# Effect of towing speed on retention of zooplankton in bongo nets

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Long-term time series of zooplankton data provide invaluable information about the fluctuations of species abundance and the stability of marine community structure. These data have demonstrated that environmental variability have a profound effect on zooplankton communities across the Atlantic basin (Beaugrand et al., 2002; Frank et al., 2005; Pershing et al., 2005). The value of these time series increases as they lengthen, but so does the likelihood of changes in sampling or processing methods. Sampling zooplankton with nylon nets is highly selective and biased because of mesh selectivity, net avoidance, and damage to fragile organisms. One sampling parameter that must be standardized and closely monitored is the speed of the net through the water column. Tow speed should be as fast as possible to minimize net avoidance by the organisms, but not so fast as to damage soft bodied zooplankters or extrude them through the mesh (Tranter et al., 1968; Anderson and Warren, 1991).

The bongo plankton sampler (Posgay and Marak, 1980) has been used by many investigators to monitor plankton populations throughout the world's oceans (e.g., Lough et al., 1985; Kane, 1993; Licandro et al., 2001). Tow speed on bongo surveys has ranged from approximately 1 to 4 knots, depending on the target population of the survey program. With the growing interest in long-term time series, the purpose of our study was to evaluate differences in catches with bongo nets towed at two of the common speeds: 1.5 and 3.5 knots. If the differences can be quantified, zooplankton data collected at the two towing speeds could be used to compare or extend time series at the regional level. We made replicate collections at the two different tow speeds and compared species composition, community structure, and overall biomass.

## Materials and methods

Plankton samples were collected aboard the RV *Delaware II* from March 29 to April 9 1999 in northeastern U.S. continental shelf waters (Fig. 1). Initially a cross-shelf transect of 10 stations was surveyed, extending from the island of Martha's Vineyard out to just beyond the 200-m isobath. For the remainder of the cruise, samples were collected at 29 stations in a saw tooth pattern throughout the Georges Bank region, most within the 200-m isobath.

At each sampling location two consecutive hauls were conducted with a 61-cm bongo frame fitted with a white colored 0.333-mm mesh net towed obliquely to a maximum depth of 200 m or to within 5 m from the bottom and back to the surface. Wire was payed out at 50 m/min and retrieved at 20 m/min during both tows and a conductivity-temperature-depth (CTD) probe was attached above the bongo to measure sampling depth. A flowmeter was suspended in the center of the bongo frame to measure the volume of water filtered during each tow. The first tow was performed at a ship speed of 1.5 knots, which varyied slightly at times to maintain an approximately 45º wire angle. The sampler was depressed with a simple 45-kg lead ball. After the first tow had been completed, the vessel returned to the exact location where the tow was initiated. The gear was redeployed with a wedge-shaped 1.2-m 108-kg vfin depressor and towed at 3.5 knots without regard to the wire angle. Specimens from all samples were preserved in 5% formalin.

In the laboratory, biomass was measured by displacement volume. The plankton sample, with preserving liquid, was measured in a graduated cylinder, poured through a mesh cone into a second cylinder, and drained until the interval between drops was 15 seconds. The liquid in the second cylinder was measured and the displacement volume of the sample was the difference between readings. Samples were then reduced to approximately 500 organisms by subsampling with a modified box splitter. Zooplankton were sorted, counted, and identified to the lowest possible taxa. Abundance and biomass were expressed as number/100 $m^3$ and cubic centimeters/100 $m^3$, respectively.

Abundance of dominant taxa, defined as those contributing on average >1% to the total abundance, were compared between tow speeds. Survey mean abundance values were tested for significant differences by using the conventional paired *t*-test, and its nonparametric counterpart, the Wilcoxon test, was used to compare median abundance levels. The stage distribution of the five most abundant copepods was also examined for significant differences by using the same statistical methods.

