Are all bony fishes oxygen regulators? Evidence for oxygen regulation in a putative oxygen conformer, the swamp eel Synbranchus marmoratus

This study investigated the oxygen consumption of the putative oxygen conformer marbled swamp eel Synbranchus marmoratus during progressive hypoxia. Earlier studies have not reached agreement on whether S. marmoratus is a conformer or regulator. Our results support the view that S. marmoratus is an oxygen regulator, like most bony fishes.

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Boldness in early emerging rainbow trout: A metabolic cost with no return?

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Publication status: Accepted/In press
Organisations: Section for Aquaculture, National Institute of Aquatic Resources
Contributors: Skov, P. V., de Jesus Gregersen, J., Gesto, M., Jokumsen, A.
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Effects of water flow rates on growth and welfare of Nile tilapia (Oreochromis niloticus) reared in a recirculating aquaculture system

The effects of water exchange on growth and welfare of Nile tilapia (Oreochromis niloticus) were investigated in a recirculating aquaculture system during an 8-week trial. Fish of initial body mass of ~27 g (n=8 per tank) were reared in 60-L tanks with water exchange rates, corresponding to 1.5 (LE), 3 (ME) and 6 (HE) tank volumes/h. Treatments were triplicated and fish were fed at 3% of their biomass each day. The LE treatment resulted in significantly higher (p<0.05) levels of ammonia nitrogen and phosphate in the culture water relative to the higher water exchange treatments. The specific growth rate (SGR) of fish cultured under the HE treatment (2.74% day⁻¹) was significantly higher than the SGR (2.21% day⁻¹) of the LE fish. Mean final body weights of the LE, ME and HE fish were 97.67±8.13, 110.50±22.45 and 123.92±10.00 g, respectively. Higher prevalence of dermal ulcerations, oral lesions and poor fin conditions were associated with the LE and ME fish. After 4 weeks, 34 and 24% of the LE and ME fish, respectively, had advanced mouth lesions compared to 0% for the HE fish. Haematological indicators of long-term oxygen stress and disease conditions, as evidenced by erythrocyte and platelet indices, were generally higher in fish under the LE and ME treatments. This study has shown that although the Nile tilapia is a hardy species, long-term exposure to poor water conditions can result in reduced growth and compromised welfare.

Proactive coping style in early emerging rainbow trout carries a metabolic cost with no apparent return

The timing with which salmonid larvae emerge from their gravel nests is thought to be correlated with a particular suite of behavioural and physiological traits that correspond to the stress coping style of the individual. Among these traits, aggressiveness, dominance and resilience to stress, are potentially interesting to exploit in aquaculture production. In the present study a series of experiments were performed, with the purpose of characterising behavioural, metabolic and production related traits in rainbow trout juveniles from different emergence fractions. Newly hatched rainbow trout were sorted according to their emergence time from an artificial redd. The early, middle, and late fractions were retained and assessed for their physiological response to stress, growth performance, metabolism, fasting tolerance, and potential for compensatory growth. The early emerging fraction showed proactive behavioural traits; they were faster to reappear following startling, showed a reduced cortisol response following stress, and a reduced metabolic cost of recovery. Emergence time was not correlated with any differences in standard or maximum metabolic rates, but was however, correlated with higher routine metabolic rates, as demonstrated by significantly bigger weight losses during fasting in the early emerging group. Growth rates and feed conversion efficiencies were not significantly different when fish were co-habituated under a restrictive feeding regime, suggesting that early emerging fish are not able to monopolise food resources. The intermediate emerging group, which makes up the bulk of a population and is often ignored, appears to possess the best growth performance traits, possibly because they do not expend excessive energy on dominance behaviour such as the early emerging group, while they are also not overly timid or stress prone such as the late emerging group.
Survival of discarded plaice (Pleuronectes platessa) from Norway lobster (Nephrops norvegicus) otter-trawl fishery

The introduction of landing obligations in the European Union common fisheries policy, has increased the focus on discard survival. Since species with scientifically proven high survival rates may be exempted from the landing obligations, the economic significance for the fishing industry is large. Landing obligations include individuals below the minimum conservation reference size (MCRS), which are not allowed to be sold for human consumption. The Norway lobster (Nephrops norvegicus) fishery is a high value fishery, but with a substantial amount of bycatch of plaice (Pleuronectes platessa) below the MCRS. In the present study, observations were made on the short-term survival of plaice at or below the MCRS, discarded from a small otter board trawler targeting Nephrops in Skagerrak (ICES 3a). The average short-term survival of plaice was 15% at haul level, ranging from 0% to 39%, after 10 days of captive observation. Survival significantly decreased with time on deck and the retention of debris in the codend (p < 0.0001), while survival was not correlated to size. Vitality assessments, using a combined reflex impairment and injury score, were tested as predictor of survival and were significantly associated to survival (p < 0.0001) both for individual fish and when grouped by hauls. Seabird predation behaviour was assessed and it was estimated that seabirds predated or pursued 85% of discarded plaice below the MCRS.

Assessing physiological stress to understand collateral mortality in the Antarctic krill (Euphausia superba) trawl fishery

General information
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Organisations: Section for Ecosystem based Marine Management, National Institute of Aquatic Resources, Section for Aquaculture, Institute of Marine Research, SINTEF
Contributors: Krag, L. A., Krafft, B. A., Herrmann, B., Skov, P. V.
Dietary supplementation of yeast (Saccharomyces cerevisiae) improves growth, stress tolerance, and disease resistance in juvenile Nile tilapia (Oreochromis niloticus)

The yeast Saccharomyces cerevisiae is one of the commonest probiotics incorporated in aquafeeds. An 84-day feeding trial was conducted to evaluate the effects of varying dietary inclusions of S. cerevisiae, 0% (control), 3% (YF3), 5% (YF5), and 7% (YF7), on growth, stress tolerance, and disease resistance in juvenile (body mass ~ 21 g) Nile tilapia (Oreochromis niloticus). Fish were randomly distributed in groups of 20 into 12 1-m³ hapas and fed isoenergetic (~ 17 kJ g⁻¹ gross energy) and isonitrogenous (~ 300 g kg⁻¹ crude protein) diets at 3% of their bulk weight daily. Specific growth rates were significantly higher for the yeast-fed fish (0.77–0.78% day⁻¹) than for the control fish (0.60% day⁻¹) and resulted in significantly higher mean final weights for the yeast-treated groups. Protein and lipid retention efficiencies were also significantly higher in the yeast-fed fish than in the control group. In subsequent stress challenge trials, the yeast-fed fish had greater tolerance to acute heat as well as hypoxia exposure than the control fish. Survival rates of the yeast-treated groups following sudden exposure to elevated water temperature (40 °C) ranged from 82.5 to 100% compared to 15% for the control. Mean survival rates following a 24-h hypoxia exposure were also generally significantly higher for the yeast-fed fish. The probiotic groups recorded a relative percent survival (RPS) of 75% after a 14-day Aeromonas hydrophila infection challenge. The results of this study indicate that S. cerevisiae as an additive in Nile tilapia diets has beneficial impacts on growth, stress tolerance, and disease resistance.
Short-term feed and light deprivation reduces voluntary activity but improves swimming performance in rainbow trout Oncorhynchus mykiss
Rainbow trout Oncorhynchus mykiss (~180 g, 16 °C and <5 kg m−3) that were feed deprived and kept in total darkness showed a significant increase in critical swimming speed (Ucrit) between 1 and 12 days of deprivation (from 3.35 to 4.46 body length (BL) s−1) with no increase in maximum metabolic rate (MMR). They also showed a significant decrease in the estimated metabolic rate at 0 BL s−1 over 12 days which leads to a higher factorial aerobic metabolic scope at day 12 (9.38) compared to day 1 (6.54). Routine metabolic rates were also measured in ~90 g rainbow trout that were swimming freely in large circular respirometers at 16 °C. These showed decreasing consumption oxygen rates and reductions in the amount of oxygen consumed above standard metabolic rate (a proxy for spontaneous activity) over 12 days, though this happened significantly faster when they were kept in total darkness when compared to a 12:12-h light–dark (LD) photoperiod. Weight loss during this period was also significantly reduced in total darkness (3.33% compared to 4.98% total body weight over 12 days). Immunological assays did not reveal any consistent up- or downregulation of antipathogenic and antioxidant enzymes in the serum or skin mucus of rainbow trout between 1 and 12 days of feed and light deprivation. Overall, short periods of deprivation do not appear to significantly affect the performance of rainbow trout which appear to employ a behavioural energy-sparing strategy, albeit more so in darkness than under a 12:12-h LD regime.

The effects of acute and long-term exposure to CO 2 on the respiratory physiology and production performance of Atlantic salmon (Salmo salar) in freshwater
A high-level of free CO2 is a prevalent feature of intensive RAS and chronic exposure is common for most species during the production process. Currently, standard operating procedures, regulations and “safe” levels of CO2 are based on values that do not necessarily represent a point at, up to which, production and fish performance are unaffected. The high solubility of CO2 in water and the large input from fish respiration also means that current practices for the removal of CO2...
are often inadequate for the scale of production. High CO2 levels can be addressed by the control of alkalinity, thereby creating a scenario where the majority of CO2 exists as carbonate and bicarbonate. Any acute reduction in pH can shift the equilibrium towards a large and sudden conversion of inorganic carbon to free CO2, which can have a detrimental effect on fish. The current investigations aimed to determine the effects of both; acute increases in dissolved CO2 on the physiological capacity of Atlantic salmon, as well the effects of chronic exposure to different CO2 concentrations on production in freshwater. Results show that acute exposure (up to 40mgL−1) significantly reduces aerobic capacity and the rate of recovery from stress. They also show that these effects are driven primarily by CO2 exposure, and to a much lesser extent by the associated reduction in pH. Growth and feed conversion experiments during chronic exposure suggest that there is no CO2 concentration where production performance is unaffected.

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The potential direct and indirect effects of grey seal on Baltic cod

General information
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Organisations: Section for Marine Living Resources, National Institute of Aquatic Resources, Section for Oceans and Arctic, Section for Ecosystem based Marine Management, Section for Aquaculture, Thunen-Institut, University of Copenhagen, Aarhus University, Lund University, Zoological Museum
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Event: Abstract from EUfishmeal 2018,.
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Acute and long-term CO2 exposure reduces the performance of Atlantic salmon in RAS

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Publisher: Technical University of Denmark, National Institute for Aquatic Resources
Editor: Dalsgaard, A. J. T.
Bigger is not better: cortisol-induced cardiac growth and dysfunction in salmonids

Stress and elevated cortisol levels are associated with pathological heart growth and cardiovascular disease in humans and other mammals. We recently established a link between heritable variation in post-stress cortisol production and cardiac growth in salmonid fish too. A conserved stimulatory effect of the otherwise catabolic steroid hormone cortisol is probably implied, but has to date not been established experimentally. Furthermore, whereas cardiac growth is associated with failure of the mammalian heart, pathological cardiac hypertrophy has not previously been described in fish. Here, we show that rainbow trout (Oncorhynchus mykiss) treated with cortisol in the diet for 45 days have enlarged hearts with lower maximum stroke volume and cardiac output. In accordance with impaired cardiac performance, overall circulatory oxygen-transporting capacity was diminished as indicated by reduced aerobic swimming performance. In contrast to the well-known adaptive/physiological heart growth observed in fish, cortisol-induced growth is maladaptive. Furthermore, the observed heart growth was associated with up-regulated signature genes of mammalian cardiac pathology, suggesting that signalling pathways mediating cortisol-induced cardiac remodelling in fish are conserved from fish to mammals. Altogether, we show that excessive cortisol can induce pathological cardiac remodelling. This is the first study to report and integrate the etiology, physiology and molecular biology of cortisol-induced pathological remodelling in fish.

General information

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Source: FindIt
Source-ID: 2358424962
Research output: Contribution to journal › Journal article – Annual report year: 2017 › Research › peer-review

Blood O2 affinity of a large polar elasmobranch, the Greenland shark Somniosus microcephalus

The Greenland shark (Somniosus microcephalus. Bloch & Schneider 1801) is a polar elasmobranch that is hypothesised to possess a unique metabolic physiology due to its extreme large size, the cold waters it inhabits and its slow swimming lifestyle. Our results therefore provide the first insight into the metabolic physiology of this unique shark, with a focus on blood O2 affinity. An evaluation of blood O2 affinity at 2 °C using tonometry revealed a P50 of 11.7 mmHg at a PCO2 of 2.25 mmHg and a Bohr effect (binding sensitivity of blood to pH, \( \phi = \Delta \log P50/\Delta pH \)) of ~0.26. A comparative evaluation of blood O2 affinity across elasmobranch fishes suggests that S. microcephalus has a high blood O2 affinity (i.e., low P50) and a small Bohr effect but these are common traits in sluggish elasmobranch fishes, with little evidence for any relationship of blood O2 affinity to the low metabolic rates, low environmental temperatures, or large body mass of S.
microcephalus. After gathering this physiology data, a subsidiary aim attempted to understand whether a warming scenario would impose a negative effect on blood O2 binding. Incubating blood to a slightly elevated temperature of 7 °C resulted in a small but significant reduction of blood O2 affinity, but no significant change in the Bohr effect. The Hill’s cooperativity coefficient (nH) was also small (1.6–2.2) and unaffected by either PCO2 or temperature. The moderate sensitivity of Greenland shark blood O2 affinity to warming potentially implies little vulnerability of functional O2 supply to the temperature changes associated with the regular vertical movements of this species or warming of polar seas resulting from directional climate change.

