Non-calanoid Copepods at the Bermuda Atlantic Time-Series Study (BATS) Station: Community Structure and Ecology, 1995-1999

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Abstract

Zooplankton was sampled on a monthly basis at the Bermuda Atlantic Time-series Study (BATS) site from January 1995 to December 1999. Samples were collected using a 1 m2, 200 µm mesh net towed obliquely through the euphotic zone to a mean depth of 200m. One day and one night tow from each cruise was examined microscopically to determine the community structure of the non-calanoid copepods. A total of 118 tows were examined and most copepods were identified to the species level with *Oithona* counted as a genus. The dominant orders in terms of overall abundance were the Cyclopoida and Poecilostomatoida.

The cyclopoid genus *Oithona* was most abundant with an overall average of 4,769 individuals m-2. Following *Oithona spp.* in abundance were the Poecilostomatoid genera *Oncaea*, *Farranula* and *Corycaeus* with 4449, 1712 and 1291 animals m-2, respectively. Harpacticoids were also common but about an order of magnitude less abundant at 114 m-2 and were dominated by *Macrosetella gracilis*. The most common Poecilostomatoid species was *Oncaea media* with females alone accounting for nearly half of all *Oncaea* copepods enumerated. Pronounced seasonal signals were noted. In general the copepod genera *Oithona*, *Oncaea*, *Corycaeus*, *Farranula*, *Sapphirina* and *Copilia* had their highest numbers in the spring and summer with winter being the season of lowest abundance. The one Poecilostomatoid group to counter this trend was the genus *Lubbokia*. *L. squillimana*, which made up nearly 100% of this genus, was almost 3 times more abundant in summer and fall than spring and winter. The harpacticoids on the other hand were nearly 3 times more numerous in the fall and winter than in spring and summer. Generic seasonal trends were not necessarily followed by each species. For example, *Corycaeus speciosus* was most abundant in fall and *Farranula gracilis* had peak populations in fall. Interannual trends, although present, were much less pronounced than seasonal signals. Representatives of the Mormonilloida and Siphonostomatoida were also frequently encountered, although in much lower numbers. Future work includes comparison of results of this study to those of previous investigations conducted at Hydrostation "S" in the same region. In addition to the community structure, the ecological roles in terms of C and N cycling of the Miraciid harpacticoids and the Poecilostomatoid copepods of the genus *Oncaea* and family Corycaeidae at BATS will be evaluated.

Introduction

The Bermuda Atlantic Time-series Study (BATS) in the Sargasso Sea (31º 50' N, 64º 10'W) was formed in 1988 as part of the US Joint Global Ocean Flux Study (JGOFS) program with the intent to better understand ocean biogeochemistry on seasonal as well as decadal time scales and in particular the role of the world's oceans in the carbon cycle (Steinberg et al. 2001).

An important driver of oceanic biogeochemical cycling is the biota. In fact, the maintenance of the geochemical disequilibrium of carbon on earth is the result of a myriad of comparatively small biological export processes in the ocean known collectively as the biological pump.

Zooplankton (>200µm) contribute to the biological pump by producing compact fast-sinking fecal pellets that contribute to gravitational fluxes (Paffenhofer and Knowles 1979; Small et al. 1983) and they augment recycling by excreting nitrogen and other nutrients in the photic zone (Legendre and Rivkin 2002; Zhang et al. 1995). Lastly, zooplankton can actively transport elements out of the upper layers of the water column by excreting material at depth (typically 300-600m) that was consumed in the sunlit regions of the ocean (Longhurst et al. 1989; Steinberg et al. 2000 and Al-Mutairi and Landry 2001).

Copepods are usually the most important component of the zooplankton generally comprising >70% of the total (Omori and Ikeda, 1984). They are therefore the dominant players in the passive and active transport of elements in the ocean. Most ecological and biological studies of copepods have focused on the calanoids and much of what we know about pelagic copepod biology and ecology is skewed towards them. However, the paucity of studies of the non-calanoid copepods (orders Cyclopoida, Harpacticoida, Poecilostomatoida, Siphonostomatoida and Mormonilloida) is not in keeping with their importance in the marine pelagic system. In fact, it just may be that the order Cyclopoida represented by the family Oithonidae and the order Poecilostomatoida which contains the family Oncaeidae are the most numerous metazoans on earth (Bottgerschnack 1996; Gallienne and Robins 2001 and Hopcroft et al. 2001).

