Easter Baltic cod recruitment revisited—dynamics and impacting factors

The Eastern Baltic cod abundance started rapidly to increase in the mid-2000s as evidenced by analytical stock assessments, due to increased recruitment and declining fishing mortality. Since 2014, the analytical stock assessment is no longer available, leaving the present stock status unclear and casting doubts about the magnitude of the recent increase in recruitment. Earlier studies identified main factors impacting on cod reproductive success to be related to the loss of two out of three spawning areas in the 1980s caused by lack of major Baltic inflows with a concurrent reduction in salinity and oxygen. Other important factors include prey availability for first-feeding larvae, egg predation by sprat and herring and cannibalism on juveniles, all in one way or the other related to the prevailing hydrographic conditions. These factors cannot explain increased reproductive success in the last decade, as the period was characterized by an absence of large-scale Baltic inflows since 2003 and persistent anoxic conditions in the bottom water of the deep Baltic basins. This questions the perception of the increased recruitment in later years and challenges our present understanding of cod recruitment dynamics in the Baltic Sea. In this contribution, we review evidence from the recent literature supplemented by information from latest research cruises to elucidate whether cod reproductive success indeed has increased during the last decade, and we suggest the key processes responsible for the recent dynamics in cod recruitment and outline directions for future research.
Female nutrition and assisted reproduction in European eel: influences on oogenesis and egg quality

The European eel (Anguilla anguilla) has an enigmatic life-cycle. One of its most unique features is the 5000 to 6000 km separating the growth areas in Europe and North Africa from the spawning grounds in the Sargasso Sea. Even more enigmatic is the fact that naturally matured eels have never been caught and thus, spawning in the wild has never been observed. Because sexual maturation is blocked until the silvering phase and start of spawning migration, eels do not mature spontaneously in captivity and gonad development is induced by the application of exogenous hormones. In female eels, induction of egg production involves a long-term hormonal treatment of salmon or carp pituitary extracts (SPE or CPE) followed by the induction of oocyte maturation and ovulation which includes a SPE primer and a maturation-inducing hormone (MIH), generally 17α, 20β-dihydroxy-4-pregn-3-one (DHP).

Recent progress in techniques for induction of maturation and fertilization of the eggs has enabled the production of many viable eggs and yolk-sac larvae that are able of exogenous feeding. The present studies have contributed to this progress by addressing some of the challenges commonly associated with the induction of female maturation and egg quality. The main objectives of this PhD study were to improve female response to hormonal treatments and resulting egg quality. These challenges were addressed by working with both cultured and wild female eels, testing different broodstock diets and hormonal treatments, and identifying possible factors associated with egg quality. The results showed that dietary fatty acid composition has a significant influence on ovarian development in response to hormonal treatments. During oocyte maturation and ovulation, the expression of hormone receptors at the time SPE and DHP were administrated differed between high and low egg quality groups. It appears that a mismatch between hormone receptor expression and the administration of SPE and DHP may be determinant for acquisition of oocyte developmental competence. Moreover, lipid analysis of eggs obtained from wild-caught female eels showed that the level of most fatty acids were similar between high and low quality eggs. Additionally, levels of essential fatty acids were considerable different from those reported elsewhere for cultured European female eel.

Experiments part of this PhD project resulted in a high number of high quality eggs which enabled us to determine the relation between oocyte stage at the time oocyte maturation and ovulation are induced, and egg quality for the first time. As a result, we presented improved guidelines to induce oocyte maturation and ovulation, based on a lipid droplet-based oocyte maturation scale, which may result in an increase in production of viable European eel eggs. Overall, this PhD project contributed to the development of assisted reproduction procedures by providing new and valuable knowledge about the factors influencing the maturational response of European female eels to hormonal treatments and resulting egg quality.

General information
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Organisations: National Institute of Aquatic Resources, Section for Marine Living Resources, Section for Ecosystem based Marine Management
Authors: da Silva, F. (Intern), Tomkiewicz, J. (Intern), Støttrup, J. G. (Intern)
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Temperature effects on gene expression and morphological development of European eel, Anguilla anguilla larvae

Temperature is important for optimization of rearing conditions in aquaculture, especially during the critical early life history stages of fish. Here, we experimentally investigated the impact of temperature (16, 18, 20, 22 and 24°C) on thermally induced phenotypic variability, from larval hatch to first-feeding, and the linked expression of targeted genes [heat shock proteins (hsp), growth hormone (gh) and insulin-like growth factors (igf)] associated to larval performance of European eel, Anguilla anguilla. Temperature effects on larval morphology and gene expression were investigated throughout early larval development (in real time from 0 to 18 days post hatch) and at specific developmental stages (hatch, jaw/teeth formation, and first-feeding). Results showed that hatch success, yolk utilization efficiency, survival, deformities, yolk utilization, and growth rates were all significantly affected by temperature. In real time, increasing temperature from 16 to 22°C accelerated larval development, while larval gene expression patterns (hsp70, hsp90, gh and igf-1) were delayed at cold temperatures (16°C) or accelerated at warm temperatures (20-22°C). All targeted genes (hsp70, hsp90, gh, igf-1, igf-2a, igf-2b) were differentially expressed during larval development. Moreover, expression of gh was highest at 16°C during the jaw/teeth formation, and the first-feeding developmental stages, while expression of hsp90 was highest at 22°C, suggesting thermal stress. Furthermore, 24°C was shown to be deleterious (resulting in 100% mortality), while 16°C and 22°C (~50 and 90% deformities respectively) represent the lower and upper thermal tolerance limits. In conclusion, the high survival, lowest incidence of deformities at hatch, high yolk utilization efficiency, high gh and low hsp expression, suggest 18°C as the optimal temperature for offspring of European eel. Furthermore, our results suggest that the still enigmatic early life history stages of European eel may inhabit the deeper layer of the Sargasso Sea and indicate vulnerability of this critically endangered species to increasing ocean temperature.

General information
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Temperature induced variation in gene expression of thyroid hormone receptors and deiodinases of European eel (Anguilla anguilla) larvae

Thyroid hormones (THs) are key regulators of growth, development, and metabolism in vertebrates and influence early life development of fish. TH is produced in the thyroid gland (or thyroid follicles) mainly as T4 (thyroxine), which is metabolized to T3 (3,5,3'-triiodothyronine) and T2 (3,5-diiodothyronine) by deiodinase (DIO) enzymes in peripheral tissues. The action of these hormones is mostly exerted by binding to a specific nuclear thyroid hormone receptor (THR). In this study, we i) cloned and characterized thr sequences, ii) investigated the expression pattern of the different subtypes of thrs and dios, and iii) studied how temperature affects the expression of those genes in artificially produced early life history stages of European eel (Anguilla anguilla), reared in different thermal regimes (16, 18, 20 and 22°C) from hatch until first-feeding. We identified 2 subtypes of thr (thrα and thrβ) with 2 isoforms each (thrαA, thrαB, thrβA, thrβB) and 3 subtypes of deiodinases (dio1, dio2, dio3). All thr genes identified showed high similarity to the closely related Japanese eel (Anguilla japonica). We found that all genes investigated in this study were affected by larval age (in real time or at specific developmental stages), temperature, and/or their interaction. More specifically, the warmer the temperature the earlier the expression response of a specific target gene. In real time, the expression profiles appeared very similar and only shifted with temperature. In developmental time, gene expression of all genes differed across selected developmental stages, such as at hatch, during teeth formation or at first-feeding. Thus, we demonstrate that the expression of thrs and dios show sensitivity to temperature and are involved in and during early life development of European eel.

General information
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Organisations: Section for Marine Ecology and Oceanography, National Institute of Aquatic Resources, Section for Marine Living Resources, IFREMER, GEOMAR - Helmholtz Centre for Ocean Research Kiel
Authors: Politis, S. N. (Intern), Servili, A. (Ekstern), Mazurais, D. (Ekstern), Zambonino-Infante, J. (Ekstern), Miest, J. J. (Ekstern), Tomkiewicz, J. (Intern), Butts, I. A. E. (Intern)
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Web of Science (2015): Indexed yes
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BFI (2013): BFI-level 1
Scopus rating (2013): SJR 1.192 SNIP 1.242 CiteScore 2.96
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Scopus rating (2010): SJR 1.05 SNIP 0.978
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Scopus rating (2009): SJR 1.095 SNIP 0.948
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Abundance of specific mRNA transcripts impacts hatching success in European eel, Anguilla anguilla L.

Maternal mRNA governs early embryonic development in fish and variation in abundance of maternal transcripts may contribute to variation in embryonic survival and hatch success in European eel, Anguilla anguilla. Previous studies have shown that quantities of the maternal gene products β-tubulin, insulin-like growth factor 2 (igf2), nucleoplasm (npm2), prohibitin 2 (phb2), phosphatidylinositol glycan biosynthesis class F protein 5 (pigf5), and carnitine O-palmitoyltransferase liver isoform-like 1 (cpt1) are associated with embryonic developmental competence in other teleosts. Here, the relations between relative mRNA abundance of these genes in eggs and/or embryos and egg quality, was studied and analyzed. We compared egg quality of the two groups: i) batches with hatching and ii) batches with no hatching. Results showed no significant differences in relative mRNA abundance between the hatch and no hatching groups for any of the selected genes at 0, 2.5, and 5 HPF. However, at 30 HPF the hatch group showed significantly higher abundance of cpt1a, cpt1b, β-tubulin, phb2, and pigf5 transcripts than the no hatch group. Therefore, these results indicate that up-regulation of the transcription of these genes in European eel after the mid-blastula transition, may be needed to sustain embryonic development and hatching success.
Baltic cod recruitment – the impact of changing environmental conditions

Development of a broodstock diet to improve developmental competence of embryos in European eel, Anguilla anguilla

We examined the effect of dietary arachidonic acid (ARA) and eicosapentaenoic acid (EPA) on the production of embryos and hatched larvae in the European eel, Anguilla anguilla. Two diets with high and intermediate levels of ARA and low and intermediate levels of EPA (Feed 1: ARA 1.9%, EPA 4.2%; Feed 2: ARA 1.2%, EPA 5.1% of total fatty acids) were tested against a commercial diet (DE: ARA: 0.5%, EPA: 8.2% of total fatty acids). After 24 weeks of feeding, ARA levels in the muscles and ovaries increased to 0.9% and 1.3% of total fatty acids, respectively, in Feed 1 and were significantly higher than in Feed 2 and DE. Female broodstock was not fed during hormonal treatment to induce vitellogenesis and ovulation. EPA levels in females fed the test diets decreased in the both muscle and ovary and were significantly lower in eggs from
females fed Feed 1. The highest percentage of stripped females, producing viable eggs and larvae, were those females fed the highest dietary ARA levels (Feed 1). The level of lipid peroxidation products in eggs was similar among treatment, indicating that the lowest dietary levels of vitamin C and vitamin E were sufficient. In the unfertilized eggs, ARA levels were also highest (1.1% of total fatty acids) in the diet with highest ARA levels (Feed 1).

**General information**

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Authors: Støttrup, J. G. (Intern), Tomkiewicz, J. (Intern), Jacobsen, C. (Intern), Butts, I. (Intern), Holst, L. (Ekstern), Krüger-Johnsen, M. (Intern), Graver, C. (Ekstern), Lauesen, P. (Ekstern), Fontagné-Dicharry, S. (Ekstern), Heinsbroek, L. (Ekstern), Corraze, G. (Ekstern), Kaushik, S. (Ekstern)
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- Web of Science (2016): Indexed yes
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- BFI (2014): BFI-level 1
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- Web of Science (2014): Indexed yes
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- BFI (2011): BFI-level 1
- Scopus rating (2011): SJR 1.216 SNIP 1.654 CiteScore 2.15
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- BFI (2010): BFI-level 1
- Scopus rating (2010): SJR 1.089 SNIP 1.161
- BFI (2009): BFI-level 1
- Scopus rating (2009): SJR 0.894 SNIP 0.916
- BFI (2008): BFI-level 2
- Scopus rating (2008): SJR 1.125 SNIP 1.095
- Web of Science (2008): Indexed yes
- Scopus rating (2007): SJR 1.192 SNIP 1.257
- Scopus rating (2006): SJR 1.04 SNIP 1.201
- Scopus rating (2005): SJR 1.038 SNIP 0.94
- Web of Science (2005): Indexed yes
- Scopus rating (2004): SJR 0.778 SNIP 0.867
Ecosystem indicators in the context of fisheries management: example of cod in the Baltic Sea

General information
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Organisations: National Institute of Aquatic Resources, Section for Ecosystem based Marine Management, Section for Marine Ecology and Oceanography, Institute Management
Authors: Eero, M. (Intern), Casini, M. (Ekstern), Hüssy, K. (Intern), Köster, F. (Intern), MacKenzie, B. (Intern), Neuenfeldt, S. (Intern), Tomkiewicz, J. (Intern)
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Effects of salinity and sea salt type on egg activation, fertilization, buoyancy and early embryology of European eel, Anguilla anguilla

Improper activation and swelling of in vitro produced eggs of European eel, Anguilla anguilla, has been shown to negatively affect embryonic development and hatching. We investigated this phenomenon by examining the effects of salinity and sea salt type on egg dimensions, cell cleavage patterns and egg buoyancy. Egg diameter after activation, using natural seawater adjusted to different salinities, varied among female eels, but no consistent pattern emerged. Activation salinities between 30–40 practical salinity unit (psu) produced higher quality eggs and generally larger egg diameters. Chorion diameters reached maximal values of 1642 ± 8 μm at 35 psu. A positive relationship was found between egg neutral buoyancy and activation salinity. Nine salt types were investigated as activation and incubation media. Five of these types induced a substantial perivitelline space (PVS), leading to large egg sizes, while the remaining four salt types resulted in smaller eggs. All salt types except NaCl treatments led to high fertilization rates and had no effect on fertilization success as well as egg neutral buoyancies at 7 h post-fertilization. The study points to the importance of considering ionic composition of the media when rearing fish eggs and further studies are encouraged.

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Organisations: National Institute of Aquatic Resources, Section for Marine Ecology and Oceanography
Authors: Sørensen, S. R. (Intern), Butts, I. (Intern), Munk, P. (Intern), Tomkiewicz, J. (Intern)
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BFI (2015): BFI-level 1
First-feeding by European eel larvae: A step towards closing the life cycle in captivity
First evidence of first-feeding European eel larvae that have been reared in captivity. Up to 50% of larvae ingested a diet composed of concentrated rotifer paste, with or without natural feeding stimulants. Documentation of a significant increase in feeding success under higher light intensities. Results move us a step closer towards understanding an undisclosed phase in the European eel life cycle.

General information
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Organisations: National Institute of Aquatic Resources, Section for Marine Ecology and Oceanography
Authors: Butts, I. (Intern), Sørensen, S. R. (Intern), Politis, S. N. (Intern), Tomkiewicz, J. (Intern)
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First production of larvae using cryopreserved sperm: Effects of preservation temperature and cryopreservation on European eel sperm fertilization capacity
Sperm cryopreservation is a useful tool in captive fish reproduction management, that is to synchronize gamete production, especially in the case of species as the European eel, where the time of female spawning readiness is unpredictable. Several protocols to cryopreserve sperm of this species have been described, but until recently fertilization trials were not feasible. This study evaluated the effect of cold storage of diluted sperm prior to fertilizations and tested whether a previously defined protocol for European eel sperm cryopreservation can be successfully applied in fertilization trials to produce viable offspring. In our experiment, the sperm motility was evaluated after the extraction and the best samples were selected and pooled. Until stripping of eggs and fertilization, diluted sperm samples were maintained at either 4 or 20°C, or cryopreserved, following existing protocols. Fertilization of two egg batches was attempted. Diluted sperm caused a similar percentage of fertilized eggs and a similar number of embryos and larvae, independently of storage temperature (4 or 20°C). The cryopreserved sperm resulted in a lower percentage of fertilized eggs, but embryos developed and a few larvae (‘cryolarvae’) were obtained 55 h after fertilization in one of the two egg batches. This result evidences that the tested cryopreservation protocol is applicable for eel reproduction management, although improvements will be required to enhance fertilization success.
Functional characterization of eel dopamine D2 receptors and involvement in the direct inhibition of pituitary gonadotrophins

In various vertebrate species, dopamine (DA) exerts an inhibitory action on reproduction. In the European eel, DA plays a pivotal role in the inhibitory control of gonadotroph function and the blockade of puberty. In vivo studies have suggested that this effect is mediated by receptors pharmacologically related to the D2 family. In the European eel, two distinct D2 receptor (D2-R) paralogous genes have been identified (D2A-R and D2B-R) and both were shown to be expressed in the pituitary. We investigated the potential role of each paralogue in the control of gonadotroph function in this species. Eel recombinant D2A-R or D2B-R were expressed in HEK 293 cells, with a universal Gα subunit, and receptor activation was followed by inositol phosphate production. Recombinant D2-Rs exhibited a comparable affinity for DA, although they had differential affinities for mammalian D2-R agonists and antagonists, supporting subtle structure/activity differences. Furthermore, using eel pituitary cell primary cultures, the expression by gonadotroph cells of both native eel D2-R paralogues was examined by in situ hybridisation of D2A-R or D2B-R transcripts, coupled with immunofluorescence of luteinising hormone (LH)β or follicle-stimulating (FSH)β. LH and to a lesser extent, FSH cells expressed both D2-R transcripts but with a clear predominance of D2B-R. Notably, D2B-R transcripts were detected for the majority of LH cells. Accordingly, using these cultures, we showed that DA potently inhibited basal and testosterone-stimulated LHβ expression and less potently basal and activin-stimulated FSHβ expression. We also tested some D2-R antagonists, aiming to select the most adequate one to be used in innovative protocols for induction of eel sexual maturation. We identified eticlopride as the most potent inhibitor of DA action on basal and stimulated LH expression in vitro. Our data suggest a differential functionalisation of the duplicated receptor genes and demonstrate that mainly D2B-R is involved in the dopaminergic inhibitory control of eel gonadotroph function.
Interactive effects of dietary composition and hormonal treatment on reproductive development of cultured female European eel, Anguilla anguilla

Farmed female eels were fed two experimental diets with similar proximate composition but different n-3 polyunsaturated fatty acid (PUFA) levels. Both diets had similar levels of arachidonic acid (ARA), while levels of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) in one diet were approximately 4.5 and 2.6 times higher compared to the other diet, respectively. After the feeding period, each diet group was divided into two and each half received one of two hormonal treatments using salmon pituitary extract (SPE) for 13 weeks: i) a constant hormone dose of 18.75mg SPE/kg initial body weight (BW) and ii) a variable hormone dosage that increased from 12.5mg SPE/kg initial BW to 25mg SPE/kg initial BW. Results showed a significant interaction between diets and hormonal treatments on gonadosomatic index (GSI), indicating that the effect of broodstock diets on ovarian development depends on both nutritional status and hormonal regime. Females fed with higher levels of n-3 series PUFAs and stimulated with the constant hormonal treatment reached higher GSIs than those receiving the variable hormonal treatment. However, when females were fed lower levels of n-3 series PUFAs there was no difference in the effect of hormonal treatments on GSI. We also found that, independent of hormonal treatment, the diet with higher levels of n-3 series PUFAs led to the most advanced stages of oocyte development, such as germinal vesicle migration. Concentration of sex steroids (E2, T, and 11-KT) in the plasma did not differ between diets and hormonal treatments, but was significantly correlated with ovarian developmental stage. In conclusion, increasing dietary levels of n-3 PUFAs seemed to promote oocyte growth, leading to a more rapid progression of ovarian development in European eel subjected to hormonal treatment.

