Establishment of blue mussel beds to enhance fish habitats

Human activity has impacted many coastal fjords causing degeneration of the structure and function of the fish habitats. In Nørre fjord, Denmark, local fishermen complained of declining fish catches which could be attributed to eutrophication and extraction of sediments over several decades. This study aimed to establish blue mussel beds (Mytilus edulis) to increase structural complexity and increase the abundance of fish and epifauna in Nørre fjord. It was expected that the mussels would improve water transparency and increase the depth range and coverage of eelgrass (Zostera marina). New methods for mussel production and -bed construction were investigated in collaboration with local volunteer fishermen. The effect of the artificial mussel beds was most evident on a small scale. Video observations directly at the beds (Impact area) demonstrated increased biodiversity and a three times higher abundance of mesopredator fish compared to the Control area. Water clarity and eelgrass coverage were unchanged. Two methods for establishing mussel beds were tested. A total of 44 tons of blue mussels were produced and established in beds over an area of 121,000 m2. Production of blue mussels directly on hemp sacs hanging on long-lines was the most effective method. This new method is potentially a useful management tool to improve fish habitats.
Effects of dietary fatty acids on the production and quality of eggs and larvae of Atlantic cod (Gadus morhua L.)

Cultivated Atlantic cod (Gadus morhua) entering their first year of gamete maturation were fed diets with different levels of arachidonic acid (ARA) and eicosapentaenoic acid (EPA) for 6.5 months prior to commencement of spawning. Gravid females were stripped three times: at the beginning, peak and end of spawning. Lipid composition and egg and larval quality of 34 family crosses were investigated. Results indicated that ARA uptake into eggs from broodstock diet was highly efficient achieving proportions of ARA up to 84% higher in eggs than in the diet. EPA was 42–76% higher, and DHA was 155–173% higher in eggs than in diets. Cod fed the diet with the lowest EPA/ARA ratio had the greatest egg production. Eggs from fish on a diet with high ARA level had significantly higher fertilization and hatching success than those fed low levels of ARA. This diet produced on average 71 viable eggs g⁻¹ female compared with 32.5 and 4 eggs in diet B and C, respectively. Furthermore, larval survival until 8 days posthatch was higher in diets with lower ARA levels. The combined results showed that ARA dietary supplementation and low EPA/ARA ratio yielded a greater number of viable larvae kg⁻¹ female

General information
State: Published
Organisations: National Institute of Aquatic Resources, Section for Ecosystem based Marine Management, National Food Institute, Division of Industrial Food Research, Section for Marine Ecology and Oceanography, Section for Marine Living Resources, Fisheries and Oceans Canada
Authors: Røjbek, M. (Intern), Støttrup, J. (Intern), Jacobsen, C. (Intern), Tomkiewicz, J. (Intern), Nielsen, A. (Intern), Trippel, E. (Ekstern)
Pages: 654-666
Publication date: 2014
Main Research Area: Technical/natural sciences

Publication information
Journal: Aquaculture Nutrition
Volume: 20
Issue number: 6
ISSN (Print): 1353-5773
Forage fish quality: seasonal lipid dynamics of herring (Clupea harengus L.) and sprat (Sprattus sprattus L.) in the Baltic Sea.

