Mortality of Calanus helgolandicus: Sources, differences between the sexes and consumptive and nonconsumptive processes

While losses from mortality are as important as gains from reproduction in zooplankton population dynamics, the former are more challenging to quantify. We used two approaches to provide complementary insights into the mortality of a biomass-dominant copepod, Calanus helgolandicus, at Station L4 in the English Channel. Using a neutral-red staining method, we found that dead carcasses represented a mean of 9% of the C. helgolandicus copepodites sampled. The resulting nonconsumptive mortality rates are the first that have been derived for C. helgolandicus, and estimates suggest a contribution of 0–54% (median of 4.4%) to the total mortality rate. Consumptive mortality (i.e., that due to removal by predation), dominated for most of the year and contributed a mean of 89% to total mortality. Nonconsumptive mortality increased during summer and winter, and was positively related to maximum wind speed during the preceding 72 h, indicating that extreme weather events may lead to increased mortality. Using the Vertical Life Table approach, mortality rates across the CV-adult male stage pair were on average ~ 2.5 times greater than those of CV-adult females. Adult male consumptive mortality rates were ~ 6 times greater than those for females; adult male nonconsumptive rates were twice those of females, suggesting that predation is of greater significance to male loss rates. Summer CV-adult mortality rates were positively correlated to temperature, and to the abundance of predatory chaetognaths and siphonophores, suggesting that the gelatinous predator assemblage is the dominant agent for population control of late stage copepodites of C. helgolandicus at L4.
Insect temperature-body size trends common to laboratory, latitudinal and seasonal gradients are not found across altitudes

Body size affects rates of most biological and ecological processes, from individual performance to ecosystem function, and is fundamentally linked to organism fitness. Within species, size at maturity can vary systematically with environmental temperature in the laboratory and across seasons, as well as over latitudinal gradients. Recent meta-analyses have revealed a close match in the magnitude and direction of these size gradients in various arthropod orders,
suggesting that these size responses share common drivers. As with increasing latitude, temperature also decreases with increasing altitude. Although the general direction of body size clines along altitudinal gradients has been examined previously, to our knowledge altitude-body size (A-S) clines have never been synthesised quantitatively, nor compared with temperature-size (T-S) responses measured under controlled laboratory conditions. Here we quantitatively examine variation in intraspecific A-S clines among 121 insect species from 50 different global locations, representing 12 taxonomic orders. While some taxa were better represented in the literature than others, our analysis reveals extensive variation in the magnitude and direction of A-S clines. Following the assumption that temperature on average declines by 1°C per 150 m increase in altitude, order-specific A-S clines in the field appear to deviate from laboratory T-S responses. Specifically, the magnitude of A-S clines and T-S responses are more closely matched in some taxonomic orders (e.g. Diptera) than others (e.g. Orthoptera). These findings contrast with the strong co-variation observed between latitude-size clines and T-S responses, and between laboratory and seasonal T-S responses. The lack of clear size relationships with elevation, and hence temperature, is likely due to the counteracting effects of other major drivers with altitude, including season length and oxygen partial pressure. Switches in voltinism within species across altitude, and the dispersal of individuals across different elevations, may also obscure trends.

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Seasonality of Oithona similis and Calanus helgolandicus reproduction and abundance: contrasting responses to environmental variation at a shelf site

The pelagic copepods Oithona similis and Calanus helgolandicus have overlapping geographic ranges, yet contrast in feeding mode, reproductive strategy and body size. We investigate how these contrasting traits influence the seasonality of copepod abundance and reproductive output under environmental variation, using time series data collected over 25 years at the Western Channel Observatory station, L4. The proportional change in egg production rate (EPR, eggs female⁻¹ d⁻¹) over the annual cycle was ~10-fold and similar for both species, although EPR of O. similis was only ~11% that of C. helgolandicus. The timing of EPR maxima for O. similis coincided with increased sea surface temperature (SST) in summer, likely due to a temperature-dependent brooding period. Conversely, EPR of broadcast spawning C. helgolandicus was more strongly related to net heat flux and diatom biomass, both parameters associated with the spring phytoplankton bloom. In both species, female body mass correlated negatively with SST, with a 7.5% reduction in body mass per °C in C. helgolandicus compared to just 2.3% in O. similis. Finally, seasonality of EPR and adult and copepodite abundance was strongly decoupled in both species, suggesting that optimum conditions for reproduction and abundance occurred at different times of the year.