General information
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Authors: da Silva, F. (Intern), Støttrup, J. G. (Intern), Kjørsvik, E. (Ekstern), Tveiten, H. (Ekstern), Tomkiewicz, J. (Intern)
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Ontogeny and growth of early life stages of captive-bred European eel

Captive breeding of European eel, Anguilla anguilla is challenged by the complex hormonal control of Anguillid eel reproduction and the distinctive ontogeny of the leptocephalus larvae that are unique to the Elopomorph superorder. Recent experimental research has succeeded in the production of viable eggs and larvae of European eel, providing the basis for studies on early life stages of this species in captivity. In this study, we describe and illustrate morphological characteristics of eggs, embryos, and larvae from fertilization to termination of the yolk sac stage and provide a comparison with additional commercially important eel species. Furthermore, we model growth during the critical first phase in larval ontogeny, i.e. the yolk sac stage, and test for maternal effects. The eggs of A. anguilla typically have numerous oil droplets that coalesce into a single large oil droplet, while the zygote forms a large perivitelline space, reaching an egg diameter of 1.45 ± 0.12 mm at 3.0 to 3.5 h post fertilization. Embryonic development from fertilization to larval hatch lasted ~46–48 h at 20 °C with the larvae emerging in a relatively undeveloped stage with a protuberant yolk sac. During the period of yolk and oil absorption, the larvae undertook significant changes in head and body morphology. At the completion of yolk sac absorption, the largely transparent larvae had a set of protruding teeth, pigmented eyes and tail, and a simple alimentary tract. Larvae appeared capable of feeding at ~12 days post hatch at 20 °C, and were able to survive another ~10 days without feeding. Larval length approached and symptotic maximum of 6.8mma round day 10 in non-fed larvae. Larval batches from different maternal origins varied in yolk sac size and the extent of yolk sac resources influenced larval size at the end of the yolk sac stage. The ontogenetic description presented here fills a gap in knowledge about the yet undiscovered early life stages of native European eel, which can provide a framework of reference for the development of hatchery technology. Such progress is urgently needed for a self-sustained aquaculture of this high-value and critically endangered species. Statement of relevance: European eel is a high-value species in aquaculture, however, production is presently hampered by reliance on wild caught fry. Captive production of glass eels will reopen markets in Europe and Asia, benefiting European eel producers. The results presented here document recent progress within assisted reproduction and larval culture of this species in aquaculture and aid establishing hatchery technology of this species.
Three nuclear and two membrane estrogen receptors in basal teleosts, Anguilla sp.: Identification, evolutionary history and differential expression regulation

Estrogens interact with classical intracellular nuclear receptors (ESR), and with G-coupled membrane receptors (GPER). In the eel, we identified three nuclear (ESR1, ESR2a, ESR2b) and two membrane (GPERa, GPERb) estrogen receptors. Duplicated ESR2 and GPER were also retrieved in most extant teleosts. Phylogeny and synteny analyses suggest that they result from teleost whole genome duplication (3R). In contrast to conserved 3R-duplicated ESR2 and GPER, one of 3R-duplicated ESR1 has been lost shortly after teleost emergence. Quantitative PCRs revealed that the five receptors are all widely expressed in the eel, but with differential patterns of tissue expression and regulation. ESR1 only is consistently up-regulated in vivo in female eel BPG-liver axis during induced sexual maturation, and also up-regulated in vitro by estradiol in eel hepatocyte primary cultures. This first comparative study of the five teleost estradiol receptors provides bases for future investigations on differential roles that may have contributed to the conservation of multiple estrogen receptors.

General information
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Organisations: National Institute of Aquatic Resources, Section for Marine Ecology and Oceanography, Sorbonne Universités
Authors: Lafont, A. G. (Ekstern), Rousseau, K. (Ekstern), Tomkiewicz, J. (Intern), Dufour, S. (Ekstern)
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BFI (2014): BFI-level 1
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Scopus rating (2013): SJR 1.192 SNIP 1.242 CiteScore 2.96
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BFI (2012): BFI-level 1
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ISI indexed (2012): ISI indexed yes
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BFI (2011): BFI-level 1
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Ultrasonographic predictors of response of European eels (Anguilla anguilla) to hormonal treatment for induction of ovarian development

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Authors: Müller, A. V. (Ekstern), McEvoy, F. (Ekstern), Tomkiewicz, J. (Intern), Politis, S. N. (Intern), Amigo, J. (Ekstern)
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Scopus rating (2016): SJR 0.649 SNIP 0.806 CiteScore 1.08
Web of Science (2016): Indexed yes
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BFI (2014): BFI-level 2
Scopus rating (2014): SJR 0.994 SNIP 1.062 CiteScore 1.6
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 0.921 SNIP 0.886 CiteScore 1.4
ISI indexed (2013): ISI indexed yes
Duplicated leptin receptors in two species of eel bring new insights into the evolution of the leptin system in vertebrates

Since its discovery in mammals as a key-hormone in reproduction and metabolism, leptin has been identified in an increasing number of tetrapods and teleosts. Tetrapods possess only one leptin gene, while most teleosts possess two leptin genes, as a result of the teleost third whole genome duplication event (3R). Leptin acts through a specific receptor (LEPR). In the European and Japanese eels, we identified two leptin genes, and for the first time in vertebrates, two LEPR genes. Synteny analyses indicated that eel LEPRα and LEPRβ result from teleost 3R. LEPRβ seems to have been lost in the teleost lineage shortly after the elopomorph divergence. Quantitative PCRs revealed a wide distribution of leptins and LEPRs in the European eel, including tissues involved in metabolism and reproduction. Noticeably, leptin1 was expressed in fat tissue, while leptin2 in the liver, reflecting subfunctionalization. Four-month fasting had no impact on the expression of leptins and LEPRs in control European eels. This might be related to the remarkable adaptation of silver eel metabolism to long-term fasting throughout the reproductive oceanic migration. In contrast, sexual maturation induced differential increases in the expression of leptins and LEPRs in the BPG-liver axis. Leptin2 was strikingly upregulated in the liver, the central organ of the reproductive metabolic challenge in teleosts. LEPRs were differentially regulated during sexual maturation, which may have contributed to the conservation of the duplicated LEPRs in this species. This suggests an ancient and positive role of the leptin system in the vertebrate reproductive function. This study brings new insights on the evolutionary history of the leptin system in vertebrates. Among extant vertebrates, the eel represents a unique case of duplicated leptins and leptin receptors as a result of 3R.

General information
State: Published
Organisations: National Institute of Aquatic Resources, Section for Marine Ecology and Oceanography, Museum National d'Histoire Naturelle, Leiden University
Authors: Morini, M. (Ekstern), Pasquier, J. (Ekstern), van den Thillart, G. (Ekstern), Tomkiewicz, J. (Intern), Rousseau, K. (Ekstern), Dufour, S. (Ekstern), Lafont, A. (Ekstern)
Publication date: 2015
Main Research Area: Technical/natural sciences
Fecundity regulation, maturation progression and spawning fidelity in relation to size, condition and age of Baltic herring (Clupea harengus L.)

General information
State: Published
Organisations: National Institute of Aquatic Resources, Section for Marine Ecology and Oceanography
Authors: Bucholtz, R. H. (Intern), Nyengaard, J. R. (Ekstern), Andersen, J. B. (Ekstern), Tomkiewicz, J. (Intern)
Female ovarian abnormalities and reproductive failure of autumn-spawning herring (Clupea harengus membras) in the Baltic Sea

Fecundity and reproductive potential are important factors to be considered in evaluating trajectories and demographic predictions of fish populations. Therefore, characterizing the nature and quantifying the extent of any reproductive failure should be considered in fisheries studies. Here, we describe morphological changes in developed ovaries of autumn-spawning herring (Clupea harengus membras) caught in the northern Baltic Sea and evaluate the magnitude of this phenomenon during 3 consecutive years. Visibly, abnormal ovaries were histologically characterized by irregular-shaped oocytes in a vitellogenic or final maturation stage with coagulative necrosis and liquefaction of the yolk sphere, degraded follicle membranes, and fibrinous adhesion among oocytes. Such degeneration is presumed to cause complete infertility in the fish. The frequency of fish with abnormal ovaries varied annually between 10 and 15% among all females sampled. However, specific sampling events showed up to 90% females with abnormal gonads. The specific cause of this abnormality remains unknown; however, prevalence was associated with unfavourable environmental conditions encountered before spawning. Thus, ovarian abnormality was positively related to water temperatures, with the highest level found at ≥15°C and negatively related to the frequency of strong winds. The frequency of occurrence of abnormal gonads decreased with the progression of spawning from August to October. The observed abnormality and associated spawning failure will negatively affect the realized fecundity of autumn herring in the Baltic Sea and may act as a limiting factor for recovery of the stock, which has experienced profound depression during the last three decades.
Impact of dietary fatty acids on muscle composition, liver lipids, milt composition and sperm performance in European eel

In order for European eel aquaculture to be sustainable, the life cycle should be completed in captivity. Development of broodstock diets may improve the species’ reproductive success in captivity, through the production of high-quality gametes. Here, our aim was to evaluate the influence of dietary regime on muscle composition, and liver lipids prior to induced maturation, and the resulting sperm composition and performance. To accomplish this fish were reared on three “enhanced” diets and one commercial diet, each with different levels of fatty acids, arachidonic acid (ARA), eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA). Neutral lipids from the muscle and liver incorporated the majority of the fatty acid profile, while phospholipids incorporated only certain fatty acids. Diet had an effect on the majority of sperm fatty acids, on the total volume of extractable milt, and on the percentage of motile sperm. Here, our results suggest that the total volume of extractable milt is a DHA-dependent process, as we found the diets with the highest DHA levels induced the most milt while the diet with the lowest DHA level induced the least amount of milt. The diet with the highest level of ARA induced medium milt volumes but had the highest sperm motility. EPA also seems important for sperm quality parameters since diets with higher EPA percentages had a higher volume of milt and higher sperm motility.

In conclusion, dietary fatty acids had an influence on fatty acids in the tissues of male eel and this impacted sperm performance.

General information
State: Published
Organisations: National Institute of Aquatic Resources, Section for Marine Ecology and Oceanography, Section for Ecosystem based Marine Management, National Food Institute, Division of Industrial Food Research, Universidad Politecnica de Valencia
Authors: Butts, I. (Intern), Baeza, R. (Ekstern), Støttrup, J. (Intern), Krüger-Johnsen, M. (Intern), Jacobsen, C. (Intern), Pérez, L. (Ekstern), Asturiano, J. (Ekstern), Tomkiewicz, J. (Intern)
Light impacts embryonic and early larval development of the European eel, Anguilla anguilla

Musculoskeletal anatomy and feeding performance of pre-feeding engyodontic larvae of the European eel (Anguilla anguilla)

Being part of the elopomorph group of fishes, Anguillidae species show a leptocephalus larval stage. However, due to largely unknown spawning locations and habitats of their earliest life stages, as well as their transparency, these Anguilla larvae are rarely encountered in nature. Therefore, information regarding the early life history of these larvae, including their exogenous feeding strategy and feeding performance, is rather scarce. To better understand the structural basis and functional performance of larval feeding in captivity, the functional morphology of the cranial musculoskeletal system in pre- and first-feeding engyodontic leptocephali of the European eel (Anguilla anguilla) was studied. A 3D reconstruction of the feeding apparatus (head of the leptocephali <1mm) was used to visualize and describe the musculoskeletal changes throughout these stages. To analyze the ontogenetic changes in the functionality of the feeding apparatus towards the active feeding phase, 3D data of joints, levers and muscles derived from the reconstructions were used to estimate bite and joint reaction forces (JRFs). Observing a maximum estimated bite force of about 65μN (and corresponding JRFs of 260μN), it can be hypothesized that leptocephalus larvae are functionally constrained to feed only on soft food particles. Additionally, potential prey items are size delimited, based on the theoretically estimated average gape of these larvae of about 100μm. This hypothesis appears to be in line with recent observations of a diet consisting of small and/or gelatinous prey items (Hydrozoa, Thaliacea, Ctenophora, Polycystenia) found in the guts of euryodontic leptocephalus larvae

Musculoskeletal anatomy and feeding performance of pre-feeding engyodontic larvae of the European eel (Anguilla anguilla)

General information
State: Published
Organisations: National Institute of Aquatic Resources, Section for Marine Ecology and Oceanography, Ghent University, Billund Aquaculture Service Aps
Authors: Bouilliart, M. (Ekstern), Tomkiewicz, J. (Intern), Lauesen, P. (Ekstern), De Kegel, B. (Ekstern), Adriaens, D. (Ekstern)
Pages: 325-340
Publication date: 2015
Main Research Area: Technical/natural sciences
Ontogeny of the immune response during early life history of European eel and its temperature dependence

**General information**

State: Published
Organisations: National Institute of Aquatic Resources, Section for Marine Ecology and Oceanography
Authors: Miest, J. (Ekstern), Politis, S. N. (Intern), Adamek, M. (Ekstern), Butts, I. (Intern), Tomkiewicz, J. (Intern)
Publication date: 2015
Event: Poster session presented at Aquaculture Europe 2015, Rotterdam, Netherlands.
Main Research Area: Technical/natural sciences
Publication: Research › Poster – Annual report year: 2015

Thermal effects on early life history stages of European eel Anguilla anguilla

**General information**

State: Published
Organisations: National Institute of Aquatic Resources, Section for Marine Ecology and Oceanography
Authors: Politis, S. N. (Intern), Miest, J. (Ekstern), Adamek, M. (Ekstern), Servili, A. (Ekstern), Mazurais, D. (Ekstern), Zambonino, J. (Ekstern), Tomkiewicz, J. (Intern), Butts, I. (Intern)
Publication date: 2015
Event: Abstract from Aquaculture Europe 2015, Rotterdam, Netherlands.
Main Research Area: Technical/natural sciences
Publication: Research › Conference abstract for conference – Annual report year: 2015

Eels in culture, fisheries and science in Denmark

**General information**

State: Published
Organisations: National Institute of Aquatic Resources, Secretariat for Management and Communication, Section for Marine Ecology and Oceanography, Centre for Ocean Life, Section for Freshwater Fisheries Ecology, Section for Marine Living Resources, Section for Administration and Service, Danish Eel Farmers Association
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.
European eel as experimental model I: Assisted reproduction technology and standardized fertilization methods for mass production of viable embryos and larvae

General information
State: Published
Organisations: National Institute of Aquatic Resources, Section for Marine Ecology and Oceanography
Authors: Tomkiewicz, J. (Intern)
Publication date: 2014
Event: Abstract from DAFINET and Targetfish FP7 Workshop –Fish models in Research, Copenhagen, Denmark.
Main Research Area: Technical/natural sciences
Publication: Research - peer-review › Journal article – Annual report year: 2014

Ichthyodinium identified in the eggs of European eel (Anguilla anguilla) spawned in captivity
A presumed parasitic protozoan was found in the eggs of European eel obtained from an experiment on captive breeding of eel, Anguilla anguilla, based on silver eels from a freshwater lake in the northern part of Denmark. Gross morphology of the organism was comparable to that of early stages of Ichthyodinium, a syndinian dinoflagellate parasite found in pelagic eggs of various marine fish species. Sequences of genes coding for small subunit ribosomal RNA confirmed that the organism was an Ichthyodinium species, and molecular phylogenetic analysis demonstrated the presence of two Ichthyodinium genotypes: one occurring in the Atlantic Ocean and adjacent coastal waters and one in the Pacific Ocean area. The inclusion of several GenBank-derived environmental gene sequences, from the Caribbean Sea, revealed to represent Ichthyodinium, suggesting that this parasite genus is ubiquitous in the World's oceans

General information
State: Published
Organisations: National Institute of Aquatic Resources, Section for Marine Ecology and Oceanography, University of Copenhagen
Light impacts embryonic and early larval development of the European eel, Anguilla anguilla

Little is known about the natural ecology of European eel during early life history. We extend our understandings on the ecology of this species by studying how early life stages perform under various light regimes. We assessed the effects of intensity, photoperiod (12:12 and 24:0 h light/dark) and spectral composition on embryonic survival, hatch success, larval morphology and survival at 5 days post-hatch. Treatments consisted of low intensity white (full spectrum, 2.2 μmol m-2 s-1), blue (~470 nm, 0.7 μmol m-2 s-1), green (~530 nm, 0.4 μmol m-2 s-1), red (~690 nm, 0.2 μmol m-2 s-1) and high intensity white (full spectrum, 10.5 μmol m-2 s-1), blue (~470 nm, 3.9 μmol m-2 s-1), green (~530 nm, 1.5 μmol m-2 s-1), and red light (~690 nm, 1.1 μmol m-2 s-1). Additionally, offspring were reared in continuous darkness (0:24 h light/dark). Results showed that light critically influenced early life stages. In particular, for the 12:12 h photoperiod, embryonic survival, until 26 h post-fertilization was significantly higher when reared under low light than those reared under high intensity light. Furthermore, offspring reared in low light had a higher hatch success than those reared in high intensity light. Larval survival was significantly affected by light regime, such that larvae reared in low light intensity had higher survival than those reared in high intensity light. Under continuous darkness, development and survival of offspring was as high as the best intensity-photoperiod-spectral composition regime. For all early life history traits, a strong maternal effect was evident, such that offspring of ‘poorer’ quality showed lower adaptability to extrinsic factors than offspring of higher quality. Together, these findings suggest a preference for no or low light during embryogenesis and no or 12:12 h low red light during the pre-leptocephalus stage.
Microbial interference and potential control in culture of European eel (Anguilla anguilla) embryos and larvae

