Environmental effects on sprat (Sprattus sprattus) physiology and growth at the distribution frontier: A bioenergetic modelling approach

Sprat, Sprattus sprattus, is a small pelagic fish species with a wide distribution along the European continental shelf, the Mediterranean Sea, the Black Sea and the Baltic Sea. The Baltic Sea is the coldest area of the species distribution range. Even here, sprat is still numerous and holds a key role in the ecosystem. However, the population is sensitive to small changes in environmental conditions. In this paper, we set up a bioenergetic model of Baltic sprat and evaluate how variability and seasonal changes in the physical environment affects the physiology and growth of individual sprat. The model is dynamic and seasonally resolved. It is parameterised based on sprat from the Bornholm Basin. Our model results suggest that the optimal temperature for sprat growth is 17.5 °C, which is only observed in the Central Baltic Sea in the top water layer during a short period in summer. During 41/2 winter months individual sprat do not grow and utilize stored energy from the previous growth season. We analysed the maximum attainable individual body size as a function of temperature. The model predicted reduced maximum body sizes with increasing temperature. The model can be used for studying climate change scenarios on individual growth, egg production and condition of Baltic sprat.
Physiology, phenotype, and behavioural strategies of forage fish: Studied by bioenergetic modeling

Forage fish are small individuals, and are very abundant in numbers and can form dense schools. Forage fish are important within the food webs of the oceans, as they are at the lower trophic levels. Forage fish prey on zooplankton and they are themselves preyed on by piscivore fish. The individual forage fish and its growth dynamics are governed by an interplay between physiological rates, e.g. metabolism and consumption and the ambient environment as the rates are temperature dependent. The topic of this thesis is to describe the strong link between the individual and the environment through bioenergetic modeling. The bioenergetic model is based on the Wisconsin framework, and assumes that ingested energy is deducted losses to egestion, excretion, standard dynamic action and metabolic costs. Surplus energy, if available, is divided between growth in two structure pools; somatic tissue and reserves. The model includes an additional structure pool; gonads, to which energy is transferred during the spawning season. During periods of poor feeding, energy to cover metabolic costs are firstly taken from the reserve pool and secondly, if the reserves are depleted, from the somatic tissue pool. The model is forced by the ambient temperature experienced by the individual and prey. The bioenergetic model reveals how the physiology and the link to the environment are governing factors determining the growth dynamics of the individual. The model includes evaluation of the life history of an individual allowing study of individual behaviour, making the model a strong tool, for investigating hypotheses of life history and behavioural strategies in forage fish. The model is parameterized for Baltic Sea sprat and was used for determination of the importance of temperature on physiology, growth and egg production of adult female sprat.
Particular emphasis is placed on the allocation of energy inside the individual, whether energy is invested in growth or reproduction. The simulations reveal that a constant division of surplus energy between the lipid and soma pools leads to seasonal variations in growth and size matching observations. Also an increase in the soma growth potential as a function of temperature was observed, but that the maximum size will decrease with increasing temperature. Temperature is especially important for Baltic sprat as the Baltic Sea is at the species northernmost distribution limit with regard to temperature. Climate scenarios for the Baltic Sea predict a significant warming and the impact of predicted future climate changes and the prey phenology on growth, egg production and fitness was determined. We find the warmer future climate reduces egg production and fitness. The larger the temporal match of the prey with spawning season, the larger is the egg production and fitness. Therefore the effects of temperature on the sprat stock can be lowered if prey phenology responds to the climate. The bioenergetic framework is also used to investigate effects of individual behaviour on the fitness of an individual. Baltic Sea herring are observed to skip spawning when individuals have low condition. This phenomenon and its implications to individual fitness are quantified and are linked to the individual and environmental conditions as well as spawning season. Changes in the individual condition were affecting the number of skipped spawning events and age at first spawning. Spring spawning was found to be the better strategy compared to autumn spawning. Another behavioural strategy which was investigated was the burrowing strategy seen in 5 sandeel in the North Sea. The trade off by this strategy whereby the energy intake is lowered but the strategy also reduces potential predation is quantified. This revealed that the strongest trade off for the individual is to reduce mortality rather than to seek an opportunity to grow larger and thereby be able to produce more eggs.

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**Effects of future climate on physiology and egg production in Baltic Sea sprat**

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**Overwintering strategy of sandeel ecotypes from an energy/predation trade-off perspective**

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Bioenergetic, life-history modeling of sprat

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Organisations: Section for Population- and Ecosystem Dynamics, National Institute of Aquatic Resources
Authors: Frisk, C. (Intern), Andersen, K. H. (Intern), Kraus, G. (Ekstern)
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Main Research Area: Technical/natural sciences

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Publication date: 2008
Main Research Area: Technical/natural sciences

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Implementering af et biologisk og kemisk modul til COHERENS modellen for Mariager Fjord

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Organisations: Section for Population Ecology and Genetics, National Institute of Aquatic Resources, Section for Ocean Ecology and Climate
Authors: Frisk, C. (Intern), Bendtsen, J. (Ekstern), Nielsen, T. G. (Intern)
Publication date: 2007
Main Research Area: Technical/natural sciences
Projects:

Rekruttering af brisling

National Institute of Aquatic Resources

Period: 01/01/2008 → 22/08/2012

Number of participants: 6

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Supervisor:

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Main Supervisor:

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Examiner:

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Peck, Myron A. (Ekstern)

Financing sources

Source: Internal funding (public)

Name of research programme: Offentlig finansiering

Project: PhD

Modelling the impact of hydrography and lower trophic production on fish recruitment (MODREC) (38114)

The recruitment of fish stocks is strongly influenced by fluctuations in climate and physical environment leading to strong and seemingly unpredictable year-to-year variations in year class strength. The aim of this project is to develop a model framework for conducting detailed recruitment studies on fish stocks. The framework will be applied for two commercially important fish stocks: sprat and sandeel, in order to improve the understanding of climate effects via bottom-up control and explain the observed high variability in reproductive success in these stocks. The framework will be built on existing hydrographic models by adding descriptions of primary and zooplankton production.

The project is coordinated by DTU Aqua.

National Institute of Aquatic Resources

Section for Marine Ecology and Oceanography

Aarhus University

Danish Meteorological Institute

Period: 01/01/2007 → 31/12/2009

Number of participants: 5

Research area: Marine Populations and Ecosystem Dynamics

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Mariani, Patrizio (Intern)

Project Manager, academic:

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Project:

Scaling from individuals to populations (SLIP) (38726)

The research school SLIP (Scaling from Individuals to Populations) focuses on how individual behavior and mutual interactions generate the dynamics observed at the population level. This topic forms the link between the basic and applied marine ecological research environments in Denmark and requires input from biology, mathematics and statistics. SLIP is one of the five research networks and research schools under the Danish Network for Aquaculture and Fisheries Research (Fishnet). SLIP has arranged a number of national and international PhD courses and workshops and has served to focus the interest on size and trait-based modeling, as well as on improved understanding of the physiology,
genetics and behavior of marine organisms, in particular fish.

The project is coordinated by DTU Aqua.

DTU Data Analysis
National Institute of Aquatic Resources
Section for Marine Living Resources
Roskilde University
Royal Veterinary and Agricultural University
Aarhus University

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Period: 01/01/2000 → 31/12/2008
Number of participants: 9
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