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Bridging food webs, ecosystem metabolism, and biogeochemistry using ecological stoichiometry theory

Although aquatic ecologists and biogeochemists are well aware of the crucial importance of ecosystem functions, i.e., how biota drive biogeochemical processes and vice-versa, linking these fields in conceptual models is still uncommon. Attempts to explain the variability in elemental cycling consequently miss an important biological component and thereby impede a comprehensive understanding of the underlying processes governing energy and matter flow and transformation. The fate of multiple chemical elements in ecosystems is strongly linked by biotic demand and uptake; thus, considering elemental stoichiometry is important for both biogeochemical and ecological research. Nonetheless, assessments of ecological stoichiometry (ES) often focus on the elemental content of biota rather than taking a more
holistic view by examining both elemental pools and fluxes (e.g., organismal stoichiometry and ecosystem process rates). ES theory holds the promise to be a unifying concept to link across hierarchical scales of patterns and processes in ecology, but this has not been fully achieved. Therefore, we propose connecting the expertise of aquatic ecologists and biogeochemists with ES theory as a common currency to connect food webs, ecosystem metabolism, and biogeochemistry, as they are inherently concatenated by the transfer of carbon, nitrogen, and phosphorus through biotic and abiotic nutrient transformation and fluxes. Several new studies exist that demonstrate the connections between food web ecology, biogeochemistry, and ecosystem metabolism. In addition to a general introduction into the topic, this paper presents examples of how these fields can be combined with a focus on ES. In this review, a series of concepts have guided the discussion: (1) changing biogeochemistry affects trophic interactions and ecosystem processes by altering the elemental ratios of key species and assemblages; (2) changing trophic dynamics influences the transformation and fluxes of matter across environmental boundaries; (3) changing ecosystem metabolism will alter the chemical diversity of the non-living environment. Finally, we propose that using ES to link nutrient cycling, trophic dynamics, and ecosystem metabolism would allow for a more holistic understanding of ecosystem functions in a changing environment.

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**Organisations:** National Institute of Aquatic Resources, Centre for Ocean Life, University of Eastern Finland, University of Oldenburg, Ecole Polytechnique Federale de Lausanne (EPFL), Montana State University, University of Maryland, University of Wisconsin-Milwaukee, Queen Mary University of London, The Ohio State University, Florida International University, Cornell University, University of California, St. Catherine University

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Disentangling the counteracting effects of water content and carbon mass on zooplankton growth

Zooplankton vary widely in carbon percentage (carbon mass as a percentage of wet mass), but are often described as either gelatinous or non-gelatinous. Here we update datasets of carbon percentage and growth rate to investigate whether carbon percentage is a continuous trait, and whether its inclusion improves zooplankton growth models. We found that carbon percentage is continuous, but that species are not distributed homogenously along this axis. To assess variability of this trait in situ, we investigated the distribution of biomass across the range of carbon percentage for a zooplankton time series at station L4 off Plymouth, UK. This showed separate biomass peaks for gelatinous and crustacean taxa, however, carbon percentage varied 8-fold within the gelatinous group. Species with high carbon mass had lower carbon percentage, allowing separation of the counteracting effects of these two variables on growth rate. Specific growth rates, $g \,(d^{-1})$, were negatively related to carbon percentage and carbon mass, even in the gelatinous taxa alone, suggesting that the trend is not driven by a categorical difference between these groups. The addition of carbon percentage doubled the explanatory power of growth models based on mass alone, demonstrating the benefits of considering carbon percentage as a continuous trait.
Ontogenetic body-mass scaling of nitrogen excretion relates to body surface area in diverse pelagic invertebrates

Many physiological and ecological processes depend on body size and the supply of limiting nutrients. Hence, it is important to derive quantitative predictions based on a mechanistic understanding of the influence of body size on metabolic rate and on the ratios of consumed to excreted elements. Among diverse pelagic invertebrates that change shape during ontogeny, recent analysis has demonstrated a significant positive correlation between the body-mass allometry of respiration rates (measured as the ontogenetic body mass-scaling exponent \( b_R \)) and the allometry of body surface area (\( b_A \), as predicted from body-shape changes using a Euclidean model). As many pelagic invertebrates use a large portion of their external body surface for both resource uptake and waste excretion, we predicted that body-mass scaling exponents for rates of excretion of soluble N (\( b_N \)) should also then relate to the degree of body-shape change during growth. We tested this hypothesis using literature data on \( b_N \) for 39 species of pelagic invertebrates across five different phyla, and find strong support: \( b_N \) is significantly positively correlated with predicted \( b_A \), whilst also co-varying with \( b_R \). Intraspecific differences between \( b_N \) and \( b_R \) values reveal ontogenetic shifts in the ratio of O2-consumed to N-excreted. We suggest that a variety of factors, including adaptive developmental shifts in the relative anabolism and catabolism of proteins and lipids, may cause these shifts in consumption-excretion ratios. Diverse pelagic invertebrates that dominate vast open water ecosystems falsify the predictions of general metabolic scaling theories built upon resource-transport networks, but support predictions of surface-area dependent theory.
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Seasonal body size reductions with warming covary with major body size gradients in arthropod species