General information
State: Published
Organisations: National Institute of Aquatic Resources, Section for Marine Ecology and Oceanography, Section for Aquaculture, Billund Aquaculture Service Aps, Ghent University
Authors: Sørensen, S. R. (Intern), Skov, P. V. (Intern), Lauesen, P. (Ekstern), Tomkiewicz, J. (Intern), Bossier, P. (Ekstern), Schryver, D. (Ekstern)
Pages: 1-8
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Main Research Area: Technical/natural sciences

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Scopus rating (2015): SJR 1.103 SNIP 1.254 CiteScore 2.12
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.002 SNIP 1.34 CiteScore 2.16
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 1.136 SNIP 1.3 CiteScore 2.18
ISI indexed (2013): ISI indexed yes
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Scopus rating (2011): SJR 1.294 SNIP 1.542 CiteScore 2.39
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 1.151 SNIP 1.394
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 0.941 SNIP 1.263
Muscle development in European eel Anguilla anguilla yolksac larvae and effects of egg incubation temperature

General information
State: Published
Organisations: National Institute of Aquatic Resources, Section for Marine Ecology and Oceanography, Norwegian University of Science and Technology
Authors: Kjørsvik, E. (Ekstern), Wold, P. A. (Ekstern), Bardal, T. (Ekstern), Davidsen, M. (Ekstern), da Silva, F. (Intern), Tomkiewicz, J. (Intern), Sørensen, S. R. (Intern)
Publication date: 2014
Main Research Area: Technical/natural sciences
Publication: Research - peer-review › Journal article – Annual report year: 2014

On the way to successful European eel larval rearing: Impact of biophysical conditions and gamete quality
The European eel is a widely distributed fish species of economic and cultural importance. It inhabits both coastal and freshwater systems, and is targeted by fisheries and treasured as food item. Although eels are reared in aquaculture, this industry relies solely of wild-caught juvenile glass eels that arrive to the European coasts after a 6000 km journey from the Sargasso Sea, where they were hatched. The adolescent eels start their long migration from the European continent back to their spawning area in the Sargasso Sea in late autumn as sliver eels. As long as the eels are within the European continent, they are in an immature stage, and they do not start migration and maturation until the silvering stage. This stage is however tightly controlled by brain and pituitary hormones, preventing maturation of gonads remote from their natural breeding area. This hormonal inhibition of maturation is the main reason why it is difficult to reproduce European eel in captivity. Although, attempted since 1930ies, utilizing maturational hormones primarily from other fish species, we only recently succeeded in refining reproduction protocols that enable rich quantities of viable gametes from this species. In view of these obstacles, the last decade’s research has shown substantial progress. This PhD has contributed to this progress through new knowledge and development of procedures for successful egg activation and fertilization as well as incubation and larvae culture. My PhD work addressed biophysical determinants fundamental to producing healthy eggs and larvae. One of my aims was to improve methods and results of in vitro fertilization. This research included characterisation of sperm density, “optimal” sperm to egg ratios and gamete mixing. Eel gametes are activated by salt water and incubated in a marine aquatic environment. In this regard, my aim was to identify suited salinities and seawater sources, supporting a good embryonic development. Embryonic development lasts two days from fertilization to hatch. During this time, as well as in early larval stages, mortality is high.
Here, my aim was to assess effects of temperature and microbial interference during incubation and larval rearing on order to reduce this mortality in cultures. The results have provided valuable new insights, contributing to progress of in vitro fertilization methods and reduced mortality in egg and larval culture. Our fertilisation procedures initially applied spermocrit as for sperm quantification technique to standardise sperm:egg ratio. Although being a practical method, it featured moderate precision. Spectrophotometry in contrast, showed high precision in addition to being a fast and practical and subsequently supported experiments that identified optimal sperm:egg ratio. Egg activation and swelling are among the processes often seen to fail in experiments. Activation salinity was found to be a determinant of egg fertilisation, buoyancy, and egg size although egg size effects differed among individual females. Fertilization percent was typically high in the range 30 and 40 ppt, while rate of un-activated and dead eggs rose in higher salinities. Egg swelling could be optimized using certain artificial salt types and impeded using others. During egg incubation, microbial interference was found to be a major obstacle for hatch, rather caused by microbial activity than presence. Larval mortality was highly dependent on whether antimicrobial conditions were bacteriostatic of bactericidal. This calls for future technology and microbial management, e.g. by matured water integrated in RAS technology. The results obtained through these studies have added to Danish progress within artificial reproduction in European eel by improved fertilization protocols and identification of important parameters during the early life stages. Such progress has led to present focus on eel larval culture and feeding, which has brought attention to eel as a potential “new species” in aquaculture.

**General information**

State: Published

Organisations: National Institute of Aquatic Resources, Section for Marine Ecology and Oceanography

Authors: Sørensen, S. R. (Intern), Tomkiewicz, J. (Intern), Munk, P. (Intern), Bossier, P. (Ekstern)

Number of pages: 100

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**Standardization of fertilization protocols for the European eel, Anguilla anguilla**

Standardization of artificial fertilization protocols for the European eel, Anguilla anguilla, is a prerequisite for optimizing the use of available gametes in hatchery facilities and for conserving sperm from high quality males, which is either cryopreserved or in living gene banks. The objectives of this research were to provide a rapid, accurate and precise method to quantify sperm density by examining the relationship between sperm density and absorbance by use of a spectrophotometer, determine the optimal number of sperm required to fertilize eggs in a controlled setting, and explore how long eggs are receptive to fertilization post-stripping. Mean sperm density and absorbance at 350nm were 1.54e+10±4.95e+9 sperm/mL and 1.91±0.22 nm, respectively. Regression analysis demonstrated a highly significant positive relationship between sperm density and absorbance using a spectrophotometer at 350nm (R²=0.94, p<0.001, y=2.273e+10x-2.805e+10); significant but slightly weaker relationships were also detected at 400, 500, and 600nm (R²≥0.93, p<0.001). Fertilization success using sperm to egg ratios ranging from 1.3e+3 to 1.0e+6 sperm per egg increased from 37.5 to 68.1%, respectively. Sperm to egg ratio had a significant effect on fertilization success (p<0.001), where fertilization success increased from 1.3e+3 to 2.5e+4 sperm per egg; adding greater than 2.5e+4 sperm per egg had no significant effect. Furthermore, the duration of time post-stripping had a significant effect on egg fertilization success (p<0.0001), such that between 0 and 10min post-stripping 57.4 to 78.2% of the eggs were fertilized while at 15min post-stripping a significant decrease in fertilization success was detected (47.5%). For all statistical models, the female variance component was significant for fertilization success (p<0.0001) and explained ≤84% of the models variance. In conclusion, European eel eggs should be fertilized within 10min post-stripping using 2.5e+4 sperm per egg. Together, these findings will contribute to the development of European eel breeding technology and further our understanding on sperm biology and reproductive biology in fishes.

**General information**

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Organisations: National Institute of Aquatic Resources, Section for Marine Ecology and Oceanography, University of Windsor

Authors: Butts, I. (Intern), Sørensen, S. R. (Intern), Politis, S. N. (Intern), Pitcher, T. (Ekstern), Tomkiewicz, J. (Intern)

Pages: 9-13

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Main Research Area: Technical/natural sciences

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Scopus rating (2015): SJR 1.103 SNIP 1.254 CiteScore 2.12
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.002 SNIP 1.34 CiteScore 2.16
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 1.136 SNIP 1.3 CiteScore 2.18
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BFI (2012): BFI-level 1
Scopus rating (2012): SJR 1.212 SNIP 1.487 CiteScore 2.32
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Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 1.294 SNIP 1.542 CiteScore 2.39
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 1.151 SNIP 1.394
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 0.941 SNIP 1.263
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 0.909 SNIP 1.173
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 1.019 SNIP 1.318
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 1.008 SNIP 1.689
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 0.915 SNIP 1.236
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 1.016 SNIP 1.627
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 1.121 SNIP 1.926
Web of Science (2003): Indexed yes
Scopus rating (2002): SJR 0.992 SNIP 1.418
Web of Science (2002): Indexed yes
Scopus rating (2001): SJR 1.049 SNIP 1.317
Web of Science (2001): Indexed yes
Scopus rating (2000): SJR 0.908 SNIP 1.113
Web of Science (2000): Indexed yes
Scopus rating (1999): SJR 1.049 SNIP 1.251
A review on broodstock nutrition of marine pelagic spawners: the curious case of the freshwater eels (Anguilla spp.)

To sustain eel aquaculture, development of reproduction in captivity is vital. The aim of this review is to assess our current knowledge on the nutrition of broodstock eels in order to improve the quality of broodstock under farming conditions, drawing information from wild adult eels and other marine pelagic spawners. Freshwater eels spawn marine pelagic eggs with an oil droplet (type II), and with a large perivitelline space. Compared with other marine fish eggs, eel eggs are at the extreme end of the spectrum in terms of egg composition, even within this type II group. Eel eggs contain a large amount of total lipids, and a shortage of neutral lipids has been implied a cause for reduced survival of larvae. Eel eggs have higher ARA but lower EPA and DHA levels than in other fish. Too high levels of ARA negatively affected reproduction in the Japanese eel, although high levels of 18:2n-6 in the eggs of farmed eels were not detrimental. The total free amino acid amount and profile of eel eggs appears much different from other marine pelagic spawners. Nutritional intervention to influence egg composition seems feasible, but responsiveness of farmed eels to induced maturation might also require environmental manipulation. The challenge remains to succeed in raising European eel broodstock with formulated feeds and to enable the procurement of viable eggs and larvae, once adequate protocols for induced maturation have been developed.
Biochemical, histological and molecular study of digestive tract development in European eel larvae (Anguilla anguilla) prior to exogenous feeding

General information
State: Published
Organisations: Section for Population Ecology and Genetics, National Institute of Aquatic Resources, Section for Marine Ecology and Oceanography, IFREMER, Norwegian University of Science and Technology
Authors: Mazurais, D. (Ekstern), Kjørsvik, E. (Ekstern), World, P. (Ekstern), Politis, S. N. (Intern), Cahu, C. (Ekstern), Tomkiewicz, J. (Intern), Zambonino-Infante, J. (Ekstern)
Publication date: 2013
Event: Poster session presented at Aquaculture Europe 13, Trondheim, Norway.
Main Research Area: Technical/natural sciences
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Comparison of broodstock lipid stores in farmed and wild European eel (Anguilla anguilla) in link with reproductive performance

General information
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Organisations: National Institute of Aquatic Resources, Section for Ecosystem based Marine Management, Section for Marine Ecology and Oceanography
Authors: Corraze, G. (Ekstern), Støttrup, J. (Intern), Larroquet , L. (Ekstern), Tomkiewicz, J. (Intern), Kaushik, S. (Ekstern)
Publication date: 2013
Event: Poster session presented at Aquaculture Europe 13, Trondheim, Norway.
Main Research Area: Technical/natural sciences
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https://www.was.org/easonline/AbstractDetail.aspx?i=2067
Development of a broodstock diet to improve embryonic development competence in female European eel, Anguilla anguilla

General information
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Organisations: National Institute of Aquatic Resources, Section for Marine Ecology and Oceanography, National Food Institute, Division of Industrial Food Research
Authors: Støttrup, J. (Intern), Tomkiewicz, J. (Intern), Jacobsen, C. (Intern), Krüger-Johnsen, M. (Intern), Holst, L. (Ekstern), Lauesen, P. (Intern)
Publication date: 2013
Main Research Area: Technical/natural sciences
Links: https://www.was.org/easonline/Mobile/Paper.aspx?i=2048

Development of techniques and technology for embryonic and larval rearing of the European eel

General information
State: Published
Organisations: National Institute of Aquatic Resources, Section for Marine Ecology and Oceanography
Authors: Butts, I. (Intern), Sørensen, S. R. (Intern), Politis, S. N. (Intern), Lauesen, P. (Intern), Tomkiewicz, J. (Intern)
Publication date: 2013
Event: Poster session presented at Larvi 2013, Ghent, Belgium.
Main Research Area: Technical/natural sciences
Publication: Research › Poster – Annual report year: 2014

Effect of preservation temperature and cryopreservation on European eel sperm fertilization capacity. First production of larvae using cryopreserved sperm

General information
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Organisations: National Institute of Aquatic Resources, Section for Marine Ecology and Oceanography
Authors: Asturiano, J. (Ekstern), Sørensen, S. R. (Intern), Pérez, L. (Ekstern), Lauesen, P. (Intern), Tomkiewicz, J. (Intern)
Publication date: 2013
Event: Poster session presented at 4th International Workshop on Biology of Fish Gametes, Faro, Portugal.
Main Research Area: Technical/natural sciences
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Evaluation of methods to determine sperm density for the European eel, Anguilla anguilla

European eel, Anguilla anguilla, is a target species for future captive breeding, yet best methodology to estimate sperm density for application in in vitro fertilization is not established. Thus, our objectives were to evaluate methods to estimate European eel sperm density including spermatocrit, computer-assisted sperm analysis (CASA) and flow cytometry (FCM), using Neubauer Improved haemocytometer as benchmark. Initially, relationships between spermatocrit, haemocytometer counts and sperm motility were analysed, as well as the effect of sperm dilution on haemocytometer counts. Furthermore, accuracy and precision of spermatocrit, applying a range of G-forces, were tested and the best G-force used in method comparisons. We found no effect of dilution on haemocytometer sperm density estimates, whereas motility associated positively with haemocytometer counts, but not with spermatocrit. Results from all techniques, spermatocrit, CASA and FCM, showed significant positive correlations with haemocytometer counts. The best correlation between spermatocrit and haemocytometer counts was obtained at 6000 × g (r = 0.68). Of two CASA variants, one or three photographic fields (CASA-1 and CASA-2), CASA-2 showed a very high accuracy to haemocytometer counts (r = 0.93), but low precision (CV: CASA-2 = 28.4%). FCM was tested with and without microfluorospheres (FCM-1 and FCM-2), and relationships to haemocytometer counts were highly accurate (FCM-1: r = 0.94; FCM-2: r = 0.88) and precise (CV: FCM-1 = 2.5; FCM-2 = 2.7%). Overall, CASA-2 and FCM-1 feature reliable methods for quantification of European eel sperm, but FCM-1 has a clear advantage featuring highest precision and accuracy. Together, these results provide a useful basis for gamete management in fertilization protocols

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Evaluation of methods to determine sperm density for the European eel, Anguilla anguilla

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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.
Individual behaviour of Baltic cod (Gadus morhua) in relation to sex and reproductive state

Information from data storage tags (DSTs) is conventionally used to infer movement patterns or reveal characteristics (e.g. temperature or salinity) of the environment surrounding tagged fish. Here we link data derived from DSTs with the reproductive physiology of tagged fish. Individual vertical activity of adult male and female Atlantic cod Gadus morhua L. in the Bornholm Basin was derived from DST measures and related to the individual histologically determined reproductive phase. Spawning migrations were identified by movements towards deeper and more saline waters. No difference was observed between sexes in the timing of the onset of migration and the duration of migration from feeding grounds to the spawning area. While there was no significant difference in duration of the spawning period between females and males, the histological indices suggest that females finish spawning before males. Irrespective of gender, vertical swimming activity was most pronounced during spawning, with descents towards the bottom dominating the movements. During spawning, males stayed significantly deeper than females. In conclusion, the present results suggest that initiation of spawning migration and duration of the spawning period differs between sexes, as does the level of activity during spawning events. Not all individuals followed the general pattern; a considerable number of individuals were found to spawn in shallow water in the Arkona Basin, and juvenile fish undertook the migration without spawning.
Sexual maturation patterns of 22 North Atlantic stocks of cod (Gadus morhua) were examined and related to geographical distribution area, ambient water temperature, growth and surplus production. Four patterns were identified, i.e. sexual maturation early in life at small size, early in life at large size, late in life at small size and lastly, late in life at large size. These maturation patterns were geographically clustered and associated with differences in growth and surplus production. Stocks maturing late in life at small size were characterised by slow growth and low surplus production (e.g. stocks in the Gulf of St. Lawrence, Labrador/Newfoundland). Stocks maturing early in life at large size exhibited high to intermediate growth and surplus production (e.g. Celtic Sea, North Sea). Stocks maturing late in life at large size had low to intermediate growth rates and surplus production (e.g. Iceland, North East Arctic), while stocks maturing early in life at small size generally showed intermediate growth and surplus production (e.g. Baltic stocks). Production of recruits per unit biomass showed a latitudinal trend, but appeared largely independent of maturation pattern, growth rate and surplus production. Recruit production of northernmost stocks was lowest and variability highest, mid-latitude stocks exhibited highest productivity and least variability, while stocks at the southern distribution range also showed low productivity. Thus, southern Gulf of St. Lawrence and eastern Scotian Shelf cod maturing late in life at small size with slow growth and low surplus production showed highest recruit production in the Western Atlantic, while the early maturing, fast growing and productive Icelandic and Faroese stocks showed the lowest recruitment production of all Eastern Atlantic stocks. This comparative analysis suggests that maturation patterns relate to growth potential and surplus production whereas annual production of recruits per unit biomass appears unrelated to average size at sexual maturation.

**General information**

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- **Organisations:** National Institute of Aquatic Resources, Institute Management, Section for Population Ecology and Genetics
- **Authors:** Köster, F. (Intern), Trippel, E. (Ekstern), Tomkiewicz, J. (Intern)
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Microbial interference and potential control in the production of European eel Anguilla anguilla larvae

General information
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Microbial interference with hatch and survival of European eel larvae

Recent research has significantly improved our knowledge and capabilities in the field of in vitro production of yolk sac larvae from European eel (Anguilla anguilla). Female broodstock European eels are matured by weekly administration of pituitary extract and male eels with hCG (human chorionic gonadotropin), which afford gametes for in vitro fertilization studies. The maturing process may lead to mass hatchings of up to ½ million larvae of which some survive the entire yolk sac phase. However, the rearing of larvae suffers from high larval mortalities, and water quality might be a crucial factor for larval survival in rearing systems. By applying antibiotic treatment as a research tool, it was possible to determine the extent of microbial interference in the production of high numbers of good quality larvae. By controlling microbiota during egg and larval incubation, the egg hatching success and larval longevity more than doubled. Using scanning electron microscopic analysis it was observed that microbe inhibiting treatments reduced bacterial colonization of the eggs surface, which possibly cause reduced gas and ionic exchange across chorionic membrane.

