Climate change has altered zooplankton-fuelled carbon export in the North Atlantic

Marine plankton have been conspicuously affected by recent climate change, responding with profound spatial relocations and shifts in the timing of their seasonal occurrence. These changes directly affect the global carbon cycle by altering the transport of organic material from the surface ocean to depth, with consequences that remain poorly understood. We investigated how distributional and abundance changes of copepods, the dominant group of zooplankton, have affected biogenic carbon cycling. We used trait-based, mechanistic models to estimate the magnitude of carbon transported downward through sinking faecal pellets, daily vertical migration and seasonal hibernation at depth. From such estimates for over 200,000 community observations in the northern North Atlantic we found carbon flux increased along the northwestern boundary of the study area and decreased in the open northern North Atlantic during the past 55 years. These changes in export were primarily associated with changes in copepod biomass, driven by shifting distributions of abundant, large-bodied species. Our findings highlight how recent climate change has affected downward carbon transport by altering copepod community structure and demonstrate how carbon fluxes through plankton communities can be mechanistically implemented in next-generation biogeochemical models with size-structured representations of zooplankton communities.

Resting eggs in free living marine and estuarine copepods

Marine free living copepods can survive harsh periods and cope with seasonal fluctuations in environmental conditions using resting eggs (embryonic dormancy). Laboratory experiments show that temperature is the common driver for resting egg production. Hence, we hypothesize (i) that seasonal temperature variation, rather than variation in food abundance is the main driver for the occurrence of the resting eggs strategy in marine and estuarine copepod species; and (ii) that the thermal boundaries of the distribution determine where resting eggs are produced and whether they are produced to cope with warm or cold periods. We compile literature information on the occurrence of resting egg production and relate this to spatio-temporal patterns in sea surface temperature and chlorophyll a concentration obtained.
from satellite observations. We find that the production of resting eggs has been reported for 42 species of marine free living copepods. Resting eggs are reported in areas with high seasonal variation in sea surface temperature (median range 11°C). Temporal variation in chlorophyll a concentrations, however, seems of less importance. Resting eggs are commonly produced to cope with both warm and cold periods and, depending on the species, they are produced at the upper or lower thermal boundaries of a species’ distribution.

A trait database for marine copepods

The trait-based approach is gaining increasing popularity in marine plankton ecology but the field urgently needs more and easier accessible trait data to advance. We compiled trait information on marine pelagic copepods, a major group of zooplankton, from the published literature and from experts and organized the data into a structured database. We collected 9306 records for 14 functional traits. Particular attention was given to body size, feeding mode, egg size, spawning strategy, respiration rate, and myelination (presence of nerve sheathing). Most records were reported at the species level, but some phylogenetically conserved traits, such as myelination, were reported at higher taxonomic levels, allowing the entire diversity of around 10 800 recognized marine copepod species to be covered with a few records. Aside from myelination, data coverage was highest for spawning strategy and body size, while information was more limited for quantitative traits related to reproduction and physiology. The database may be used to investigate relationships between traits, to produce trait biogeographies, or to inform and validate trait-based marine ecosystem models. The data can be downloaded from PANGAEA, doi:10.1594/PANGAEA.862968
Plankton biogeography: An exploration of patterns, drivers, functions, and predictability

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A trait database for marine copepods

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Spatial structuration of life history traits: congruence between multiple taxa and environmental drivers in the North Sea

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The predictive skill of species distribution models for plankton in a changing climate

The statistical species distribution models (SDMs) are increasingly used to project spatial relocations of marine taxa under future climate change scenarios. However, tests of their predictive skill in the real-world are rare. Here, we use data from the Continuous Plankton Recorder program, one of the longest running and most extensive marine biological monitoring programs, to investigate the reliability of predicted plankton distributions. We apply three commonly used SDMs to 20 representative plankton species, including copepods, diatoms, and dinoflagellates, all found in the North Atlantic and adjacent seas. We fit the models to decadal subsets of the full (1958–2012) dataset, and then use them to predict both forward and backward in time, comparing the model predictions against the corresponding observations. The probability of correctly predicting presence was low, peaking at 0.5 for copepods, and model skill typically did not outperform a null model assuming distributions to be constant in time. The predicted prevalence increasingly differed from the observed prevalence for predictions with more distance in time from their training dataset. More detailed investigations based on four focal species revealed that strong spatial variations in skill exist, with the least skill at the edges of the distributions, where prevalence is lowest. Furthermore, the scores of traditional single-value model performance metrics were contrasting and some implied overoptimistic conclusions about model skill. Plankton may be particularly challenging to model, due to its short life span and the dispersive effects of constant water movements on all spatial scales, however there are few other studies against which to compare these results. We conclude that rigorous model validation, including comparison against null models, is essential to assess the robustness of projections of marine planktonic species under climate change.

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Trait biogeography of marine copepods - an analysis across scales

Functional traits, rather than taxonomic identity, determine the fitness of individuals in their environment: traits of marine organisms are therefore expected to vary across the global ocean as a function of the environment. Here, we quantify such spatial and seasonal variations based on extensive empirical data and present the first global biogeography of key traits (body size, feeding mode, relative offspring size and myelination) for pelagic copepods, the major group of marine zooplankton. We identify strong patterns with latitude, season and between ocean basins that are partially (c. 50%) explained by key environmental drivers. Body size, for example decreases with temperature, confirming the temperature-size rule, but surprisingly also with productivity, possibly driven by food-chain length and size-selective predation. Patterns unrelated to environmental predictors may originate from phylogenetic clustering. Our maps can be used as a test-bed for trait-based mechanistic models and to inspire next-generation biogeochemical models.

Ecological niches of open ocean phytoplankton taxa

We characterize the realized ecological niches of 133 phytoplankton taxa in the open ocean based on observations from the MAREDAT initiative and a statistical species distribution model (MaxEnt). The models find that the physical conditions (mixed layer depth, temperature, light) govern large-scale patterns in phytoplankton biogeography over nutrient availability. Strongest differences in the realized niche centers were found between diatoms and coccolithophores. Diatoms (87 species) occur in habitats with significantly lower temperatures, light intensity and salinity, with deeper mixed layers, and with higher nitrate and silicate concentrations than coccolithophores (40 species). However, we could not statistically separate the realized niches of coccolithophores from those of diazotrophs (two genera) and picophytoplankton (two genera). Phaeocystis (two species) niches only clearly differed from diatom niches for temperature. While the realized niches of diatoms cover the majority of niche space, the niches of picophytoplankton and coccolithophores spread across an intermediate fraction and diazotroph and colonial Phaeocystis niches only occur within a relatively confined range of environmental conditions in the open ocean. Our estimates of the realized niches roughly
match the predictions of Reynolds' C-S-R model for the global ocean, namely that taxa classified as nutrient stress tolerant have niches at lower nutrient and higher irradiance conditions than light stress tolerant taxa. Yet, there is considerable within-class variability in niche centers, and many taxa occupy broad niches, suggesting that more complex approaches may be necessary to capture all aspects of phytoplankton ecology.

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Measuring evolutionary adaptation of phytoplankton with local field observations

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Modelled niche centres and niche breadths of open ocean phytoplankton taxa

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The predictive potential of ecological niche models for plankton in the North Atlantic

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Understanding observed copepod distributions with a trait data base

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Projects:

A trait-based approach to Plankton Biogeography
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