Major biological and biogeographical rules link body size variation with latitude or environmental temperature, and these rules are often studied in isolation. Within multivoltine species, seasonal temperature variation can cause substantial changes in adult body size, as subsequent generations experience different developmental conditions. Yet, unlike other size patterns, these common seasonal temperature–size gradients have never been collectively analysed. We undertake the largest analysis to date of seasonal temperature-size gradients in multivoltine arthropods, including 102 aquatic and terrestrial species from 71 global locations. Adult size declines in warmer seasons in 86% of the species examined. Aquatic species show approximately 2.5-fold greater reduction in size per °C of warming than terrestrial species, supporting the hypothesis that greater oxygen limitation in water than in air forces aquatic species to exhibit greater plasticity in body size with temperature. Total percentage change in size over the annual cycle appears relatively constant with annual temperature range but varies between environments, such that the overall size reduction in aquatic-developing species (approx. 31%) is almost threefold greater than in terrestrial species (approx. 11%). For the first time, we show that strong correlations exist between seasonal temperature–size gradients, laboratory responses and latitudinal–size clines, suggesting that these patterns share common drivers.

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A global synthesis of seasonal temperature-size responses in copepods: Seasonal temperature-size responses in copepods

Aim Body size is a master trait with significant ecological importance. Seasonal changes in body size within diverse ectothermic species can result from different environmental conditions experienced during ontogeny in subsequent generations. Whilst intraspecific changes in adult size have been well studied under controlled experimental conditions and across geographical ranges, comprehensive analyses of temporal changes are lacking, and there remains considerable unexplained variation in body size responses within aquatic taxa. Using planktonic copepods as an exemplar taxon, we quantify variation in adult body mass within seasonally varying marine and freshwater environments. We describe how size variation relates to temperature, food concentration (chlorophyll-a) and life-history characteristics, including feeding strategy. Location Global.

Methods Using a meta-analytic approach we extract quantitative data from published literature on seasonal size responses of copepods. We analyse competing models to determine the best predictors of these responses, and compare the relative importance of temperature and chlorophyll-a concentration in explaining variation in body size. Results We quantify 140 seasonal size responses from 33 different global locations, representing 48 planktonic copepod species from four taxonomic orders. We find that temperature ($r^2 = 0.50$), rather than food ($r^2 = 0.22$), is the dominant explanatory variable of changes in adult body size across seasons. A striking
outcome is that calanoid copepods, which utilize feeding currents to capture prey, exhibit a four-fold greater reduction in adult body mass per degrees C (-3.66%) compared with cyclopoid copepods (-0.91%), which are ambush feeders. By contrast, species body size or reproductive strategy did not explain variation in the seasonal temperature-size response.

Main conclusions Our findings lead us to suggest that feeding strategies may play a significant role in dictating the magnitude of seasonal temperature-size responses in copepods, with potential implications for other ectotherms with diverse feeding methods. Seasonal temperature-size responses were typically much more variable than responses in laboratory studies that provided excess food, suggesting that field conditions modify the temperature-size response.