This study investigates lipid content and fatty acid composition of two important forage fish, sprat (Sprattus sprattus) and herring (Clupea harengus) in the Baltic Sea ecosystem. Seasonal variation in lipids was studied during three periods following the annual reproductive cycle considering potential differences relating to fish size, sex, and reproductive status. The isopod Saduria entomon, being at times an important prey for predatory fish, was included for comparison. In both sprat and herring, lipid content and absolute contents of essential polyunsaturated fatty acids (PUFAs) varied seasonally with high levels towards the end of the annual zooplankton production cycle, succeeded by a decline. Lipid content and fatty acid composition differed significantly between sprat and herring. Sprat lipid content was higher than herring,
increasing with fish size and characterized by large proportions of monounsaturated fatty acids. Herring lipid content was related to the reproductive cycle and proportions of PUFAs were high compared with sprat. Levels of essential PUFAs were high in S. entomon compared with clupeids rendering it a valuable alternative prey species in the Baltic Sea ecosystem. The lipid dynamics of forage fish and benthos, combined with changes in availability and abundance, will affect growth and reproduction of their predators.
In recent decades, Baltic cod has experienced a period of low recruitment. In the same period the pelagic Baltic Sea ecosystem experienced a regime shift, due to hydrographic changes, affecting all trophic levels. The rationale for the thesis is built on the hypothesis that the regime shift has resulted in decreased dietary value of clupeids in terms of lipid content and essential fatty acids (EFA) which originates from phytoplankton and is transferred up through the food web. Clupeids are main prey for cod in the Central Baltic Sea and a decreased dietary value is hypothesised to affect cod reproduction. The overall objective of the thesis is to investigate the role of lipids in reproduction of cod (Gadus morhua) in the Central Baltic Sea. The first objective is to examine the seasonal variation in content of lipid and EFA in whole prey species of cod (Paper I). The second objective is to investigate the variation in lipid content, EFA and antioxidants of female Baltic cod gonads and livers during the reproductive cycle (Paper II) and to examine whether there is a deficiency in lipid energy and dietary EFA that could explain the delayed spawning time observed in the Baltic cod (Paper III). The third objective is to investigate experimentally if EFA levels, comparable to those observed in Baltic clupeids, delayed timing of spawning and influenced egg production and quality in cod (Paper IV). The study combines field data of cod and its main prey species; sprat (Sprattus sprattus), herring (Clupea harengus) and the isopod Saduria entomon from the Baltic Sea sampled during 2002-2004 and 2008-2009 in different seasons and experimental data of farmed broodstock cod. Lipid composition of whole prey species and ovaries and livers of cod in different maturity stages were analyzed and lipid composition in samples of mature cod was compared with samples of North Sea cod with no delay in spawning time. A feeding experiment was carried out to test the dietary effect of different levels of the essential polyunsaturated n-6 arachidonic acid (ARA) and n-3 eicosapentaenoic acid (EPA) on spawning period, realized fecundity, and egg and larval quality under controlled conditions. Lipid content and fatty acid composition (FAC) differs significantly between sprat, herring and S. entomon (Paper I). Sprat has in general high lipid content and proportion of the monounsaturated fatty acid, oleic acid, compared to herring, which in contrast, has high proportion of the polyunsaturated fatty acid, docosahexaenoic acid (DHA). This suggests that sprat feeds more on the copepods Pseudocalanus sp. than herring which mainly feeds on Temora longicornis. Hence, altered ratios of sprat and herring abundance available for cod may impact lipid content and FAC in cod. High proportions of ARA, EPA and the antioxidant, astaxanthin, in S. Entomon, compared to 9 clupeids, render it a valuable constituent in the diet of Baltic cod. However, the abundance of S. Entomon has declined in recent decades in the Baltic. FAC of ovary and liver varies with maturity stage in Baltic cod (Paper II and III). Low content of ARA in sprat and herring in spring and summer is reflected in cod ovaries and coincide with the timing of the maturation period of cod in the Central Baltic Sea (Paper I and II). Fatty acids trophic markers indicates that dinoflagellates dominated during the years examined which may have resulted in a reduction of ARA level in both sprat and herring compared to periods with domination of diatoms (Paper I). No limitation in lipid energy is evident in Baltic cod but a deficiency in ARA is indicated (Paper II). Selective retention of ARA in ovaries during ovarian maturation is evident (Paper II) but despite mobilization of ARA from liver, the level is not sufficient to keep up with the requirement in ovaries and ARA decreases in late maturation and during spawning. The antioxidants α-tocopherol and astaxanthin accumulates in cod ovaries compared to prey and decreases in late maturation and spawning due to antioxidant protection activity (Paper II). ARA level, important for eicosanoid activity, is lower in ovaries of Baltic Sea cod than in North Sea cod (Paper III), indicating that this fatty acid may be important for spawning time. However the spawning period is not influenced by different ARA levels and EPA:ARA ratios in farmed cod (Paper IV). Uptake of DHA, EPA and ARA into cod eggs from broodstock diet is highly efficient (Paper IV). Diet with low EPA:ARA ratio has significantly higher realized fecundity and eggs from fish fed a diet with high ARA level has higher fertilization success and survival to 8 days post hatch compared to fish fed low level of ARA. The combined
results strongly indicate that the low ARA levels in Baltic cod ovaries, reflecting ARA levels in prey, result in low fertilization success and survival of eggs and larvae. This PhD provides novel information about lipid dynamics in Baltic sprat and herring which is important because these species occupy a central position in the Baltic ecosystem. The results contribute to a better understanding of the lipid requirements and fatty acid mobilization during maturation in cod but do not explain the delayed spawning time in Baltic cod. The improved knowledge of the effect of dietary EFA on realized fecundity and egg and larval quality in cod is of great importance for estimating recruitment but also to cod farming because egg quality in cultured cod is one of the limiting factors for successful mass production of fish fry. EFA proved a useful tool as trophic markers in the Baltic Sea ecosystem and the results indicate that EFA may also be useful as ecosystem state indicators.