General information
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Organisations: National Institute of Aquatic Resources, Section for Aquaculture, University of Auckland, University of Copenhagen, Indiana University-Purdue, NOAA, Dalhousie University
Contributors: Herbert, N., Skov, P. V., Tirsgaard, B., Bushnell, P. G., Brill, R. W., Harvey Clark, C., Steffensen, J. F.
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Crosstalk between innate immunity and circadian rhythm: Do fish immune defences have a sense of time?

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Contributors: Lazado, C. C., Lund, I., Skov, P. V., Jokumsen, A., Gesto, M., Huy, N. Q., Pedersen, P. B.
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Effect of some common West African farm-made feeds on the oxygen consumption and ammonia excretion rates of Nile tilapia, Oreochromis niloticus

General information
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Contributors: Obirikorang, K. A., Amisah, S., Skov, P. V.
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Publication information
Emergence time and skin melanin spot patterns do not correlate with growth performance, social competitive ability or stress response in farmed rainbow trout

In wild salmonid fish, specific individual behavioral traits have been correlated with the timing of fry emergence from their gravel spawning nests; Early emerging fish display more aggressive behavior and have a higher probability of becoming socially dominant, compared to fish that emerge at a later stage. Apart from aggression and dominance, other behavioral and metabolic traits, such as boldness, metabolic rate, or growth, have also been linked to emergence time. Altogether, the traits of early- and late-emerging fish resemble those of the proactive and reactive stress-coping style, respectively. As proactive fish are considered more resilient to stress, it may be desirable to select these for aquaculture production. However, it is currently unclear to what extent the link between emergence time and stress-coping styles is maintained in the selective breeding of farmed fish. In the present study, eyed eggs from a commercial supplier were hatched, and larvae fractionated according to their emergence time. Later on, juvenile fish from different emergence fractions were subjected to a stress challenge and also tested to evaluate their competitive ability for food. Beyond some slight dissimilarities in the acute stress responses, emergence fraction displayed no correlation with growth rates, or the ability to compete for feed. Within the whole group of fish utilized in the experiments, no relationship between skin melanin spot pattern and growth performance, stress response intensity, or competitive ability was found. Altogether, the differences in physiological traits related to emergence time were not as strong as those found in earlier studies. It is hypothesized, that the origin and degree of domestication of the fish might be partly responsible for this. The predictive value of skin spots or emergence time to infer the fish stress coping style in farmed fish is also discussed.
Reflex impairment, physiological stress, and discard mortality of European plaice Pleuronectes platessa in an otter trawl fishery

The reformed European Common Fisheries Policy introduced a discard ban, with a possibility of exempting species where a high discard survival can be demonstrated. This necessitates a validation of the methods used for estimating the discard mortality of candidate species. In this study, we assess whether reflex impairment can predict short-term mortality in commercially trawled European plaice upon landing and after air exposure of up to 90 min. Sub-lethal stress was assessed by a suite of physiological variables. Over a 10-day period, mortality was monitored for a total of 199 plaice following trawl and air exposure of varying duration, and for 50 control fish scored for reflex impairment on board the vessel. Mortality was only observed in fish exposed to air for >60 min, and averaged 11.1% (95% CI = 7.1–16.3%). Reflex impairment was found to be a significant (P < 0.001) predictor of mortality in a generalized linear model, excluding other initially included variables by using a stepwise method. Plasma cortisol, hematocrit, and plasma osmolality all indicated a profound and increasing level of stress with air exposure, accompanied by a near depletion of muscle phosphocreatine and nucleotides. Fishing site had an unexpected, but significant (p < 0.05) effect on stress levels, which was also reflected in reflex impairment and mortality. Based on these findings, a possible exemption from the discard ban should include considerations on the duration of air exposure.

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Contributors: Methling, C., Skov, P. V., Madsen, N.
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Stress and recovery from trawl capture of Norway lobster (Nephrops norvegicus) and potential for live storage

General information
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Contributors: Skov, P. V., Methling, C., Larsen, B. K., Unmack, C. P., Karlsen, J. D., Behrens, J.
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Event: Abstract from Dansk Havforskermøde, Helsingør, Denmark.
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2017 › Research

The influence of ration size on energetics and nitrogen retention in tilapia (Oreochromis niloticus)

Proper nutrient management is essential for the environmental sustainability of aquaculture. While increasing daily rations generally may lead to improved growth rates, this does not necessarily mean that nutrients are utilized more efficiently. To investigate how ration size affects partitioning of dietary nutrient intake, the effects of meal size on growth and metabolism were examined in triplicate groups of adult Nile tilapia (Oreochromis niloticus) receiving daily rations corresponding to 1, 2, 3, or 4% of their biomass. While biomass gain and specific growth rates were positively correlated with ration size, feed conversion and protein retention were most efficient at ration sizes of 3%. Although the magnitude of the SDA response following feeding also increased with ration size, this was not proportionate to meal size. Therefore the metabolic cost of meal processing (SDA coefficient) was found to be lowest in the 3% ration group. The lowest rates of nitrogen excretion as well as the lowest SDA coefficients were also observed for fish receiving meal sizes corresponding to 3% of their body mass. In contrast, fish fed ration sizes of 1% displayed a reduction in apparent digestibility of protein, nitrogen free extract and dry matter, in addition to excreting a disproportionate amount of ingested nitrogen as ammonia and urea.
Discontinuation of anti-VEGF cancer therapy promotes metastasis through a liver revascularization mechanism

The impact of discontinuation of anti-VEGF cancer therapy in promoting cancer metastasis is unknown. Here we show discontinuation of anti-VEGF treatment creates a time-window of profound structural changes of liver sinusoidal vasculatures, exhibiting hyper-permeability and enlarged open-pore sizes of the fenestrated endothelium and loss of VE-cadherin. The drug cessation caused highly leaky hepatic vasculatures permit tumour cell intravasation and extravasation.
Discontinuation of an anti-VEGF antibody-based drug and sunitinib markedly promotes liver metastasis. Mechanistically, host hepatocyte, but not tumour cell-derived vascular endothelial growth factor (VEGF), is responsible for cancer metastasis. Deletion of hepatocyte VEGF markedly ablates the 'off-drug'-induced metastasis. These findings provide mechanistic insights on anti-VEGF cessation-induced metastasis and raise a new challenge for uninterrupted and sustained antiangiogenic therapy for treatment of human cancers.

**General information**
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Source: FindIt
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Research output: Contribution to journal › Journal article – Annual report year: 2016 › Research › peer-review

Growth performance, feed utilization and sensory characteristics of Nile Tilapia, Oreochromis niloticus fed diets with high inclusion levels of copra meal
Background: The low cost and wide-availability of copra meal in many tropical countries where aquaculture is practiced have generated much interest in its potential inclusion in fish diet formulations. The present study was designed to investigate the effect of very high inclusions of autoclaved copra meal on the growth and feed utilization parameters as well as the sensory qualities of the Nile tilapia, Oreochromis niloticus. Methods: Fish were fed three experimental diets, a control (CTRL) diet which had fishmeal as the main protein source at an inclusion of 365 g kg⁻¹ and two test diets which contained copra meal at 680 g kg⁻¹ inclusions for a 6-week period. One of the copra meal diets contained sesame meal supplementation (CM+S) as a natural high source of methionine which is the first limiting essential amino acid in copra meal. Results: The dietary treatments had no differential effects on growth, feed intake, or feed utilization parameters in O. niloticus. With the exception of the significantly higher lipid content of the CM+S group, the whole body compositions of the different fish groups were not significantly affected by the different dietary treatments. Remarkably, the high dietary inclusions of copra meal did not have any significant effects on fillet sensory attributes. Conclusions: The results of this study demonstrate that it is possible to include autoclaved copra meal up to 680 g kg⁻¹ in Nile tilapia diets without any deleterious effects on fish growth or on flesh sensory characteristics.

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Volume: 1
Increasing levels of dietary crystalline methionine affect plasma methionine profiles, ammonia excretion, and the expression of genes related to the hepatic intermediary metabolism in rainbow trout (Oncorhynchus mykiss)

Strictly carnivorous fish with high requirements for dietary protein, such as rainbow trout (Oncorhynchus mykiss) are interesting models for studying the role of amino acids as key regulators of intermediary metabolism. Methionine is an essential amino acid for rainbow trout, and works as a signalling factor in different metabolic pathways. The study investigated the effect of increasing dietary methionine intake on the intermediary metabolism in the liver of juvenile rainbow trout. For this purpose, five diets were formulated with increasing methionine levels from 0.60 to 1.29% dry matter. The diets were fed in excess for six weeks before three sampling campaigns carried out successively to elucidate (i) the hepatic expression of selected genes involved in lipid, glucose and amino acid metabolism; (ii) the postprandial ammonia excretion; and (iii) the postprandial plasma methionine concentrations. The transcript levels of enzymes involved in lipid metabolism (fatty acid synthase, glucose 6 phosphate dehydrogenase and carnitine palmitoyl transferase 1 a), gluconeogenesis (fructose-1,6-biphosphatase) and amino acid catabolism (alanine amino transferase and glutamate dehydrogenase) were significantly affected by the increase in dietary methionine. Changes in gene expression reflected to some extent the decrease in ammonia excretion (P=0.022) and in the hepatosomatic index (HSI; P

Innate immune defenses exhibit circadian rhythmicity and differential temporal sensitivity to a bacterial endotoxin in Nile tilapia (Oreochromis niloticus)

The present study investigated the daily dynamics of humoral immune defenses and the temporal influence in the sensitivity of these responses to a bacterial endotoxin in Nile tilapia (Oreochromis niloticus). The first experiment subjected the fish to two photoperiod conditions, 12L:12D (LD) and 0L:24D (DD), for 20 days to characterize the rhythms of humoral immunity. Serum alkaline phosphatase (ALP), lysozyme (LYZ), peroxidase (PER) and protease (PRO) exhibited significant rhythmicity under LD but not in DD. No significant rhythms were observed in esterase (ESA) and anti-protease (ANTI) in both photoperiod conditions. Fish reared under LD were subsequently subjected to DD while the group previously under DD was exposed to LD, and this carried on for 3 days before another set of samples was collected. Results revealed that the rhythms of LYZ, PER and PRO but not ALP persisted when photoperiod was changed from LD to DD. Nonetheless, immune parameters remained arrhythmic in the group subjected from DD to LD. Cluster analysis of the humoral immune responses under various light conditions revealed that
each photic environment had distinct daily immunological profile. In the second experiment, fish were injected with bacterial endotoxin lipopolysaccharide (LPS) either at ZT3 (day) or at ZT15 (night) to evaluate the temporal sensitivity of humoral immunity to a pathogen-associated molecular pattern. The results demonstrated that responses to LPS were gated by the time of day. LPS significantly modulated serum ALP and ANTI activities but only when the endotoxin was administered at ZT3. Serum LYZ and PER were stimulated at both injection times but with differing response profiles. Modulated LYZ activity was persistent when injected at ZT3 but transient when LPS was applied at ZT15. The magnitude of LPS-induced PER activity was higher when the endotoxin was delivered at ZT3 versus ZT15. It was further shown that plasma cortisol was significantly elevated but only when LPS was administered at ZT3. On the other hand, plasma melatonin was significantly affected by LPS injection but only when exposed at ZT15. Taken together, this study shows that several key components of humoral immunity in tilapia exhibit circadian rhythms and adapt to photoperiodic changes. Further, results of the bacterial endotoxin challenge suggest that responsiveness of serum humoral factors to a biological insult is likely mediated by the time of day, highlighting the importance of circadian rhythm in the immunological functions of fish.

