## 5. Copepods (large and small)

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### Background

The large copepod species were defined as the V and VI copepodites stages of *Calanus finmarchicus*, *Metridia lucens*, and *Centropages typicus*. The small copepods were defined as stage I-IV copepodites of the large copepod species and the I-VI copepodites stages of *Centropages hamatus*, *Pseudocalanus* spp., *Temora longicornis*, *Paracalanus parvus*, *Nannocalanus minor*, and *Clausocalanus arcuicornis*. The ten taxa included here make up, on average, 63.3 % of the total zooplankton organisms taken during the six seasons for the 1995 through 2000 period. All ten taxa were present at some sampled sites during all six seasons with mean seasonal abundances ranging from 5 to 20,000 /100 $m^3$. Maximum abundances for each taxon exceeded 100,000/100 $m^3$ at some locations during the period. The highest recorded station abundance (1,260,000/100 $m^3$) was recorded in early autumn for the copepod *Centropages typicus.*

### Data Sources and Abundance Estimates

The mean abundance (#/10$m^2$) of large copepods and small copepods were calculated for bimonthly subsets (Jan-Feb, Mar-Apr…) of the ECOMON zooplankton time series from the 1996-2000 period (Table 5.1). Plankton samples were collected seasonally on two types of cruises: 1) broadscale surveys dedicated to plankton where sampling was done at standard or randomly selected stations spaced approximately 8-35 km apart; and 2) trawl and dredge surveys where plankton stations were selected from a stratified random plan at locations uniformly distributed over the region. Samples were all collected with a 61 cm bongo frame fitted with a 0.333 mm mesh net towed obliquely to a maximum depth of 200 m or 5 m from the bottom and back to the surface. A digital flowmeter was suspended in the center of the bongo frame to measure volume of water filtered during the tow. Specimens were preserved in 5% formalin. Samples were then reduced to approximately 500 organisms by subsampling with a modified box splitter. Zooplankton was sorted, counted, and identified to the lowest possible taxon at the Polish Sorting and Identification Center.

Total counts of zooplankton within the ecosystem were highest during late summer when dense concentrations pervade throughout the MAB and within the shallow waters of the SNE and GB subregions. These high aggregations persist through late autumn, nearly disappear during winter, and began to reappear during early spring. Overall abundance was lowest in the GOM region, but there was a band of high abundance along the southwestern coastal zone that was present in all seasons except winter.

Samples were numerically dominated by three copepod species: *Calanus finmarchicus*, *Centropages typicus*, and *Pseudocalanus minutus*. These three species, on average, accounted for 46% of the total number of organisms present in our samples. Of the three species, *C. typicus* was the most abundant of the zooplankton community. This warm water omnivore dominates ecosystem waters from late summer through early winter. Its density was high year-round in the southern half of the region and became elevated in the more temperate northern half of the ecosystem during late summer. Ecosystem abundance peaks in late autumn when the copepod abundance is above 10,000/100 $m^3$ throughout most of the region.

The herbivores *Calanus finmarchicus* and *Pseudocalanus minutus* utilize the spring phytoplankton bloom and dominate early and late spring samples. Both species have similar annual abundance cycles but differ in their spatial distribution. *Pseudocalanus* spp. abundance rises sharply in early spring when it concentrates in coastal areas of the MAB, throughout SNE, and the western and eastern margins of the GOM. Peak seasonal abundances occurred in late spring with high values found throughout SNE, in the more shallow waters of GB, and along coastal GOM. *C. finmarchicus* abundance was high year-round in the GOM and on GB from early spring through late summer. Dense concentrations of this copepod were also found in the offshore waters of SNE and the MAB in late spring and late summer. Abundance was low year-round in the coastal waters of these latter two regions.

The annual abundance cycle and spatial distribution of *Metridia lucens* was very similar to *Calanus finmarchicus*, though overall abundance levels were much lower. Density is highest during late spring and the largest concentrations were usually found in the western GOM and along the outer shelf of the MAB and SNE subregions. Abundance was low year-round in southern coastal waters and within the central shoals of GB.

The copepod *Centropages hamatus* reached peak abundance during the late summer when dense concentrations formed in the central shoals region of GB and persisted there through late autumn. High levels were also found in MAB and SNE coastal waters during early and late spring. The copepod was sparsely distributed year-round in the GOM and during the latter half of the year in the MAB and SNE subregions.

Mean abundance of *Acartia* spp. peaked during late summer when they concentrated in shallow coastal waters throughout the ecosystem. Numbers remained high inshore through late autumn in the southern half of the ecosystem. They became scarce in the GOM during winter and early spring. *Temora longicornis* mean abundance also peaked during late summer when high concentrations of the copepod were found scattered in shallow waters throughout the ecosystem. It also was very scarce in the GOM during the colder months.

*Oithona* spp. were captured year round in nearly all samples from the ecosystem. However, there was no strong seasonal cycle and only relatively large concentrations were found scattered throughout the MAB and SNE regions. It should be noted that the abundance levels of this comparatively small copepod species is underestimated because it is not quantitatively caught with the nets used in our surveys. *Paracalanus parvus* abundance was at its maximum during late autumn when high concentrations were found across SNE and GB. It was present year-round in the SNE and MAB subregions and became very rare in GOM and GB waters during the spring seasons.

**Biomass Estimates**

Copepod abundance by size group was converted to biomass using the length to wet weight (W) equation given by Pearre (1980):

(EQ. 5.1) $$W=0.08810L^{2.8514}$$

This equation is based on Petipa (1957) and others using prosome lengths (L) of various copepod species obtained from the literature (Table 5.1).

