# MOCNESS estimates of the size and abundance of a pelagic gonostomatid fish *Cyclothone pallida* off the Bahamas

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Depth patterns of size and abundance in a pelagic bristlemouth fish *Cyclothone pallida* (Stomiformes: Gonostomatidae) are reported. Sampling was conducted during the day and night at two sites in the Bahamas using a Multiple Opening and Closing Net and Electronic Sensing System (MOCNESS). All samples show peak abundance in the 500–700 m depth range irrespective of time or sampling location. The mean and variance of body length increased with depth, and size–depth patterns do not significantly differ among samples. Results suggest that these populations of *C. pallida* do not exhibit diel vertical migration.

## INTRODUCTION

Depth patterns of body size and abundance in marine environments constitute a major class of biogeographic phenomena with broad implications for energy flow and community structure. For the icthyofauna, trends along depth gradients have been documented by several researchers for both demersal (Macpherson & Duarte, 1991; Haedrich & Merrett, 1992; Stefanescu et al., 1992) and pelagic assemblages (Cushing, 1982; Brooks & Saenger, 1991; Macpherson, 1994). Bathymetric patterns of body size also have been well described for the benthic fauna (reviewed in Rex & Etter, 1998). Here we analyse depth patterns of size and abundance in a pelagic bristlemouth fish, *Cyclothone pallida* Brauer, 1906 (Stomiformes: Gonostomatidae), collected off the Bahamas from MOCNESS samples to show whether size–depth patterns have an underlying temporal and spatial structure. The ∼60 species of bristlemouths (Gonostomatidae) are among the most abundant fish in the ocean (Moyle & Cech, 1982).

## MATERIALS AND METHODS

Sampling was carried out at two sites in the Bahamas by using a Multiple Opening and Closing Net and Electronic Sensing System (MOCNESS) deployed from the RV 'Seward Johnson'. This sampling device allows an operator to remotely trigger the opening and closing of nine, $330\,\mu m$ mesh (opening of $1\,m^2$) plankton nets at specific depths. For this study, samples were taken within the following depth ranges for 10 min each: 100–200, 200–300, 300–400, 400–500, 500–600, 600–700, 700–800, and 800–900 metres. Tows were taken during the night and day at two sites (Table 1). After retrieval, fish were preserved in 10% formalin, identified, and measured for total length (to the nearest millimetre) using calipers onboard.

A Kolmogorov–Smirnov test was performed to determine whether fish abundance distributions were significantly different among sampling times or sites. Relationships between depth and size in the water column were tested for heterogeneity among the four separate tows using an Analysis of Covariance (ANCOVA).

## RESULTS

The bristlemouth, *Cyclothone pallida*, was the numerically dominant fish in our tows. All samples, irrespective of time or sampling location, show peak abundance in the 500–700 m depth range (Figure 1). Site 1 day showed a peak 100 m shallower than Site 1 night, but the difference was not significant. Neither site nor time affected the distribution of individuals with depth (Kolmogorov–Smirnov test: $P>0.10$ for all possible combinations). Thus no diel vertical migration of the assemblage was evident using these samples.

The relationship between body length and depth is shown in Figure 2. The mean and variance of sizes collected increases with depth. This trend of increasing size with depth is consistent with the growing body of literature showing a positive correlation between depth and size for some pelagic, demersal, and benthic species. Analysis of covariance shows that neither slopes nor elevations differ significantly by site or sampling time (Table 2). Underwood (1997) recommends using Cochran's C to test the assumption of homoscedasticity for ANOVA and ANCOVA. The variances are heterogeneous ($P=0.000039$) for bristlemouth size, meaning an increased probability of a Type I error occurring. Multiple transformations were conducted on the data set, but no improvement was made in heteroscedasticity. If no significant difference occurs then the violation of this assumption does not affect the interpretation (Underwood, 1997) because a Type I error cannot be committed. The trends of size and abundance distributions reported here are consistent with the previous studies demonstrating similar patterns in Sagami Bay, central Japan (Miya & Nemoto, 1987, 1991).