In addition to their numerical importance, certain groups of non- calanoid copepods can have ecological impacts that set them apart from most other planktonic crustaceans. Among these groups is the Poecilostomatoid genus *Oncea*. Several studies have shown strong associations between *Oncea spp.* and discarded larvacean houses (e.g. as Alldredge 1972; Ohtsuka et al. 1993 and Green and Dagg 1996).

Oncea species were found to preferentially feed on food collecting filters of discarded larvacean houses. This demonstrated the existence of a direct link between nanoplankton (<20µm) that were concentrated by the filtering actions of the larvacean prior to abandonment and relatively large metazoans such as copepods that could not filter such small particles from the water column themselves. Another potentially important ecological role of non-calanoid copepods lies with the harpacticoid family Miraciidae that includes the species *Macrosetella gracilis*. This family of copepods are well known associates of the cyanobacterium Trichodesmium spp. Miraciid copepods, and Macrosetella gracilis in particular, have been shown to use *Trichodesmium spp.* colonies as a physical substrate as well as a source of food. In fact , as Bjonberg (1965) demonstrated, Miraciid nauplii and copepodites were dependent on *Trichodesmium spp.* for survival.

Studies by Roman (1978), O'Neil et al. (1996) and O'Niel (1998) have confirmed on the ability of *M. gracilis* as well as other species of Miraciid harpacticoids to ingest *Trichodesmium spp.* and assimilate its carbon and nitrogen. These results point to their importance as a direct link between cyanobacterial production and higher trophic levels. This may be especially important in oligotrophic regions of the world's oceans such as the Sargasso Sea.

Materials and methods

Zooplankton samples used in this study were gathered as described in Madin et al. (2001). The following is a brief summary of the methods used. Zooplankton were collected at the BATS site in the Sargasso Sea (31º 50' N, 64º 10'W) on a semi-monthly basis employing a 1m2 rectangular net with 202µm mesh. Replicate day and night tows were made to a target depth of 200m. The net was fitted with a flow-meter (General Oceanics) as well as time temperature and depth recorder (Vemco Minilog recorder) from June 1995 onwards. Prior to June 1995 depth was estimated from the wire out and the wire angle. Average depth sampled was 194m (range = 93-292m). Volume filtered was estimated from the flow-meter counts and the mouth area of the net corrected to an effective mouth area and averaged 635 m3 with a minimum of 246 and maximum of 2345 m3.

Zooplankton from the tows were split into 2 parts with one part wet sieved and frozen for biomass determinations and the other half was used to make a silhouette photograph and then preserved in 5% buffered formalin seawater solution.

For this study, preserved samples representing 118 tows were analyzed. In general 1/32 of the preserved sample was used (range = 1/8 -1/256).

Results and Discussion

General Community Structure

Overall, the non-calanoid copepod community was dominated numerically by the genera *Oithona spp.* and *Oncaea spp.* and they were nearly equal in abundance. Roughly, they contributed approximately 60-80% of total non-calanoid copepod numbers (range = 35,613 to 896 ind m-2). The next most *important groups were the genera Farranula and Corycaeus. Farranula spp.* was generally twice as abundant as *Corycaeus spp.* Together they comprised approximately 20-25% of overall non-calanoid copepod abundance. The remaining groups, including the harpacticoids, *Sapphirina spp.*, *Copilia spp* and *Lubbockia spp.* all contributed less than 5% of total abundance.

Non-calanoid Families and Species identified at BATS

Miraciidae

Macrosetella gracilis — *Oculosetella gracilis* — *Maracia efferata* — *Distioculus minor*

Ectinosomatidae

Microsetella rosea — *Microsetella norvegica*

Clytemnestridae

Clytemnestra scutellata

Sapphirinidae

Sapphirina metallina — *Sapphirina intestinata* — *Sapphirina spp.* — *Copilia mirabilis*
Copilia quadrata — *Copilia vitrea* — *Vettoria granulosa* — *Corissa parva*

Oncaeidae

Lubbokia squillimana — *Lubbokia aculeata* — *Oncaea media* — *Oncaea mediterranea*
Oncaea venusta — *Oncaea conifera* — *Oncaea minuta* — *Oncaea dentipes*
Pacos punctatum

Corycaeidae

Corycaeus speciosus — *Corycaeus clausi* — *Corycaeus typicus* — *Corycaeus limbatus*
Corycaeus flaccus — *Corycaeus latus* — *Corycaeus lautus* — *Corycaeus giesbrechtii*
Corycaeus furcifer — *Corycaeus minimus* — *Farranula gracilis* — *Farranula rostrata*

Oithonidae

Oithona spp.