Modelling the effects of dietary methionine level and form on postprandial plasma essential amino acid profiles in rainbow trout (Oncorhynchus mykiss)

Aquafeed formulation is susceptible to affect amino acid (AA) availability for metabolic functions. Statistical models were applied to quantify the effect of dietary methionine level (from 6.01 to 16.17 g kg⁻¹ dry matter) and form (free, coated or bound) on postprandial concentrations of plasma essential amino acid (EAA) in rainbow trout. Twelve diets were formulated with pea and soya protein concentrate or fish meal as the main protein ingredients and were supplemented or not with increasing amount of either crystalline or agar-coated methionine. Fish were acclimatized to one of the 12 diets for 6 weeks before postprandial plasma sampling (six sampling points up to 36 h, seven fish each time), further analysed for EAA content. Using generalized additive models, we show that (i) dietary methionine level and form explained 74% postprandial methionine plasma variations and that (ii) the methionine dietary form and plasma concentrations significantly affected the plasma concentrations of the other EAAs. Finally, linear model revealed a positive relationship (R² > 0.9) between plasma concentrations of the three branched-chain AAs under the present experimental conditions. The results obtained add new information on the dietary effects on EAAs in the plasma availability and the interactions between them.
Dietary methionine level affects growth performance and hepatic gene expression of GH-IGF system and protein turnover regulators in rainbow trout (Oncorhynchus mykiss) fed plant protein-based diets

The effects of dietary level of methionine were investigated in juvenile rainbow trout (Oncorhynchus mykiss) fed five plant-based diets containing increasing content of crystalline methionine (Met), in a six week growth trial. Changes in the hepatic expression of genes related to i) the somatotropic axis: including the growth hormone receptor I (GHR-I), insulin-like growth hormones I and II (IGF-I and IGF-II, respectively), and insulin-like growth hormone binding protein-1b (IGFBP-1b); and ii) protein turnover: including the target of rapamycin protein (TOR), proteasome 20 delta (Prot 20D), cathepsin L, calpains 1 and 2 (Capn 1 and Capn 2, respectively), and calpastatin long and short isoforms (CAST-L and CAST-S, respectively) were measured for each dietary treatment. The transcript levels of GHR-I and IGF-I increased linearly with the increase of dietary Met content (P <0.01), reflecting overall growth performances. The apparent capacity for hepatic protein degradation (derived from the gene expression of TOR, Prot 20D, Capn 1, Capn 2, CAST-L and CAST-S) decreased with increasing dietary Met level in a relatively linear manner. Our results suggest that Met availability affects, directly or indirectly, the expression of genes involved in the GH/IGF axis response and protein turnover, which are centrally involved in the regulation of growth. (C) 2014 Elsevier Inc. All rights reserved.
Digestibility and postprandial ammonia excretion in Nile tilapia (Oreochromis niloticus) fed diets containing different oilseed by-products

The present study was undertaken to evaluate the potential for using oilseed by-products (soybean, copra and palm kernel meals) as partial replacements of fishmeal in feeds for Nile tilapia (Oreochromis niloticus). Nutrient digestibility and postprandial ammonia excretion rates were examined. A fishmeal-based diet served as control against three test diets in which 30% of each of the oilseed by-products was included. Diets were randomly assigned to triplicate groups of fish (similar to 1 kg bulk weight) for the digestibility trials which spanned a total of 9 days. The partial inclusion of oilseed meals did not significantly affect apparent protein digestibility, although lipid, ash and dry matter digestibilities were significantly affected (p <0.05). Fish fed the soybean meal diets significantly reduced their feed intake and showed lower growth and feed utilization efficiencies over the trial period. The inclusions of the plant proteins caused a reduction in ammonia excretion rates with the palm kernel meal diet recording the lowest mean excretion rates of 117 mg kg(-1) day(-1) which was twofold lower than the highest mean daily ammonia excretion rate of the fish group fed the fishmeal-based control diets. Overall, the study confirmed the potential of using copra and palm kernel meals to partially replace fishmeal in Nile tilapia diets based on their effects on short-term growth and feed utilization, nutrient digestibilities and lower ammonia excretion rates, while soybean meal in an unrefined form is not a promising replacement for fishmeal in tilapia diets.
Effect of plant proteins and crystalline amino acid supplementation on postprandial plasma amino acid profiles and metabolic response in rainbow trout (Oncorhynchus mykiss)

The use of aquafeeds formulated with plant protein sources supplemented with crystalline amino acids (CAAs) is believed to influence amino acid (AA) uptake patterns and AA metabolic fate. Oxygen consumption and ammonia excretion rates were measured in rainbow trout (468.5 ± A 86.5 g) force fed 0.75 % of their body mass with a diet based on either (1) fish meal (FM), (2) pea protein concentrate (PPC), or (3) pea protein concentrate supplemented with histidine, lysine, methionine and threonine (PPC+) to mimic FM AA profile. The specific dynamic action and nitrogen quotient (NQ) were calculated for 48 h of the postprandial period. In parallel, plasma AA concentrations were measured in blood samples withdrawn from the caudal vein before and then 2, 4, 6, 8, 12, 20, 32 and 48 h after feed administration. The unbalanced diet PPC had a significantly higher NQ compared to FM (0.29 +/- A 0.09 and 0.18 +/- A 0.04, respectively), and plasma profiles of essential AAs reflected the dietary deficiencies. Supplementation with CAA in diet PPC+ resulted in an intermediary NQ (0.21 +/- A 0.04) and significantly affected plasma AA profiles, presenting greater and faster rises followed by sharp decreases compared to FM. The strongest effect was observed for methionine, presenting threefold higher concentrations at peak time for PPC+ compared to FM (297.0 +/- A 77.0 and 131.8 +/- A 39.0 nmol ml(-1), respectively). The differences in AA availability and metabolic profile in the pea diets compared to the FM diet were believed to be caused by an unbalanced dietary AA profile and CAA supplementation, rather than inclusion of plant protein...
Effects of dietary inclusions of oilseed meals on physical characteristics and feed intake of diets for the Nile Tilapia, Oreochromis niloticus

The present study investigated the effects of the inclusion of three oilseed by-products (soybean, copra and palm kernel meals) on some physical characteristics of pelletized feeds as well as on voluntary feed intake and faecal matter production by the Nile tilapia, Oreochromis niloticus. The dietary inclusion of soybean meal resulted in a significantly higher feed bulk density relative to the fishmeal control diet. The inclusions of copra and palm kernel meals, however, resulted in lower feed bulk densities. Sinking rates, water stabilities and nutrient retention efficiencies of feed pellets were directly related to feed bulk densities. The soybean meal diet had the fastest sinking velocities, greatest water stability and highest nutrient retention rates. The dietary inclusion of soybean meal, however, significantly impaired feed intake compared to the other three diets. Mean daily feed intakes of the control, palm kernel meal and copra meal diets corresponded to 28.88, 27.01 and 28.31g during the experimental period and varied significantly from the mean daily intake of the soybean meal diet which corresponded to 20.01g. Faecal matter production (g dry mass kg−1 ingested feed) was significantly higher in the tilapia groups fed the copra and palm kernel meals. The results obtained from this study show that 30% inclusions of unrefined forms of copra and palm kernel meal in Nile tilapia diets is possible, without adversely affecting feed intake or pellet nutrient losses prior to ingestion.
Evaluation of locally-available agroindustrial byproducts as partial replacements to fishmeal in diets for Nile Tilapia (Oreochromis niloticus) production in Ghana

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Fast-starting after a breath: air-breathing motions are kinematically similar to escape responses in the catfish Hoplosternum littorale

Fast-starts are brief accelerations commonly observed in fish within the context of predator–prey interactions. In typical C-start escape responses, fish react to a threatening stimulus by bending their body into a C-shape during the first muscle contraction (i.e. stage 1) which provides a sudden acceleration away from the stimulus. Recently, similar C-starts have been recorded in fish aiming at a prey. Little is known about C-starts outside the context of predator–prey interactions, though recent work has shown that escape response can also be induced by high temperature. Here, we test the hypothesis that air-breathing fish may use C-starts in the context of gulping air at the surface. Hoplosternum littorale is an air-breathing freshwater catfish found in South America. Field video observations reveal that their air-breathing behaviour consists of air-gulping at the surface, followed by a fast turn which re-directs the fish towards the bottom. Using high-speed video in the laboratory, we compared the kinematics of the turn immediately following air-gulping performed by H. littorale in normoxia with those of mechanically-triggered C-start escape responses and with routine (i.e. spontaneous) turns. Our results show that air-breathing events overlap considerably with escape responses with a large stage 1 angle in terms of turning rates, distance covered and the relationship between these rates. Therefore, these two behaviours can be considered kinematically comparable, suggesting that air-breathing in this species is followed by escape-like C-start motions, presumably to minimise time at the surface and exposure to avian predators. These findings show that C-starts can occur in a variety of contexts in which fish may need to get away from areas of potential danger.

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Improved growth performance in rainbow trout Oncorhynchus mykiss reared at high densities is linked to increased energy retention

Behaviour has been suggested as an underlying factor influencing how rearing density affects growth performance in Salmonid fishes. At low densities there is an elevated intensity of aggressive interactions and the formation of dominance hierarchies. As density increases, it is commonly assumed that aggression decreases, as the cost and effort required to establish and maintain dominance hierarchies increase. The increased energy expenditure associated with aggressive interactions has been identified as one mechanism causing a reduced efficiency in feed utilisation and therefore decreased growth performance. Manipulating aggressive behaviour through density may have advantages from a practical perspective. In the present study the energetic expenditure of rainbow trout held at three densities, 25, 80 and 140 kg m(-3), were related to growth performance parameters. Measurements for growth performance and parameters of energetics were investigated at the three densities during a four week growth period. The results showed a significant increase in routine metabolism in fish reared at 25 kg m(-3) compared to groups reared at higher densities. The study concludes that in fish reared at density of 25 kg m(-3), a higher fraction of the dietary energy intake was used to fuel activity rather than growth, as evidenced by significantly higher routine metabolism, reduced feed utilisation efficiency and a tendency for lower growth performance compared to fish reared at the higher densities. These results indicate a bioenergetic advantage of crowding. (C) 2015 Published by Elsevier B.V.
diets using low-cost and locally available plant by-products for use in fish grow-out facilities, particularly in tilapia production, which accounts for over 80% of aquaculture production. This review thus identifies local agro-industrial byproducts with potential use in fish feeds based on their nutritional composition, total annual production, competition for and seasonal availability and dynamics of these products as well as prices. The effects of dietary inclusions of these by-products on fish growth and feed utilisation are also reviewed. Based on the published works and other practical information reviewed, these by-products represent huge potentials as alternative aquafeed protein sources because of their abundance, very affordable prices and healthy nutritional profiles for fish growth. Although this review focuses on Ghana, it can also be of direct benefit to fish farmers, feed manufacturers, researchers and the policy-makers in other regions of the world where these crops and their resulting by-products are produced in commercial quantities.

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No evidence for a bioenergetic advantage from forced swimming in rainbow trout under a restrictive feeding regime
Sustained swimming at moderate speeds is considered beneficial in terms of the productive performance of salmonids, but the causative mechanisms have yet to be unequivocally established. In the present study, the effects of moderate exercise on the bioenergetics of rainbow trout were assessed during a 15 week growth experiment, in which fish were reared at three different current speeds: 1 BL s(-1), 0.5 BL s(-1) and still water (approximate to 0 BL s(-1)). Randomly selected groups of 100 fish were distributed among twelve 600 L tanks and maintained on a restricted diet regime. Specific growth rate (SGR) and feed conversion ratio (FCR) were calculated from weight and length measurements every 3 weeks. Routine metabolic rate (RMR) was measured every hour as rate of oxygen consumption in the tanks, and was positively correlated with swimming speed. Total ammonia nitrogen (TAN) excretion rates showed a tendency to decrease with increasing swimming speeds, yet neither they nor the resulting nitrogen quotients (NQ) indicated that swimming significantly reduced the fraction of dietary protein used to fuel metabolism. Energetic budgets revealed a positive correlation between energy expenditure and the current speed at which fish were reared, fish that were forced to swim and were fed restrictively consequentially had poorer growth and feed utilization. The results show that for rainbow trout, water current can negatively affect growth despite promoting minor positive changes in substrate utilization. We hypothesize that this may be the result of either a limited dietary energy supply from diet restriction being insufficient for both covering the extra costs of swimming and supporting enhanced growth.

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Dietary LC-PUFA deficiency early in ontogeny induces behavioural changes in pike perch (Sander lucioperca) larvae and fry
This study examined whether dietary supply of DHA and phospholipids during early ontogeny affected the outcome of behavioural challenges in pike perch larvae and fry, and whether the history of lipid nutrition carried over in long-term effects on learning ability. Pike perch larvae were fed Artemia enriched with either refined olive oil high in oleic acid (A); refined olive oil supplemented with a low (B) or a high (C) level of DHA; or refined olive oil acid supplemented with fish oil with a high content of phospholipids (PL) and DHA (D). The enriched live diets were provided until 28 days post hatch (dph), at which time larval behavioural responses to visual and mechano-sensory stimuli were assessed. All dietary groups were subsequently fed an identical enriched live feed (diet D) and gradually weaned to an extruded dry feed, on which they were maintained for 112 days. At the end of this period, assessment of fry avoidance behaviour was repeated and individuals were tested for spatial learning ability in a maze. At the larval stage, individuals maintained on Artemia rich in DHA showed a 5–8 fold increase in swimming speed when subjected to a visually simulated predator test, a response that was not observed for larvae on diets low in DHA content. Independent of the predator simulation, larvae deficient or low in DHA exhibited significantly more time swimming along the edge of a test arena and had overall higher locomotor activities compared to larvae fed a diet with a high DHA content. Larvae on DHA rich diets showed an ability to achieve significantly higher peak acceleration rates during the escape response, which was maintained at 112 dph. Time spent locating the exit of a maze decreased with repetitious training sessions, although fish fed diets low in DHA spent longer time in the maze, caused by extended periods of inactivity or “freezing” behaviour (time lag) prior to the onset of active searching behaviour. The consistency of behavioural responses to mechano-sensory stimuli in larvae and fry suggests long-term effects on the neuromuscular pathway involved in escape responses. A longer period of freezing in the learning test may reflect a more anxious and fragile behaviour profile in fish fed low levels of DHA. Further studies should aim at verifying whether this affects performance related traits, such as immune competence and robustness.