These results suggest that future eel larviculture should not only focus on optimizing physical incubation conditions, but certainly also on the control over microbial interference.

Modification of essential fatty acid composition in broodstock of cultured European eel Anguilla anguilla L.

Farmed eels had lower levels of arachidonic acid (20:4 n-6) (ARA) and higher ratios of eicosapentaenoic acid (20:5 n-3) (EPA):ARA compared to wild European eels collected from the Baltic Sea and southern Norwegian coast. Eels fed a formulated feed (JD) with a distribution of essential fatty acids (EFA) resembling wild European eel were sampled after 0, 5, 10, 14 and 44 weeks of feeding to examine changes in fatty acid composition (FAC) in ovaries, visceral fat and muscle. The results showed a slow but steady incorporation of EFA. Lipids are incorporated in the oocytes early in oogenesis, and the leading cohort of oocytes is rich in lipid droplets before the onset of vitellogenesis. This indicates that feeding with optimized broodstock feeds should start early to allow the incorporation of EFA in the first cohort of oocytes. At least 14 weeks of feeding is required to change lipid EFA in broodstock eel to resemble EFA in the diet or in wild fish. After 44 weeks of feeding, ARA was significantly higher in the neutral lipids of ovaries (1.9%) compared to visceral fat (1.2%) or muscle (1.0%). EPA:ARA ratios decreased two- to threefold in all tissues examined during that time. ARA and docosahexaenoic acid (22:6 n-3) (DHA) had accumulated in ovarian polar lipids.
Oogenesis, fecundity and condition of Baltic herring (Clupea harengus L.): A stereological study

Herring (Clupea harengus) is a capital breeder that stores energy reserves in muscle tissue. Individual potential fecundity relies on the size and weight of female fish. Poor condition during the maturation process can lead to a heavy down-
regulation of fecundity through atresia and, in the extreme, cause skipped spawning. Herring in the Central Baltic Sea exist in a variable environment where food availability fluctuates substantially. Compared to other herring populations their condition is generally poor. In the present study, the oocyte dynamics and fecundity in relation to the condition of Central Baltic herring was investigated. A modern stereological method, the physical fractionator, was used to quantify the number of oocytes in previtellogenic (PG), cortical alveoli (CA) as well as successive vitellogenic (VT1 and VT2) stages in central Baltic herring during ovarian maturation. The potential fecundity, i.e. the number of VT2 oocytes, was low compared to other Atlantic stocks but the relative potential fecundity was higher. The latter decreased by 71% when comparing early-maturing individuals with CA oocytes and late-maturing individuals with VT2 oocytes, suggesting a substantial down-regulation of fecundity. Although determined as spring spawners by otolith hatch type, 15% of the randomly sampled females were characterized by oocytes in CA stage in the prespawning period, indicating skipped spawning. The condition of these females was poor, which might have resulted in skipped spawning. Ovary weight was a good predictor of potential fecundity within maturing stages of females. Combined with estimates of skipped spawning, this ovary weight could be used to estimate egg production thereby improving Central Baltic herring stock-recruitment models.

**General information**

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Spawning migration and behavior of Baltic cod (Gadus morhua) based on DST-derived individual information

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Organisations: National Institute of Aquatic Resources, Section for Marine Ecology and Oceanography
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Stereology as a tool to assess reproduction strategy and fecundity of teleost fishes: Integrated studies in Central Baltic herring (Clupea harengus L.)

In fish stock assessment, spawning stock biomass (SSB) is used as an index of stock reproductive potential (SRP), and proportionality is assumed between SSB and recruitment, i.e. offspring production. SSB is calculated as the sum of biomass proportions of sexually mature individuals per age group. However, evidence that SSB is not a reliable SRP indicator has accumulated over the past decades. The SSB estimation does not consider individual differences in fecundity, skipped spawning, timing of spawning or differences in reproductive traits between sexes, which may all fluctuate significantly, influenced by individual physiological condition. The Central Baltic herring has experienced a radical decline in SSB over the past decades. This is mainly due to overfishing. However, significant changes in Baltic Sea salinity and temperature have also altered herring prey composition and abundance, while reduction in the number of cod has caused sprat numbers and thereby food competition to increase. Together, this has resulted in a significant drop in Central Baltic herring physiological condition. The influence which this lowered condition may have on herring SRP, in terms of increased down-regulation and thereby lowered fecundity, skipped spawning and timing of spawning, has not been investigated and is not considered in assessment of the stock.

The objective of the study was two-fold. Firstly, improve methods for quantification of oocyte recruitment dynamics by adapting and applying modern stereological methods to assess fecundity and reproductive strategies. The strength of the stereological method being that, in combination with conventional histological analysis, quantification of all oocyte categories is possible, as well as registration of qualitative characteristics relating to spawning history of individuals, and further that statistical evaluation of estimates and method is possible. Secondly, apply the stereological methods to fill in gaps in knowledge about Baltic Sea herring reproductive strategy under current environmental conditions, including oocyte recruitment pattern, fecundity determination and down-regulation, skipped spawning and spawning fidelity, and to understand how factors like condition may influence individual decision making and fitness regarding these reproductive traits. The stereological methods applied in this project constituted a powerful set of tools for quantification of oocyte dynamics in fish and were successfully implemented in herring ovaries for quantification of both oocyte numbers and sizes as well as total volume fraction of atretic oocytes, introducing a negligible error to the total variance of estimates. The histological nature of the stereological methods facilitated a ready validation of maturity data, distinguishing first time spawners from repeat spawners, as well as a ready recognition of ongoing oocyte recruitment in early maturity stages, early stage atresia, POFs and residual eggs.

Analyzing a sample of females all collected during a short time frame in March 2008 covering various stages of maturation progression, we saw that oocyte recruitment followed the characteristic pattern of an iteroparous total spawner with determinate fecundity and group synchronous oocyte development. However, a significant fecundity down-regulation was apparent, which followed a three-step mechanism, resulting in low potential fecundity, but high relative potential fecundity compared to other herring stocks. Individual maturation progression revealed a substantial number of specimens with early developing ovaries, thereby being skipped or delayed spawners in accordance to the spring spawning season. Individual condition generally did not appear to influence fecundity regulation, but showed a strong correlation with degree of maturation progression, skipped or delayed spawners having significantly poorer condition than specimens expected to spawn during the spring spawning season. Results further indicated, that spawning occurs throughout the year in the Central Baltic herring population and that spawning time appears to be independent of individual hatch type, but rather relying on especially condition, but also size and age. Bioenergetic modeling showed that an individual condition factor threshold may control timing of spawning. These results may all influence Central Baltic herring SRP.
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 α-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.
Lipid dynamics of herring (Clupea harengus L.) and sprat (Sprattus sprattus) as major prey species in the Baltic Sea

General information
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Organisations: National Institute of Aquatic Resources, Section for Coastal Ecology, Section for Population Ecology and Genetics, National Food Institute, Division of Industrial Food Research
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Multiple kisspeptin receptors in early Osteichthyans provide new insights into the evolution of this receptor family

Deorphanization of GPR54 receptor a decade ago led to the characterization of the kisspeptin receptor (Kissr) in mammals and the discovery of its major role in the brain control of reproduction. While a single gene encodes for Kissr in eutherian mammals including human, other vertebrates present a variable number of Kissr genes, from none in birds, one or two in teleosts, to three in an amphibian, xenopus. In order to get more insight into the evolution of Kissr gene family, we investigated the presence of Kissr in osteichthyans of key-phylogenetical positions: the coelacanth, a representative of early sarcopterygians, the spotted gar, a non-teleost actinopterygian, and the European eel, a member of an early group of teleosts (elopomorphs). We report the occurrence of three Kissr for the first time in a teleost, the eel. As measured by quantitative RT-PCR, the three eel Kissr were differentially expressed in the brain-pituitary-gonadal axis, and differentially regulated in experimentally matured eels, as compared to prepubertal controls. Subfunctionalisation, as shown by these differences in tissue distribution and regulation, may have represented significant evolutionary constraints for the conservation of multiple Kissr paralogs in this species. Furthermore, we identified four Kissr in both coelacanth and spotted gar genomes, providing the first evidence for the presence of four Kissr in vertebrates. Phylogenetic and syntenic analyses supported the existence of four Kissr paralogs in osteichthyans and allowed to propose a clarified nomenclature of Kissr (Kissr-1 to -4) based on these paralogs. Syntenic analysis suggested that the four Kissr paralogs arose through the two rounds of whole genome duplication (1R and 2R) in early vertebrates, followed by multiple gene loss events in the actinopterygian and sarcopterygian lineages. Due to gene loss there was no impact of the teleost-specific whole genome duplication (3R) on the number of Kissr paralogs in current teleosts

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Organisations: National Institute of Aquatic Resources, Section for Population Ecology and Genetics, Museum National d'Histoire Naturelle, National Kaohsiung Marine University, Leiden University, National Taiwan Ocean University
Reproduction of European Eel in Aquaculture (REEL): Consolidation and new production methods

Project aim: Enhance methods and technology applied to produce and culture European eel larvae as basis for the development of a future self-sustained eel aquaculture.

Background: The severe decline of the European eel stock calls for conservation measures including national eel management plans and establishment of a self-sustained eel aquaculture. In 2005, the National Institute of Aquatic
Resources at the Technical University of Denmark (DTU Aqua), the Faculty of Life Sciences at Copenhagen University (KU-Life) and the eel aquaculture industry started to build up a research and technology platform for the development of methods to reproduce European eel in aquaculture. Two major projects: Artificial Reproduction of Eels II and III (ROE II and III) succeeded during 2005-2008 to produce viable eggs and larvae that lived up to 12 days. The larvae thereby accomplished the yolk-sac stage and became ready to start feeding. The results were in particular promising because they evidenced that methods successfully applied to Japanese eel has a potential for application also to the European eel.

ROE II and III were supported by the Ministry of Food, Agriculture and Fisheries and the European Commission through the Financial Instrument for Fisheries Guidance (FiFG) and the Danish Food Research Program 2006, respectively.

Results: The REEL project accomplished through three series of experiments to consolidate previous results. The longevity of larvae was extended from 12 to 20 days after hatch in first feeding experiments thereby entering the leptocephalus phase. Maturation potential and methods to induce maturation were further tested, and farmed and wild eel broodstocks as well as different treatments were compared. In particular, fertilisation procedures to produce fertilised eggs and embryos and monitoring techniques were enhanced. The technology needed to culture embryos and larvae was substantially improved. The potential for new hormonal treatments was explored and recombinant eel hormones have been produced. New broodstock diets were developed with focus on the lipid composition essential for development and survival of fish larvae. In addition, the experimental facility established by DTU Aqua at Lyksvad Fish Farm was enhanced by improving the experimental and laboratory facilities. The REEL project provided the basis for the establishment of an EU collaborative research project: Reproduction of European Eel: Towards a Self-sustained Aquaculture (PRO-EEL) coordinated by DTU Aqua. REEL included the partners DTU Aqua, KU-Life, Danish Eel Farmers Association (DEFA), Billund Aquaculture Service (BA), BioMar, and Bioneer of which four are integrated in the PRO-EEL project that in total has 15 international partners.

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Authors: Tomkiewicz, J. (Intern), Støttrup, J. (Intern), Sørensen, S. R. (Intern), Lauesen, P. (Intern), Jacobsen, C. (Intern), Kaushik, S. (Ekstern), Corraze, G. (Ekstern), Dufour, S. (Ekstern), Lafont, A. (Ekstern), Kjørsvik, E. (Ekstern), van Delsen, B. (Ekstern), Holst, L. (Ekstern)
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Reproduction of European eel: towards a self-sustained aquaculture (PRO-EEL)

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Robustness of egg production methods as a fishery independent alternative to assess the Eastern Baltic cod stock (Gadus morhua callarias L.)

At present, several cod stocks are outside safe biological limits and are managed under recovery plans. For these stocks, Total Allowable Catches (TAC's) are generally low and quotas are accompanied by a broad variety of technical measures influencing the fishing patterns. Consequently, the input data to stock assessment models relying on catch statistics from the commercial fisheries is potentially biased and the perception of stock status may be incorrect. Egg production methods (EPM) provide a fishery independent alternative. Additionally, they provide better estimates of stock reproductive potential (SRP). Eastern Baltic cod (Gadus morhua callarias L) has severely declined throughout the 2nd half of the 1980s and 1st half of the 1990s due to climate-driven adverse hydrographic conditions and high fishing intensity. Since 2007 the stock is managed under a long-term management plan and showed signs of recovery in most recent years. Since 1986, egg surveys have been carried out regularly in the Bornholm Basin, the most important spawning area of Eastern Baltic cod since mid-1980s. In the present paper the robustness of EPM towards simplification of spawning parameters and toward reduction of the number of egg surveys is tested applying three different methods requiring different numbers of egg surveys. We applied the annual egg production method (AEPM) requiring full egg survey coverage of the spawning season to estimate cod abundances in the Bornholm Basin. In addition, the daily fecundity reduction method (DFRM) and the daily egg production method (DEPM) were tested, the latter two methods requiring only single egg surveys, but require more complex reproduction input parameters. All three methods provided a comparable result, which was also expected as many spawning parameters were derived from the same underlying data sets. In a sensitivity analysis several input parameters were varied simultaneously up to 20% in both directions. EPM were especially sensitive towards change in proportions of mature female at age, whereas changes in the various fecundity parameters and spawning fraction were less influential. EPM results followed the large scale spawning stock trends of the Baltic International Trawl Survey index, whereas the year to year variations of the index were not captured to well. EPM yielded spawning stock sizes in the same order of magnitude as provided by a spatially down-scaled multi-species stock assessment model.
Assessment of testis development during induced spermatogenesis in the European eel Anguilla anguilla

In a study of reproduction in male European eels Anguilla anguilla, we induced spermatogenesis through hormone injection and established a spermatogenic maturity index (SMI) as a novel quantification of testis development. Eels in the experiments were sacrificed weekly and testis tissue was sampled for histological analysis of spermatogenesis. Testis development was followed over 18 weeks, during which the males continued to develop spermatocytes and produce spermatozoa. The SMI describes testis development from estimation of the area fractions of various tissue categories characterized by progressive gamete development stages in histological sections of the testes. The index weighs the volume fractions of the different tissues (somatic cells and germ cell stages) and describes development on a scale of 0 to 1. The method improves the existing histological classification, providing a quantitative measure that reflects the spermatogenic process and can be correlated with morphological and physiological parameters. In this study, the SMI reacted immediately to the onset of spermatogenesis and increased linearly over time, tracking the development of spermatozoa and spermatocysts. In week 7, the SMI reached a stable level of around 0.75, where it remained, with limited fluctuations, until the end of the experiment. This reflected the composition of different germ cell stages in the testis tissue with a continuous generation of spermatocysts and production of spermatozoa. In comparison, the gonadosomatic index showed a delayed response to the onset of spermatogenesis and fluctuated substantially during the sperm production period. The properties of the SMI made it a useful index for describing spermatogenesis in male European eels during this experiment and a promising tool for quantifying testis development and describing male reproductive strategy in other fish species.
Cut & count - stereology as a tool to understand fish biology

Emerging issues and methodological advances in fisheries reproductive biology

Although incorporating detailed reproductive data into all stock assessments is not a practical goal, the need to understand how reproductive biology affects population productivity is being increasingly recognized. More research focused on reproductive biology—coupled with a shift towards a resilience perspective in fisheries science—is resulting in challenges to many long-held assumptions; the emergence of important new issues; and identification of the need to improve data and methods used in reproductive studies. Typically, data for reproductive studies are based on an assessment of gonadal development, which is most accurately evaluated with histology. This special section of Marine and Coastal Fisheries contains contributions from a workshop on the gonadal histology of fishes that was held in Cadiz, Spain, during June 2009. These papers cover a wide range of species and reproductive topics while introducing improved and new histological techniques. In this introduction, we address the following needs: (1) to employ standardization, thereby improving our ability to conduct comparative studies; (2) to better understand patterns of gonadal development and spawning events over time; and (3) to move beyond the spawning stock biomass paradigm. We identify the
contributions of special section papers to these topics and conclude by suggesting needs.

**General information**
State: Published
Organisations: Section for Population Ecology and Genetics, National Institute of Aquatic Resources
Authors: Lowerre-Barbieri, S. K. (Ekstern), Brown-Peterson, N. J. (Ekstern), Murua, H. (Ekstern), Tomkiewicz, J. (Intern), Wyanski, D. M. (Ekstern), Saborido-Rey, F. (Ekstern)
Pages: 32-51
Publication date: 2011
Main Research Area: Technical/natural sciences

**Publication information**
Journal: Marine and Coastal Fisheries
Volume: 3
Issue number: 1
ISSN (Print): 1942-5120
Ratings:
Web of Science (2017): Indexed Yes
Scopus rating (2016): SJR 0.613 SNIP 0.718 CiteScore 1.22
Web of Science (2016): Indexed yes
Scopus rating (2015): SJR 0.836 SNIP 1.139 CiteScore 1.52
Scopus rating (2014): SJR 1.339 SNIP 1.594 CiteScore 2.45
Scopus rating (2013): SJR 1.242 SNIP 1.211 CiteScore 1.93
ISI indexed (2013): ISI indexed yes
Scopus rating (2012): SJR 0.992 SNIP 1.039 CiteScore 1.6
ISI indexed (2012): ISI indexed no
Scopus rating (2011): SJR 0.729 SNIP 1.016
ISI indexed (2011): ISI indexed no
Web of Science (2011): Indexed yes
Scopus rating (2010): SJR 0.405 SNIP 1.1
Web of Science (2010): Indexed yes
Original language: English
Electronic versions:
Jonna artikel 2011.pdf
DOIs:
10.1080/19425120.2011.555725
Source: orbit
Source-ID: 277073
Publication: Research - peer-review › Journal article – Annual report year: 2011

**Gonadal maturation of herring (Clupea harengus L.) assessed by histological and macroscopic characteristics**

**General information**
State: Published
Organisations: Section for Population Ecology and Genetics, National Institute of Aquatic Resources, Section for Public Sector Consultancy
Authors: Bucholtz, R. H. (Intern), Tomkiewicz, J. (Intern), Dalskov, J. (Intern)
Publication date: 2011
Event: Poster session presented at PICES/ICES/NAFO Symposium on Reproductive and Recruitment Processes of Exploited Marine Fish Stocks, Lisbon, Portugal.
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 279058
Publication: Research › Poster – Annual report year: 2011

**Linking size and age of attaining sexual maturation to growth and stock productivity in Atlantic cod stocks**

**General information**
State: Published
Organisations: National Institute of Aquatic Resources, Institute Management, Section for Marine Ecology and Oceanography
Skipped spawning in fishes: More common than you might think

The traditional view of iteroparity in fishes is one of an annual reproductive cycle that culminates each year in spawning. More recently, a more flexible view of fish reproduction has been adopted, including the potential for mature fish to skip spawning. Here, we review the abundance of recent research on skipped spawning, covering a broad range of fishes with diverse life history strategies. Evidence for skipped spawning has been collected by use of traditional histological techniques as well as modern technological advances, such as satellite tags and the ability to track fish movements based on elemental and isotope signatures. Skipped spawning is most commonly attributed to deficient diet and poor nutritional condition. Advances made in this field of study in recent years include descriptions of hormonal changes that precede and perhaps initiate skipped spawning, the development of life history models that incorporate the potential for skipped spawning, and estimates of the degree to which skipped spawning influences the reproductive potential of fish populations. In addition to summarizing this new research, we attempt to advance current knowledge by (1) providing the first review discussion of skipped spawning in males, (2) exploring skipped spawning in anadromous fishes by using the Atlantic salmon Salmo salar as an example, and (3) discussing the potential for and difficulties in identifying skipped spawning in species with indeterminate fecundity.
Spatial and interannual variability in Baltic sprat batch fecundity

Absolute and relative batch fecundity of Baltic sprat (Sprattus sprattus balticus S.) during peak spawning time was investigated for several years over the last two decades by applying the hydrated oocyte method. Batch fecundity was analysed for three important spawning areas of sprat in the central Baltic Sea, namely the Bornholm Basin, Gdansk Deep and Southern Gotland Basin. Environmental parameters such as hydrography, fish condition and stock density were tested in order to investigate the observed variability in sprat fecundity. Absolute batch fecundity was found to be positively related to fish length and weight. Significant differences in absolute and relative batch fecundity of Baltic sprat among areas and years were detected, and could partly be explained by hydrographic features of the investigated areas. A non-linear multiple regression model taking into account fish length and ambient temperature explained 70% of variability in absolute batch fecundity. Oxygen content and fish condition were not related to sprat batch fecundity. Additionally, a negative effect of stock size on sprat batch fecundity in the Bornholm Basin was revealed. The obtained data and results are important to assess the stock reproductive potential of this important Baltic fish stock.