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Role of zooplankton dynamics for Southern Ocean phytoplankton biomass and global biogeochemical cycles

Global ocean biogeochemistry models currently employed in climate change projections use highly simplified representations of pelagic food webs. These food webs do not necessarily include critical pathways by which ecosystems interact with ocean biogeochemistry and climate. Here we present a global biogeochemical model which incorporates ecosystem dynamics based on the representation of ten plankton functional types (PFTs): six types of phytoplankton, three types of zooplankton, and heterotrophic prokaryotes. We improved the representation of zooplankton dynamics in our model through (a) the explicit inclusion of large, slow-growing macrozooplankton (e.g. krill), and (b) the introduction of trophic cascades among the three zooplankton types. We use the model to quantitatively assess the relative roles of iron vs. grazing in determining phytoplankton biomass in the Southern Ocean high-nutrient low-chlorophyll (HNLC) region during summer. When model simulations do not include macrozooplankton grazing explicitly, they systematically overestimate Southern Ocean chlorophyll biomass during the summer, even when there is no iron deposition from dust. When model simulations include a slow-growing macrozooplankton and trophic cascades among three zooplankton types, the high-chlorophyll summer bias in the Southern Ocean HNLC region largely disappears. Our model results suggest that the observed low phytoplankton biomass in the Southern Ocean during summer is primarily explained by the dynamics of the Southern Ocean zooplankton community, despite iron limitation of phytoplankton community growth rates. This result has implications for the representation of global biogeochemical cycles in models as zooplankton faecal pellets sink rapidly and partly control the carbon export to the intermediate and deep ocean.
Shape shifting predicts ontogenetic changes in metabolic scaling in diverse aquatic invertebrates

Metabolism fuels all biological activities, and thus understanding its variation is fundamentally important. Much of this variation is related to body size, which is commonly believed to follow a 3/4-power scaling law. However, during ontogeny, many kinds of animals and plants show marked shifts in metabolic scaling that deviate from 3/4-power scaling predicted by general models. Here, we show that in diverse aquatic invertebrates, ontogenetic shifts in the scaling of routine metabolic rate from near isometry (bR = scaling exponent approx. 1) to negative allometry (bR < 1), or the reverse, are associated with significant changes in body shape (indexed by bL = the scaling exponent of the relationship between body mass and body length). The observed inverse correlations between bR and bL are predicted by metabolic scaling theory that emphasizes resource/waste fluxes across external body surfaces, but contradict theory that emphasizes resource transport through internal networks. Geometric estimates of the scaling of surface area (SA) with body mass (bA) further show that ontogenetic shifts in bR and bA are positively correlated. These results support new metabolic scaling theory based on SA influences that may be applied to ontogenetic shifts in bR shown by many kinds of animals and plants.
Equal temperature-size responses of the sexes are widespread within arthropod species

Sexual size dimorphism (SSD) is often affected by environmental conditions, but the effect of temperature on SSD in ectotherms still requires rigorous investigation. We compared the plastic responses of size-at-maturity to temperature between males and females within 85 diverse arthropod species, in which individuals of both sexes were reared through ontogeny under identical conditions with excess food. We find that the sexes show similar relative (proportional) temperature-body size (T-S) responses on average. The high degree of similarity occurs despite an analysis that includes a wide range of animal body sizes, variation in degree of SSD and differences in the sign of the T-S response. We find no support for Rensch's rule, which predicts greater variation in male size, or indeed the reverse, greater female size variation. SSD shows no systematic temperature dependence in any of the 17 arthropod orders examined, five of which (Diptera, Orthoptera, Lepidoptera, Coleoptera and Calanoida) include more than six thermal responses. We suggest that the same proportional T-S response may generally have equivalent fitness costs and benefits in both sexes. This contrasts with effects of juvenile density, and food quantity/quality, which commonly result in greater size plasticity in females, suggesting these variables have different adaptive effects on SSD.
How does Calanus helgolandicus maintain its population in a variable environment? Analysis of a 25-year time series from the English Channel

Calanus helgolandicus is a key copepod of the NE Atlantic and fringing shelves, with a distribution that is expanding northwards with oceanic warming. The Plymouth L4 site has warmed over the past 25-years, and experiences large variations in the timing and availability of food for C. helgolandicus. Here we examine the degree to which these changes translate into variation in reproductive output and subsequently C. helgolandicus population size. Egg production rates (eggs female-1 day-1) were maximal in the spring to early-summer period of diatom blooms and high ciliate abundance, rather than during the equally large autumn blooms of autotrophic dinoflagellates. Egg hatch success was lower in spring however, with a greater proportion of naupliar deformities then also. Both the timing and the mean summer abundance of C. helgolandicus (CI-CVI) reflected those of spring total reproductive output. However this relationship was driven by inter-annual variability in female abundance and not that of egg production per female, which ranged only two-fold. Winter abundance of C. helgolandicus at L4 was much more variable than abundance in other seasons, and reflected conditions from the previous growing season. However, these low winter abundances had no clear carry-over signal to the following season's population size. Overall, the C. helgolandicus population appears to be surprisingly resilient at this dynamic, inshore site, showing no long-term phenology shift and only a four-fold variation in mean abundance between years. This dampening effect may reflect a series of mortality sources, associated with the timing of stratification in the early part of the season, likely affecting egg sinking and loss, plus intense, density-dependent mortality of early stages in mid-summer likely through predation