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Forced swimming in rainbow trout does not confer a bioenergetic advantage but reduces the fraction of protein oxidized to fuel.

Microbial interference and potential control in culture of European eel (Anguilla anguilla) embryos and larvae.

Temperature and oxygen as determining factors in post-stress recovery profiles of Norwegian lobster Nephrops norvegicus.

Drifts- og miljømæssig optimering af recirkulerede opdrætsanlæg.
Effects of dietary energy density and digestible protein: energy ratio on de novo lipid synthesis from dietary protein in gilthead sea bream (Sparus aurata) quantified with stable isotopes

The effects of varying dietary digestible protein (DP) and digestible energy (DE) content on performance, nutrient retention efficiency and the de novo lipogenesis of DP origin were examined in triplicate groups of gilthead sea bream (Sparus aurata), fed nine extruded experimental diets. In order to trace the metabolic fate of dietary protein, 1.8% fishmeal was replaced with isotope-labelled whole protein (.98% 13C). The experiment was divided into a growth period lasting 89 d, growing fish from approximately 140 to 350 g, followed by a 3 d period feeding isotope-enriched diets. Isotope ratio MS was applied to quantify the 13C enrichment of whole-body lipid from dietary DP. Between 18.6 and 22.4% of the carbon derived from protein was recovered in the lipid fraction of the fish, and between 21.6 and 30.3% of the total lipid deposited could be attributed to dietary protein. DP retention was significantly improved by reductions in dietary DP:DE ratio, while the opposite was true for apparent digestible lipid retention. Both overall DE retention and whole-body proximate composition of whole fish were largely unaffected by dietary treatments, while feed conversion ratios were significantly improved with increasing dietary energy density. The present study suggests that gilthead sea bream efficiently utilises dietary nutrients over a wide range of DP:DE ratios and energy densities. In addition, they appear to endeavour a certain body energy status rather than maximising growth, which in the present trial was apparent from inherently high de novo lipogenesis originating from DP.

Glycogenesis and de novo lipid synthesis from dietary starch in juvenile gilthead sea bream (Sparus aurata) quantified with stable isotopes

The effects of replacing a digestible energy source from fat (fish oil) with carbohydrate (wheat starch) on performance, glycogenesis and de novo lipogenesis was examined in triplicate groups of juvenile gilthead sea bream (Sparus aurata), fed four extruded experimental diets. In order to trace the metabolic fate of dietary starch, 0.7% wheat starch was replaced
with isotope-labelled starch (98% 13C). Fish were fed the experimental diets for three consecutive 10 d periods, and isotope ratio MS was applied to quantify 13C enrichment of liver and whole-body glycogen and lipid pools over the three feeding periods. Glycogenesis originating from dietary starch accounted for up to 68.8% of the liver and 38.8% of the whole-body glycogen pools, respectively, while up to 16.7% of the liver lipid could be attributed to dietary starch. Between 5 and 8% of dietary starch carbon was recovered in whole-body lipid, and estimated deposition rates of de novo synthesised lipid originating from starch ranged from 18.7 to 123.7 mg/kg biomass per d. Dietary treatments did not significantly affect growth, feed performance or body composition of the fish, while the hepatosomatic index and glycogen content of whole fish and livers correlated directly with dietary starch inclusion level. The study suggests that gilthead sea bream efficiently synthesises glycogen from both dietary starch and endogenous sources. In contrast, lipogenesis from carbon derived from starch seems to play a minor role in overall lipid synthesis and deposition under the specified experimental conditions.

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**Hypercapnia adversely affects postprandial metabolism in the European eel (Anguilla anguilla)**

The present study examined the effects of elevated CO2 partial pressure on the specific dynamic action (SDA) and ammonia excretion in European eel (Anguilla anguilla) following forced feeding. Two different hypercapnic scenarios were investigated; one in which pCO2 oscillated between 20 and 60 mm Hg over 24 hour cycles, and one in which pCO2 was constant at 60 mm Hg. Since high CO2 results in low pH with unchanged alkalinity, a normocapnic group at low pH (pCO2 ≈ 3 mm Hg, pH = 6.5) was included to investigate possible direct effects of pH. Constant hypercapnia (60 mm Hg) and low pH (pH = 6.5) both significantly increased the duration of the SDA response by 22% and 29%, respectively. Hypercapnia had no effect on standard metabolic rate, while constant or oscillating hypercapnia significantly lowered the maximum metabolic rate compared to controls, causing a significant reduction of the aerobic scope during constant hypercapnia. Under conditions of oscillating pCO2, the temporal and spatial postprandial increase in ammonia nitrogen excretion was significantly reduced. This group also excreted significantly less ammonia after ingesting a meal. No significant effects on the magnitude or duration of postprandial ammonia excretion were observed at high pCO2 or low pH/normocapnia. The results demonstrate that despite an exceptional tolerance towards elevated pCO2 and acidosis, postprandial metabolic processes of the European eel are adversely affected by hypercapnia and low pH.

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Influence of inclusion level and form of dietary methionine in plant protein based diets on growth performances, ammonium excretion and postprandial methionine plasma levels in rainbow trout (Oncorhynchus mykiss).

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Introduction of the stress hormone cortisol through food pellets induces cardiac remodelling in rainbow trout Oncorhynchus mykiss

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Microbial interference and potential control in the production of European eel Anguilla anguilla larvae

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Nutrient digestibility and growth in rainbow trout (Oncorhynchus mykiss) are impaired by short term exposure to moderate supersaturation in total gas pressure

Excess levels of dissolved nitrogen gas (N2) may occur in recirculating aquaculture systems, as a result of aeration efforts, localized occurrences of denitrification, or from insufficient degassing of makeup water. If levels of dissolved N2 are sufficiently high, or if oxygen (O2) is also maintained at or above saturation, this leads to a supersaturation in total gas pressure (TGP). Depending on severity, total gas pressures above saturation may lead to gas bubble trauma, evident by visual inspection of the fish. Physiological effects of subclinical levels of TGP are not well known and have not been investigated for rainbow trout. The present study examined the effects of N2 supersaturation, with or without simultaneous excess TGP. Supersaturation with N2 (ΔP 22mmHg) without total gas supersaturation (ΔTGP −6mmHg) did not have any significant effects on feed intake, feed conversion or growth. Short term (16days) exposure to N2 supersaturation (ΔP 36mmHg) in combination with a ΔTGP of 23mmHg did not affect feed intake, nor did it cause GBT or any apparent changes in behaviour. Excess TGP did, however, significantly reduce apparent lipid digestibility, feed conversion, and the thermal growth coefficient, compared to control treatments in which N2 and O2 were maintained below saturation levels. In addition to a significant decrease in available metabolizable energy (energy intake corrected for faecal loss), this group also had significantly higher cost of growth. These results suggest that even moderate TGP supersaturation negatively affect aquaculture production by a dual effect on energy uptake and energy expenditure, possibly caused by a general stress response to dissolved gases. Continuing the experiment over 25days eliminated any significant differences on production variables, suggesting that rainbow trout exposed to moderate excess levels of TGP for longer periods were able to adapt to some degree

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The effects of temperature on specific dynamic action and ammonia excretion in pikeperch (Sander lucioperca)
The magnitude and kinetics of the postprandial metabolic response are strongly affected by temperature. From an aquaculture perspective, it is of interest to determine the temperature at which the lowest digestive energy expenses occur. We have previously demonstrated that the optimal aerobic scope for pikeperch ranges between 11°C and 27°C. The aim of the present study was to investigate the thermal biology of pikeperch, by examining how specific dynamic action (SDA) and total ammonia nitrogen excretion (TAN) are affected by temperature, within this optimal temperature range. From oxygen consumption rate and TAN excretion measurements, we established nitrogen quotients at 13°C, 19°C, and 25°C. Nitrogen quotients were used to calculate instantaneous protein catabolism at the different temperatures. We found, that protein usage (17%–29%) was unaffected by temperature during fasting, but increased significantly in the course of digestion, where it became the main energy source at all experimental temperatures. Energy spent on digestion and the relationship between excreted and ingested nitrogen were unchanged with temperature. However, SDA was of shorter duration at 19°C than at 13°C, and a smaller fraction of metabolic scope was utilized for digestion at 19°C, compared to at 25°C. We therefore conclude that 19°C is a more favorable metabolic temperature for this species.

General information
Publication status: Published
**AquaResp® — free open-source software for measuring oxygen consumption of resting aquatic animals**

AquaResp® is a free open-source software program developed to measure the oxygen consumption of aquatic animals using intermittent flow techniques. This free program is based on Microsoft Excel, and uses the MCC Universal Library and a data acquisition board to acquire analogue readings from up to four input ports and output control via two digital and two analogue ports. In addition AquaResp can read one COM-port if the oxygen analyser has a RS-232 output signal. The present version of the program has options for parsing data strings generated by two major fibre optic oxygen electrode manufacturers. AquaResp was developed with the intention of automating data acquisition and control by programming in commonly-available software (Microsoft Excel) and allowing customization by the user without restrictions. The program has been tested in different laboratories for an extended period.

**General information**
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Organisations: National Institute of Aquatic Resources, Section for Aquaculture, Indiana University-Purdue, University of Copenhagen
Contributors: Svendsen, M. B. S., Skov, P. V., Bushnell, P. G., Steffensen, J. F.
Publication date: 2012
Peer-reviewed: No
Event: Poster session presented at Society for Experimental Biology Annual Main Meeting, Salzburg, Austria.
Research output: Contribution to conference – Poster – Annual report year: 2012 – Research

**Dietary supplementation of essential fatty acids in larval pikeperch (Sander lucioperca); short and long term effects on stress tolerance and metabolic physiology**

The present study examined the effects of feeding pike perch larvae Artemia, enriched with either docosahexanoic acid (DHA), arachidonic acid (ARA), oleic acid (OA), olive oil (OO) or a commercial enrichment DHA Selco (DS) on tissue lipid deposition, stress tolerance, growth and development, and metabolic rate. There was higher tissue retention of ARA than DHA at comparable inclusion levels. No differences were observed between diets on the percentage contribution of ARA or DHA to the fatty acid profile of tissues (head and trunk). Total fatty acid content (mgg⁻¹) was significantly higher in the head, reflecting its high content of neural tissue. Observations on larval erratic behaviour and mortality following exposure to salinity stress suggested that high inclusions levels of DHA had an alleviating effect, while ARA did not. Particularly larval groups reared for 16days on diets enriched with OO and OA had mortality rates approaching 100% within two hours. Interestingly, this tendency, although not as pronounced, was also apparent in juvenile fish after 120days of rearing on a common diet. Standard metabolic rate in larvae on an OO enriched diet was significantly elevated, but otherwise no groups had significant changes to their respiratory physiology. In addition to increased stress challenge sensitivity, early feeding with OA had long term impact on pike perch neural development indicated by a smaller brain size in juvenile fish. In conclusion, lack of DHA in the diet of pikeperch larvae suggests that this long chain polyunsaturated fatty acid is involved in processes that increase stress tolerance and that lack of dietary DHA in early larval stage caused increased stress sensitivity and long-term impaired neural development, while it does not appear to affect metabolic rate at rest.