Zooplankton community structures from the two tow speeds were compared by using multivariate statisti-

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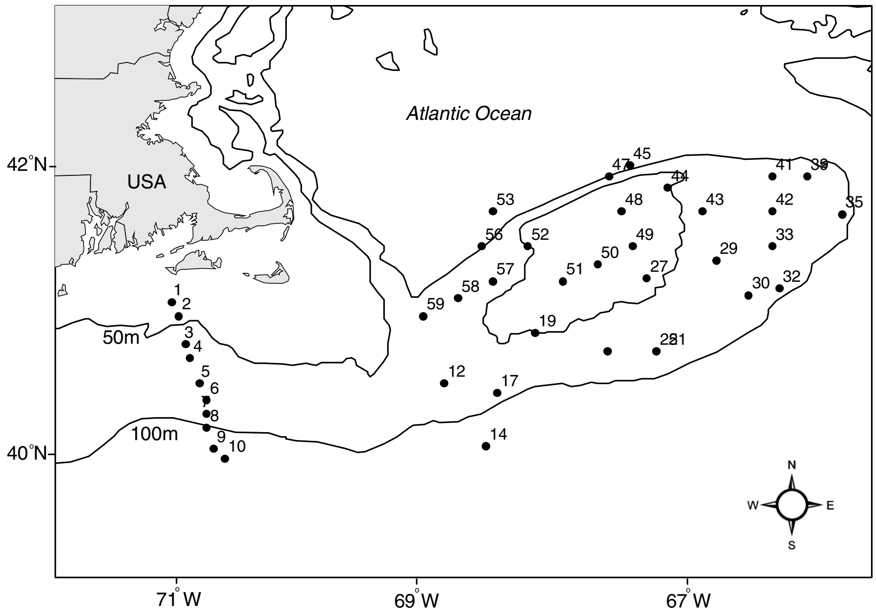


**Figure 1**

Locations surveyed with the RV *Delaware II* for effect of towing speed on retention of zooplankton in bongo nets. Sampling was conducted from March 29 to April 1999 at two tow speeds: 1.5 and 3.5 knots. Locations are labeled with the station number.

cal and ordination techniques from the PRIMER 6.1.5 software package (PRIMER-E Ltd, Plymouth, UK). Initially, data were log transformed and the biotic relationship between any two samples was represented by the Bray-Curtis index (Bray and Curtis, 1957), which measures the similarity (or dissimilarity) in species composition. The triangular matrix of similarity between each sample was then classified into groups by using two techniques: 1) hierarchical agglomerative cluster analysis, and 2) nonmetric multidimensional scaling (MDS). Clusters of samples that were found to be statistically significant ($P<0.05$) by the similarity profile test (SIMPROF) and also to be isolated by low stress (<0.20) MDS ordinations, were judged to be samples with similar zooplankton community structure. The significance of the resultant groupings was tested by using the nonparametric permutation procedure ANOSIM (analysis of similarity).

## Results

Nine taxa dominated the zooplankton community captured during the survey (Table 1). All dominant taxa were common to both tow speeds and their mean abundance ranked in nearly the same order. The only difference was found for the copepods *Temora longicornis* and *Oithona* spp., which were the seventh and eighth most abundant taxa in the 1.5-knot tows, and eighth and seventh most abundant in the 3.5-knot tows (Table 1). The mean and median abundance levels of the dominant species were not significantly different ($P>0.05$) between tow speeds.

The copepodite stage distributions of the dominant copepods were equally represented at the two tow speeds. Mean abundance levels of all *Calanus finmarchicus* life stages and *Pseudocalanus* spp. stage-V copepodites were nearly identical from both hauls (Fig. 2) and not significantly different ($P>0.05$). Slightly higher mean numbers of late-stage copepodites of *Metridia lucens*, *Centropages typicus*, and *Centropages hamatus,* and adults of *Pseudocalanus* spp. were captured at the higher tow speed (Fig. 2), but the values also were not significantly different ($P>0.05$). These similar mean numbers for the various life-stages indicate that there was no substantial difference in the size of particles retained or extruded by the nets at the two tow speeds.

