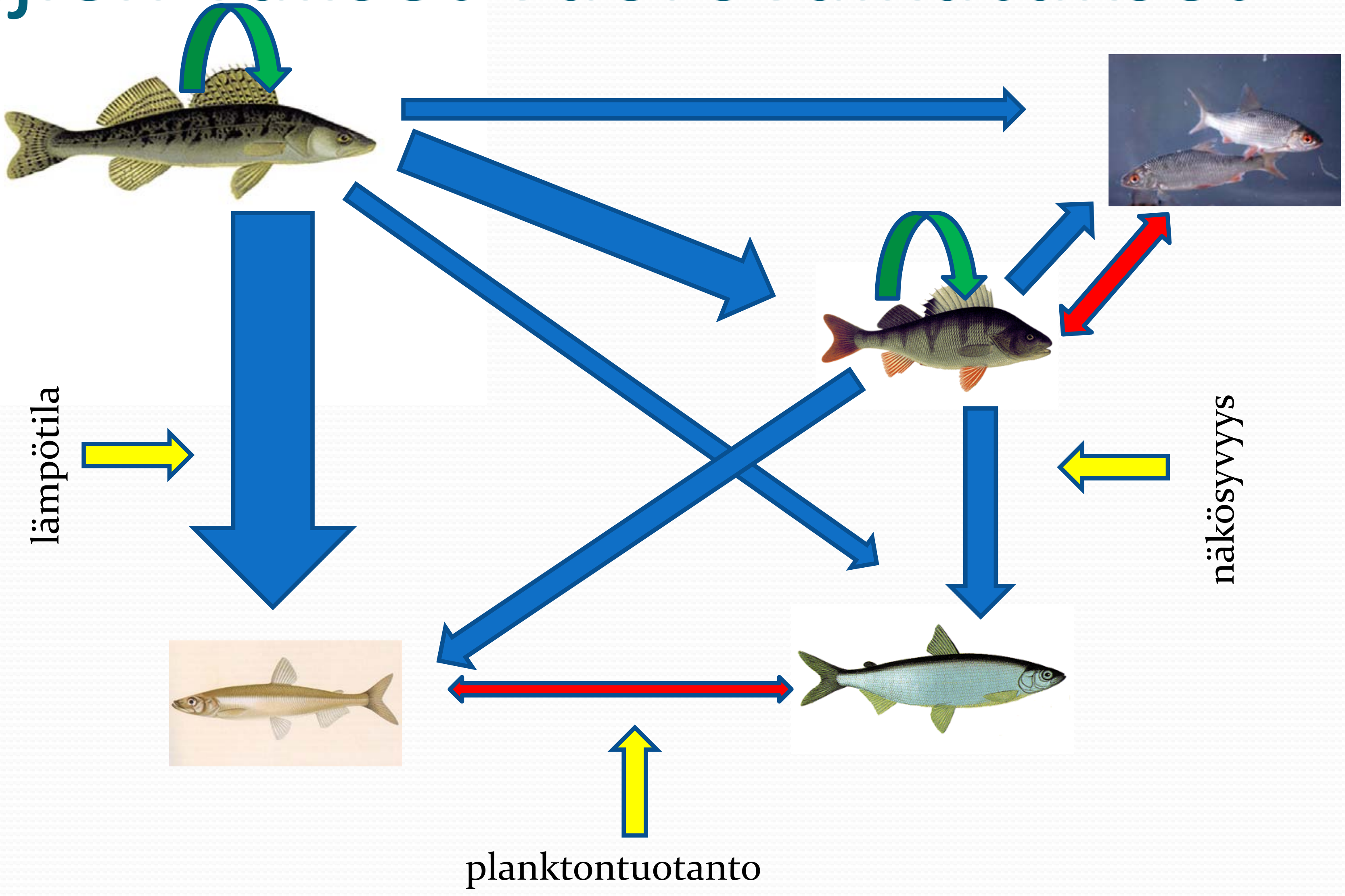
tacks, one at 12° C and two at 16° C. Ruffe made many more unsuccessful attacks than perch (X^2-test, $P<0.001$) (Table 2), but the number of unsuccessful attacks did not vary significantly with temperature (Table 2).

Reaction distance experiments

different at each locality (X^2-test, $P<0.001$ in all cases) (Fig. 4). Perch were more abundant in the epilimnion than in the hypolimnion at all localities except in North Lake Bolmen and West Lake Fegen where perch were equally abundant in both (Fig. 4, Table 4). For ruffe, no general pattern between abundance and depth was found, and it occurred both in the epilimnion and the hypolim-

Bergman 1987

Lajien väliset vuorovaikutukset



lämpötila

näkösyvyys

planktontuotanto

Sopeutujasektorit

- Ammattikalastus
- Kalavesien hoito (istutukset)
- Kalanviljely
- Hallinto
- Neuvonta

Kysymyksiä

- Ammattikalastus
    - Troolauskausi pitenee
    - Muikkukannat??
    - Riittävätkö ahven/kuhakannat ammattikalastukseen?
- Pitääkö taantuvia lajeja tukea istutuksin vai panostaa menestyvien lajien istutuksiin?
- Kalanviljely
    - Vesitys, taudit