**General information**
Effects of stocking density and sustained aerobic exercise on growth, energetics and welfare of rainbow trout

Two stocking densities, "low" (L, between ~19 and ~25 kg m⁻³) and "high" (H, between ~75 and ~100 kg m⁻³) were compared for effects on specific growth rate (SGR), feed conversion, energetics and welfare of rainbow trout reared at 14 °C either in static water (S) or swimming in a gentle current of ~0.9 bodylengths s⁻¹ (C). Trout (initial mass ~110 g) were reared for 9 weeks in circular tanks (volume 0.6 m³), in triplicate of four conditions (LS, LC, HS, HC). Fish were fed ad libitum daily; waste pellets were swirl-collected at the outflow to calculate feed intake. SGR was measured each three weeks for the last six weeks of the trial. The tanks functioned as intermittent stopped flow respirometers, to permit metabolic rate to be measured as instantaneous oxygen uptake once per hour. Mean (±SD) SGR was significantly lower at H than L (1.51±0.03 vs 1.44±0.04 % day⁻¹, respectively, n=6) and lowest in HC. When compared over a similar interval of mass gain, H groups had approximately 25% higher metabolic rates than L, with the highest rates in the HC condition. As a result, fish in the H groups dissipated a greater amount of feed energy as metabolism and, across all groups, there was a direct negative relationship between the quantity of energy dissipated and their SGR. There was no evidence of a neuroendocrine stress response, plasma cortisol was around 1 ng ml⁻¹ in all conditions. An acute crowding stress increased plasma cortisol to above 120 ng ml⁻¹ in all groups, but C groups recovered to control levels within 8 h whereas S groups required 20 h. Respirometry on individuals revealed that H fish had approximately 14% higher metabolic rates than L fish, indicating that increased metabolic rate in rearing tanks was in part physiological. The H groups had approximately 15% lower critical swimming speeds than the L groups which, together with their raised metabolic rate, indicated a physiological impairment. Thus, high density reduced SGR by raising energy dissipation, at least partially as a physiological response by the fish, although there was no evidence of an endocrine stress response. The only beneficial effect of C was in recovery from acute stress.
Fast-starting for a breath: Air breathing in Hoplosternum littorale

Fast starts are brief accelerations commonly observed in fish within the context of predator–prey interactions. In typical C-start escape responses, fish react to a threatening stimulus by bending their body into a C-shape. Recently, similar C-starts have been recorded in archerfish stimulated by the fall of a prey item on the water surface, and in tapping motions of goldfish, a behaviour that was interpreted to be food-related. Little is known about C-starts being used outside the context of escaping or feeding. Here, we test the hypothesis that air-breathing fish may use C-starts when gulping air at the surface. Air breathing is a common behaviour in many fish species when exposed to hypoxia, although certain species perform air-breathing in normoxia to fill their swim bladders for buoyancy control and/or sound transduction. Hoplosternum littorale is an air-breathing freshwater catfish found in South America. Field video observations reveal that their air-breathing behaviour consists of a fast air-gulping motion at the surface, followed by swimming towards the bottom. Using high-speed video in the laboratory, we compared the kinematics of spontaneous air-gulping performed by H. littorale in normoxia, with those of mechanically-triggered C-start escape responses. Our results show that these two behaviours overlap considerably in their kinematics (turning rates and distance covered), suggesting that air breathing in this species is performed using escape-like C-start motions. This demonstrates that C-starts in fish do not need external stimulation and can be spontaneous behaviours used outside the context of predator–prey interactions.

Influence of protein source on amino acid uptake patterns and protein utilization in rainbow trout Oncorhynchus mykiss

Matrices of different protein sources (fish and plant products) combined with the use of crystalline amino acids allow for formulation of diets that meet fish requirements with little or no effect on protein digestibility and/or feed intake. Despite this, a total or partial replacement of fish meal induces reduced growth performances that remain partly unexplained. The aim of the current study was to investigate the effect of exchanging the protein source on protein utilization. Marine (fish meal) and vegetable (pea protein) sources were used with or without supplementation of crystalline amino acids to the fishmeal diet level (see Table 1). Amino acid uptake patterns were assessed by the appearance of amino acids in the bloodstream following the ingestion of a meal, while dietary protein utilization was evaluated by examining the metabolic response to digestion and ammonium and urea excretion rates during digestion. Four treatments, 3 diets and 1 control (no feeding), were applied to rainbow trout with an average body mass of 500 grams. Fish were either force fed one of the 3 diets at a ration corresponding to 0.75% of the body mass, or no force feeding. Four fish at a time (one per treatment) were placed in individual chambers for the above described time sampling. Fish were killed by a blow in the head and blood was collected from the caudal vein with heparinized syringes. Plasma and red blood cells content were stored separately at -80 for amino acid content analysis.

The ammonium excretion profiles (Figure 1) will be correlated with the amino acid profile in the blood and oxygen consumption during digestion to investigate the effect on protein utilization for each treatment.
The effects of stocking density and low level sustained exercise on the energetic efficiency of rainbow trout (Oncorhynchus mykiss) reared at 19°C

A 9 week growth trial was performed at two rearing densities; low (~25 kg m⁻³) and high (~100 kg m⁻³), in combination with either static water or a water current corresponding to 0.9 body lengths s⁻¹, to investigate the effects of density and exercise on the bioenergetics of rainbow trout reared at 19 °C, particularly routine metabolic rate (RMR), specific growth rate (SGR), and feed conversion ratio (FCR). The growth trial showed that high rearing density resulted in significantly lower SGR and increased FCR, with no significant alleviating effects ofawater current, although slight improvement in both parameters were observed at low density. A significant linear relationship between SGR and FCR suggested that increased energy expenditure was the primary cause of reduced growth. Hourly measurements of instantaneous oxygen uptake, during a period of similar growth (200–350 g), revealed clear effects of the experimental conditions. Energetic budgets were calculated from feed intake and routinemetabolic rate (RMR) and revealed that whilst feed intake was similar for all groups, a higher RMR in the high density groups resulted in a higher daily rate of energy utilization for routine activity, leading to slower growth. However, a lowerRMR in fish subjected to a current resulted in a greater proportion of energy being retained, leading to significantly higher SGR for the selected period, at both low and high density. Furthermore, the presence of a water current was observed to induce schooling behaviour, which is known to reduce aggression and stress. It is thereby likely that the presence of a current had a positive effect on welfare in addition to its effect on energy metabolism. We conclude that the presence of a water current to some extent could alleviate the negative effects of high density at 19 °C, a relatively high temperature experienced in farming of rainbow trout during hot seasons.

Thermal optimum for pikeperch (Sander lucioperca) and the use of ventilation frequency as a predictor of metabolic rate

Pikeperch is of increasing interest to the aquaculture industry, as a novel high value species. To our knowledge there is currently no information available on the metabolic rates of adult pikeperch. The present study determined the standard and maximum metabolic rates and ventilation frequency at six temperatures, ranging from 13 to 28 °C, in order to identify the temperature where pikeperch has the largest metabolic scope (MS). Between 13 and 25 °C, standard metabolic rate (SMR) increased as expected with a Q10=1.8 in response to increasing temperatures, while maximum metabolic rate (MMR) did not change significantly within this temperature range. As a result, MS was not significantly affected by acclimation temperature between 13 and 25 °C. Above 25 °C, SMR increased significantly with a Q10=2.5 while MMR declined, resulting in a decreased MS. In the present study, the maximum MS (MSMAX) was found at 18.8 °C. Defining
the optimal temperature as the thermal range where fish can maintain 80% of MSMAX, shows that adult pike perch have a broad thermal optimum between 10.4 and 26.9 °C. Since earlier studies on juvenile pike perch have reported an optimal temperature range of 25–30 °C, we show that pike perch have an ontogenetic shift in their thermal optimum, emphasizing the importance of considering fish size when deciding the temperature in aquaculture facilities. As a secondary objective we investigated whether gill ventilation frequency (fV) could be used as an accurate predictor of oxygen consumption rate (M_ O2), during normoxia and progressive hypoxia. A strong correlation was found between fV and M_ O2 across all temperatures, and fV could predict M_ O2 with a high degree of accuracy in normoxia.

General information
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Organisations: Section for Aquaculture, National Institute of Aquatic Resources
Contributors: Frisk, M., Skov, P. V., Steffensen, J. F.
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Volume: 324-325
ISSN (Print): 0044-8486
Ratings:
BFI (2012): BFI-level 1
Scopus rating (2012): CiteScore 2.32 SJR 1.222 SNIP 1.485
Web of Science (2012): Impact factor 2.009
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
Original language: English
DOIs:
10.1016/j.aquaculture.2011.10.024
Source: orbit
Source-ID: 286993
Research output: Contribution to journal › Journal article – Annual report year: 2011 › Research › peer-review

The temperature challenges on cardiac performance in winter-quiescent and migration-stage eels Anguilla anguilla
The present study was undertaken to examine cardiac responses to some of the temperature challenges that eels encounter in their natural environment. The contractile properties of ventricular muscle was studied on electrically paced tissue strips after long term acclimation at 0 °C, 10 °C, or 20 °C, and following acute ± 10 °C temperature changes. The time-course of contraction, and thus maximal attainable heart rates, was greatly influenced by working temperature, but was independent of acclimation history. The absolute force of contraction and power production (i.e. the product of force and stimulation frequency) was significantly influenced by acute temperature decrease from 20 °C to 10 °C. The role of adrenaline as a modulator of contraction force, power production, rates of contraction and relaxation, and minimum time in contraction was assessed. Increased adrenergic tonus elicited a positive inotropic, temperature-dependent response, but did not influence twitch duration. This suggests that adrenaline acts as an agent in maintaining an adequate contractile force following temperature challenges. A significant increased relative ventricular mass was observed in 0 °C and 10 °C-acclimated eels compared to 20 °C-acclimated, which suggests that at low temperatures, eels secure cardiac output by heart enlargement. Inhibition of specific sarcolemmal Ca 2 + channels by selective drug treatment revealed that, depending on temperature, L-type channels is the major entry site, but also that reverse-mode Na+/Ca 2 +-exchange and store operated calcium entry contribute to the pool of activator Ca 2 +

General information
Publication status: Published
Organisations: National Institute of Aquatic Resources, Section for Aquaculture, University of Copenhagen
Contributors: Methling, C., Steffensen, J. F., Skov, P. V.
Pages: 66-73
Publication date: 2012
Peer-reviewed: Yes

Publication information
Journal: Comparative Biochemistry and Physiology - Part A: Molecular & Integrative Physiology
Volume: 163
Issue number: 1
ISSN (Print): 1095-6433
Ratings:
BFI (2012): BFI-level 1
Consistent boldness behaviour in early emerging fry of domesticated Atlantic salmon (Salmo salar): Decoupling of behavioural and physiological traits of the proactive stress coping style

Individual variation in the way animals cope with stressors has been documented in a number of animal groups. In general, two distinct sets of behavioural and physiological responses to stress have been described: the proactive and the reactive coping styles. Some characteristics of stress coping style seem to be coupled to the time to emerge of fry from spawning redds in natural populations of salmonid fishes. In the present study, behavioural and physiological traits of stress coping styles were compared two and five months after emergence in farmed Atlantic salmon (Salmo salar), using individuals with an early or late time to emerge. Initially, compared to late emerging individuals, early emerging individuals showed a shorter time to resume feeding after transfer to rearing in isolation. Resumption of feeding after isolation was suggested to be related to boldness behaviour, rather than hunger, in the present study. This observation was repeated five months after emergence, demonstrating behavioural consistency over time in this trait. However, in other traits of proactive and reactive stress coping styles, such as social status, resting metabolism or post stress cortisol concentrations, early and late emerging individuals did not differ. Therefore, this study demonstrates that boldness in a novel environment is uncoupled from other traits of the proactive and reactive stress coping styles in farmed salmonids. It is possible that this decoupling is caused by the low competitive environment in which fish were reared. In natural populations of salmonids, however, the higher selection pressure at emergence could select for early emerging individuals with a proactive coping style.