General information
State: Published
Organisations: Section for Population Ecology and Genetics, National Institute of Aquatic Resources
Authors: Haslob, H. (Ekstern), Tomkiewicz, J. (Intern), Hinrichsen, H. (Ekstern), Kraus, G. (Intern)
Pages: 289-297
Publication date: 2011
Main Research Area: Technical/natural sciences

Publication information
Journal: Fisheries Research
Volume: 102
Issue number: 2
ISSN (Print): 0165-7836
Ratings:
BFI (2018): BFI-level 1
BFI (2017): BFI-level 1
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 2.21 SJR 1.12 SNIP 1.136
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 1.067 SNIP 1.133 CiteScore 2.01
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 1.105 SNIP 1.312 CiteScore 2.17
Enhancing European eel culture

General information
State: Published
Organisations: Section for Population Ecology and Genetics, National Institute of Aquatic Resources
Authors: EFSA Publication
Pages: 33-36
Publication date: 2010
Main Research Area: Technical/natural sciences
Seasonal lipid dynamics of sprat (Sprattus sprattus) and herring (Clupea harengus) in the Baltic Sea

General information
State: Published
Organisations: Section for Coastal Ecology, National Institute of Aquatic Resources, Division of Seafood Research, National Food Institute, Section for Population Ecology and Genetics
Authors: Røjbek, M. (Intern), Jacobsen, C. (Intern), Tomkiewicz, J. (Intern), Støttrup, J. (Intern)
Publication date: 2010
Event: Poster session presented at 101st AOCS Annual Meeting, Phoenix, AZ, United States.
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 268794
Publication: Research › Poster – Annual report year: 2010

Determination of fish gender using fractal analysis of ultrasound images

General information
State: Published
Organisations: Section for Population- and Ecosystem Dynamics, National Institute of Aquatic Resources, Section for Coastal Ecology
Authors: McEvoy, F. J. (Ekstern), Tomkiewicz, J. (Intern), Støttrup, J. (Intern), Overton, J. L. (Intern), McEvoy, C. (Ekstern), Svalastoga, E. (Ekstern)
Pages: 519-524
Publication date: 2009
Main Research Area: Technical/natural sciences

Publication information
Journal: Veterinary Radiology & Ultrasound
Volume: 50
Issue number: 5
ISSN (Print): 1058-8183
Ratings:
BFI (2018): BFI-level 1
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): SJR 0.888 SNIP 1.142 CiteScore 1.22
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.674 SNIP 1.033 CiteScore 1.02
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 1.245 SNIP 1.244 CiteScore 1.55
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 1.194 SNIP 1.34 CiteScore 1.4
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 1.249 SNIP 1.197 CiteScore 1.39
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.876 SNIP 1.05 CiteScore 1.12
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.89 SNIP 0.98
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 0.809 SNIP 1.091
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 0.93 SNIP 1.058
Scopus rating (2007): SJR 1.151 SNIP 1.199
Development of a manual to determine gonadal maturity of herring (Clupea harengus L.)

General information
State: Published
Organisations: Section for Population- and Ecosystem Dynamics, National Institute of Aquatic Resources, Section for Public Sector Consultancy
Authors: Bucholtz, R. H. (Intern), Tomkiewicz, J. (Intern), Dalskov, J. (Intern)
Publication date: 2009
Event: Poster session presented at 4th Workshop on Gonadal Histology of Fishes, Cadiz, Spain.
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 249744
Publication: Research - peer-review › Journal article – Annual report year: 2009

Dioxin og biologisk effektmontering i ålekvabbe i kystnære danske farvande

General information
State: Published
Organisations: Department of Civil Engineering, Section for Population- and Ecosystem Dynamics, National Institute of Aquatic Resources
Authors: Strand, J. (Ekstern), Bossi, R. (Ekstern), Dahllöf, I. (Ekstern), Jensen, C. A. (Ekstern), Simonsen, V. (Ekstern), Taïrova, Z. (Ekstern), Tomkiewicz, J. (Intern)
Publication date: 2009

Publication information
Publisher: Aarhus Universitet. Danmarks Miljøundersøgelser
ISBN (Print): 978-87-7073-128-7
Original language: Danish
Series: Faglig rapport fra DMU
Number: 743
Main Research Area: Technical/natural sciences
Links:
http://www.dmu.dk/Pub/FR743.pdf
Source: orbit
Source-ID: 252233
Publication: Research › Report – Annual report year: 2009

Estimating oocyte numbers in the ovaries of teleost fish

General information
State: Published
Organisations: Section for Population- and Ecosystem Dynamics, National Institute of Aquatic Resources
Authors: Bucholtz, R. H. (Intern), Tomkiewicz, J. (Intern), Andersen, J. B. (Ekstern), Nyengaard, J. R. (Ekstern), Gundersen, H. J. G. (Ekstern)
Publication date: 2009
Event: Poster session presented at 10th European Congress of Stereology and Image Analysis”, 22-26 June, Milano, Italy, .
Genetic population structure of European sprat (Sprattus sprattus L.): differentiation across a steep environmental gradient in a small pelagic fish

Factors such as oceanographic retention, isolation by distance and secondary contact zones have, among others, been suggested to explain the low, but statistically significant, neutral population structure observed in many marine fishes. European sprat Sprattus sprattus is not known to display philopatric spawning behaviour or to exhibit local retention of eggs and larvae. It thus constitutes a good model for studying population structure in a characteristic small pelagic fish with high dispersal potential and an opportunistic life history. We analysed 931 specimens of sprat from nine spawning locations in and around the North- and Baltic Sea area and from a geographically distant population from the Adriatic Sea. Analyses of nine microsatellite loci revealed a sharp genetic division separating samples from the Northeastern Atlantic and the Baltic Sea (pairwise θ = 0.019–0.035), concurring with a steep salinity gradient. We found, at most, weak structure among samples within the Northeastern Atlantic region and within the Baltic Sea (pairwise θ = 0.001–0.009). The Adriatic Sea population was highly differentiated from all northern samples (pairwise θ = 0.071–0.092). Overall, the observed population structure resembles that of most other marine fishes studied in the North/Baltic Sea areas. Nevertheless, spatially explicit differences are observed among species, likely reflecting specific life-histories. Such fine-scale population structure should be taken into account, e.g. in ecosystem-based stock management.
Optimization of fatty acid composition in the diet for female broodstock eels

General information
State: Published
Organisations: Section for Aquatic Lipids and Oxidation, National Institute of Aquatic Resources, Section for Population- and Ecosystem Dynamics, Section for Coastal Ecology
Authors: Jacobsen, C. (Intern), Tomkiewicz, J. (Intern), Støttrup, J. (Intern)
Publication date: 2009
Event: Abstract from 7th EuroFedLipid Congress, Graz, Austria, October, Graz, Austria, .
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 239769
Publication: Research › Conference abstract for conference – Annual report year: 2009

Produktion af torskelarver til udsætning i den østlige Østersø – RESTOCK

General information
State: Published
Organisations: Section for Coastal Ecology, National Institute of Aquatic Resources, Section for Population- and Aquaculture, Section for Fish Diseases
Number of pages: 143
Publication date: 2009

Host publication information
Title of host publication: Program og abstracts
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 253917
Publication: Research › Conference abstract in proceedings – Annual report year: 2009

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 inhydrographic 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.

General information
State: Published
Organisations: National Institute of Aquatic Resources, Section for Ecosystem based Marine Management, Section for Marine Ecology and Oceanography, National Food Institute, Division of Industrial Food Research, Institute Management
Authors: Røjbek, M. (Intern), Tomkiewicz, J. (Intern), Støttrup, J. (Intern), Jacobsen, C. (Intern), Köster, F. (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

**Spatial and temporal variation in Baltic sprat (Sprattus sprattus balticus S.) batch fecundity**
Over the last decade the size of the Baltic sprat spawning stock declined from a record high of over 1.7 million tonnes in 1996 to 910,000 tonnes in 2008. From the perspective of stock recovery it is of central interest how reproductive parameters have changed over this period of strongly changing stock size. Batch fecundity of Baltic sprat (Sprattus sprattus balticus S.) during peak spawning time was investigated in relation to fish length and weight applying the hydrated oocyte method. A series of ten years was established covering important spawning areas in the Central Baltic Sea, i.e., the Bornholm Basin, the Gdansk Deep and for some years the Gotland Basin. Analysis of Covariance (ANCOVA) showed significant differences in batch fecundity of Baltic sprat between areas and years. To detect possible causes for this variation in batch fecundity, environmental factors such as water temperature, salinity, oxygen content as well as fish and stock size were tested as explanatory variables. The data obtained in this investigation were used to develop a predictive model of Baltic sprat batch fecundity. Coupling these results with existing ichthyoplankton survey and stock structure data will allow applying the daily egg production method.

General information
State: Published
Organisations: National Institute of Aquatic Resources, Section for Marine Ecology and Oceanography, Leibniz Institute of Marine Sciences, Johann Heinrich von Thünen-Institute
Authors: Haslob, H. (Ekstern), Tomkiewicz, J. (Intern), Hinrichsen, H. (Ekstern), Kraus, G. (Ekstern)
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

**Stereology as a tool to assess reproduction strategy and fecundity of teleost fishes**

General information
State: Published
Organisations: Section for Population- and Ecosystem Dynamics, National Institute of Aquatic Resources
Authors: Bucholtz, R. H. (Intern), Tomkiewicz, J. (Intern), Andersen, J. B. (Ekstern), Nyengaard, J. R. (Ekstern), Gundersen, H. J. G. (Ekstern)
Publication date: 2009

Host publication information
Title of host publication: Book of Abstracts
Main Research Area: Technical/natural sciences
Conference: 4th Workshop on Gonadal Histology of Fishes, Cadiz, Spain, 16/06/2009 - 16/06/2009
Source: orbit
Source-ID: 253942
Publication: Research › Conference abstract in proceedings – Annual report year: 2009

**The evaluation of reference points and stock productivity in the context of alternative indices of stock reproductive potential**

General information
Characteristics of semen during induced spermatogenesis in European eel Anguilla anguilla

General information
State: Published
Organisations: Section for Population- and Ecosystem Dynamics, National Institute of Aquatic Resources
Authors: Kofoed, T. (Intern), Tomkiewicz, J. (Intern), Lehn-Jensen, H. (Ekstern), Lauesen, P. (Ekstern), Graver, C. (Ekstern)
Publication date: 2008
Event: Poster session presented at Aquaculture Europe 08, Krakow, Poland.
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 238846
Publication: Research › Poster – Annual report year: 2008

Kunstig reproduktion af ål: Roe II og IIB

General information
State: Published
Organisations: Section for Population- and Ecosystem Dynamics, National Institute of Aquatic Resources, FF secretariat
Authors: Tomkiewicz, J. (Intern), Jarlbæk, H. (Intern)
Number of pages: 79
Publication date: 2008

Publication information
Publisher: Institut for Akvatiske Ressourcer, Danmarks Tekniske Universitet
ISBN (Print): 87-74-81066-7
Original language: Danish
Series: DTU Aqua-rapport
Number: 180-08
Main Research Area: Technical/natural sciences
Electronic versions: 180-08_elektronisk_samlet.pdf
Links: http://www.aqua.dtu.dk/Publikationer/Forskningsrapporter/Forskningsrapporter_siden_2008
Source: orbit
Source-ID: 227692
Publication: Research › Report – Annual report year: 2008

Manual to determine gonadal maturity of Baltic herring

General information
State: Published
Organisations: Section for Population- and Ecosystem Dynamics, National Institute of Aquatic Resources, Section for Monitoring
Authors: Bucholtz, R. H. (Intern), Tomkiewicz, J. (Intern), Dalskov, J. (Intern)
Number of pages: 45
Publication date: 2008
Rationale for restocking the Eastern Baltic cod stock

The Danish Institute for Fisheries Research and Bornholm’s Salmon Hatchery examined the potential for restocking Baltic cod (Gadus morhua callarias L.) in the eastern Baltic Sea. This cod population has adapted to the unique brackish water conditions where successful spawning depends on regular inflows of oxygenated saltwater from the North Sea. Hydrographical conditions are therefore considered to constitute the principal bottleneck for recruitment of this population. Successful recruitment is also dependent upon food availability and predation pressure from mainly herring (Clupea harengus L.) and sprat (Sprattus sprattus L.). A 2- to 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 would enhance the average population of 2-year-olds by 10% and be biologically and economically the most feasible scenario.
Sådan ændres produktionsål til moderfisk

General information
State: Published
Organisations: Section for Aquatic Lipids and Oxidation, National Institute of Aquatic Resources, Section for Population- and Ecosystem Dynamics, Section for Coastal Ecology
Authors: Jacobsen, C. (Intern), Tomkiewicz, J. (Intern), Støttrup, J. (Intern)
Publication date: 2008
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 227560
Publication: Research › Journal article – Annual report year: 2008

Seasonal prevalence and intensity of follicular atresia in Baltic cod Gadus morhua callarias L.

In the present study, 307 ovaries of eastern Baltic cod Gadus morhua callarias sampled during the prespawning and spawning season 2000 were analysed histologically to estimate the seasonal prevalence and intensity of atresia. The number of atretic oocytes per ovary was estimated using a combination of the physical dissector method and volume fraction (Delesse principle). Atretic oocytes were observed in 32% of the ovaries. Prevalence of atresia was independent of female size, but increased significantly with declining female condition from prespawning and through the spawning stages. The relative intensity of atresia, i.e. number of atretic oocytes in relation to normally developed vitellogenic oocytes, was low amounting to 1.4% on average. Similar to prevalence, relative intensity of atresia differed significantly between maturity stages and increased with decreasing female condition. The population egg loss due to atresia amounted to 4.6% indicating that Baltic cod was performing close to maximum productivity, i.e. potential egg production.

