Journal of Marine Science: Research & Development

Jones, J Marine Sci Res Dev 2023, 13:6

Case Report

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Arctic deep-sea system functioning and vulnerability among study limitations

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Abstract

Most important for the deep sea, juveniles are less dependent on either limited or variable food availability. Yet indirect development, including plankto-trophic and lecitho-trophic larvae, was almost equally prevalent in the epi-faunal taxa of our study area, which, in general, supports our hypothesis. This finding is consistent with a growing number of studies documenting the occurrence of pelagic larvae in both polar waters and deep-sea areas. Among larval development types, lecitho-trophs were most common in our study area. This is similar to findings in the NE Greenland, the deep-sea of the North-East Atlantic, and Antarctica, where more echinoderms were found to reproduce with pelagic larvae, the majority of which were lecitho-trophs.

Keywords: Pelagic larvae; Lecito-trophs; Epi-fauna; Chukchi borderland; Epi-benthic communities; Sessile fauna

Introduction

Development with pelagic larvae allowing dispersal over broader areas is an advantage, in particular for species with limited mobility, which were found in high numbers in our study area [1]. In a work by Mercier and Hamel, depth-related shifts in life history strategies and a simultaneous combination of brooding and broadcast-spawning with lecitho-trophic larvae were reported in a deep-sea asteroid. This finding also stresses the need to species and habitat-specific work to help close many knowledge gaps that currently limit final conclusions on true diversity and plasticity of life-history traits in deep sea benthos [2]. In summary, our investigation of functional traits of deep sea epi-fauna from the Chukchi Borderland area generally supported our first hypothesis that small, non-sessile organisms are the most common, with a relatively equal proportion of direct and indirect mostly through lecitho-trophic larvae development. The hypothesized predominance of deposit feeding, however, was not found in the observed species pool, though that feeding mode was more prominent in the proportional abundance-weighted data set [3]. That modality is common in in-faunal taxa, which we did not cover here. Our analysis of trait modalities highlights instead that there is no single way to live successfully under deep-sea conditions, but rather that, similar to shallower areas, multiple strategies are in fact viable. Our hypothesis that functional traits of epi-benthic communities would change with increasing depth in the Chukchi Borderland was generally confirmed [4]. In particular, epi-fauna of deep stations reflecting more homogeneous habitat had significantly higher proportional abundance of the modalities free-living, swimming, suspension feeders, opportunists/scavengers, internal fertilization and globulose compared to the mid-depth stations, which were characterized by complex habitat structure including ridges, a plateau with pockmarks, and rocks. In addition, our data also suggest that the increasing distance from the productive Chukchi shelf corresponded with spatial patterns of functionality in addition to the depth-related patterns [5]. The higher proportional abundance of modalities free-living and mobile/swimming at greater depths is consistent with generally decreasing food availability with increasing depth in deep-sea areas, both globally and in the Arctic. In the study region, this decrease is reflected in an annual POC flux on the adjacent Chukchi Sea shelf being at least an order of magnitude higher than in the North-wind Abyssal plain [6]. Indeed, the deepest and most food limited basin station had the highest proportional abundance of the modality swimming. Conversely, lower proportional abundance of free-living and swimming modalities at mid-depth stations coincided with higher food availability at lower depths in general [7]. This pattern was, however, not robust as trawl samples in fact showed a higher proportional abundance of the modality mobile at the mid-depth stations compared to the remotely operated vehicle data, where the modality crawling was most abundant. Mobile fauna is often caught with trawls, while trawls can be less reliable in assessing density of some sessile fauna compared to remotely operated vehicle approach [8]. The combination of both tools, thus, allowed us to get more comprehensive insights into the functional structure of benthic communities. Suspension feeding was surprisingly more abundant at deeper stations in our study, where numerous persisting lebensspuren confirmed low bottom current velocity. The question arises as to what and how these organisms eat. In fact, suspension feeders are able to feed on a wide range of food items, ranging in size and quality [9]. Bacterial abundance and biomass do not decline with depth in the global ocean, thus becoming relatively more important in deeper layers and, potentially, serving as food for benthic organisms in our study area. In addition, deep-water zooplankton communities in the Arctic Deep Water may provide a food source, though their abundances are low. Adaptations that allow suspension feeders to maximize food capture even at slow current velocity might also play a role including generating feeding currents and associations with microbial communities [10]. Finally, little maintenance energy was documented for Antarctic deep-water sponges. Besides suspension-feeding, proportional abundance of opportunists/scavengers was also significantly higher at greater depths. These feeding strategies become increasingly more useful with depth as scavengers have an ability to detect sparse carrion across large distances, while opportunists can take advantage of almost whatever they come across in the food-poor environment. In turn, predation and deposit

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Received: 23-Oct-2023, Manuscript No. JMSRD-23-120711; **Editor assigned:** 26-Oct-2023, Pre-QC No. JMSRD-23-120711 (PQ); **Reviewed:** 09-Nov-2023, QC No. JMSRD-23-120711; **Revised:** 15-Nov-2023, Manuscript No. JMSRD-23-120711 (R); **Published:** 22-Nov-2023, DOI: 10.4172/2155-9910.1000423