Effects of rearing density and water current on the respiratory physiology and haematology in rainbow trout, Oncorhynchus mykiss at high temperature

General information
Publication status: Published
Organisations: Section for Aquaculture, National Institute of Aquatic Resources, Norwegian University of Life Sciences, Universidad Autonoma del Estado de Mexico, University of Glasgow
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Peer-reviewed: Yes

Publication information
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Volume: 103
Issue number: 3-4
ISSN (Print): 0031-9384
Ratings:
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Scopus rating (2011): CiteScore 3.23 SJR 1.243 SNIP 1.039
Web of Science (2011): Impact factor 2.869
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
Original language: English
DOIs:
10.1016/j.physbeh.2011.02.025
Source: orbit
Source-ID: 276362
Research output: Contribution to journal › Journal article – Annual report year: 2011 › Research › peer-review
Effects of substituting lipid with starch as metabolic fuel on performance and nutrient utilization in gilthead sea bream (Sparus aurata) juveniles

General information
Publication status: Published
Organisations: Section for Aquaculture, National Institute of Aquatic Resources
Contributors: Ekmann, K. S., Dalsgaard, A. J. T., Holm, J., Campbell, P. J., Skov, P. V.
Publication date: 2011
Peer-reviewed: No
Event: Poster session presented at European Aquaculture Society Meeting, Rhodes, Greece.
Source: orbit
Source-ID: 314635
Research output: Contribution to conference › Poster – Annual report year: 2011 › Research

Forekomst og betydning af gasovermætning: Fra: Dambrugsteknologi. Samlerapport

General information
Publication status: Published
Organisations: Section for Aquaculture, National Institute of Aquatic Resources
Contributors: Skov, P. V., Henriksen, N. H., Andreasen, A., Clausen, T.
Publication date: 2011

Optimering af driften på etablerede modeldambrug og fortsat videreudvikling af recirkuleringsstøknologien: Rapport for arbejdspakke 3b : Undersøge graden af gasovermætning samt evaluere betydningen

General information
Publication status: Published
Organisations: Section for Aquaculture, National Institute of Aquatic Resources
Contributors: Skov, P. V., Henriksen, N. H., Andreasen, A., Clausen, T.
Number of pages: 15
Publication date: 2011

Pop up satellite tags impair swimming performance and energetics of the European eel (Anguilla anguilla)

General information
Publication status: Published
Organisations: Section for Aquaculture, National Institute of Aquatic Resources
Contributors: Methling, C., Tudorache, C., Skov, P. V., Steffensen, J. F.
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Journal: PLOS ONE
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ISSN (Print): 1932-6203
Ratings:
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Scopus rating (2011): CiteScore 4.58 SJR 2.425 SNIP 1.233
Web of Science (2011): Impact factor 4.092
ISI indexed (2011): ISI indexed no
Web of Science (2011): Indexed yes
Original language: English
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http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0020797
Source: orbit
Source-ID: 277834
Research output: Contribution to journal › Journal article – Annual report year: 2011 › Research › peer-review

Embryonic suckling and maternal specializations in the live-bearing teleost Zoarces viviparus

The European eelpout follows an aplacental viviparous reproductive strategy, in which gestation lasts 4–5 months. During the last months of development yolk reserves are depleted, and embryos depend on an external source of nutrients. Here we provide evidence for novel specialized physiological, morphological and behavioural adaptations, which we propose as the responsible mechanisms for the exchange of nutrients and gases between the maternal organism and her embryos. Ovarian follicles contain an internal glomerulus-like structure within the distal tip of each follicle. Ultrastructural examination indicated a capacity for steroid synthesis and secretion. Gel electrophoresis demonstrated a protein size distribution in the follicular fluid different from that of the maternal serum, and that ovarian fluid is devoid of protein. From vascular casts and histological sections the follicle was reconstructed. The glomerulus has a central canal that is exteriorized at the tip of the follicle, allowing passage of follicular fluid. Oxygen measurements across the ovary of near-term females showed a strongly hypoxic ovary lumen, yet ovarian fluid adjacent to follicles was oxygen saturated. As another novel observation, embryos were seen engaged in suckling on follicles. We hypothesize that embryos use the follicles on the ovarian wall as placental analogues and that they use their mobile jaw apparatus to attach themselves and apply suction.

General information
Publication status: Published
Organisations: Section for Aquaculture, National Institute of Aquatic Resources, Roskilde University, University of Copenhagen
Contributors: Skov, P. V., Steffensen, J. F., Sørensen, T. F., Qvortrup, K.
Pages: 120-127
Publication date: 2010
Peer-reviewed: Yes

Publication information
Abolition of reflex bradycardia by cardiac vagotomy has no effect on the regulation of oxygen uptake by Atlantic cod in progressive hypoxia

The functional significance of chemoreflexive hypoxic bradycardia was explored in Atlantic cod Gadus morhua L. (mean mass similar to 800 g, acclimated to a seawater temperature of 11 degrees C) by investigating responses to progressive hypoxia following section of the cardiac branches of cranial nerve X Cardiac denervation had no effect on oxygen uptake rate (M-O2), gill ventilation rate (f(G)) or opercular pressure amplitude (P-OP) under normoxic conditions, but caused a significant increase in heart rate (f(H)), to 50 +/- 1 beats min(-1) by comparison to 40 +/- 2 beats min(-1) in sham-operated cod (mean +/- s.e.m., n=9). Sham-operated cod exhibited transient profound bradycardia following oxygen chemoreceptor stimulation by bolus injection of sodium cyanide into the buccal cavity (2 mg in 2 ml seawater), but this cardiac chemoreflex was abolished in denervated cod. Both groups, however, exhibited similar marked transient chemoreflexive hyperventilation following NaCN. When exposed from normoxia (P02 similar to 18 kPa) to progressive hypoxia at nominal water P02'S of 8, 6, 5, 4 and 3 kPa, both groups exhibited the same pattern of homeostatic regulation of M-O2, with no significant difference in their mean critical P02 (P-crit) values, which were 7.40 +/- 0.81 kPa and 8.73 +/- 0.71 kPa, respectively (n=9). Both groups exhibited significant bradycardia during progressive hypoxia, although denervated fish always had higher mean f(H). The incipient threshold for bradycardia coincided with P-crit in sham-operated cod whereas, in denervates, the threshold was below their P-crit and bradycardia presumably reflected direct effects of hypoxia on the myocardium. The sham-operated group displayed a significantly more pronounced ventilatory response than denervates in hypoxia, in particular for P-OP. In sham-operated cod, peak ventilatory responses occurred in deep hypoxia below P-crit whereas, in denervates, more modest peak responses coincided with Pit and, in deep hypoxia, they exhibited a significant decline in f(G) below their normoxic rate. Only a minority of shams lost equilibrium in hypoxia whereas a majority of denervates did, some of which failed to recover. The results indicate that chemoreflexive bradycardia plays no role in the homeostatic regulation of oxygen uptake by cod in hypoxia, but does contribute to maintenance of overall functional integrity below P-crit.
The primary and secondary vascular system of the Atlantic cod with special reference to the lateral line organ

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Organisations: University of Copenhagen
Contributors: Bielecki, J., Skov, P. V., Tranum-Jensen, J., Steffensen, J.
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Journal: Journal of Zoology
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ISSN (Print): 0952-8369
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Scopus rating (2008): SJR 1.19 SNIP 1.111
Web of Science (2008): Indexed yes
Original language: English
DOIs: 10.1111/j.1469-7998.2008.00455.x
Source: orbit
Source-ID: 241161
Research output: Contribution to journal › Journal article – Annual report year: 2008 › Research › peer-review

The role of adrenaline as a modulator of cardiac performance in two Antarctic fishes
The present work was performed to test the hypothesis that Antarctic teleosts rely mostly on cholinergic inhibition for autonomic modulation of the heart. The effects of adrenaline on the inotropic properties on paced, isometrically contracting muscle strips were examined in two distinct Antarctic teleosts, the haemoglobinless icefish Chaenocephalus aceratus and the red-blooded Notothenia coriiceps. All tissues examined revealed a negative force-frequency relationship. Under baseline conditions C. aceratus contracted with a force twice as great as that of N. coriiceps. While the degree to which ventricular tissues responded to adrenaline varied between species, adrenergic stimulation significantly increases myocyte contraction force in this group of fishes. Contraction and relaxation times were not significantly affected by adrenaline concentration while absolute rates of contraction were. Adrenergic stimulation does not enable tissues to achieve higher contraction frequencies, but is shown to be a potent modulator of contraction force.

General information
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Organisations: Indiana University-Purdue, University of Copenhagen
Contributors: Skov, P. V., Bushnell, P. G., Tirsgaard, B., Steffensen, J. F.
Pages: 215-223
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Volume: 32
Issue number: 2
ISSN (Print): 0722-4060
Ratings: BFI (2008): BFI-level 1
Scopus rating (2008): SJR 0.961 SNIP 0.886
Web of Science (2008): Indexed yes
Original language: English
DOIs: 10.1007/s00300-008-0522-0
Source: orbit
Source-ID: 263916
Research output: Contribution to journal › Journal article – Annual report year: 2008 › Research › peer-review
Structural basis for control of secondary vessels in the long-finned eel, Anguilla reinhardtii

General information
Publication status: Published
Organisations: University of Queensland
Contributors: Skov, P. V., Bennett, M. B.
Pages: 3339-3348
Publication date: 2004
Peer-reviewed: Yes

Publication information
Journal: Journal of Experimental Biology
Volume: 207
ISSN (Print): 0022-0949
Ratings:
Scopus rating (2004): SJR 1.527 SNIP 1.329
Web of Science (2004): Indexed yes
Original language: English
Source: orbit
Source-ID: 241157
Research output: Contribution to journal › Journal article – Annual report year: 2004 › Research › peer-review

The secondary vascular system of Actinopterygii: interspecific variation in origins and investment

General information
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Organisations: University of Queensland
Contributors: Skov, P. V., Bennett, M. B.
Pages: 55-64
Publication date: 2004
Peer-reviewed: Yes

Publication information
Journal: Zoomorphology
Volume: 123
ISSN (Print): 0720-213X
Ratings:
Scopus rating (2004): SJR 0.636 SNIP 1.042
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Original language: English
Source: orbit
Source-ID: 241156
Research output: Contribution to journal › Journal article – Annual report year: 2004 › Research › peer-review

The blood volumes of the primary and secondary circulatory system in the Atlantic cod, Gadus morhua L., using plasma bound Evans Blue and compartmental analysis
Veterinary improvements of trout RAS with focus on water quality and design (Recirk-vet) (39593)
The purpose of project Recirc-Vet is to study and evaluate the implications of altered farming practice from flow through systems to recirculated aquaculture systems in DK. The project will evaluate the rearing conditions on four selected trout RAS and try to identify important factors affecting fish and system performance. The project will compare the farms and look into temporal patterns, based on traditional water quality parameters, new microbial assays and monitoring of oxygen and carbon dioxide.

The project consists of a network, which includes veterinarians, researchers and farm managers. They will try to link rearing conditions and fish diseases as well as fish welfare indicators.

The project is coordinated by Danish Aquaculture Association and is funded by the European Maritime and Fisheries Fund (EMFF) and the Danish Fisheries Agency.

Pedersen, L., Project Participant, National Institute of Aquatic Resources, Section for Aquaculture
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Gesto, M., Project Participant, National Institute of Aquatic Resources
Skov, P. V., Project Participant, National Institute of Aquatic Resources
Olesen, N. J., Project Participant, National Institute of Aquatic Resources
Madsen, L., Project Participant, National Institute of Aquatic Resources
Schmidt, J. G., Project Participant, National Institute of Aquatic Resources
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Jensen, R. F., Project Participant, National Institute of Aquatic Resources
Frandsen, D., Project Participant, National Institute of Aquatic Resources

01/01/2017 → 31/12/2020
Keywords: Research area: Aquaculture
Project: Research

Peracetic acid as a potential treatment for amoebic gill disease (AGD) in Atlantic salmon (39544)
The overarching aim of PERAGILL is to explore the potential of peracetic acid as an alternative and sustainable treatment to amoebic gill disease, a threat in the Norwegian Atlantic salmon aquaculture.

The project includes several workpackages, in which the following topics will be:

- To investigate the amoebicidal activity of PAA and identify factors influencing this feature.
- To assess the impact of PAA treatment on fish health and welfare.
- To determine the potential environmental risk of PAA treatment.
- To develop integrative assessment toolbox to evaluate treatment impacts and efficacy.
- To characterise the different factors affecting the dynamics of PAA treatment in AGD-infected fish.
- To compare conventional AGD treatments with PAA application.
The project hence include controlled prolonged trials with Atlantic salmon post smolts (exposure and recovery), where samples of gills, skin and plasma will be analyzed. Controlled degradation trials in seawater will be performed and in vitro experiments will be conducted.

The project is coordinated by NOFIMA, Ås, Norway and is funded by the The Norwegian Seafood Research Fund (FHF). Pedersen, L., Project Manager, National Institute of Aquatic Resources, Section for Aquaculture
Skov, P. V., Project Participant, National Institute of Aquatic Resources
Sproegel, U., Project Participant, National Institute of Aquatic Resources
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Lyng, M., Project Participant, National Institute of Aquatic Resources
Larsen, O. M., Project Participant, National Institute of Aquatic Resources
Jensen, R. F., Project Participant, National Institute of Aquatic Resources
01/01/2018 → 31/12/2020
Keywords: Research area: Aquaculture
Project: Research

The role of lipid source, stress and exercise on lipid uptake and metabolism in salmonids
Pfalzgraff, T., PhD Student, National Institute of Aquatic Resources
Skov, P. V., Main Supervisor
Lund, I., Supervisor
Olsen, R. E., Supervisor
01/12/2018 → 30/11/2021
Project: PhD

Caught and released: an overview of fishes’ sensitivity to being discarded as a tool to aid pursuing ecosystem-based management (COPE) (39416)
One main goal of the project is to provide a catalogue of the survival rates of different species subject to the landing obligation under the Common Fisheries Policy (CFP) regulation seen in relation to the discard ratios of different fisheries. Another main goal is to obtain survival rates for selected important species and fishing gear.

This information can, in the cause of high survival rates, be used in proposals for exemptions from the landing obligation. Species exempted from the landing obligation can be returned to the ecosystem as discards, and contribute to reproduction and recruitment, and thus productivity of the stock. Landings of unwanted catch may cause unintentionally increase in fishing mortality and unsustainable fishery.