General information
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Temperature-size responses match latitudinal-size clines in arthropods, revealing critical differences between aquatic and terrestrial species

Two major intraspecific patterns of adult size variation are plastic temperature-size (T-S) responses and latitude-size (L-S) clines. Yet, the degree to which these co-vary and share explanatory mechanisms has not been systematically evaluated. We present the largest quantitative comparison of these gradients to date, and find that their direction and magnitude co-vary among 12 arthropod orders ($r^2 = 0.72$). Body size in aquatic species generally reduces with both warming and decreasing latitude, whereas terrestrial species have much reduced and even opposite gradients. These patterns support the prediction that oxygen limitation is a major controlling factor in water, but not in air. Furthermore, voltinism explains much of the variation in T-S and L-S patterns in terrestrial but not aquatic species. While body size decreases with warming and with decreasing latitude in multivoltine terrestrial arthropods, size increases on average in univoltine species, consistent with predictions from size vs. season-length trade-offs.
Body shape shifting during growth permits tests that distinguish between competing geometric theories of metabolic scaling

Metabolism fuels all of life’s activities, from biochemical reactions to ecological interactions. According to two intensely debated theories, body size affects metabolism via geometrical influences on the transport of resources and wastes. However, these theories differ crucially in whether the size dependence of metabolism is derived from material transport across external surfaces, or through internal resource-transport networks. We show that when body shape changes during growth, these models make opposing predictions. These models are tested using pelagic invertebrates, because these animals exhibit highly variable intraspecific scaling relationships for metabolic rate and body shape. Metabolic scaling slopes of diverse integument-breathing species were significantly positively correlated with degree of body flattening or elongation during ontogeny, as expected from surface area theory, but contradicting the negative correlations predicted by resource-transport network models. This finding explains strong deviations from predictions of widely adopted theory, and underpins a new explanation for mass-invariant metabolic scaling during ontogeny in animals and plants.
Macroevolutionary patterns of sexual size dimorphism in copepods

Major theories compete to explain the macroevolutionary trends observed in sexual size dimorphism (SSD) in animals. Quantitative genetic theory suggests that the sex under historically stronger directional selection will exhibit greater interspecific variance in size, with covariation between allometric slopes (male to female size) and the strength of SSD across clades. Rensch's rule (RR) also suggests a correlation, but one in which males are always the more size variant sex. Examining free-living pelagic and parasitic Copepoda, we test these competing predictions. Females are commonly the larger sex in copepod species. Comparing clades that vary by four orders of magnitude in their degree of dimorphism, we show that isometry is widespread. As such we find no support for either RR or for covariation between allometry and SSD. Our results suggest that selection on both sexes has been equally important. We next test the prediction that variation in the degree of SSD is related to the adult sex ratio. As males become relatively less abundant, it has been hypothesized that this will lead to a reduction in both inter-male competition and male size. However, the lack of such a
correlation across diverse free-living pelagic families of copepods provides no support for this hypothesis. By comparison, in sea lice of the family Caligidae, there is some qualitative support of the hypothesis, males may suffer elevated mortality when they leave the host and rove for sedentary females, and their female-biased SSD is greater than in many free-living families. However, other parasitic copepods which do not appear to have obvious differences in sex-based mate searching risks also show similar or even more extreme SSD, therefore suggesting other factors can drive the observed extremes.

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Re-assessing copepod growth using the Moult Rate method

Estimating growth and production rates of mesozooplankton, and copepods in particular, is important in describing flows of material and energy through pelagic systems. Over the past 30 years, the Moult Rate (MR) method has been used to estimate juvenile copepod growth rates in ~40 papers. Yet the MR method has been shown to have serious flaws. Here we re-examine the results from the majority of published MR method studies and re-estimate growth rates using the modified Moult Rate (MMR) method, which ascribes changes in mass to the appropriate time period over which it was accrued. The MR method has typically over-estimated growth rates (on 80% of occasions) for life stages where the subsequent stage is actively moulting; the median and mean MR values are 138 and 164%, respectively, of the corrected MMR values. We were unable to correct the original data for life stages that are followed by a non-moulting stage, e.g. copepodite stage 5 to adult. We performed experiments with Calanus pacificus to estimate growth of stage C5 using an alternative method. We found that the error size and sign varied between mass type (i.e. DW, C and N).