**Table 1.** *MOCNESS sampling locations and times.*

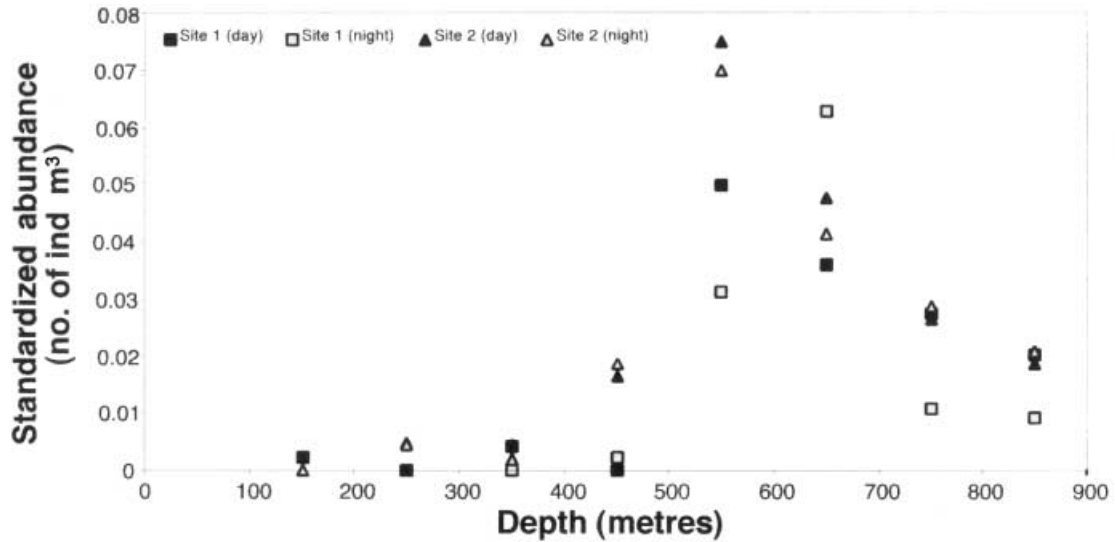| Date | Time | Location | Latitude and longitude |
|---|---|---|---|
| 11 June 1999 | 2200 h | between Conception Island and San Salvador Island | ~24°N ~74.5°W |
| 12 June 1999 | 1300 h | between Conception Island and San Salvador Island | ~24°N ~74.5°W |
| 19 June 1999 | 1300 h | between Exuma Sound and Conception Island | ~22.5°N ~77.3°W |
| 20 June 1999 | 2200 h | between Exuma Sound and Conception Island | ~22.5°N ~77.3°W |



**Figure 1.** Abundance of *Cyclothone pallida* with depth for individual MOCNESS tows off the Bahamas. See Table 1 for station data.
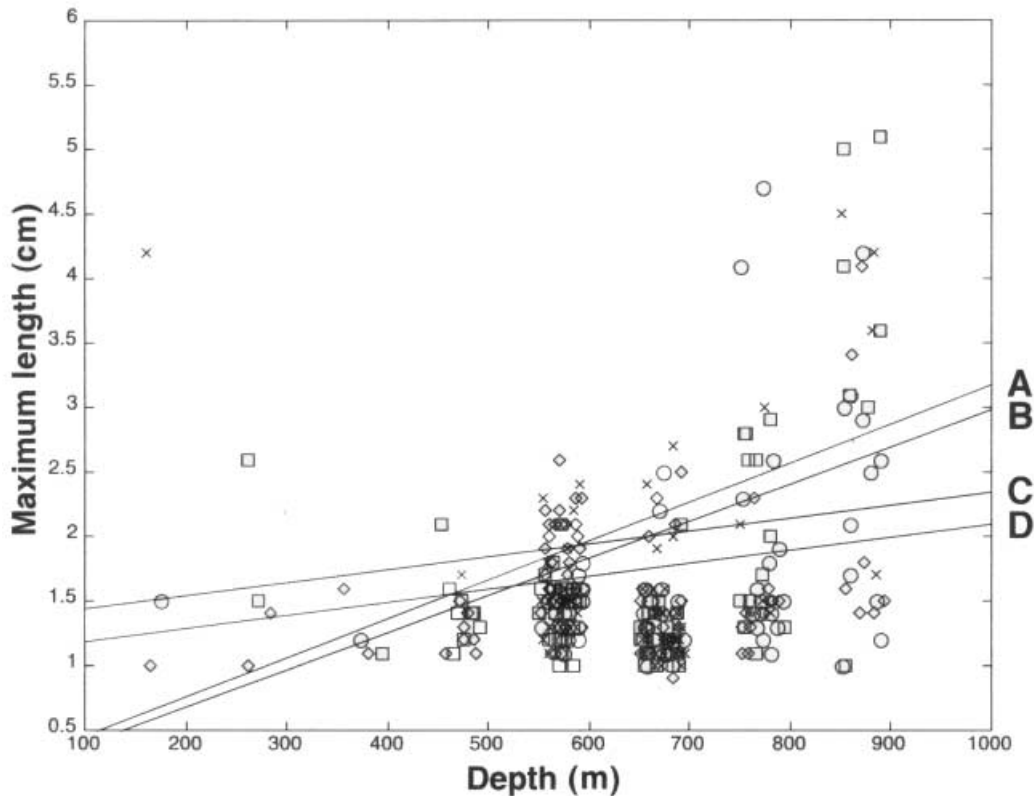