## Production

Copepod production was calculated according to Huntley and Lopez (1992) using the formula:

(EQ. 5.2) $$P = B\ 0.0445e^{0.111T}$$

where P is production; B is copepod biomass$^{-m2}$; and T is mean temperature. Mean temperatures are derived from integrated CTD temperature profiles taken at each station (Table 5.2).

## Consumption

Feeding rates were derived from Pafenhofer (1976) based on the daily weight-specific filtering rate for a calanoid copepod, *Calanus helgolandicus*. This rate, 0.20 times biomass/day, was scaled to an annual consumption rate for both copepod size groups. Thus, both groups were assumed to have the same consumption rates relative to body size.

## References


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Table 5.1. Estimates of seasonal biomass for large and small copepods (grams dry weight 10 $m^{-2}$) by EMAX Region 1996-2000.

| Large Copepods (derived from lengths using Pearre 1980) | | | | |
|---|---|---|---|---|
| Season | MAB | SNE | GBK | GOM |
| Jan-Feb | 6.08 | 5.36 | 4.34 | 9.14 |
| Mar-Apr | 9.34 | 9.84 | 12.82 | 21.88 |
| May-Jun | 9.04 | 17.30 | 22.37 | 43.81 |
| Jul-Aug | - | 17.05 | 13.10 | 54.22 |
| Sep-Oct | 3.34 | 8.32 | 18.45 | 44.36 |
| Nov-Dec | 3.54 | 11.35 | 14.40 | 35.73 |
| AVG | 5.23 | 11.54 | 14.25 | 34.85 |

| Small Copepods (derived from lengths using Pearre 1980) | | | | |
|---|---|---|---|---|
| Season | MAB | SNE | GBK | GOM |
| Jan-Feb | 1.90 | 1.75 | 2.06 | 1.01 |
| Mar-Apr | 4.18 | 9.18 | 11.50 | 11.82 |
| May-Jun | 7.66 | 14.11 | 17.72 | 17.13 |
| Jul-Aug | - | 7.45 | 7.11 | 10.42 |
| Sep-Oct | 1.44 | 2.29 | 7.51 | 5.00 |
| Nov-Dec | 3.32 | 3.24 | 4.03 | 4.02 |
| AVG | 3.08 | 6.34 | 8.32 | 8.23 |

Table 5.2. Estimates of seasonal P, B and T for large and small copepods by EMAX Region 1996-2000. B = biomass units = g dry wt 10 $m^{-2}$; T = mean water column temperature 1996-2000, <200M; P = production g dry wt 10 $m^{-2}$ $day^{-1}$.

| Large Copepods | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Season | MAB B | MAB T | MAB P | SNE B | SNE T | SNE P | GBK B | GBK T | GBK P | GOM B | GOM T | GOM P |
| Jan-Feb | 6.08 | 8.1 | 0.66458 | 5.36 | 6.8 | 0.508316 | 4.34 | 6.1 | 0.381461 | 9.14 | 5.8 | 0.777755 |
| Mar-Apr | 9.34 | 7.4 | 0.946073 | 9.84 | 6.1 | 0.859093 | 12.82 | 5.6 | 1.063897 | 21.88 | 5.1 | 1.71384 |
| May-Jun | 9.04 | 12.2 | 1.552212 | 17.30 | 9.8 | 2.286007 | 22.37 | 9.0 | 2.694004 | 43.81 | 6.6 | 4.041832 |
| Jul-Aug | - | 11.5 | | 17.05 | 14.2 | 3.673063 | 13.10 | 13.4 | 2.586063 | 54.22 | 9.6 | 6.964496 |
| Sep-Oct | 3.34 | 19.9 | 1.355482 | 8.32 | 15.8 | 2.147429 | 18.45 | 13.5 | 3.678572 | 44.36 | 9.4 | 5.601424 |
| Nov-Dec | 3.54 | 15.7 | 0.898125 | 11.35 | 13.6 | 2.280166 | 14.40 | 11.9 | 2.391141 | 35.73 | 8.5 | 4.081472 |
| AVG | | | 1.08 | | | 1.96 | | | 2.13 | | | 3.86 |

| Small Copepods | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Season | MAB B | MAB T | MAB P | SNE B | SNE T | SNE P | GBK B | GBK T | GBK P | GOM B | GOM T | GOM P |
| Jan-Feb | 1.90 | 8.1 | 0.206996 | 1.75 | 6.8 | 0.165763 | 2.06 | 6.1 | 0.181452 | 1.01 | 5.8 | 0.085758 |
| Mar-Apr | 4.18 | 7.4 | 0.42357 | 9.18 | 6.1 | 0.801963 | 11.50 | 5.6 | 0.954569 | 11.82 | 5.1 | 0.925576 |
| May-Jun | 7.66 | 12.2 | 1.3146 | 14.11 | 9.8 | 1.864271 | 17.72 | 9.0 | 2.133817 | 17.13 | 6.6 | 1.580857 |
| Jul-Aug | - | 11.5 | | 7.45 | 14.2 | 1.605211 | 7.11 | 13.4 | 1.403629 | 10.42 | 9.6 | 1.338492 |
| Sep-Oct | 1.44 | 19.9 | 0.584923 | 2.29 | 15.8 | 0.590272 | 7.51 | 13.5 | 1.497967 | 5.00 | 9.4 | 0.630965 |
| Nov-Dec | 3.32 | 15.7 | 0.842071 | 3.24 | 13.6 | 0.65012 | 4.03 | 11.9 | 0.669785 | 4.02 | 8.5 | 0.459443 |
| AVG | | | 0.67 | | | 0.95 | | | 1.14 | | | 0.84 |