(c) 2008 The Authors Journal compilation (c) 2008 The Fisheries Society of the British Isles.
Successful production of viable eggs and larvae of European eel (Anguilla anguilla)

General information

State: Published
Organisations: Section for Population- and Ecosystem Dynamics, National Institute of Aquatic Resources, Section for Ocean Ecology and Climate, Section for Coastal Ecology, Section for Aquatic Lipids and Oxidation
Authors: Tomkiewicz, J. (Intern), Munk, P. (Intern), Statrup, J. (Intern), Jacobsen, C. (Intern), Lauesen, P. (Ekstern), Graver, C. (Ekstern)
Publication date: 2008
Event: Abstract from Aquaculture Europe 08, Krakow, Poland.
Main Research Area: Technical/natural sciences
3D-mapping of fish habitats in design of dynamic fishing closures

General information
State: Published
Organisations: Section for Software and GIS development, National Institute of Aquatic Resources, Section for Population- and Ecosystem Dynamics, Section for Management Systems, Section for Ocean Ecology and Climate, National Veterinary Institute
Authors: Geitner, K. (Intern), Kraus, G. (Intern), Sørensen, T. K. (Intern), Parner, H. (Intern), Tomkiewicz, J. (Intern), Vestergaard, O. (Intern), Borgstrøm, R. (Intern), Espersen, A. (Ekstern)
Publication date: 2007
Event: Poster session presented at BALANCE conference, 25-26th of October 2007, Copenhagen, Denmark, Copenhagen, Denmark, .
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 225487
Publication: Research › Poster – Annual report year: 2007

3D-mapping of fish habitats in design of dynamic fishing closures

General information
State: Published
Organisations: Section for Software and GIS development, National Institute of Aquatic Resources, Section for Population- and Ecosystem Dynamics, Section for Management Systems, Section for Ocean Ecology and Climate, National Veterinary Institute
Authors: Geitner, K. (Intern), Kraus, G. (Intern), Sørensen, T. K. (Intern), Parner, H. (Intern), Tomkiewicz, J. (Intern), Vestergaard, O. (Intern), Borgstrøm, R. (Intern), Espersen, A. (Ekstern)
Publication date: 2007
Event: Poster session presented at European Symposium on MPAs as a tool for fisheries Management & Ecosystem Conservation, Murcia, Spain 25 th -28 th September, Murcia, Spain, .
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 225486
Publication: Research › Poster – Annual report year: 2007

Pelagic habitat mapping: A tool for area-based fisheries management in the Baltic Sea

General information
State: Published
Organisations: National Veterinary Institute, Section for Software and GIS development, National Institute of Aquatic Resources, Section for Population- and Ecosystem Dynamics, Section for Monitoring, Institute Management, Section for Ocean Ecology and Climate, Section for Management Systems
Number of pages: 71
Publication date: 2007

Publication information
Publisher: BALANCE
Original language: English
Series: BALANCE interim report
Number: 20
Main Research Area: Technical/natural sciences
Links:
Source: orbit
Source-ID: 224973
Publication: Research › Report – Annual report year: 2007
Report of the Workshop on Sexual Maturity Staging of Cod, Whiting, Haddock and Saithe (WKMSCWHS)

General information
State: Published
Organisations: Section for Population- and Ecosystem Dynamics, National Institute of Aquatic Resources
Number of pages: 62
Publication date: 2007

Host publication information
Title of host publication: ICES CM : ACFM
Volume: 33
Place of publication: Copenhagen
Publisher: International Council for the Exploration of the Sea
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 242825
Publication: Research › Article in proceedings – Annual report year: 2007

Successful production of European eel larvae

General information
State: Published
Organisations: Section for Population- and Ecosystem Dynamics, National Institute of Aquatic Resources, Section for Coastal Ecology, Section for Ocean Ecology and Climate, Research Secretariat, Section for Aquatic Lipids and Oxidation
Authors: Tomkiewicz, J. (Intern), Støttrup, J. (Intern), Munk, P. (Intern), Lauesen, P. (Intern), Graver, C. (Intern), Jarlbæk, H. (Intern), Jacobsen, C. (Intern), McEvoy, F. (Ekstern), Svalastoga, E. (Ekstern)
Publication date: 2007
Main Research Area: Technical/natural sciences

Bibliographical note
Abstract and oral presentation ved European Aquaculture Symposium, Istanbul, October, 2007
Source: orbit
Source-ID: 232873
Publication: Research › Conference abstract for conference – Annual report year: 2007

Baltic

General information
State: Published
Organisations: Institute Management, National Institute of Aquatic Resources, Section for Population- and Ecosystem Dynamics
Authors: Köster, F. (Intern), Möllmann, C. (Ekstern), Tomkiewicz, J. (Intern), MacKenzie, B. (Intern)
Pages: 19-32
Publication date: 2005

Host publication information
Title of host publication: Spawning and life history information for North Atlantic cod stocks
Place of publication: Copenhagen
Publisher: International Council for the Exploration of the Sea
Editor: Brander, K.
ISBN (Print): 87-7482-034-6
Series: ICES cooperative research report
Number: 274
Main Research Area: Technical/natural sciences
Links:
http://www.ices.dk/pubs/crr/crr274/crr274.pdf
Source: orbit
Source-ID: 226363
Publication: Research › Book chapter – Annual report year: 2005
Hvornår er en fisk moden og gydeklar?

General information
State: Published
Organisations: Section for Population- and Ecosystem Dynamics, National Institute of Aquatic Resources
Authors: Tomkiewicz, J. (Intern)
Pages: 48-61
Publication date: 2005
Main Research Area: Technical/natural sciences

Publication information
Journal: Fisk og Hav
Issue number: 58
ISSN (Print): 0105-9211
Ratings:
ISI indexed (2013): ISI indexed no
ISI indexed (2012): ISI indexed no
ISI indexed (2011): ISI indexed no
Original language: Danish
Links:
http://www.aqua.dtu.dk/Publikationer/Fisk-og-hav.aspx
Source: orbit
Source-ID: 227690
Publication: Research › Journal article – Annual report year: 2005

The potential for enhancing the cod stock in the Eastern Baltic

General information
State: Published
Organisations: Section for Coastal Ecology, National Institute of Aquatic Resources, Section for Aquaculture, Section for Population- and Ecosystem Dynamics
Pages: 67-71
Publication date: 2005
Conference: Lessons from the past to optimise the future: Extended abstracts and short communications of contributions presented at the International Conference, Aquaculture Europe 2005, Trondheim, Norway, August 5-9, 01/01/2005
Main Research Area: Technical/natural sciences

Publication information
Journal: Special publication / European Aquaculture Society
Volume: 35
ISSN (Print): 0774-0689
Ratings:
ISI indexed (2013): ISI indexed no
ISI indexed (2012): ISI indexed no
ISI indexed (2011): ISI indexed no
Original language: English
Source: orbit
Source-ID: 227570
Publication: Research › Conference article – Annual report year: 2005
Timing of Baltic cod spawning and spawner demography

General information
State: Published
Organisations: Section for Population- and Ecosystem Dynamics, National Institute of Aquatic Resources, Institute Management
Authors: Tomkiewicz, J. (Intern), Kraus, G. (Intern), Köster, F. (Intern)
Publication date: 2005
Main Research Area: Technical/natural sciences

Publication information
Journal: ICES C.M. 2005/
Volume: Q:23
Original language: English
Source-ID: 227698
Publication: Research › Conference article – Annual report year: 2005

Baltic cod recruitment - the role of physical forcing and species interactions

General information
State: Published
Organisations: Institute Management, National Institute of Aquatic Resources, Section for Population- and Ecosystem Dynamics, Section for Fisheries- and Monitoring Technology, Section for Population Ecology and Genetics
Pages: 1-41
Publication date: 2004
Main Research Area: Technical/natural sciences

Publication information
Journal: ICES C. Council Meeting
ISSN (Print): 1015-4744
Ratings:
ISI indexed (2013): ISI indexed no
ISI indexed (2012): ISI indexed no
ISI indexed (2011): ISI indexed no
Web of Science (2003): Indexed yes
Original language: English
Source-ID: 226365
Publication: Research › Conference article – Annual report year: 2004

En hjælpende hånd til torsk i Østersøen

General information
State: Published
Organisations: Section for Coastal Ecology, National Institute of Aquatic Resources, Section for Population- and Ecosystem Dynamics, Section for Aquaculture, Technical University of Denmark
Authors: Støttrup, J. (Intern), Tomkiewicz, J. (Intern), Paulsen, H. (Intern), Pedersen, P. B. (Intern), Overton, J. L. (Intern), Möllmann, C. (Ekstern), Lauesen, P. (Intern)
Pages: 62-71
Publication date: 2004
Main Research Area: Technical/natural sciences

Publication information
Journal: Fisk og Hav
Issue number: 58
ISSN (Print): 0105-9211
Available information for estimating reproductive potential of Northwest Atlantic groundfish stocks
The availability of data to improve indices of stock reproductive potential was reviewed for 42 Northwest Atlantic groundfish stocks comprising gadoids, flatfishes, redfishes and grenadiers. For many of the stocks, information on population parameters such as stock size and size/age composition estimates exists for three or more decades. Data on fish age, weight, maturity and sex ratios in the population have also been extensively collected, often allowing for establishment of time series of annual data that could be used for assessing spawning stock biomass and female spawning stock. However, possibilities for estimating stock potential egg production are constrained by scarcity of fecundity data. Data on fish condition, which can be useful in developing fecundity models, were seldom collected in earlier times, but have increased in recent decades. A data richness index, combining information about data quantity and quality, ranked most gadoid stocks as "data comprehensive" with a high proportion of stocks possessing some fecundity information. Flatfish stocks generally were "data moderate" owing to slightly shorter time series of data, while redfish and grenadier stocks in general were "data restricted". Published studies linking aspects of reproductive potential with parental characteristics and/or recruitment have become more frequent as "data richness" has improved for many stocks, but generally the prevalence of such studies remains low.

General information
State: Published
Organisations: Section for Population- and Ecosystem Dynamics, National Institute of Aquatic Resources
Authors: Tomkiewicz, J. (Intern), Morgan, M. (Ekstern), Burnett, J. (Ekstern), Saborido-Rey, F. (Ekstern)
Pages: 1-21
Publication date: 2003
Main Research Area: Technical/natural sciences

Publication information
Journal: Journal of Northwest Atlantic Fishery Science
Volume: 33
ISSN (Print): 0250-6408
Ratings:
BFI (2018): BFI-level 1
BFI (2017): BFI-level 1
BFI (2016): BFI-level 1
Scopus rating (2016): SJR 0.317 SNIP 0.442 CiteScore 0.83
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.831 SNIP 1.67 CiteScore 1.33
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.448 SNIP 0.634 CiteScore 0.91
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.246 SNIP 0.566 CiteScore 0.75
ISI indexed (2013): ISI indexed no
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.199 SNIP 0.423 CiteScore 0.33
ISI indexed (2012): ISI indexed no
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.646 SNIP 0.816 CiteScore 2.24
ISI indexed (2011): ISI indexed no
Web of Science (2011): Indexed yes
Developing alternative indices of reproductive potential for use in fisheries management: Case studies for stocks spanning an information gradient

There is accumulating evidence to suggest that spawning stock biomass (SSB) may not be directly proportional to reproductive potential. The wide-ranging implications of this conclusion necessitate that it be tested for as many stocks as possible. Undertaking such tests is complicated by the fact that fish stocks vary in the amount and type of information that is available to estimate reproductive potential. In this review, nine stocks illustrate the range of approaches that are being taken to developing alternative indices of reproductive potential from existing data resources. Three stocks had sufficient data to reconstruct a time series of total egg production (TEP), whereas, the remaining stocks were limited to estimating proxies for stock reproductive potential. For some of the case studies the alternative indices explained a higher amount of recruitment variation than did SSB. Other case studies provided evidence that characteristics of the spawning stock, e.g., age diversity and female-only SSB, influence recruitment in ways that are not properly accounted for by using SSB as the sole index of reproductive potential. This is further evidence that the assumption of proportionality between SSB and TEP is invalid. The data-rich stocks showed the relationship between SSB and TEP to be variable and characterized by distinct time trends. This variability will impact the ability of biomass-based reference points to conserve reproductive potential. Consequently, management protocols should be adapted to incorporate the detailed information on reproductive potential that is increasingly becoming available rather than being restricted to approaches that have been designed for data-poor situations.

General information
State: Published
Organisations: Section for Population- and Ecosystem Dynamics, National Institute of Aquatic Resources, Institute Management
Authors: Marshall, C. (Ekstern), O’Brien, L. (Ekstern), Tomkiewicz, J. (Intern), Marteinsdottir, G. (Ekstern), Morgan, M. (Ekstern), Saborido-Rey, F. (Ekstern), Köster, F. (Intern), Blanchard, J. (Ekstern), Secor, D. (Ekstern), Kraus, G. (Intern), Wright, P. (Ekstern), Mukhina, N. (Ekstern), Björnsson, H. (Ekstern)
Pages: 161-190
Publication date: 2003
Main Research Area: Technical/natural sciences

Publication information
Journal: Journal of Northwest Atlantic Fishery Science
Volume: 33
ISSN (Print): 0250-6408
Ratings:
BFI (2018): BFI-level 1
Fish stock development in the Central Baltic Sea (1976-2000) in relation to variability in the environment

**General information**

State: Published

Organisations: Institute Management, National Institute of Aquatic Resources, Section for Population- and Ecosystem Dynamics, Section for Fisheries Advice, Section for Population Ecology and Genetics

Authors: Köster, F. (Intern), Möllmann, C. (Ekstern), Neuenfeldt, S. (Intern), Vinther, M. (Intern), St. John, M. (Intern), Tomkiewicz, J. (Intern), Voss, R. (Ekstern), Hinrichsen, H. (Ekstern), Kraus, G. (Intern), Schnack, D. (Ekstern)

Pages: 294-306

Publication date: 2003

Main Research Area: Technical/natural sciences
Micro- and macroscopic characteristics to stage gonadal maturation of female Baltic cod

General information
State: Published
Organisations: Section for Population- and Ecosystem Dynamics, National Institute of Aquatic Resources, Danish Institute for Fisheries Research
Authors: Tomkiewicz, J. (Intern), Tybjerg, L. (Ekstern), Jespersen, Å. (Ekstern)
Pages: 253-275
Publication date: 2003
Main Research Area: Technical/natural sciences

Publication information
Journal: Journal of Fish Biology
Volume: 62
Issue number: 2
ISSN (Print): 0022-1112
Ratings:
BFI (2018): BFI-level 1
BFI (2017): BFI-level 1
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 1.57 SJR 0.741 SNIP 0.882
Recruitment of Baltic cod and sprat stocks: identification of critical life stages and incorporation of environmental variability into stock-recruitment relationships
The availability of data for estimating reproductive potential for selected stocks in the North Atlantic

General information
State: Published
Organisations: Section for Population- and Ecosystem Dynamics, National Institute of Aquatic Resources
Authors: Morgan, M. (Ekstern), Burnett, J. (Ekstern), Tomkiewicz, J. (Intern), Saborido-Rey, F. (Ekstern)
Number of pages: 378
Publication date: 2003

Publication information
Place of publication: Dartmouth
Publisher: Northwest Atlantic Fisheries Organization
Original language: English

Series: Scientific Council Studies
Number: 37
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 226687
Publication: Research › Report – Annual report year: 2003

Egg production of Baltic cod in relation to variable sex ratio, maturity and fecundity

General information
State: Published
Organisations: Section for Population- and Ecosystem Dynamics, National Institute of Aquatic Resources, Institute Management
Authors: Kraus, G. (Intern), Tomkiewicz, J. (Intern), Köster, F. (Intern)
Pages: 1908-1920
Publication date: 2002
Main Research Area: Technical/natural sciences

Publication information
Journal: Canadian Journal of Fisheries and Aquatic Sciences
Volume: 59
Issue number: 12
ISSN (Print): 0706-652X
Ratings:
BFI (2018): BFI-level 2
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 2.56 SJR 1.322 SNIP 1.163
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.256 SNIP 1.051 CiteScore 2.22
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.443 SNIP 1.379 CiteScore 2.6
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.421 SNIP 1.081 CiteScore 2.25
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 1.324 SNIP 1.196 CiteScore 2.29
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
Manual to determine gonadal maturity of Baltic cod

General information
State: Published
Organisations: Section for Population- and Ecosystem Dynamics, National Institute of Aquatic Resources, Section for Management Systems
Authors: Tomkiewicz, J. (Intern), Tybjerg, L. (Ekstern), Holm, N. (Intern), Hansen, A. (Ekstern), Broberg, C. (Ekstern), Hansen, E. (Intern)
Number of pages: 49
Publication date: 2002

Publication information
Place of publication: Charlottenlund
Publisher: Danmarks Fiskeriundersøgelser
ISBN (Print): 87-90968-38-7
Original language: English

Series: DFU-rapport
Number: 116-02
Main Research Area: Technical/natural sciences
Electronic versions:
116-02_manual_to_determine_gonadal_maturity.pdf
Links:
Developing Baltic cod recruitment models II : Incorporation of environmental variability and species interaction

We investigate whether a process-oriented approach based on the results of field, laboratory, and modelling studies can be used to develop a stock-environment-recruitment model for Central Baltic cod (Gadus morhua). Based on exploratory statistical analysis, significant variables influencing survival of early life stages and varying systematically among spawning sites were incorporated into stock-recruitment models, first for major cod spawning sites and then combined for the entire Central Baltic. Variables identified included potential egg production by the spawning stock, abiotic conditions affecting survival of eggs, predation by clupeids on eggs, larval transport, and cannibalism. Results showed that recruitment in the most important spawning area, the Bornholm Basin, during 1976-1995 was related to egg production; however, other factors affecting survival of the eggs (oxygen conditions, predation) were also significant and when incorporated explained 69% of the variation in 0-group recruitment. In other spawning areas, variable hydrographic conditions did not allow for regular successful egg development. Hence, relatively simple models proved sufficient to predict recruitment of 0-group cod in these areas, suggesting that key biotic and abiotic processes can be successfully incorporated into recruitment models.
A robust method for compiling trawl survey data used in the assessment of central Baltic cod (Gadus morhua L.)

Annual stratified bottom trawl surveys have been used since 1982 to estimate cod abundance in the central Baltic Sea. Catch at age from national research vessels is included in a common database, but data compilation is hampered by large differences in fishing power between vessels, mainly due to differences in gear size and design. In this study, indices of cod abundance and biomass are developed from arithmetic mean catch rates per depth stratum scaled by stratum areas, but with national trawl catches corrected for gear specific fishing power. The correction factors were estimated from catch rates of adult cod of all ages aggregated to minimise the effects of age determination discrepancies. The established index of spawning stock biomass did not correlate significantly better with VPA estimates than simpler indices ignoring depth stratification and fishing power. However, the method is preferable because it considers factors known to influence survey trawl catches.

