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Characteristic sizes of life in the oceans - from bacteria to whales

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Adult and offspring size in the ocean over 17 orders of magnitude follows two life history strategies

Explaining variability in offspring vs. adult size among groups is a necessary step to determine the evolutionary and environmental constraints shaping variability in life history strategies. This is of particular interest for life in the ocean where a diversity of offspring development strategies is observed along with variability in physical and biological forcing factors in space and time. We compiled adult and offspring size for 407 pelagic marine species covering more than 17 orders of magnitude in body mass including Cephalopoda, Cnidaria, Crustaceans, Ctenophora, Elasmobranchii, Mammalia, Sagittoidea, and Teleost. We find marine life following one of two distinct strategies, with offspring size being either proportional to adult size (e.g., Crustaceans, Elasmobranchii, and Mammalia) or invariant with adult size (e.g., Cephalopoda, Cnidaria, Sagittoidea, Teleosts, and possibly Ctenophora). We discuss where these two strategies occur and how these patterns (along with the relative size of the offspring) may be shaped by physical and biological constraints in the organism’s environment. This adaptive environment along with the evolutionary history of the different groups shape observed life history strategies and possible group-specific responses to changing environmental conditions (e.g., production and distribution).

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Explaining life history variation in a changing climate across a species' range

Timing of reproduction greatly influences offspring success and resulting population production. Explaining and predicting species' dynamics necessitates disentangling the intrinsic (genotypic) and extrinsic (climatic) factors controlling reproductive timing. Here we explore temporal and spatial changes in spawning time for 21 populations of Atlantic cod (Gadus morhua) across the species' range (40 degrees to 80 degrees N). We estimate spawning time using a physiologically relevant metric that includes information on fish thermal history (degree-days, DD). First, we estimate spawning DD among years (within populations) to show how recent changes in spawning time can be explained by local changes in temperature. Second, we employ spawning DD to identify temperature-independent trends in spawning time among populations that are consistent with parallel adaptive evolution and the evolutionary history of the species. Finally, we use our results to estimate spawning time under future climate regimes, and discuss the implications for cod ecology across the species' range.

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Explaining variation in life history timing across a species range: Effects of climate on spawning time in an exploited marine fish

The capacity of a species to tolerate and/or adapt to environmental conditions will shape its response to future climate change including climate extremes. Of the many life-history processes affected by climate change, timing of reproduction greatly influences offspring success and resulting population production. Here we explore temporal and spatial changes in spawning time for Atlantic cod (Gadus morhua) across the species’ range (4 to 80°N). We estimate spawning time using a physiologically relevant metric that includes information on fish thermal history (degree days, DD). First, we estimate spawning DD among years (within populations) to show recent changes in spawning time can be explained by local changes in temperature. Second, we employ spawning DD to identify temperature independent trends in spawning time among populations that are consistent with the evolutionary history of the species. Combined, these results shed light on the adaptive capacity of the species in the face of changing climate. We use our results to estimate expected spawning time under future climate regimes, and discuss the implications for codecology and management across the species’ range, and in the greater ecosystem

Characteristic sizes of life in the oceans - from bacteria to whales

Food for thought: Overconfidence in model projections

There is considerable public and political interest in the state of marine ecosystems and fisheries, but the reliability of some recent projections has been called into question. New information about declining fish stocks, loss of biodiversity, climate impacts, and management failure is frequently reported in the major news media, based on publications in prominent scientific journals. Public and political awareness of the generally negative changes taking place in marine ecosystems is welcome, especially if it results in effective remedial action, but the scientific basis for such action must be reliable and uncertainties arising from models and data shortcomings must be presented fully and transparently. Scientific journals play an important role and should require more detailed analysis and presentation of uncertainties.
This project investigated large-scale patterns and variations of life in the ocean, focusing primarily on fishes. The theme used fishes to investigate how processes associated with climate change and human impacts (e.g., fishing and eutrophication) influence fish life histories, biodiversity and the dynamics of populations and species over large time and space scales. Studies have focussed on key processes affecting life histories and distribution of populations and species, including reproduction, mortality, and migration.

The project had one full-time PhD student, and 5 postdoctoral scientists. The relatively high number of postdocs in a short period was due to their success at finding permanent jobs as tenure-track assistant professors, or as research scientists or managers in either industry or academia.

Key results by DTU Aqua colleagues in the project include the following:
- A pan-Atlantic analysis and discovery of how temperature affects reproductive timing in cod, with evidence for local adaptation of cod thermal physiology and counter-gradient evolution. Our ongoing work is now investigating the consequences of this adaptation for match-mismatch of cod larval production with the timing of the peak production of major zooplankton prey species (e.g., Calanus finmarchicus, Pseudocalanus sp.)
- New estimates of the numbers, locations and volumes of the mesopelagic provinces of the world’s oceans, and based for the first time on the dynamics of ocean primary productivity, C sedimentation and photic zones. These new habitat descriptors of the mesopelagic ocean will provide new contexts for studies of ocean biodiversity, and the distribution and productivity of mesopelagic fishes and other biota.
- New models of fish lifetime reproductive output which demonstrated that a fish’s annual reproductive output was strongly related to maximum body size. Moreover, indeterminate spawners had ca. 10-fold higher reproductive output per unit weight than determinate spawners suggesting possible differences in survival rates among the early life history stages between these two groups of fishes.
- Estimates of how climate change will affect the spawning locations and timing for herring in the North Sea, based on climate change scenarios, lab studies of temperature effects on egg survival rate and substrate requirements for herring egg deposition.
- Global patterns in taxonomic and functional descriptors of fish biodiversity and how these are inter-related and affected by ocean conditions (e.g., primary production, ecosystem size). Ongoing work is relating these patterns to biodiversity protection (e.g., MPA coverage).

The project was coordinated by University of Copenhagen, Denmark. The project was funded by the Danish National Research Foundation.