General information
State: Published
Organisations: National Institute of Aquatic Resources, Section for Coastal Ecology
Authors: Røjbek, M. (Intern), Støttrup, J. (Intern)
Number of pages: 199
Publication date: 2012

Publication information
Place of publication: Charlottenlund
Publisher: DTU aqua, National Institute of Aquatic Resources
Original language: English
Main Research Area: Technical/natural sciences
Electronic versions:
Maria_thesis_final_260612.pdf
Publication: Research › Ph.D. thesis – Annual report year: 2012

Linking lipid dynamics with the reproductive cycle in Baltic cod Gadus morhua
This study describes lipid composition and antioxidants of Baltic cod Gadus morhua L. during the reproductive cycle, and investigates whether they reflect its dominant prey and whether levels of fatty acids important for reproductive performance were low. Reasons for a shift in peak spawning time of Baltic cod from spring/early summer to midsummer since the early 1990s remain unresolved and may partly be diet related. This study demonstrated that a substantial amount of lipid was invested in cod ovarian development, and that lipid composition varied substantially with the reproductive cycle. Selective retention of the essential fatty acids docosahexaenoic acid (DHA) and arachidonic acid (ARA) in ovaries during maturation was evident, but despite mobilization from the liver, ARA levels were low in ovaries during late maturation and spawning. Astaxanthin and a-tocopherol accumulated in cod ovaries and decreased in late maturing and spawning fish, most likely due to their antioxidant protection activity. The fatty acid composition of cod liver reflected its clupeid prey. The ratio of 18:1n-9 to DHA was almost twice as high in sprat as in herring and indicated the ratio of sprat and herring in cod diet, while the level of 16:1n-7 and astaxanthin indicated the presence of the isopod Saduria entomon in cod diet. It is likely that food web alterations in the Baltic ecosystem related to environmental and hydrographic changes caused a decrease in ARA availability. Low ARA content coincides with cod ovarian development in the central Baltic Sea, and may be associated with the delay in spawning and affect egg and larval survival; however, this needs further verification in experimental studies.

General information
State: Published
Organisations: National Institute of Aquatic Resources, Section for Coastal Ecology, National Food Institute, Division of Industrial Food Research, Section for Population Ecology and Genetics
Authors: Røjbek, M. (Intern), Jacobsen, C. (Intern), Tomkiewicz, J. (Intern), Støttrup, J. (Intern)
Pages: 215-234
Publication date: 2012
Main Research Area: Technical/natural sciences

Publication information
Journal: Marine Ecology Progress Series
Volume: 471
ISSN (Print): 0171-8630
Ratings:
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 2.4
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 2.56
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 2.75
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 2.79
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 2.9
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): CiteScore 2.85
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 2
Web of Science (2008): Indexed yes
Web of Science (2007): Indexed yes
Web of Science (2006): Indexed yes
Web of Science (2005): Indexed yes
Web of Science (2004): Indexed yes
Web of Science (2003): Indexed yes
Web of Science (2002): Indexed yes
Web of Science (2001): Indexed yes
Web of Science (2000): Indexed yes
Original language: English
Electronic versions:
6.pdf
DOI:
10.3354/meps10012
Links:
Publication: Research - peer-review › Journal article – Annual report year: 2012

Lipid dynamics of herring (Clupea harengus L.) and sprat (Sprattus sprattus) as major prey species in the Baltic Sea