General information
State: Published
Organisations: Section for Population- and Ecosystem Dynamics, National Institute of Aquatic Resources
Authors: Sparholt, H. (Ekstern), Tomkiewicz, J. (Intern)
Pages: 125-151
Publication date: 2000
Main Research Area: Technical/natural sciences

Publication information
Journal: Archive of Fishery and Marine Research
Volume: 48
Issue number: 2
ISSN (Print): 0944-1921
Ratings:
BFI (2008): BFI-level 1
Scopus rating (2006): SJR 0.289 SNIP 0.495
Scopus rating (2005): SJR 0.389 SNIP 0.933
Scopus rating (2004): SJR 0.302 SNIP 0.84
Recruitment of Baltic cod and sprat stocks: Identification of critical life stages and incorporation of environmental variability and spatial heterogeneity into stock-recruitment relationships

General information
State: Published
Organisations: Institute Management, National Institute of Aquatic Resources, Section for Population Ecology and Genetics, Section for Population- and Ecosystem Dynamics
Authors: Köster, F. (Intern), Hinrichsen, H. (Ekstern), Schnack, D. (Ekstern), St. John, M. (Intern), MacKenzie, B. (Intern), Tomkiewicz, J. (Intern), Möllmann, C. (Ekstern), Kraus, G. (Intern), Plikshs, M. (Ekstern), Makarchouk, A. (Ekstern)
Pages: 1-43
Publication date: 2000
Main Research Area: Technical/natural sciences

Baltic cod reproduction in the Gotland Basin: annual variability and possible causes

General information
State: Published
Organisations: Institute Management, National Institute of Aquatic Resources, Section for Population- and Ecosystem Dynamics
Authors: Plikshs, M. (Ekstern), Hinrichsen, H. (Ekstern), Köster, F. (Intern), Tomkiewicz, J. (Intern), Berzins, V. (Ekstern)
Pages: 1-26
Publication date: 1999
Main Research Area: Technical/natural sciences

Histological evaluation of gonadal and sexual maturity in female Baltic cod (Gadus morhua): Preliminary results

General information
State: Published
Stock-recruitment relationships of Baltic cod incorporating environmental variability and spatial heterogeneity

General information
State: Published
Organisations: Institute Management, National Institute of Aquatic Resources, Section for Population Ecology and Genetics, Section for Population- and Ecosystem Dynamics
Authors: Köster, F. (Intern), Hinrichsen, H. (Ekstern), St. John, M. (Intern), Schnack, D. (Ekstern), MacKenzie, B. (Intern), Tomkiewicz, J. (Intern), Plikshs, M. (Ekstern)
Pages: 1-20
Publication date: 1999
Main Research Area: Technical/natural sciences

A robust way of compiling trawl survey data for the use in the Central Baltic cod stock

General information
State: Published
Organisations: Section for Population- and Ecosystem Dynamics, National Institute of Aquatic Resources
Authors: Sparholt, H. (Ekstern), Tomkiewicz, J. (Intern)
Pages: 1-33
Publication date: 1998
Main Research Area: Technical/natural sciences
Oceanographic influences on the distribution of Baltic cod, Gadus morhua, during spawning in the Bornholm Basin of the Baltic Sea

The Baltic Sea is a stratified, semi-enclosed sea typified by a low-salinity surface layer and a deep saline layer of varying volume, salinity, temperature and oxygen concentration. The relationships between these oceanographic factors and the distribution of Baltic cod are presented, utilizing results from a survey carried out during the 1995 spawning period in the Bornholm Basin, at present the main spawning area of this stock. Cod distribution, abundance and population structure were estimated from hydroacoustic and trawl data and related to hydrographic parameters as well as to bottom depth. In the central basin, cod were aggregated in an intermediate layer about 15 m thick. This area of peak abundance was defined at its upper limit by the halocline and at the lower limit by oxygen content. The majority of individuals caught in the basin centre were in spawning or pre-spawning condition with a high proportion of males to females. On the basin slopes, aggregations of cod were found near the bottom. These individuals were mainly immature and maturing stages with an increasing proportion of females to males with size. Salinity and oxygen conditions were found to be the major factors influencing the vertical and horizontal distribution of adult cod. Abundance of immature cod was also positively related to decreasing bottom depths. The effect of temperature was minor. The observed size- and sex-dependent spawning aggregation patterns, in association with habitat volume and stock size, may influence cod catchability and thereby the assessment and exploitation patterns of this stock.
Quantifying and disaggregating the spawner effect: Incorporating stock structure, spatial distribution and female influences into estimates of annual population egg production

Maturity ogives and sex ratios for Baltic cod: establishment of a database and time series
Baltic cod recruitment project (CORE)

General information
State: Published
Organisations: Institute Management, National Institute of Aquatic Resources, Section for Monitoring, Section for Population Ecology and Genetics, Section for Population- and Ecosystem Dynamics
Pages: 1-21
Publication date: 1996
Main Research Area: Technical/natural sciences

Publication information
Journal: ICES Council Meeting
ISSN (Print): 1015-4744
Ratings:
ISI indexed (2013): ISI indexed no
ISI indexed (2012): ISI indexed no
ISI indexed (2011): ISI indexed no
Web of Science (2003): Indexed yes
Original language: English

Bibliographical note
Source: orbit
Source-ID: 227338
Publication: Research › Conference article – Annual report year: 1996

Influence of salinity, oxygen and temperature on spawning aggregation and spatial distribution of Baltic cod (Gadus morhua L.)

General information
State: Published
Organisations: Section for Population- and Ecosystem Dynamics, National Institute of Aquatic Resources, Section for Fisheries- and Monitoring Technology, Section for Population Ecology and Genetics
Authors: Tomkiewicz, J. (Intern), Stæhr, K. (Intern), Lehmann, K. (Ekstern), St. John, M. (Intern)
Pages: 1-10
Publication date: 1996
Main Research Area: Technical/natural sciences

Publication information
Journal: ICES Council Meeting
Volume: C+J:3
ISSN (Print): 1015-4744
Ratings:
ISI indexed (2013): ISI indexed no
ISI indexed (2012): ISI indexed no
ISI indexed (2011): ISI indexed no
Web of Science (2003): Indexed yes
Original language: English
Source: orbit
Source-ID: 227691
Publication: Research › Conference article – Annual report year: 1996

Age composition, sex ratio and biomass of the Baltic cod spawning stock in the Bornholm Basin: Results of a pilot study

General information
State: Published
Organisations: Section for Population- and Ecosystem Dynamics, National Institute of Aquatic Resources
Authors: Tomkiewicz, J. (Intern), Degnbol, P. (Ekstern)
Publication date: 1995
Baltic cod recruitment project

General information
State: Published
Organisations: Institute Management, National Institute of Aquatic Resources, Section for Monitoring, Section for Population Ecology and Genetics, Section for Population- and Ecosystem Dynamics
Authors: Schnack, D. (Ekstern), Köster, F. (Intern), Wieland, K. (Intern), St. John, M. (Intern), MacKenzie, B. (Intern), Tomkiewicz, J. (Intern), Nissling, A. (Ekstern)
Pages: J:23
Publication date: 1995
Main Research Area: Technical/natural sciences

Publication information
Journal: ICES CM 1995
ISSN (Print): 1015-4744
Ratings:
- ISI indexed (2013): ISI indexed no
- ISI indexed (2012): ISI indexed no
- ISI indexed (2011): ISI indexed no
- Web of Science (2003): Indexed yes
Original language: English
Source: orbit
Source-ID: 227688
Publication: Research › Conference article – Annual report year: 1995

Preliminary observations of a size at settling and food resource utilization of juvenile (O-group) Baltic cod (Gadus morhua)

General information
State: Published
Organisations: Section for Population- and Ecosystem Dynamics, National Institute of Aquatic Resources
Authors: Hüssy, K. (Intern), Tomkiewicz, J. (Intern)
Publication date: 1995
Main Research Area: Technical/natural sciences

Publication information
Journal: ICES CM 1995/
Volume: J:27
Original language: English
Source: orbit
Source-ID: 225862
Publication: Research › Conference article – Annual report year: 1995
Projects:

Reproductive Physiology of Female European Eel

National Institute of Aquatic Resources
Period: 15/12/2016 → 14/12/2019
Number of participants: 4
Phd Student:
Jørgensen, Michelle Grace Pinto (Intern)
Supervisor:
Kjørsvik, Elin (Ekstern)
Eg Nielsen, Einar (Intern)
Main Supervisor:
Tomkiewicz, Jonna (Intern)

Financing sources
Source: Internal funding (public)
Name of research programme: Institut stipendie (DTU)
Project: PhD

Eastern Baltic cod - New knowledge of growth and mortality is the way to improved management advice (39366)
The aim of the project is to improve the knowledge and data basis for stock assessment and management for cod in the eastern Baltic Sea.

In later years, changes in growth and natural mortality of cod have presumably taken place and new knowledge on these parameters is essential for restoring analytical stock assessment for Eastern Baltic cod that is currently lacking. Improved knowledge on cod growth and mortality is therefore a prerequisite for being able to evaluate the stock status in relation to management targets and implement management plans that are built on quantitative stock assessment.

Ecological situation in the Baltic Sea has changed in later years, which requires updated biological information. This is done in the project using different approaches, bringing together expertise of different research areas. The approaches applied include molecular-genetic analyses of cod growth, bioenergetic modelling, and analyses of monitoring data on predation and condition/growth of cod. An important component of the project is cooperation with fishing industry to support tagging experiments of Baltic cod, to obtain updated estimates of cod growth.

Finally, the project combines the new knowledge on cod that becomes available from this and other relevant projects to ensure that the assessment of stocks status and management advice is based on best available scientific information.

This project is coordinated by DTU Aqua.

The project is funded by the Ministry of Environment and Food of Denmark and the European Maritime and Fisheries Fund (EMFF).

National Institute of Aquatic Resources
Section for Ecosystem based Marine Management

Danish Fishermen's Association
University of Copenhagen
Period: 15/08/2016 → 15/08/2018
Number of participants: 8
Research areas: Ecosystem based Marine Management & Fish Biology & Marine Populations and Ecosystem Dynamics & Population Genetics & Marine Living Resources & Fisheries Management

Project participant:
Storr-Paulsen, Marie (Intern)
Tomkiewicz, Jonna (Intern)
Hansen, Jakob Hemmer (Intern)
Neuenfeldt, Stefan (Intern)
Christensen, Asbjørn (Intern)
Kindt-Larsen, Lotte (Intern)
Berg, Casper Willestofte (Intern)

Project Coordinator:
Eero, Margit (Intern)  
Project

**Egg quality and Offspring Performance in European Eel**

National Institute of Aquatic Resources  
Period: 15/12/2015 → 14/01/2019  
Number of participants: 3  
PhD Student:  
Kottmann, Johanna Sarah (Intern)  
Supervisor:  
Butts, Ian (Intern)  
Main Supervisor:  
Tomkiewicz, Jonna (Intern)  

**Financing sources**  
Source: Internal funding (public)  
Name of research programme: Grundforskningsfonden  
Project: PhD

**BONUS BIO-C3 Cruise (39117-DCH)**  
The multidisciplinary research cruise (16-30 September 2015) was aiming to investigate the distribution, abundance, biomass, production, nutritional condition and genetic diversity of several, trophically interconnected Baltic key species, ranging from zoo-, and ichthyoplankton over gelatinous organisms to adult fish, including non-indigenous species. The collected samples and data are used in the BONUS project Biodiversity changes—causes, consequences and management implications (BIO-C3), aiming to significantly advance our knowledge base towards the importance and management of the Baltic Sea biodiversity in an ecosystem perspective.

Using the contrasting environments of the Arkona, Bornholm, Gdansk and Gotland Basin, the major scientific goals of the cruise have been to resolve:
- Physiological preferences and tolerances of key meso-zooplankton species (*Pseudocalanus acuspes, Temora longicornis, Centropages hamatus* and *Acartia spp*), through controlled experiments on board with specimens caught in different areas of the central Baltic in contrasting environments, including a verification of species based on genetics,
- Abundance, distribution, nutritional condition and phenology of key zooplankton (see above) and their life stages as well as gelatinous plankton species (*Aurelia aurita, Cyanea capillata, Mertensia ovum, Mnemiopsis leidyi*) in different areas of the central Baltic, through net-sampling and deploying hydroacoustics and optics, as well as biochemical analyses,
- Individual condition, abundance and distribution of spawning herring and cod based on trawl sampling and hydroacoustics including biochemical investigations on the quality of spawning products,
- Abundance and survival of herring and cod ichthyoplankton, through net-sampling based stage specific production estimates, including age determination, nutritional condition and growth in relation to abundance, phenology and composition of zooplankton prey,
- Predation pressure on copepods and fish early life stages by herring and sprat as well as gelatinous plankton (see above) through resolving the spatial overlap between predator and prey at relevant scales as well as diet composition analyses,
- Distribution (vertical and horizontal) of sprat and herring through trawl sampling and hydroacoustics in relation to hydrography, zooplankton prey and predator (cod) abundance, with specific focus on growth, condition and survival of young of the year sprat in different areas of the central Baltic.

This project was coordinated by DTU Aqua.  
The project was funded by Danish Center for Marine Research.

National Institute of Aquatic Resources  
Section for Marine Ecology and Oceanography  
Arctic Section  
GEOMAR - Helmholtz Centre for Ocean Research Kiel  
National Marine Fisheries Research Institute  
University of Hamburg  
Leibniz-Institute for Baltic Sea Research
Eel hatchery technology for a sustainable aquaculture (EEL-HATCH) (39181)

Hatchery and rearing technology for commercial production of glass eels is fundamental to sustainable and profitable eel aquaculture. The vision is to enhance existing technology to rear European eel larvae to the glass eel stage, thereby closing the lifecycle in captivity. Pioneering research of the consortium has raised eel breeding from a state of reproductive failure to stable production of viable larvae.

Objectives include: Design “state of the art” hatchery facilities, optimize broodstock feeds, enhance assisted reproductive technology, and develop larval culture systems and diets. The main success criterion is achievement of large scale culture of larvae throughout the larval stage, leading to glass eel production. The establishment of sustainable aquaculture of this endangered species, presently relying on captive glass eel will rebuild the highly profitable market for eel aquaculture and suppliers as well as assist in conservation and stock management plans.

Results obtained during the half of the project period include the design and establishment of a dedicated research facility in relation to DTU Aqua in Hirtshals, involving several partners. The facility applies recirculation aquaculture systems with emphasis on matured water technology and microbial control. Scientific highlights include successful production of recombinant European eel gonadotropic hormones; enhanced reproduction, fertilization and incubation procedures; and optimized larval culture conditions, including e.g. temperature, salinity, and light regime. Larval diets have been developed and tested in first feeding and behavioral experiments, leading to the first published work on larval feeding for this species. Experiments on improved diets and optimized rearing tanks for larval growth are ongoing.

This project is coordinated by DTU Aqua.

The project is funded by Innovation Fund Denmark.

National Institute of Aquatic Resources
Section for Marine Living Resources
Billund Aquaculture Service Aps
BioMar A/S
North Sea Science Park
Bioneer A/S
STMI
Danish Aquaculture Association
Period: 01/04/2014 → 30/09/2017
Number of participants: 9
Research areas: Fish Biology & Aquaculture & Coastal Ecology
Project participant:
Butts, Ian (Intern)
Støttrup, Josianne Gatt (Intern)
Lund, Ivar (Intern)
European eel larval ontogeny and physiology
National Institute of Aquatic Resources
Period: 01/04/2014 → 12/03/2018
Number of participants: 3
PhD Student:
Politis, Sebastian Nikitas (Intern)
Main Supervisor:
Tomkiewicz, Jonna (Intern)

Financing sources
Source: Internal funding (public)
Name of research programme: Samfinansieret - Andet
Project: PhD

Biodiversity changes - causes, consequences and management implications (BIO-C3) (39117)
BIO-C3 will investigate the dynamics of biodiversity in the Baltic Sea, their causes and the consequences for the function of food webs, including implications for biodiversity management policies.

Baltic biodiversity is historically dynamic responding to various drivers operating at different time and space scales. Species diversity is generally low and contains many recent immigrants and glacial relict species because of low salinity and relatively young age. Nevertheless, Baltic food webs sustain many goods and services valued by society.

We focus on functional consequences of ongoing and projected distributional and compositional changes of benthic and pelagic communities with a focus on invasive and resident key species. Using spatial and temporal projections of abiotic/biotic drivers including their interaction (climate change, eutrophication, species invasions, fisheries), we will assess how biodiversity (e.g., of species, traits, habitats) responds in time, space and along gradients of human impact and hydrography. We will investigate the potential and genetic basis for colonisation, acclimation and adaptation of species and populations to the Baltic Sea, and how compositional and adaptive changes of Baltic biodiversity affect ecosystem functions with an emphasis on trophic linkage and food web dynamics.

Results will feed into impact assessments that guide management policies including improved operationalization of status indicators, and guidelines for MPAs.

The project is coordinated by Helmholtz Centre for Ocean Research, Kiel (GEOMAR). DTU Aqua is co-coordinator.

The project is funded equally by EU, BONUS (Science for a Better Future of the Baltic Sea Region), ERA-NET.

National Institute of Aquatic Resources
Section for Marine Ecology and Oceanography
GEOMAR - Helmholtz Centre for Ocean Research Kiel
University of Hamburg
Stockholm University
National Marine Fisheries Research Institute
University of Tartu
Reproduction capacity of European eel in captivity: Fecundity, follicular maturation and developmental competence of embryos and larvae

National Institute of Aquatic Resources
Period: 01/05/2012 → 30/09/2017
Number of participants: 7
Phd Student:
da Silva, Filipa (Intern)
Supervisor:
Kjørsvik, Elin (Ekstern)
Stattrup, Josianne Gatt (Intern)
Main Supervisor:
Tomkiewicz, Jonna (Intern)
Examiner:
Hansen, Jakob Hemmer (Intern)
Hamre, Kristin (Ekstern)
Rosenfeld, Hanna (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Institut stipendie (DTU)
Project: PhD

Assessing and improving the quality of aquatic animal gametes to enhance aquatic resources – The need to harmonize and standardize evolving methodologies and improve transfer from academia to industry (AQUAGAMETE) (39130)
The aim of the AQUAGAMETE COST Action is to reach a consensus on protocols and guidelines (using internationally defined terminology, units of measurement and format of reporting) that permit the use of results in relational databanks for sound and common application in aquaculture research and commerce. There is an urgent need towards a universal scale to assess both the precise state of sexual maturation (for secure broodstock use) and related life history traits (gamete quality assessment, incubation of eggs) in teleost fish and other commercially important invertebrates used in
either bioassays or aquaculture.

During the past six years, three international workshops on fish gametes demonstrated a rapid development of methodologies that encompass extensive opportunities for promising use in basic reproductive biology, genetic research, biotechnology and aquaculture practice. All of these can have far-reaching consequences on conservation of endangered species, assessment of anthropogenic and climatic impacts on aquatic species and application in aquaculture, as well as in fisheries management. In particular, it has been recognized that there are many highly diverging details in the practical application of these new methods used by most scientists and laboratories, which can cause highly variable if not contradicting results, even using the same species.

COST action management and scientific activities comprise meetings, congresses and workshops, training schools and short term training mission (STSM) program. The action has funded participation of delegates Jonna Tomkiewicz and Ian A.E. Butts in action management meetings and three AQUAGAMETE conferences, participation of two students in training schools, six short term missions (STSM) of MSC and PhD students performing work at the labs of international collaborators as well as their participation in AQUAGAMETE conferences. Exchange of students and collaboration has resulted in a series of publications enhanced through collaboration as well as enriched learning by students through international networking.

Other partners than DTU Aqua (countries and number of institutes): Austria (1), Belgium (1), Bulgaria (2), Croatia (1), Czech Republic (1), Finland (3), France (3), Macedonia (1), Germany (1), Greece (4), Hungary (1), Israel (2), Italy (2), Netherlands (1), Norway (1), Poland (2), Portugal (1), Serbia (1), Slovenia (2), Spain (10), Sweden (2), Turkey (2), UK (2), International Partner Countries (IPC): Brazil, Japan (1), Singapore, South Africa (1).

AQUAGAMETE is funded by COST, EU (European Cooperation in Science and Technology).

National Institute of Aquatic Resources
Section for Marine Ecology and Oceanography
Period: 01/01/2012 → 31/12/2016
Number of participants: 2
Research areas: Fish Biology & Marine Populations and Ecosystem Dynamics
Project participant:
Tomkiewicz, Jonna (Intern)
Butts, Ian (Intern)

Reproduction of European eel: Towards a self-sustained aquaculture (PRO-EEL) (38793)

Reproduction of European eel (*Anguilla anguilla*) in culture has become a research priority area due to a severe decline of natural stocks and an increasing interest to breed eels for a self-sustained aquaculture. As eels do not reproduce naturally in captivity, development of methodology and technology was needed for production of viable eggs and larvae from broodstock in a regular and predictable way.