Ordinations of zooplankton community structures from the two speeds were very similar. Cluster analysis of data from both tow speeds produced five significant ($P<0.05$) groupings that were also evident in the low-stress MDS plots (Fig. 3). These station clusters for the two tow speeds were nearly identical, both reflecting the different depth strata and areas sampled during the survey. The two large clusters were essentially inshore and offshore station groupings, and the remaining three were different deepwater (>200 m) sites (Figs. 1 and 3). The community composition of the samples collected at the two speeds was not significantly different (ANOSIM procedure, $P=0.40$).

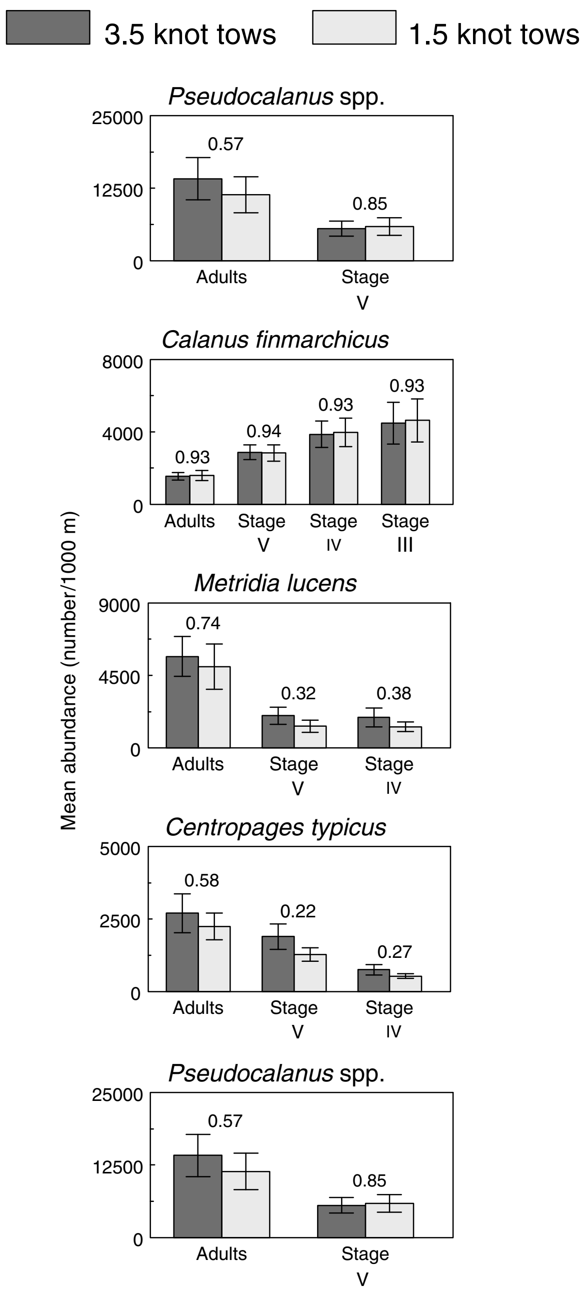


**Figure 2**

Comparison of mean abundance at 3.5 and 1.5 knot tow speeds for different life stages of the five dominant copepods sampled during the cruise. Only the mean abundance of adults and copepodite stages (denoted as stage III, IV, or V) that were captured quantitatively with the 0.333-mm mesh nets are shown. Mean values for the two tow speeds were not significantly different ($P$ values from $t$-test results are given above each tested pair). Error bars represent one standard error. Please note that $y$-axis scales are different.