Recommendations for practical future assessments of growth in copepods are made.

General information

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Web of Science (2015): Indexed yes
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Shifts in mass-scaling of respiration, feeding, and growth rates across life-form transitions in marine pelagic organisms

The metabolic rate of organisms may be viewed as a basic property from which other vital rates and many ecological patterns emerge and that follows a universal allometric mass scaling law, or it may be considered a property of the organism that emerges as a result of the adaptation to the environment, with consequently fewer universal mass scaling properties. Here, we examine the mass scaling of respiration and maximum feeding (clearance and ingestion rates) and growth rates of heterotrophic pelagic organisms over an ~10^15 range in body mass. We show that clearance and respiration rates have life-form-dependent allometries that have similar scaling but different intercepts, such that the mass-specific rates converge on a rather narrow size-independent range. In contrast, ingestion and growth rates follow a near-universal taxa-independent ~3/4 mass scaling power law. We argue that the declining mass-specific clearance rates with size within taxa is related to the inherent decrease in feeding efficiency of any particular feeding mode. The transitions between feeding mode and simultaneous transitions in clearance and respiration rates may then represent adaptations to
the food environment and be the result of the optimization of trade-offs that allow sufficient feeding and growth rates to balance mortality.

**General information**

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BFI (2016): BFI-level 2

Scopus rating (2016): CiteScore 3.63 SJR 2.823 SNIP 1.363

Web of Science (2016): Indexed yes

BFI (2015): BFI-level 2

Scopus rating (2015): SJR 2.841 SNIP 1.356 CiteScore 3.52

BFI (2014): BFI-level 2

Scopus rating (2014): SJR 3.283 SNIP 1.6 CiteScore 4.22

Web of Science (2014): Indexed yes

BFI (2013): BFI-level 2

Scopus rating (2013): SJR 3.206 SNIP 1.638 CiteScore 4.52

ISI indexed (2013): ISI indexed yes

BFI (2012): BFI-level 2

Scopus rating (2012): SJR 3.446 SNIP 1.666 CiteScore 4.68

ISI indexed (2012): ISI indexed yes

BFI (2011): BFI-level 2

Scopus rating (2011): SJR 3.911 SNIP 1.703 CiteScore 4.72

ISI indexed (2011): ISI indexed yes

BFI (2010): BFI-level 2

Scopus rating (2010): SJR 4.26 SNIP 1.751

BFI (2009): BFI-level 2

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Data compilation of respiration, feeding, and growth rates of marine pelagic organisms
The metabolic rate of organisms may either be viewed as a basic property from which other vital rates and many ecological patterns emerge and that follows a universal allometric mass scaling law; or it may be considered a property of the organism that emerges as a result of the organism's adaptation to the environment, with consequently less universal mass scaling properties. Data on body mass, maximum ingestion and clearance rates, respiration rates and maximum growth rates of animals living in the ocean epipelagic were compiled from the literature, mainly from original papers but also from previous compilations by other authors. Data were read from tables or digitized from graphs. Only measurements made on individuals of known size, or groups of individuals of similar and known size were included. We show that clearance and respiration rates have life-form-dependent allometries that have similar scaling but different elevations, such that the mass-specific rates converge on a rather narrow size-independent range. In contrast, ingestion and growth rates follow a near-universal taxa-independent ~3/4 mass scaling power law. We argue that the declining mass-specific clearance rates with size within taxa is related to the inherent decrease in feeding efficiency of any particular feeding mode. The transitions between feeding mode and simultaneous transitions in clearance and respiration rates may then represent adaptations to the food environment and be the result of the optimization of tradeoffs that allow sufficient feeding and growth rates to balance mortality.

Female-biased sex ratios in marine pelagic copepods: Comment on Gusmao et al. (2013)
Gusmao et al. (2013; Mar Ecol Prog Ser 482:279-298) review causes of sex ratio skew in pelagic copepods and in doing so repeatedly dispute the paper of Hirst et al. (2010) 'Does predation control adult sex ratios and longevities in marine pelagic copepods?' Here we respond to some important errors in their citation of our paper and briefly highlight where future work is needed in order to attribute the causes of strong sex ratio skew seen in some copepod families.
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Web of Science (2014): Indexed yes
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