Exemptions from the landing obligation may facilitate the implementation of the CFP, especially for small vessels in the mixed fishery for which there is a mismatch between the size of the deck area and the number of species and size groups in a catch that needs to be kept separately during sorting. Also, exemptions from the landing obligation can improve the economic viability of fisheries as the CFP does not allow landed catch below the minimum conservation reference size to be used directly for human consumption, which mostly limits the utility to low value products.

The project is coordinated by DTU Aqua and is funded by the European Maritime and Fisheries Fund (EMFF) and the Ministry of Environment and Food of Denmark
Karlsen, J. D., Project Coordinator, National Institute of Aquatic Resources, Section for Ecosystem based Marine Management
Savina, E., Project Participant, National Institute of Aquatic Resources
Noack, T., Project Participant, National Institute of Aquatic Resources
Skov, P. V., Project Participant, National Institute of Aquatic Resources
13/09/2016 → 31/12/2018
Keywords: Research area: Fisheries Technology
Project: Research

Influence of Parasite Load on the Growth and Bioenergetics of Baltic cod
Plambech Ryberg, M., PhD Student, National Institute of Aquatic Resources
Behrens, J., Main Supervisor
Skov, P. V., Supervisor
Samfinansieret - Andet
01/08/2017 → 31/07/2020
Award relations: Influence of Parasite Load on the Growth and Bioenergetics of Baltic cod
Project: PhD
Effects of seal-related liver worm on Baltic cod growth and mortality (39411)
The number of grey seals has increased markedly in the Baltic Sea within recent years. Grey seal is final host for the liver worm Contracecum osculatum, where cod is one of several transport hosts. Concurrent with the rise in number of grey seal, the prevalence (number of infected cod) and intensity of infection (number of liver worms per infected cod) with liver worm has increased, and up to 340 worms can now be found in single cod livers. Field studies have shown that intensity of infection correlates negatively with the condition of the fish, indicating that liver worm may have a negative effect on the health status of the fish. Yet, from field investigations it is difficult to separate potentially negative effects of liver worms from that of reduced food availability or poor oxygen conditions. In the present study we will perform controlled laboratory experiments to i) determine the potential costs of housing liver worm, ii) estimate the effects of liver worm on cod growth and mortality, and iii) use data generated in i) and ii) in bioenergetic modeling to calculate the effect of liver worm on the maximal food consumption and growth of individual cod. This will subsequently be scaled to the level of the population.

The project is coordinated by University of Copenhagen and is funded by the European Maritime and Fisheries Fund (EMFF) and the Danish Fisheries Agency.
Behrens, J., Project Manager, National Institute of Aquatic Resources, Section for Marine Living Resources
Skov, P. V., Project Participant, National Institute of Aquatic Resources
Andersen, N. G., Project Participant, National Institute of Aquatic Resources
08/09/2016 → 15/12/2018
Keywords: Research area: Marine Living Resources
Collaborators: University of Copenhagen, Danish Fishermen’s Association
Project: Research

Resource efficiency in practice: from sugar beet waste to fish feed ingredient (Starfish) (39368)
Sugar beet is a commonly cultivated crop in Denmark and the waste pulp is primarily sold as cow feed. The pulp, however, contains a potential prebiotic compound (pectin) that, if added to fish feed at low concentrations is hypothesized to:
1) improve the feed utilisation by the fish allowing more fish to be produced per amount of feed applied
2) stabilize the structure of the faecal waste so that it may be easier collected and removed reducing the discharge of nitrogen- and phosphorous
3) improve the overall immunological system/health status of the fish whereby the use of medicine and therapeutics may be reduced.
The objective of the project is to test these potential, beneficial effects of pectin in rainbow trout (Oncorhynchus mykiss) and tilapia (Oreochromis niloticus) by adding different molecular sizes and concentrations to the feed and measuring the effects on feed utilisation, faecal structure and fish health.
The project is coordinated by DTU Aqua.
The project is funded by Ministry of Environment and Food of Denmark through the Green Development and Demonstration Program (GUDP).
Dalsgaard, A. J. T., Project Coordinator, National Institute of Aquatic Resources, Section for Aquaculture
Larsen, B. K., Project Participant, National Institute of Aquatic Resources
Skov, P. V., Project Participant, National Institute of Aquatic Resources
de Jesus Gregersen, J., PhD Student, National Institute of Aquatic Resources
01/08/2016 → 31/07/2019
Keywords: Research area: Aquaculture
Collaborators: University of Copenhagen, Danish Fishermen’s Association
Project: Research

Discard survival (DISCO) (39152)
This project has developed methods and accumulated competencies and facilities, to be able to estimate discard survival and generate knowledge about the factors that affect this. The focus was on two commercially important species, plaice and Norway lobster. These species are relevant because there is a likelihood of a substantial survival. The first trial was conducted from November to March from a less commercial trawler with Hirtshals as port. There was fishing for plaice with a consumption trawls and towed time was 3 hours. Test plaice were collected at four different time periods exposed to air on the deck, with a half-hour intervals up to one and a half hour. Furthermore, control plaice were collected from hauls with short duration. Plaice was stored in tanks on the vessel and transported to storage tanks on land at the North Sea Science Park in Hirtshals. Here, they were observed for 10 days. On the vessel were also carried out tests of reflexes and damage. The overall mortality rate increased by residence time on the deck of 0% and up to 24% after one and a half hours on the deck. The total mortality was estimated to 11%. Most plaice was above the minimum landing size. Reflexes decreased with increased time on the deck. There was no mortality in the control group. There were also carried out measurements of physiological stress indicators comparing with a reference group.
Another plaice study was conducted in Norway lobster fishing from Skagen in June and July from the same vessel. The place was stored in the same way at the vessel as the first experiment, and was transported in a pickup from Skagen to observation side in Hirtshals. Most plaice was below the minimum size. Mortality was totally 86% for test plaice and 0% to 16% for the control groups.
A final test was conducted to determine the mortality of lobsters. It was estimated to be from 100% to 52% of the individual hauls. Overall the mortality was 84% after 8 days here except experiments where there the refrigerated container was not functioning. Had these individuals been included, the mortality would have been lower. However, there
were also deaths in the control group (total 18%) and generating more uncertainty for the estimates. This project was coordinated by DTU Aqua.

The project was funded by the Danish Ministry of Food, Agriculture and Fisheries and the European Fisheries Fund (EFF).

Madsen, N., Project Coordinator, National Institute of Aquatic Resources, Section for Ecosystem based Marine Management

Methling, C., Project Participant, National Institute of Aquatic Resources

Skov, P. V., Project Participant, National Institute of Aquatic Resources

01/03/2014 → 23/05/2015

Keywords: Research areas: Fisheries Technology & Aquaculture

Project: Research

**Sustainable fish feed development in Ghana (Susfeed) (39158)**

The overall objective of the project is to enable Kwame Nkrumah University of Science and Technology (KNUST) to serve as a centre of excellence for sustainable development of aquaculture and to take a scientific approach to the continued improvement of fish feed formulation using local raw materials, through controlled experiments and in collaboration with the private sector in Ghana. The immediate objectives of the project are to formulate cost effective tilapia feeds assessed for digestibility, nutritional value and amino acid profiles based on local feed ingredients; to facilitate the growth of the tilapia aquaculture industry in Ghana through promoting the production and application of locally developed high quality feeds; to achieve a zero change in nutrient discharge to the environment through the application of balanced feed and efficient feeding strategies; and to improve the methodological and scientific capacity at KNUST to provide a platform of excellence in research and teaching.

The project is funded by DANIDA, Ministry of Foreign Affairs of Denmark.

Skov, P. V., Project Manager, National Institute of Aquatic Resources, Section for Aquaculture

Lund, I., Project Participant, National Institute of Aquatic Resources

Larsen, B. K., Project Participant, National Institute of Aquatic Resources

01/04/2014 → 31/03/2017

Keywords: Research area: Aquaculture

Collaborators: Kwame Nkrumah University of Science and Technology

Project: Research

**Amino acid uptake patterns in fish fed plant based protein and the effects on protein utilization.**

Rolland, M., PhD Student, National Institute of Aquatic Resources

Skov, P. V., Main Supervisor

Dalsgaard, A. J. T., Supervisor

Holm, J., Supervisor

Lund, I., Examiner

Espe, M., Examiner

Skiba-Cassey, S., Examiner

Ansat eksternt

01/04/2011 → 27/08/2014

Award relations: Amino acid uptake patterns in fish fed plant based protein and the effects on protein utilization.

Project: PhD

**Welfare in farmed rainbow trout, social and environmental preferences**

Laursen, D. C., PhD Student, National Institute of Aquatic Resources

Högglund, E., Main Supervisor

Skov, P. V., Supervisor

Jokumsen, A., Examiner

Kristiansen, T. S., Examiner

Sneddon, L. U., Examiner

1/3 FUU, 1/3 inst 1/3 Andet

01/03/2010 → 03/07/2013

Award relations: Welfare in farmed rainbow trout, social and environmental preferences

Project: PhD

**Individual variation in developmental rate in rainbow trout larvae; implications for welfare and production aspects in modern aquaculture**

Åberg Andersson, M., PhD Student, National Institute of Aquatic Resources

Högglund, E., Main Supervisor

Steffensen, J. F., Supervisor

Skov, P. V., Examiner

Metcalfe, N. B., Examiner

Winberg, S., Examiner
Welfare, health and individuality in farmed fish (WIN-FISH) (39236)

In modern aquaculture, production costs are the major driver. This has resulted in culture practices and rearing environments aimed at maximizing production capacity. Consequently, fish are exposed to unavoidable stressors, which can be detrimental to animal health and welfare. Moreover, it is increasingly clear that individuality in stress reactions have to be included in the concept of animal welfare. Such differences often take the form of suites of traits, or stress coping styles (SCS), where traits like sympathetic reactivity, aggression and the tendency follow and develop routines show positive relationships. In addition, these traits show a negative relationship with plasma cortisol levels and are also associated with differences in immune function. The project will validate behavioural and physiological welfare indicators for selected fish species at the individual and rearing unit level. This will generate new information about responses to environmental factors, knowledge that can be applied to improve husbandry and management practices. Recirculating aquaculture systems (RAS) have been developed as a sustainable alternative with low ecological consequences compared to traditional flow through systems. However, in RAS factors such as higher rearing densities and water quality parameters may challenge the welfare of fish. In WIN-FISH, health, welfare and production related effects of RAS rearing of species at different densities will be monitored. In order to account for individual variation, these studies will be performed on fish screened for SCS. Similarly, in flow through systems, health, welfare and production related effects of rearing densities will be further investigated in sea bream differing in SCS. Generally, environmental enrichment has positive effects on animal welfare. WIN-FISH will investigate effects of environmental enrichment on rainbow trout with contrasting SCS. In an attempt to generate genetic markers for selective breeding to optimize performance and welfare of farmed Atlantic salmon, a genome-wide association analysis will be performed on salmon with divergent SCS, focusing on proactive fish differing in aggressive behaviour. In addition, zebrafish will be used as a model to gain additional knowledge on mechanisms underlying SCS and aggressive behaviour.

This project is coordinated by DTU Aqua.

The project is funded by EU, Framework Programme 7.

Gesto, M., Project Coordinator, National Institute of Aquatic Resources, Section for Aquaculture

Skov, P. V., Project Participant, National Institute of Aquatic Resources

18/05/2015 → 17/05/2018

Keywords: Research area: Aquaculture

Collaborators: Universidad Politécnica de Madrid, Uppsala University, Instituto Zooprofilattico Sperimentale delle Venezie, Institute of Agri-food Research and Technology , IFREMER

Project: Research

New possibilities for growth and robustness in organic aquaculture (ROBUSTFISH) (39159)

Main aim:
To support the credibility, growth and robustness in the production of healthy and stress resilient Danish organic rainbow trout, considering environmental, ethical as well as economic aspects.

Sub goals:
1) Develop methods for selecting robust fry.
2) Investigating how sustainable non-fish based feed given early in the development affect the robustness of the fry.
3) Include welfare and environmental aspects in relation to water treatment procedures.
4) Improve economic competiveness of Danish organic aquaculture.

This project is funded by Organic RDD 2 Programme, which is coordinated by the International Centre for Research in Organic Food Systems (ICROFS). It has received grants from the Danish Ministry of Food, Agriculture and Fisheries through the Green Growth and Development Programme (GUDP).
The Danish nephrops fishery is important with an annual value of the landings of approximately 300 million DKK. The quota is high as many nephrops inhabit the inner Danish waters. However, cod is a frequent by-catch which is problematic due to low cod quotas, and resultantly, nephrops quota a rarely fully exploited. Furthermore, nephrops are traditionally fished with bottom trawl which exerts high impact on the seabed. The first aim of the project is to solve the cod by-catch issues by using trawling speed as a selective mechanism, which will take advantage of the superior swimming capabilities of cod as compared to nephrops. Lowering the trawling speed will enable cod to escape the trawl while still ensuring nephrops catch. The second aim is to design and implement a new type of trawl doors that do not touch the seabed and highly reduce impact of the sweeps. Besides, materials used for the new trawl will be produced in much lighter and stronger materials than the traditional trawls. Altogether this reduces the drag in the water and fuel consumption considerably.