General information
State: Published
Organisations: National Institute of Aquatic Resources, Section for Coastal Ecology, Section for Population Ecology and Genetics, National Food Institute, Division of Industrial Food Research
Authors: Røjbek, M. (Intern), Tomkiewicz, J. (Intern), Jacobsen, C. (Intern), Støttrup, J. (Intern)
Publication date: 2012
Event: Abstract from ICES/PICES Symposium on Forage Fish Interactions, Nantes, France.
Main Research Area: Technical/natural sciences
Publication: Research › Conference abstract for conference – Annual report year: 2013

Slutrapport for Projekt BioRev 2010-2012

General information
Effects of dietary acids on ovarian maturation, spawning time and egg and larvae of wild and captive cod (Gadus morhua)

General information
State: Published
Organisations: National Institute of Aquatic Resources, Section for Coastal Ecology
Authors: Røjbek, M. (Intern)
Publication date: 2011
Event: Abstract from Fish reproduction and Fisheries, Vigo, Spain.
Main Research Area: Technical/natural sciences
Electronic versions:

http://www.youtube.com/watch?v=6LVROU1CePw&feature=relmfu

Influence of lipids and fatty acid composition on Baltic cod (Gadus morhua L.) maturation and timing of spawning

General information
State: Published
Organisations: Section for Population Ecology and Genetics, National Institute of Aquatic Resources, Section for Coastal Ecology, Section for Aquatic Lipids and Oxidation, Institute Management
Authors: Tomkiewicz, J. (Intern), Støttrup, J. (Intern), Jacobsen, C. (Intern), Røjbek, M. (Intern), Köster, F. (Intern)
Publication date: 2010
Main Research Area: Technical/natural sciences
Electronic versions:

http://www.ices.dk/products/cmdocsindex.asp

Bibliographical note
Extended abstract
Source: orbit
Source-ID: 256650

Seasonal lipid dynamics of sprat (Sprattus sprattus) and herring (Clupea harengus) in the Baltic Sea
Seasonal lipid dynamics of herring and sprat in the Baltic Sea and possible implications for cod reproduction

The Baltic Sea experienced a regime shift in the 1980ies with major changes in food web dynamics. These ecosystem alterations were related to climatic driven changes in hydrographic conditions affecting phyto- and zooplankton assemblage and hence the food availability for clupeids. Sprat abundance increased dramatically in the early 1990ies. The changes in plankton communities in combination with increased competition resulted in declined condition of clupeids. Polyunsaturated fatty acids originate from phytoplankton and are transmitted through the food web. The present study investigates if the seasonal variation in lipid composition of herring and sprat reflects the changes in plankton. Fish were sampled five times over a year and the lipid composition of different size groups was analyzed. Significant seasonal variation in average lipid content in sprat was found: 14.00% in November, 11.26% in January, 7.47% in March and 9.60% in June. The lipid content in herring also varied within season but was lower than sprat: 7.42% in November, 6.71% in January and 4.70% in March. The seasonal lipid dynamic was reflected in variation of specific fatty acids. Clupeids are the major prey of Baltic cod so deficiencies of essential fatty acids could be a limiting factor for cod reproduction.

Kystfodring og kystøkologi: Evaluering af revlefodring ud for Fjaltring

Kystfodring og kystøkologi: Evaluering af revlefodring ud for Fjaltring

General information
State: Published
Organisations: Section for Coastal Ecology, National Institute of Aquatic Resources, Section for Shellfish, Section for Aquaculture
Authors: Støttrup, J. (Intern), Dolmer, P. (Intern), Røjbek, M. (Intern), Nielsen, E. (Intern), Ingvardsen, S. (Ekstern), Sørensen, P. (Ekstern), Sørensen, S. R. (Intern)
Publication date: 2009
Event: Poster session presented at ICES/PICES/UNCOVER Symposium 2009 on Rebuilding Depleted Fish Stocks, Warnemünde/Rostock, Germany.
Main Research Area: Technical/natural sciences
Publication: Research › Poster – Annual report year: 2009
Udvikling af opdræt af aborre – en alternativ art i ferskvandsopdræt

General information
State: Published
Organisations: Section for Aquaculture, National Institute of Aquatic Resources, Section for Coastal Ecology
Authors: Paulsen, H. (Intern), Overton, J. L. (Intern), Røjbek, M. (Intern)
Number of pages: 43
Publication date: 2007