Rataniidae

Ratania flava

Pontoeciellidae

Pontoeciella abyssicola

Mormonillidae

Mormonilla minor

Diel Changes

Diel variability was investigated by using data generated from analysis of day-night pairs from each cruise. Paired samples t-tests at an alpha set at 0.05 were employed to test for significant differences.

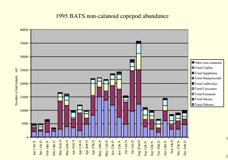
Most species analyzed for possible diel variation showed none. However, there were some notable exceptions. The Harpacticoid *Distioculus minor* showed significantly greater abundance at night (p=0.028). However, since the abundance of this species was generally low (16 vs 8 ind m-2 for night and day ,respectively).

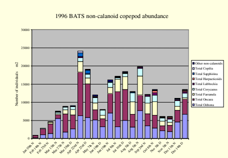
Another group that exhibited statistically significant diel differences in abundance were the Corycaeidae. *Corycaeus typicus* and *C. limbatus* males exhibited significant diel patterns (p= 0.03 and 0.02, repectively).

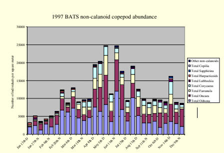
Finally, the strongest diel patterns were observed in 2 *Oncaea* species. They were *Oncaea conifera* and *O. mediterranea*. Both species displayed significant diel changes in abundance with much higher numbers taken at night in the upper 200m than during the day at the BATS Station (p = 0.02 for O. *mediterranea* and p<< 0.001 in O. conifera's case). The implications of this diel migration could have ecological significance for carbon and nitrogen cycling at BATS.

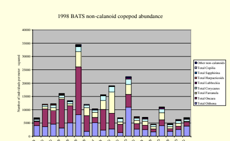
Non-calanoid Families and Species identified at BATS

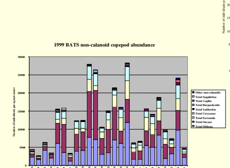
Examples of non-calanoid copepods











Interannual Variability

There were no significant differences between years in terms of the abundance of the various non-calanoid copepod groups. However, given that the lower power nonparametric Kruskal-Wallis test was used true differences may have been masked. When more samples are analyzed such that the sample sizes become balanced then more powerful parametric tests such as ANOVA will be utilized in the analysis of interannual differences that may show some interannual trends.

Seasonal Structure

Pronounced seasonal signals in abundance were observed for the BATS non-calanoid copepods in all years examined. Overall abundance of non-calanoid copepods was highest in spring followed by summer. Winter had the lowest numbers followed by fall. *Oithona spp.* had their highest abundance in spring and lowest in winter. *Oncaea spp.* were twice as abundant in spring and summer compared to fall and winter. *Farranula spp.* taken as a group masked the true seasonal patterns made up by the 2 species *F. gracilis* and *F, rostrata*. Farranula gracilis was nearly 10 times more numerous in summer and fall compared to winter and spring whereas *F. rostrata* was most abundant in spring. As a group Corycaeus spp. had similar abundance in spring, summer and fall but were 3 times less numerous in winter. Most *Corycaeus* species had their highest abundance in spring, however, there were some exceptions. *Corycaeus speciosus* was most abundant in fall and *C. latus* had its highest numbers in summer and fall.

***Sapphirina spp.* and *Copilia spp.* had their highest abundance in spring with more than double the numbers found in the other seasons. Whereas, Lubbockia spp. (nearly 100% made up of L. squillimana) had its peak abundance in summer and fall. Finally, the harpacticois were more numerous in winter and fall than spring and summer. Theses results were in line with what Deevey (1971) found after analyzing one year of zooplankton samples taken at Hydrostation "S" near the BATS station.**

Areas for Further Study

- **Examine the role of Miraciid harpacticoids in elemental alterations of *Trichodesmium spp.* at the BATS site over a 3-year period. The goal would be to quantify the amount of nitrogen transferred from *Trichodesmium spp.* N2 fixation to the rest of the autotrophic community as well as the role played by harpacticoids (e.g *Macrosetella gracilis*) in making *Trichodesmium spp.* organic carbon available to higher trophic levels**

- **Study the relationship between Poecilostomatoid copepod abundance (especially members of the genus *Oncea*) and larvacean abundance over a 5-year period as well as examine the role of Poecilostomatoid copepods in particulate matter degradation and transformation.**

- **Analyze sediment trap Poecilostomatoida"swimmer" community structure at BATS**

- **Estimate the capture efficiency of the 200µm mesh net of non-calanoid copepods by comparing samples collected by it and a 35µm mesh net at the BATS site.**

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