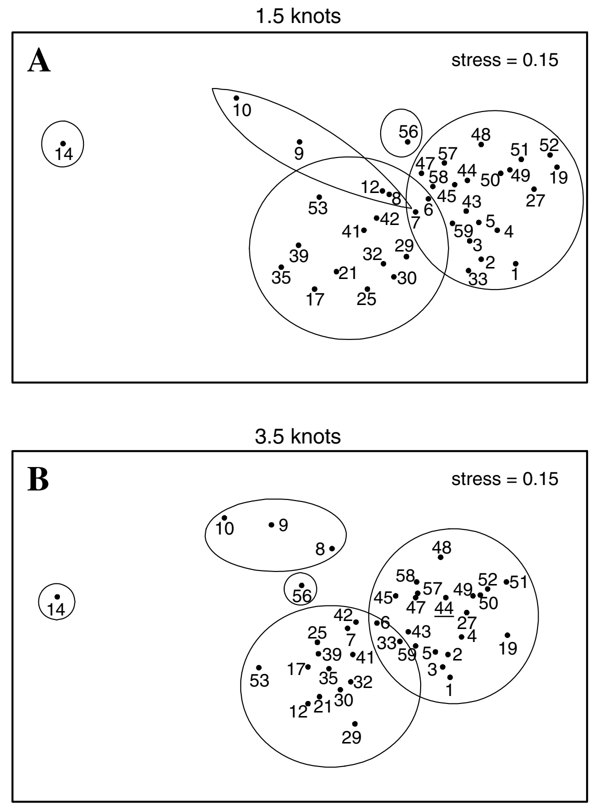


**Figure 3**

Nonmetric multidimensional scaling (MDS) plots produced after calculation of Bray-Curtis similarity index on log-transformed zooplankton station abundance data obtained with the bongo sampler towed at (**A**) 1.5 knots and (**B**) 3.5 knots. Encircled groups are stations strongly grouped by cluster analysis. The stress value is a measure of the strength of the MDS plot and is considered meaningful if <2.0.

In contrast to species abundance, mean and median displacement volume values from the 1.5-knot tows were significantly different ($P<0.05$) from the faster tows, averaging 40% higher (Table 1). Because mean and median total zooplankton counts at the two speeds were not significantly different ($P>0.05$), the increased biomass could be caused by items not counted in slower tows. These could include phytoplankton, Cnidaria fragments, and general detritus that would have been extruded through the nets at higher speed tows.

## Discussion

The degree of similarity between the overall catches at the two speeds was remarkable given the variation normally associated with replicate plankton tows (Wiebe and Holland, 1968). None of the survey mean and median abundance values of dominant taxa were significantly

**Table 1**

Average abundances (no./100 m$^3$) and proportions of the dominant taxa (arranged in order of mean abundance in the tow) collected from tows traveled at 1.5 and 3.5 knots. Placed below them are the mean and median abundance values for total zooplankton and displacement volume values (cc/100 m$^3$) for each tow speed.

| Abundance rank | Taxa | Frequency of occurrence | Mean abundance | Median abundance | Mean proportion | Cumulative % |
|---|---|---|---|---|---|---|
| 1.5 knots | | | | | | |
| 1 | *Pseudocalanus* spp. | 100.0 | 18,696 | 10,956 | 28.6 | 28.6 |
| 2 | *Calanus finmarchicus* | 100.0 | 17,478 | 9929 | 26.7 | 55.3 |
| 3 | *Metridia lucens* | 97.4 | 8812 | 6417 | 13.4 | 68.8 |
| 4 | *Centropages typicus* | 97.4 | 4067 | 2149 | 6.2 | 75.0 |
| 5 | *Centropages hamatus* | 76.9 | 3775 | 3327 | 5.7 | 80.8 |
| 6 | Balanidae | 66.7 | 3424 | 873 | 5.2 | 86.1 |
| 7 | *Oithona* spp. | 89.7 | 2971 | 1496 | 4.6 | 90.6 |
| 8 | *Temora longicornis* | 92.3 | 2352 | 1888 | 3.6 | 94.2 |
| 9 | *Sagitta elegans* | 79.5 | 719 | 567 | 1.1 | 95.3 |
| | Total zooplankton | | 65,367 | 49,230 | | |
| | Displacement volume | | 53 | 49 | | |
| 3.5 knots | | | | | | |
| 1 | *Pseudocalanus* spp. | 100 | 20,653 | 14,210 | 28.9 | 28.9 |
| 2 | *Calanus finmarchicus* | 100 | 17,023 | 8601 | 23.8 | 52.8 |
| 3 | *Metridia lucens* | 94.9 | 10,867 | 7401 | 15.2 | 68.0 |
| 4 | *Centropages typicus* | 97.4 | 5354 | 2001 | 7.5 | 75.5 |
| 5 | *Centropages hamatus* | 82.1 | 5199 | 2357 | 7.3 | 82.8 |
| 6 | Balanidae | 64.1 | 3823 | 846 | 5.4 | 88.1 |
| 7 | *Temora longicornis* | 94.9 | 2704 | 1606 | 3.8 | 91.9 |
| 8 | *Oithona* spp. | 89.7 | 2053 | 1830 | 2.9 | 94.8 |
| 9 | *Sagitta elegans* | 64.1 | 895 | 1034 | 1.3 | 96.1 |
| | Total zooplankton | | 71,388 | 65,815 | | |
| | Displacement volume | | 38 | 35 | | |