Focus of PRO-EEL project was on the primary bottlenecks in a controlled reproduction of eels, which concern deficiencies in knowledge about eel reproductive physiology and methods applied to induce and finalize gamete development. During a 4-year period, the project significantly expanded current knowledge on the eel reproductive mechanisms and hormonal control of sexual maturation. The consortium developed standardized protocols for assisted production of high quality gametes (egg and sperm) and artificial fertilization, thereby obtaining a stable production of viable embryos. Furthermore, egg incubation procedures and culture of yolksac larvae were established for the first time for European eel, leading to the first feeding stage. The project disseminated novel literature on early life stages, including their ontogeny and requirements thereby describing egg and larval stages still unknown in nature and providing important information for future development of larval diets and rearing technology. Methodology and technology was established using small scale tests and validated in full scale experimental facilities managed by DTU.

The project was an international, EU-funded research project characterized by an integrative and multidisciplinary approach. The consortium brought together leading experts in eel reproduction complemented by expertise in disciplines filling gaps in knowledge and technology. The consortium included 15 partners, comprising European research institutes and industry partners as well as an international collaboration partner country (ICPC). Within DTU, the project involved DTU Food, Research Group for Bioactives – Analysis and Application, and several DTU Aqua research areas including Fish Biology, Aquaculture, Marine Populations and Ecosystem Dynamics, and Coastal Ecology.

The project was coordinated by DTU Aqua.

The project was funded by EU, Framework Programme 7.
National Food Institute
National Institute of Aquatic Resources
Section for Marine Ecology and Oceanography
Wageningen IMARES
Leiden University
National Centre for Scientific Research "Demokritos"
Polytechnic University of Valencia
Norwegian Institute of Food, Fisheries and Aquaculture Research
Ghent University
University of Copenhagen
National Institute for Agronomic Research
Billund Aquaculture Service Aps
National Institute of Sciences and Technologies of the Sea
Institute of Marine Research
Norwegian University of Science and Technology
BioMar A/S
Period: 01/01/2010 → 31/07/2014
Number of participants: 9
Research areas: Fish Biology & Aquaculture & Marine Populations and Ecosystem Dynamics & Coastal Ecology
Project participant:
Butts, Ian (Intern)
Støttrup, Josianne Gatt (Intern)
Sørensen, Sune Riis (Intern)
Skov, Peter Vilhelm (Intern)
Steenfeldt, Svend Jørgen (Intern)
Hornum, Inger (Intern)
Project Manager, academic:
Tomkiewicz, Jonna (Intern)
Munk, Peter (Intern)
Krüger-Johnsen, Maria (Intern)

Eel Egg and Larval development in Relation to Bio-Physical Characteristics and Gamete Quality

National Institute of Aquatic Resources
Period: 01/07/2009 → 02/04/2014
Number of participants: 7
Phd Student:
Sørensen, Sune Riis (Intern)
Supervisor:
Bossier, Peter Georges Madeleine (Ekstern)
Main Supervisor:
Tomkiewicz, Jonna (Intern)
Examiner:
St. John, Michael (Intern)
Geffen, Audrey Rachelle (Ekstern)
Vadstein, Olav (Ekstern)

Financing sources
Source: Internal funding (public)
Reproduction of European eel in aquaculture: Consolidation and new production methods (REEL) (38398)

**Project aim:** Enhance methods and technology applied to produce and culture European eel larvae as basis for the development of a future self-sustained eel aquaculture.

**Background:** The severe decline of the European eel stock calls for conservation measures including national eel management plans and establishment of a self-sustained eel aquaculture. In 2005, DTU Aqua, University of Copenhagen and the eel aquaculture industry started to build up a research and technology platform for the development of methods to reproduce European eel in aquaculture.

**Two major projects:** Artificial Reproduction of Eels II and III (ROE II and III) succeeded during 2005-2008 to produce viable eggs and larvae that lived up to 12 days. The larvae thereby accomplished the yolk sac stage and became ready to start feeding. The results were in particular promising because they evidenced that methods successfully applied to Japanese eel have a potential for application also to European eel. ROE II and III LC were supported by the Danish Ministry of Food, Agriculture and Fisheries and the Financial Instrument for Fisheries Guidance (FIFG) and RO III by the Danish Food Research Program 2006.

**Results:** The REEL project has accomplished through three series of experiments to consolidate previous results and extend the longevity of larvae from 12 to 20 days after hatch in first feeding experiments. Methods to induce maturation were further tested, and farmed and wild eel broodstocks and different treatments were compared. In particular, fertilization procedures to produce fertilized eggs and embryos and monitoring techniques were enhanced. The technology needed to culture embryos and larvae was substantially improved. The potential for new hormonal treatments was explored and recombinant eel hormones have been produced. New broodstock diets were developed with focus on the lipid composition essential for development and survival of fish larvae. In addition, the experimental facility established by DTU Aqua at Lyksvad Fishfarm was enhanced by improving the experimental and laboratory facilities. The REEL project has provided the basis for the establishment of an EU research project: Reproduction of European Eel: Towards a Self-sustained Aquaculture (PRO-EEL) (38793) coordinated by DTU Aqua. REEL included the partners DTU Aqua, the Danish Eel Producers Association, Billund Aquaculture, BioMar, Bioneer and Copenhagen University of which four are integrated in PRO-EEL.

The project was coordinated by DTU Aqua.

National Food Institute
National Institute of Aquatic Resources
Section for Marine Ecology and Oceanography
University of Copenhagen
Bioneer A/S
Danish Eel Farmers Association
Billund Aquaculture Service Aps
BioMar A/S

**Period:** 01/01/2009 → 31/12/2010
**Number of participants:** 8
**Research areas:** Marine Populations and Ecosystem Dynamics & Fish Biology

**Project participant:**
Steenfeldt, Svend Jørgen (Intern)
Sørensen, Sune Riis (Intern)
Hornum, Inger (Intern)
Krüger-Johnsen, Maria (Intern)
Project Manager, academic:
Tomkiewicz, Jonna (Intern)
Munk, Peter (Intern)
Støttrup, Josianne Gatt (Intern)
Tybjerg, Lars (Intern)

**Reproductive Ecology: Effect of dietary fatty acids on ovarian maturation, spawning time and quality of eggs and larvae in Eastern Baltic cod**

National Institute of Aquatic Resources
Edible-, slaughter- and health quality of exercised rainbow trout (38395)

In Danish aquaculture the production of rainbow trout (Oncorhynchus mykiss) in intensive, recirculating systems has increased over the years and this tendency is expected to proceed. Intensive systems are characterized by their potential to apply relatively high water velocities that can be of importance to fish farmers since water currents in earlier studies have been shown to stimulate fish growth. A large part of the growth potential of modern trout strains has however been exploited through breeding and this makes it uncertain to what extent and how modern trout strains respond to increased water velocities in terms of growth. Quality is also a significant parameter in that regard. Fast growth in intensive rearing systems may have implications on trout quality through increased propensities to stimulate lipid depositions in edible parts of the fish and in buccal cavities with concomitant effects on sensory parameters and slaughter yields.

The aim of the project is to study how exercise of rainbow trout may influence their growth and quality. Through collaboration with external partners and internal collaboration in DTU Aqua that has been stimulated through the research area “Individual Biology” numerous competences are involved. The project addresses important aspects of muscle physiology, hormonal control, enzymatic activities, fatty acid metabolism, overall fish growth and industrial fish quality. More specifically, by use of different exercise levels, fish growth and feed and protein utilization is monitored by changes in weights and lengths of the fish together with differences in feed intake. Growth rates are evaluated together with blood plasma content of IGF-1. Furthermore, measurements of plasma cortisol levels together with feed shares indicate the impact on fish welfare. Slaughter yields are determined under common production conditions in industry. Changes in chemical proximate composition of fillets are studied together with fatty acid profiles and the particular change in healthy n-3 fatty acids. Muscle fiber growth and other characteristics in the swimming musculature are studied by use of histological techniques involving light microscopy as well as electron microscopy. Changes in gene expression for mTOR (the mammalian target of rapamycin) are studied for their potential role in muscle fiber hypertrophic or hyperplastic growth and proteom analyses considering other key proteins of importance to both growth and quality are also undertaken. Changes in the calpastatin/calpain system measured as gene expression and/or electrophoretic are considered important.
for development of fillet texture that is measured instrumentally. Fillet texture is additionally considered by a trained sensory panel focusing on taste, odors, texture characteristics and appearance of the fish fillets. The results obtained so far have proven positive with regards to applying exercise in rearing of modern rainbow trout strains. Negative aspects only seem to manifest when strenuous exercise levels are applied. Exercise has the potential to stimulate overall growth and reduce size differences within a stock supposedly owing to less aggression when feeding. Through several changes in muscle physiological components brought about by exercise the fillet texture may increase and there are furthermore indications that fish welfare may be improved. The project is coordinated by DTU Aqua.

National Food Institute
Section for Aquaculture
National Institute of Aquatic Resources
Aarhus University
University of Tasmania
Danforel A/S

Period: 01/01/2008 → 31/12/2011
Number of participants: 2
Research areas: Aquaculture & Fish Biology
Project participant:
Tomkiewicz, Jonna (Intern)
Project Manager, academic:
Rasmussen, Richard Skøtt (Intern)
Project

Artificial reproduction of eels: Phase III (ROE III) (38187)
The steady decline of the European eel stock has adverse consequences for the Danish eel aquaculture as all eel farming is at present capture based relying on wild caught glass eels. In 2005, DTU Aqua, University of Copenhagen and the eel aquaculture industry started to build up a research and technology platform for the development of methods to reproduce European eel in aquaculture.

The focus of ROE III was to follow up the pioneering work on artificial reproduction of European eels performed in the preceding pilot projects ROE I and II. The projects ROE II and III were a collaboration among DTU Aqua, University of Copenhagen and the eel aquaculture industry following up an initial survey ROE I of suited methodology lead by University of Copenhagen.

ROE III comprised the following activities:
(i) Experimental series with different treatment schemes and hormone dosage to improve the maturation process and optimize gamete quality;
(ii) Development of methods to monitor the maturation process on individual level using ultrasound scanning technology and ovary biopsy;
(iii) Analysis of broodstock fishes and improvement of the dietary fatty acid composition;
(iv) Investigation of parameters determining egg quality during incubation;
(v) First-feeding trials with eel larvae testing both artificial and live feed.

Three experimental series were completed focusing on methods for broodstock enhancement, maturation and fertilization plus culture of eggs and larvae. Already during the first experimental series, larvae accomplishing the entire yolk sac stage were achieved for the first time in history for European eel. The yolk sac larvae developed successfully during the period were they entirely depend on nutrition sources i.e yolk and lipid of maternal origin. The larvae were ready to start feeding day 12 post hatch. During the second experimental series, larval longevity was extended to 18 days during first feeding experiments. These recent results are a major breakthrough because they show for the first time that artificial hormone treatment can lead to viable offspring in European eel. Eggs and yolksac larvae were obtained from different hormonal treatments and mass hatchings were regularly obtained. Larval feeding using live and artificial larval feeds developed in collaboration with the food company BioMar were developed towards the end of the experiments and are ready for testing in new and coming projects.

The success of this project on improved methods, quality criteria and larval survival has led to form the basis of the project: Reproduction of European eel in aquaculture: Consolidation and new production methods and later (REEL) (38398) and later the EU FP project: Reproduction of European eel in Aquaculture: Towards a self-sustained aquaculture (PRO-EEL) (38793).

The project was coordinated by DTU Aqua.
Understanding the mechanisms of stock recovery (UNCOVER) (38104)
The UNCOVER project has produced a rational scientific basis for developing Long-Term Management Plans (LTMP) and recovery strategies for 11 of the ecologically and socioeconomically most important fish stocks/fisheries in the Norwegian and Barents Seas, the North Sea, the Baltic Sea and the Bay of Biscay and Iberian Peninsula.

UNCOVER’s objectives were to:
(i) identify changes experienced during stock depletion/collapses,
(ii) to understand prospects for recovery,
(iii) to enhance the scientific understanding of the mechanisms of fish stock/fishery recovery, and
(iv) to formulate recommendations how best to implement LTMPs/recovery plans.

The project recommends that such plans ideally should include:
(i) Consideration of stock-regulating environmental processes,
(ii) Incorporation of fisheries effects on stock structure and reproductive potential,
(iii) Consideration of changes in habitat dynamics due to global change,
(iv) Incorporation of biological and technological multispecies interactions,
(v) Integration of economically optimized harvesting,
(vi) Exploration of the socio-economic implications and political constraints from existing and alternative recovery plans,
(vii) Investigations on the acceptance of plans by stakeholders and specifically incentives for compliance by the fishery,
(viii) Agreements with and among stakeholders.

UNCOVER has provided imperative policy support underpinning the following fundamental areas:
(i) Evolution of the Common Fisheries Policy with respect to several aims of the ‘Green Paper’;
(ii) Contributing to the Marine Strategy Framework Directive with respect to fish stocks/communities;
(iii) achieving Maximum Sustainable Yield (MSY) for depleted fish stocks. This has been done by contributing to LTMPs/recovery plans for fish stocks/fisheries, demonstrating how to shift from scientific advice based on limit reference points towards setting and attaining targets such as MSY, and furthering ecosystem-based management through incorporating multispecies, environmental and habitat, climate variability/change, and human dimensions into these plans.

The project was coordinated by Institut für Ostseefischerei, Bundesforschungsanstalt für Fischerei, Germany.
Baltic Sea management: Nature conservation and sustainable development of the ecosystem through spatial planning (BALANCE) (38432)

BALANCE aimed to develop transnational marine spatial planning tools and an agreed template for marine management planning and decision-making. It was based on four transnational pilot areas demonstrating the economical and environmental value of habitat maps and marine spatial planning (exemplified through two zoning plans). The tools and zoning plans integrated biological, geological and oceanographic data with local knowledge from stakeholders. A "blue corridor" concept was developed and promoted, i.e. between protected sites adding spatial development dimensions to the implementation of EU Directives. As a part of this work it was assessed if the Baltic marine Natura 2000 network is ecologically coherent and adequately represents and protects a continuum of habitats. A communication strategy was developed for stakeholder involvement to ensure that objectives and decisions address local stakeholders’ needs.

Spatial planning tools included Baltic Sea marine landscapes presented in GIS maps, a holistic approach to marine habitat mapping integrating data on benthic, pelagic and fish habitats in four transnational pilot areas, development of habitat models for areas with little biological information, templates for zoning plans in two pilot areas, including planning guidelines and criteria to evaluate management success, meta-database for Baltic Sea marine data, outlining data formats, techniques and data availability for use by stakeholders in future planning, development of agreed protocols for habitat mapping based on intercalibration of existing national protocols, ensuring compatible data for future transnational mapping.
DTU Aqua was mainly involved in habitat modelling (coastal and pelagic fish habitats) and in development of marine spatial planning and management frameworks.

In addition to DTU Aqua, 23 partners were involved in the BALANCE project, i.e. representing governmental and non-governmental organizations and research institutes from the entire Baltic region in the fields of biology/ecology, fisheries and geology.

The project was coordinated by DTU Aqua.

National Institute of Aquatic Resources
Section for Ecosystem based Marine Management
Period: 01/01/2005 → 31/12/2007
Number of participants: 8
Research area: Ecosystem Based Marine Management
Project participant:
Sørensen, Thomas Kirk (Intern)
Geitner, Kerstin (Intern)
Sparrevohn, Claus Reedtz (Intern)
Hüssy, Karin (Intern)
Köster, Fritz (Intern)
Tomkiewicz, Jonna (Intern)
Neuenfeldt, Stefan (Intern)
Project Manager, organisational:
Vestergaard, Ole (Ekstern)

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
Critical interactions between species and their implications for a precautionary fisheries management in a variable environment – a modeling approach (BECAUSE) (38613)

Across Europe, the population of predatory fish has fallen dramatically in recent years. This has reduced the predation rate and the prey species has remained fairly stable. Therefore the balance between predators and prey species has been radically changed. No accurate scientific picture of the exact interactions between these species and their effects on non-commercial top predators is available. To maintain biodiversity and make recovery plans more effective, such an understanding is vital.

The sustainable management of European fisheries requires an adaptive approach that takes into account the long term dynamics of the entire marine ecosystem so as to protect the biodiversity of our seas. BECAUSE investigated the interaction between predator and prey, and the shifts in their relative populations and looked into how fishing affects the balance of the marine food chain. The interactions targeted for investigation included sandeel/predator fish, predators and prey of cod, and hake/prey fish.

Contributions to the policy development aimed at integrating a sustainable ecosystem approach into the EU’s Common Fisheries Policy (CFP) thereby helping the EU to meet its global fishing commitments and underwrite the sustainability of ecosystem services. Multi-species fisheries assessment were improved and enhanced policy and management measures to replenish fish stocks and ensure high yields were proposed.

The was coordinated by Universität Hamburg, Germany.

National Institute of Aquatic Resources
Section for Marine Ecology and Oceanography
Universität Hamburg
Marine and Food Technological Centre
Cefas
Finnish Game and Fisheries Research Institute
Marine Scotland
Marine Research Institute
Leibniz Institute of Marine Sciences
IFREMER
Consejo Superior de Investigaciones Científicas
Institute of Marine Research
National Centre for Marine Research
Activities:

**ICES - Workshop for maturity staging chairs - WKMATCH (External organisation)**
Period: 2012 → …
Jonna Tomkiewicz (Participant)

National Institute of Aquatic Resources
Section for Population Ecology and Genetics
Degree of recognition: International

Related external organisation

**ICES - Workshop for maturity staging chairs - WKMATCH**
Activity: Membership › Membership of committees, commissions, boards, councils, associations, organisations, or similar

**ICES - Workshop on Sexual Maturity Staging of Cod, Whiting, Haddock, Saithe and Hake - WKMSGAD (External organisation)**
Period: 2012 → …
Jonna Tomkiewicz (Participant)

National Institute of Aquatic Resources
Section for Population Ecology and Genetics
Degree of recognition: International

Related external organisation

**ICES - Workshop on Sexual Maturity Staging of Cod, Whiting, Haddock, Saithe and Hake - WKMSGAD**
Activity: Membership › Membership of committees, commissions, boards, councils, associations, organisations, or similar