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.
Effects of high-frequency strobed laser light on Atlantic cod (Gadus morhua) physiology and behavior

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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, haematocrit, 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.
Repeated intra-specific divergence in lifespan and ageing of African annual fishes along an aridity gradient

Lifespan and ageing are substantially modified by natural selection. Across species, higher extrinsic (environmentally-related) mortality (and hence shorter life expectancy) selects for the evolution of more rapid ageing. However, among populations within species, high extrinsic mortality can lead to extended lifespan and slower ageing as a consequence of condition-dependent survival. Using within-species contrasts of eight natural populations of Nothobranchius fishes in common garden experiments, we demonstrate that populations originating from dry regions (with short life expectancy) had shorter intrinsic lifespans and a greater increase in mortality with age, more pronounced cellular and physiological deterioration (oxidative damage, tumor load), and a faster decline in fertility than populations from wetter regions. This parallel intra-specific divergence in lifespan and ageing was not associated with divergence in early life history (rapid growth, maturation) or pace-of-life syndrome (high metabolic rates, active behavior). Variability across four study species suggests that a combination of different ageing and life history traits conformed with or contradicted the predictions for each species. These findings demonstrate that variation in lifespan and functional decline among natural populations are linked, genetically underpinned, and can evolve relatively rapidly. This article is protected by copyright. All rights reserved.
Stress and recovery from trawl capture of Norway lobster (Nephrops norvegicus) and potential for live storage

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The role of local adaptation in shaping fish-mussel coevolution
1. The survival of affiliate (dependent) species in a changing environment is determined by the interactions between the affiliate species and their available hosts. However, the patterns of spatial and temporal changes in host compatibility are often unknown despite host shifts having direct impact on the persistence of local populations. Bivalves of the order Unionida (freshwater mussels) are a functionally important but declining group of affiliate species, which are dependent on freshwater fish to host their parasitic larvae. The role of local adaptations and host fish resistance in shaping freshwater mussel host relationships remains poorly understood.2. We used an invasive East Asian unionid bivalve, Sinanodonta woodiana, and its potential host fishes to study the mechanisms shaping fish-mussel coevolution using a combination of laboratory cross-exposure methods and field-collected data. We tested whether generalist host use of S.woodiana is pertinent to native host species, with special attention to bitterling fishes (Cyprinidae: Acheilognathinae) that are characterised by a mutual association with freshwater mussels. We also tested whether the pattern of the parasite-host association varies temporally (between areas of ancient and recent sympatry) and spatially (at a sub-basin level in its native range).3. Results revealed the ability of S.woodiana to widely exploit non-bitterling host fishes at a global scale. In contrast, the ability of S.woodiana to exploit closely associated bitterling fishes was low in its native range (with ancient sympatry). In areas of recent sympathy (non-native S.woodiana range in Europe), S.woodiana glochidia were demonstrated to readily parasitise local, evolutionarily naive bitterling species at high density.4. The results of a population-level experiment with three native populations of S.woodiana and rose bitterling, Rhodeus ocellatus, from various sub-basins of the River Yangtze confirmed that mussel populations vary in their compatibility with particular host populations. However, there was no evidence of population-specific adaptive coevolution.5. This study provides the first evidence for a role of fish counter-adaptations against freshwater mussel glochidia, and documents the importance of population-level variation in shaping compatibility between glochidia and their host fishes. This outcome can inform predictions on the impact of biotic homogenisation on endangered affiliate species in general and freshwater mussels in particular.
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Projects:

**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 plaice 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 16%) and generating more uncertainty for the estimates.

This project was coordinated by DTU Aqua.

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