Citation: Jones A (2023) Arctic deep-sea system functioning and vulnerability among study limitations. J Marine Sci Res Dev 13: 423.

feeding were more common at the mid-depth stations, with deposit feeding being the dominant modality in the trawl samples. This might point to higher availability of deposited organic matter or prey at these mid-depth stations. Proportional abundance of the modality internal fertilization was significantly higher in the deep compared to mid-depth stations. This pattern is consistent with previous studies where internal fertilization was common [11]. In an environment where chances of finding a mate are low, internal fertilization may have a higher success rate than external fertilization once a mate has indeed been found. In addition to the depth pattern, substantial variability found in trait modality patterns was likely related to variable distance to the productive shelf rather than to depth alone. Evidence for this effect is for example the high proportional abundance of modalities tube-dwelling, sessile and deposit feeding at mid-depths stations at Northwind Ridge, which were associated with higher food input, likely from productive waters from the Chukchi shelf, as indicated by sediment pigment values and carbon content [12]. In the same mid-depth range, higher proportional abundance of the modality predators farther north in the study area was associated with a high amount of drop stones, where attached and upright predators took advantage of the presence of stones and elevated themselves to increase capture of prey. Additionally, mobile predators were occasionally observed in the vicinity to the stones, likely attracted by the enhanced amount of prey attached to the stones. Functional Metrics and Ecosystem Vulnerability at Mid-Depth and Deep Stations Both functional diversity and Functional redundancy indices showed changes with depth, where deep stations had lower functional diversity and higher Functional redundancy compared to the mid-depth stations, supporting our hypothesis [13]. The depth-related functional diversity trend was in agreement with results from the Arctic Nansen Basin, but contrary to a study from the Bering Sea, although the direct comparison of values obtained in different studies is no appropriate due to different authors using different traits or different numbers of traits in their calculations. Since functional diversity indicates the range of things organisms do in an ecosystem, higher functional diversity at the mid-depth stations indicates that these communities support more diverse ecological functions than those at greater depths. It seems likely that this pattern is linked to the more heterogeneous habitat structure at mid-depth stations providing more functional niche space for epi-faunal organisms compared to the more homogeneous deeper abyssal plain. In contrast, higher Functional redundancy at the deeper stations is, in turn, likely related to the homogeneity of the abyssal environment to which epi-fauna appear to have adapted by fewer and shared trait modalities [14]. Low Functional redundancy at mid-depth stations may render these areas less resilient to on-going and future change and potential human use as functions may be lost when species loss occurs, a conclusion consistent with studies on Arctic benthic macro-fauna. In addition, modalities such as sessile, attached, and upright body form at these stations point to higher vulnerability of mid-depth epi-fauna to predation, disturbances or decreases in food availability. The higher Functional redundancy at deeper stations in addition to high proportional abundance of modalities swimming might indicate lower vulnerability to disturbances, higher flexibility to perturbation, and higher ability for dispersal after disturbance [15]. It is important to note, however, this conclusion is potentially biased by low faunal densities and low sampling effort. It is, therefore, premature to conclude that deeper communities in the Chukchi Borderland are resilient. In support of our second hypothesis, data indicated an overall difference in functional structure of epi-fauna between mid-depth and deep stations in terms of trait composition, functional diversity, and Functional redundancy. In addition, depth, carbon content in sediments, and bottom temperature reflecting difference in water masses were the main predictors of the functional structure of epi-faunal communities, which generally supported our second hypothesis. Indeed, the presence of upright body forms in the mostly sessile species visible in our imagery, in particular at the northern mid-depth stations, indicated a vulnerability of the system to trawling, as was also suggested for example for the Barents Sea shelf. In addition, oil and gas reserves have also been quantified in this area. It has been made clear that the onset of such multiple pressures in deep sea habitats results in an urgent need for biodiversity and trait-based characterization of deep-sea fauna, a need we directly address in the present study. Our trait-based evaluation of Chukchi Borderland epi-fauna points to potentially high sensitivity of benthic community function to disturbances especially at mid-depths as indicated by high functional diversity and low Functional redundancy. In addition, rapid climate change may have a greater impact on sessile taxa reproducing with larvae of low dispersal ability than mobile species or species with high larval dispersal. Thus, traits analysis can offer insight into resilience and recovery capacity of taxa after disturbance. Our study forms the first step toward filling research gaps of Arctic deep-sea system functioning and vulnerability, though study limitations include the poorly known biology of many of the taxa encountered, as well as spatially limited sampling in a heterogeneous area.

Conclusion

We strongly recommend further study that enhances spatial and temporal coverage, uses traits generated from the actual species in question, as higher taxonomic levels contain different species, which may have distinctive trait modalities, includes more traits, in particular those that might be helpful to indicate potential effects of direct human impact such as trawling or climate-change related impacts such as warming and acidification on organisms, and generates trait information from the area of interest as, due to plasticity of organisms, modalities can change in response to local environmental settings.

Acknowledgement

None

Conflict of Interest

None

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