Publication information
Publisher: Danmarks Fiskeriundersøgelser
Original language: Danish
Main Research Area: Technical/natural sciences
Electronic versions: 171-07, elektronisk_index_ny.pdf
Source: orbit
Source-ID: 227552
Publication: Research › Report – Annual report year: 2007

Kystfodring og godt fiskeri: Undersøgelse af strandnær kystfodring ved Agger Tange

General information
State: Published
Organisations: Section for Coastal Ecology, National Institute of Aquatic Resources, Section for Shellfish, Section for Aquaculture
Authors: Støttrup, J. (Intern), Dolmer, P. (Intern), Røjbek, M. (Intern), Nielsen, E. (Intern), Ingvardsen, S. (Ekstern), Laustrup, C. (Ekstern), Sørensen, S. R. (Intern)
Number of pages: 52
Publication date: 2005

Publication information
Place of publication: Charlottenlund
Publisher: Danmarks Fiskeriundersøgelser
ISBN (Print): 87-90968-95-6
Original language: Danish
Main Research Area: Technical/natural sciences
Electronic versions: 156-05 Kystfordring og godt fiskeri_e.pdf
Links: http://www.difres.dk/dk/publication/files/23122005$156-05%20Kystfordring%20og%20godt%20fiskeri_e.pdf
Source: orbit
RESTOCK (38566) (38400 pre-project)

The aim of the pre-project was to explore the potential for restocking the cod stock in the eastern Baltic. A theoretical study was conducted to explore the potential for restocking bringing together scientists from the aquaculture sector, fisheries managers, ecological scientists and scientists with a background in stock enhancement. The ecology, biology and fisheries biology of the eastern Baltic was reviewed and provided the basis for the study. The results indicated a good potential for restocking with first-feeding cod larvae (Støttrup et al. 2008). This was the first example of a study to examine the potential for large-scale restocking prior to the release of fish. A 2-3-month delay in the spawning period compared to 20-30 years ago has altered feeding conditions and predation susceptibility in a way that may have exacerbated the decline in recruitment. Producing and releasing cod larvae during spring would mimic the spawning period recorded in previous times and would coincide with the spring peak in copepod production. An evaluation of 3 different release scenarios showed that a release of 474 million first-feeding larvae over 5 months (covering the historic and present day spawning period) would enhance the average population of 2 year old by 10% and be biologically and economically the most feasible scenario.

Three years of a six year follow up project (RESTOCK) to verify the theoretical findings was funded, but due to political changes, funding for the final three years was not possible and the project was unable to empirically ascertain the potential for restocking. During the three years, 3 cod broodstocks were established with different photoperiods and
subsequent spawning periods, together with the development of a technique to determine fish gender non-invasively (McEvoy et al., 2009). Egg and larval incubation techniques were developed and several investigations on temperature, salinity and food impacts on first feeding cod larvae to define the “window of opportunity” for release (i.e. time when the larvae were ready to start feeding to when they began to be too poor in condition to feed) (Støttrup et al., 2008; Overton et al. 2010; Meyer et al 2011a). A release strategy was developed and the first successful release of first-feeding fish larvae at 23 m depth was conducted, but needed further adjustments (Støttrup et al., 2008). An extensive disease monitoring program was established (Støttrup et al., 2008) and the presence of a protistan endoparasite generated a further study (Skovgård et al., 2010). Studies were also conducted to determine explore marking techniques for identification of released fish (Meyer et al., 2011b) and explore growth characteristics in cod larvae (Meyer et al., 2011a).

The project was coordinated by DTU Aqua.

National Institute of Aquatic Resources
Section for Ecosystem based Marine Management
National Veterinary Institute
Danish Fishermen's Association
University of Copenhagen
University of Hamburg
University of Caen

Period: 01/01/2005 → 31/12/2007
Number of participants: 9
Research area: Coastal Ecology
Project participant:
Sørensen, Sune Riis (Intern)
Røjbek, Maria (Intern)
Pedersen, Per Bovbjerg (Intern)
Tomkiewicz, Jonna (Intern)
Møllmann, Christian (Ekstern)
Sichlau, Morten (Ekstern)

Project Manager, academic:
Støttrup, Josianne Gatt (Intern)
Paulsen, Helge (Intern)
Dalsgaard, Inger (Intern)