different and the rank abundances were nearly identical. Furthermore, nearly identical life-stage distributions were derived for the dominant copepod species at the two tow speeds. There was no significant effect of tow speed on zooplankton community structure.

Catches in most tows at a single location showed good agreement between the catches of taxa at the two speeds, although occasionally there were large differences between species abundance. One reason for this discrepancy may be sampling error attributed to water movement. Although the vessel returned to the exact location where the 1.5-knot tows began, the same specific water parcel was not precisely sampled by the faster tow. Furthermore, the patchiness of zooplankton also makes it difficult to sample exactly the same community with duplicate tows. Nonetheless, these differences were averaged out when several stations were pooled and mean or median abundances were calculated.

Direct comparison between displacement volume measurements made at the two speeds is not recommended. It appears that at the slower tow speed unaccounted material is collected that is extruded through the net meshes at higher speed tows. Filtration pressure across the mesh varies with the square of the approach velocity; thus, 3.5-knot tows will exert a pressure approximately 5.4 times higher than the 1.5-knot tows (Tranter and Smith, 1968). Because this study was conducted at or near the height of the spring phytoplankton bloom in the region, sample biomass in the slower tow was likely elevated by the retention of larger diatom species that dominate the spring bloom on Georges Bank (O'Reilly and Zetlin, 1998). The results indicate that sample displacement volumes for the 3.5-knot tows conducted during early spring should be increased by 40% before comparison to levels for the 1.5-knot tows. Owing to the widespread seasonal and spatial variability of plankton populations, caution should be exercised in applying this conversion factor to other data sets. Colton et al. (1980) also reported that displacement volumes for replicate 3.5-knot tows were lower than those for 1.5-knot tows, but they found the difference was only 20.8%. Their study was conducted in the same region as ours, but samples were collected at one location in early November over a five-day period. Further comparative studies in other seasons and regions would be needed to precisely convert the displacement volumes measured for the two tow speeds.

For projects focusing on zooplankton studies, there may be a need to consider the higher tow speed as the preferred sampling procedure. The escape reaction of the dominant species to the approaching net or loss of dominant species by extrusion through the net does not appear to change substantially between 1.5 and 3.5 knots. At higher tow speeds cleaner samples are collected—samples that are easier to process because more phytoplankton and detritus are extruded from the nets. Although the slower speed has been found to be less damaging to ichthyoplankton specimens (Colton et al., 1980), the condition of the zooplankton specimens captured at the two tow speeds in this study was similar.

This study demonstrates that mean and median counts of common zooplankton taxa collected during 3.5-knot bongo tows are not significantly different from those collected during 1.5-knot tows. On the basis of these findings, we feel that zooplankton data collected at these two tow speeds can be used to compare or extend time series data at the regional level.

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