Trawling at a lower speed lessens the mechanical damage to the nephrops and this enhances their chances of survival. The project will take this one step further by establishing gentle handling routines on board the ships, in addition to reducing impact of the sweeps. Besides, materials used for the new trawl will be produced in much lighter and stronger materials than the traditional trawls. Altogether this reduces the drag in the water and fuel consumption considerably.

Selective and low impact gear for fishing live nephrops (39042)

The Danish nephrops fishery is important with an annual value of the landings of approximately 300 million DKK. The quota is high as many nephrops inhabit the inner Danish waters. However, cod is a frequent by-catch which is problematic due to low cod quotas, and resultantly, nephrops quota a rarely fully exploited. Furthermore, nephrops are traditionally fished with bottom trawl which exerts high impact on the seabed. The first aim of the project is to solve the cod by-catch issues by using trawling speed as a selective mechanism, which will take advantage of the superior swimming capabilities of cod as compared to nephrops. Lowering the trawling speed will enable cod to escape the trawl while still ensuring nephrops catch. The second aim is to design and implement a new type of trawl doors that do not touch the seabed and highly reduce impact of the sweeps. Besides, materials used for the new trawl will be produced in much lighter and stronger materials than the traditional trawls. Altogether this reduces the drag in the water and fuel consumption considerably.

Trawling at a lower speed lessens the mechanical damage to the nephrops and this enhances their chances of survival. The project will take this one step further by establishing gentle handling routines on board the ships, in addition to appropriate conditions for keeping live animals. Physiological tests will define threshold levels in relation to temperature, light and moist, and characterise the most favourable conditions for further survival. Besides optimising conditions on board the ships this knowledge will be used in relation to temporary storage and to ensure optimal conditions during transport of live nephrops to southern Europe. The final aim of the project is thus to establish an export chain of live nephros to markets in southern Europe. This can provide the fishermen up to three times the price as compared to when...
using the so-called air lift pumps aka mammoth pumps. 

Water quality parameters. Currently, the primary method for aeration, degassing and water movement is by use of air, oxygenate, degas and move water, or how to improve the efficiency of currently used methods, without compromising financial saving of DDK 17.1 million. The purpose of the project is to identify the most energetically efficient methods to produce trout. With an annual production of 35,000 tons, this corresponds to an annual reduction in CO2 emissions of 13,400 tons, and a decrease in carbon dioxide emissions. The aim is to reduce the energy requirements for trout production to 1 kWh per kg.

Energy efficiency in the aquaculture sector (38802)

The increased implementation of technologies for water recirculation and the purification, oxygenation and degassing of water used in aquaculture production, has caused the energy costs associated with fish production to dramatically increase. The current energy consumption for the production of 1 kilogram of rainbow trout is estimated at 1.7 kWh. This represents a challenge for the aquaculture industry because national and international ambitions strive for a general decrease in carbon dioxide emissions. The aim is to reduce the energy requirements for trout production to 1 kWh per kg. With an annual production of 35,000 tons, this corresponds to an annual reduction in CO2 emissions of 13,400 tons, and a financial saving of DKK 17.1 million. The purpose of the project is to identify the most energetically efficient methods to oxygenate, degas and move water, or how to improve the efficiency of currently used methods, without compromising water quality parameters. Currently, the primary method for aeration, degassing and water movement is by use of air, using the so-called air lift pumps aka mammoth pumps.
The project will collect data on annual energy consumption from 4-8 selected recirculating aquaculture facilities and compare these values with feed use and fish production. The energy consumption is considered with reference to the technologies in use at a given facility and the construction of the facility. The primary purpose is to evaluate energy efficiency of air blowers currently in use, air delivery per unit of effect, efficiency in aeration and degassing, and variations in the requirement for aeration and degassing over the daily cycle. These results will enable the documentation of any correlations between energy efficiency, technology in use, methods of operation, and will serve in the further development of alternative solutions to aeration and degassing. Emphasis will be on the physical properties and placement of air diffusers in airlift pumps and the feasibility of using trickle towers for aeration, aeriation with liquid oxygen or other alternatives. Experiments to determine energy use and efficiency of alternate oxygenation and degassing devices will allow the project to determine whether more suitable technologies exist and make an estimate of potential energy savings.

The project will terminate in a final report and a workshop where the results will be presented to stakeholders in the aquaculture industry (fish farmers, feed manufacturers and equipment suppliers). Suitable alternative technologies and methods for aeration and degassing will be presented in practice.

The project is coordinated by Danish Aquaculture Association, Denmark.
Skov, P. V., Project Manager, National Institute of Aquatic Resources, Section for Aquaculture
01/01/2010 → 01/10/2012
Keywords: Research area: Aquaculture
Collaborators: BioMar A/S, Nielsen Consult, Lokalenergi A/S, Danish Aquaculture Organisation, Danish Technological Institute, AquaCircle
Project: Research

**Strategies to improve health and welfare in rainbow trout farming (38193)**
The main aim of the project is the developing of sustainable strategies for improving the health, welfare and quality of cultured rainbow trout by implementing three interrelated approaches: management, immune prophylactics, and selective breeding. The management approach determines how increased water current at given rearing densities and water temperatures can reduce the stress of trout. The immune prophylactic approach determines the relationship between immune response profiles and induction of protective immunity at different water temperatures and hereby establishing efficient strategies for use of vaccination and feed stimulants in prevention of diseases. The selective breeding approach determines how physiological and immunological traits can improve the genetically basis for resistance of trout to stress and disease.

The project is coordinated by DTU Aqua.
Jokumsen, A., Project Manager, National Institute of Aquatic Resources, Section for Aquaculture
Höglund, E., Project Participant, National Institute of Aquatic Resources
Larsen, B. K., Project Participant, National Institute of Aquatic Resources
Skov, P. V., Project Participant, National Institute of Aquatic Resources
McKenzie, D. D., Project Participant
01/01/2007 → 31/12/2010
Keywords: Research area: Aquaculture
Collaborators: Aarhus University, University of Copenhagen
Project: Research

**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 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 yolk sac 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 ontology 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.

Munk, P., Project Manager, National Institute of Aquatic Resources
Musholm A/S, Hvalpsund Net A/S, Danish Aquaculture Association

01/01/2011 → 31/07/2014
Keywords: Research areas: Fish Biology & Aquaculture & Marine Populations and Ecosystem Dynamics & Coastal Ecology
Collaborators: Leiden University, Wageningen IMARES, University of Copenhagen, Demokritos National Centre for Scientific Research, Billund Aquaculture Service Aps, National Institute of Sciences and Technologies of the Sea, Norwegian University of Science and Technology, BioMar A/S, Institute of Marine Research, Polytechnic University of Valencia, National Institute for Agronomic Research, Nofima, Ghent University
Project: Research

Offshore aquaculture, development of technology for offshore sea farming (38925)
The Danish sea territory spans 105,000 square kilometers of relatively shallow water with salinities ranging from brackish to fully oceanic. The present Danish sea farms are located in the least exposed regions in the Danish fjords and sounds. Environmental constraints are limiting production increase, and new locations in the coastal zone are rarely allocated. The shortage of suitable inshore sites emphasizes the urge to move to more exposed sites where benthic impacts are reduced or eliminated. The offshore areas of the Danish sea territory holds vast areas with no or negligible activities apart from capture fishery. Venturing into these areas with aquaculture opens a major window of opportunity, but is also a serious challenge being too great for a single company to lift. The overall purpose of developing the offshore production system is to create the technical foundation for “farming the ocean”. In other words to make it possible to locate cage culture facilities in areas now not considered suitable for fish farming because of their exposure to the physical forces of the open sea.
The project developed and tested different cage designs, anchoring and mooring systems and serviceability for offshore production. Submersible systems were found to be too unreliable in their operation as well as being difficult to maintain and service. The project found that a modification of conventionally designed cages constructed in more heavy duty materials were well suited for offshore production. Test production of trout showed that even in locations where significant wave heights exceed 3 meters, fish production was possible. Excess water currents were found to negatively influence production efficiency, resulting in poorer feed conversion, and increased nutrient emission from fish production. Similarly, increasing salinity was found to have a major negative influence on feed utilization. Physiologically, it was found to be possible to submerge fish for periods of up to 2 weeks without adverse effects on fish. The project concludes that offshore farming is possible, but also that environmental impact from fish farming and production efficiency are influenced by the physical environment that fish are farmed in, which should be taken into account during site selection. The project was coordinated by Hvalpsund Net, Denmark.
The project was funded by the Danish Ministry of Food, Agriculture and Fisheries and the European Fisheries Fund (EFF).

Skov, P. V., Project Participant, National Institute of Aquatic Resources, Section for Aquaculture
01/01/2011 → 01/10/2015
Keywords: Research area: Aquaculture
Collaborators: Musholm A/S, Hvalpsund Net A/S, Danish Aquaculture Association
Project: Research

HPLC and amino acids uptake patterns in fish fed plant-based protein (38803)
One of the issues of the rapidly growing aquaculture sector is to find fish meal substitutes. The main focus has been on plant proteins as a substitute for fish meal in the diet formulation. However, significant incorporation of plant proteins in the fish diet often results in reduced growth and/or impaired feed efficiency. Recent trials performed at our lab have shown that the profile of amino acid uptake (timeline) varies between rainbow trout fed plant based diet and fish meal diet. This difference in amino acid availability might well influence the protein synthesis and could add to the explanation of reduced performance of fish fed plant based diets and also the observed increased ammonia excretion.
Following these initial observations made in 2011 the project will perform a series of experiments to further examine how and why amino acid uptake patterns differ. Correlations between amino acid profile in the diet and amino acid in the blood following feeding will be made for different plant protein sources and added crystalline amino acids.

The concomitant effects on liver enzyme activity and protein synthesis will be examined and relevant indicators for protein synthesis (i.e. growth) hopefully determined. Specific digestibility and nitrogen excretion studies as well as traditional growth studies will be performed to support the findings.

The project is coordinated by DTU Aqua.

Larsen, B. K., Project Manager, National Institute of Aquatic Resources, Section for Aquaculture
Skov, P. V., Project Participant, National Institute of Aquatic Resources
Dalsgaard, A. J. T., Project Participant, National Institute of Aquatic Resources
Pedersen, P. B., Project Participant, National Institute of Aquatic Resources
Rolland, M., Project Participant, National Institute of Aquatic Resources

01/01/2011 → 31/12/2015

Keywords: Research area: Aquaculture
Collaborators: BioMar A/S
Project: Research

Management and environmental improvement of recirculating aquaculture systems (38815)
The aim of this project was to identify new applicable measures and management strategies to optimize trout production in recirculating aquaculture systems (RAS), in particular the model trout farms. Model trout farms have gained lots of positive attention since their recent launch, as the rearing concept allows increased production, increased water reuse, and decreased nutrient discharge with obvious advantages for the natural fish fauna. Currently, model fish farms have generally experienced a certain fish mortality related to pathogens and suboptimal water quality. Scopes for improvement have been identified in terms of more focus on chemical and (micro-)biological water quality.

The project included four interrelated work packages:
1) Biological filtration (stable, optimal nitrification, nitrite accumulation issues, biofilter kinetics and management)
2) Denitrification: self-contained, operational end-of-pipe solution to reduce N-total from model trout farms
3) Water disinfection and sanitation: evaluation of UV systems disinfection efficacy, resulting water quality and test of easy degradable disinfectants to replace formalin
4) Gas saturation: consequences and effects of N super saturation and total gas pressure on fish performance in RAS.

Each WP addressed specific issues of concern based on current scientific knowledge and practical experience in dialogue with the aquaculture industry. The investigations included bench and pilot scale experiments conducted under controlled conditions at the research facilities at the Section for Aquaculture, DTU Aqua, Hirtshals. The project also included monitoring campaigns and experiments on commercial model trout farms in collaboration with stakeholders.

The project was coordinated by DTU Aqua.
The project was funded by the Danish Ministry of Food, Agriculture and Fisheries and the European Fisheries Fund (EFF). Pedersen, L., Project Manager, National Institute of Aquatic Resources, Section for Aquaculture
Suhr, K. I., Project Manager, National Institute of Aquatic Resources
Skov, P. V., Project Manager, National Institute of Aquatic Resources
Pedersen, P. B., Contact Person, National Institute of Aquatic Resources

01/01/2011 → 31/12/2012

Keywords: Research area: Aquaculture
Collaborators: Danish Aquaculture Organisation , UltraAqua, Model fish farmers
Project: Research

Press clippings:

Jorden rundt med Galathea 3
Peter Vilhelm Skov
08/01/2007
National Institute of Aquatic Resources, Section for Aquaculture

Media contribution (1)

Jorden rundt med Galathea 3