**Figure 2.** Length as a function of depth for *Cyclothone pallida* collected by MOCNESS. Regression lines are shown for individual tows. (A) Site 2, night (□); (B) Site 1, day (○); (C) Site 1, night (×); (D) Site 2, day (◇). See Table 1 for station data and Table 2 for regression equations and their statistics.

**Table 2.** *Regression equations and statistics for size−depth relationships shown in Figure 2, and an analysis of covariance for the slopes.*

| Sample | Equation | Regression | | | ANCOVA | | |
|---|---|---|---|---|---|---|---|
| | | df | $r^2$ | F | Test | df | F |
| Site 1, day | y=0.090+0.002x | 1,73 | 0.180 | 15.537** | Site | 1,286 | 0.049ns |
| Site 1, night | y=1.339+0.001x | 1,54 | 0.006 | 0.326ns | | | |
| Site 2, day | y=1.086+0.001x | 1,90 | 0.047 | 4.372* | Time | 1,286 | 0.673ns |
| Site 2, night | y=−0.158+0.003x | 1,74 | 0.220 | 20.337** | | | |

*, significance at α=0.05; **, significance at α=0.001.

## DISCUSSION

Despite the statistical consistency of size patterns detected, several possible sources of error should be recognized. First, no samples were taken from the surface to 100 m. It may be that individuals were migrating into this upper 100 m layer and were beyond our detection. However, this seems unlikely because peaks in the 500–700 m range (Figure 1) did not decline in numbers, which would suggest a migrating assemblage. It is possible that bristlemouths do not migrate when we sampled, but do in other seasons. Second, sequential sampling may not have captured patchiness in distributions. However, the fact that abundance/depth patterns are so consistent in space and time suggests this is probably not the case. Finally, it is recognized that these results represent a series of observations, and that verifying and fully understanding these patterns would require comprehensive and replicated sampling design that also included for the effects of lunar cycles, cloud cover, and seasonality.

The causes of these patterns are speculative. The gonostomatids are characterized by numerous small teeth and gill rakers that allow them to capture a wide variety of different prey sizes. This generalist feeding adaptation may be responsible for their success (Moyle & Cech, 1982). Migration may be unnecessary because individuals do not need to follow one particular food source. Migration patterns in fish may be linked to predator avoidance (Ohman et al., 1983; Gliwicz, 1986; Frost, 1988). Larger individuals are more abundant as depth increases below the euphotic zone; however, juveniles are found throughout the depth range sampled (Figure 2). This difference in depth distribution between the translucent juveniles and pigmented adults may result from juveniles being less conspicuous to predators at all depths, but adults realizing an escape from predators in deeper water. The consistent size–depth pattern and the apparent lack of diel migration may result from ontogenetic changes in colour and avoidance of visual predators.

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