

VERTICAL AND SEASONAL DISTRIBUTION OF PELAGIC CEPHALOPODS  
IN THE MEDITERRANEAN SEA. PRELIMINARY REPORT.

Clyde F. E. Roper\*

Although benthic and neritic cephalopods of the Mediterranean Sea have been studied since Aristotle first observed *Octopus* behavior, the pelagic forms have received very little attention. The Mediterranean Biological Studies Program of the Smithsonian Institution, an outgrowth of the Ocean Acre Program in the Sargasso Sea (see Gibbs and Roper, 1970; Gibbs *et al.*, 1971), provided the opportunity to study in detail the midwater macrofauna with particular emphasis on diel vertical distribution of species and their seasonal and geographical variation in occurrence and abundance. The precision and detail required for collecting specimens for such a study was achieved through use of a net-closing device, the discrete-depth cod-end sampler, rigged to a 3 m Isaacs-Kidd Midwater Trawl (IKMT) (Aron *et al.*, 1964). This instrument permits collecting of three replicate samples at any desired depth during a single lowering of the trawl. The closing devices are actuated from shipboard through use of a multiconductor towing warp; monitoring of depth of net and ambient temperature permits precise placement and control of the fishing depth of the trawl during each tow.

Five localities were selected as collecting stations (Figure 1) and were sampled during the summer of 1970 and the winter of 1972. The sampling regime consisted of IKMT discrete-depth tows both day and night at 50, 100, 150, 200, 300, 400, 500, 600, 800 and 1000 meters and neuston tows at the surface. Sampling at all depths for all stations was not possible to complete because of lack of time. Station I was not sampled in winter. Station data are presented elsewhere (Gibbs, 1972).

During the two cruises a total of 591 cephalopods, representing 21 species, was captured: 362 specimens representing 15 species in summer; 229 specimens representing 17 species in winter. A total of 760.2 hours was spent in trawling; trawling time was about equally divided between the two cruises (summer: 368.1 hrs; winter: 392.1 hrs). All species captured were members of the North Atlantic fauna, so no endemic component of the Mediterranean fauna is represented. A preliminary report on the cephalopods

taken during the summer cruise has appeared (Roper, 1972).

Limited space precludes a detailed report of all species here so the results for four species will be discussed as examples of the types of vertical and seasonal distributions exhibited by pelagic cephalopods in the Mediterranean. A more comprehensive account will be published elsewhere. All day and night closing-net and neuston net captures have been standardized for analysis of vertical distribution to number of specimens captured per hour of trawling (spec./hr) at any given depth. In the consideration of vertical distribution, specimens captured within 1 hour before or after sunrise or sunset were eliminated because these are the primary hours during which active vertical movements take place. In order to access the seasonal abundance and distribution all captures at each station were analyzed, e.g. discrete, oblique, open-net, neuston net and twilight-captured specimens.

SUMMARY OF RESULTS

1. Fourteen discrete specimens of *Heteroteuthis dispar*, a small sepiolid squid, were captured in summer during daytime over a range of 150-500 m at an average rate of capture of 1.7 (range 1.0-7.0) specimens per hour of trawling; 64% of the sample population was concentrated in a narrow band at 400-425 m. At night an average of 2.5 (1.0-5.3) spec./hr (30 discrete specimens) was captured between 25 and 300 m, with 81% of the sample concentrated at 25-100 m. Therefore, in the summer *H. dispar* in the Mediterranean appears to undergo a diel vertical shift where the "center" of the population moves vertically about 350 m during the morning and evening crepuscular periods. The vertical range is broad and a 150 m overlap of the day and night distributions occurs. In winter two specimens (average of 0.8 (0.7-1.0) spec./hr) were captured in the closing net during the day at 500 and 525 m. At night an average of 3.8 (1.0-6.6) spec./hr (8 specimens) was taken at 25-200 m, 90% of them at 25-100 m. Although data are less complete for winter it seems likely that a vertical shift similar to that of summer occurs. An average of 1.2 spec./hr (3 spec., one from an open net) was caught in less than 75 m in winter, while 2.7 spec./hr (29 spec.) were captured in less than 75 m in the summer.

\*Division of Mollusks, National Museum of Natural History, Smithsonian Institution, Washington, DC 20560

The determination of seasonal occurrence and relative abundance at each station utilizes all specimens captured by all gear, the result recorded as total number of specimens per hour of trawling (tot. spec./hr). The results are presented in Table I.

*H. dispar* was absent from station 1 in summer but occurred in about equal numbers at stations 2 and 3. While the species appears to be absent from station 4, fishing effort there may have been too low to pick up specimens in low abundance. Station 5, with greater effort, yielded a low rate of abundance. In winter *H. dispar* was entirely absent from stations 2 and 3 (station 1 was not sampled) but was present in equal abundance at stations 4 and 5. *H. dispar* was significantly more abundant at station 5 in winter than in summer. The absence of *H. dispar* in the northern Balearic (station 2) and Tyrrhenian (station 3) Seas in winter and in the Ionian (station 4) and Levantine (station 5) Seas in summer may indicate a seasonal shift of the population toward the eastern basins in wintertime.

2. *Pyroteuthis margaritifera*, a known strong diel vertical migrator, was represented by 22 specimens captured in the closing net. In the summer during the day an average of 1.0 (1.0-1.0) specimens per hour (4 specimens) was captured between 400 and 600 m, with 50% concentrated at 400 m. At night an average of 1.4 spec./hr (1.0-2.0) (8 specimens) was captured between 50 and 250 m with 75% of the sample population concentrated at 150-200 m. In summertime a strong diel migration is indicated that may extend over a vertical distance of 150-550 m. In winter an average of 4.0 spec./hr (4.0) (4 specimens) was captured at 400 m during daytime, while at night an average of 1.3 spec./hr (1.0-2.0) (4 specimens) was taken at 75-375 m, with 50% at 75 m. Although a diel vertical migration does occur during winter, too few data points are available for a complete description to be made.

*P. margaritifera* was absent from stations 1, 2, and 4 during summer; it was present at stations 3 and 5 in concentrations of 0.13 and 0.03 total specimens per hour respectively. Although the greatest trawling effort was at stations 3 and 5, stations 1 and 2 were adequately sampled; very little trawling was done at station 4, so the apparent absence of *P. margaritifera* may not be real. In winter, no specimens of *P. margaritifera* were captured at stations 2 and 3, but the species did occur in about equal abundance at stations 4 and 5. *P. margaritifera* appears to exhibit an eastward shift of the population in winter, leaving the summertime center of abundance in the Tyrrhenian Sea (station 3) entirely devoid of specimens in winter. The relative abundance of *P. margaritifera* in winter is about three-fifths that of summer.

3. A total of 31 specimens of *Ctenopteryx sicula* was captured in closing nets, 23 in summer and 8 in winter. In summertime during the day 7 specimens were captured at an average rate of 1.7 specimens per

hour (1.0-3.0) over a range of 100-150 m. At night 8 specimens were taken at an average of 2.7 spec./hr (1.0-4.0) at 50-150 m, with 88% taken at 50-100 m. The 8 additional specimens captured during twilight were caught at an average of 3.2 spec./hr (1.0-6.0) at 25-100 m with the center of abundance at 50-100 m. In winter an average of 2.1 (1.0-4.0) spec./hr (8 specimens) was captured at night at 50-100 m with a peak of abundance (75%) at 50-75 m. No captures were made during the day. At present it is uncertain if *C. sicula* is a vertical migrator, because, while the data show an apparent limited ascent at night to 25-100 m from 100-150 m, daytime sampling at less than 100 m was minimal.

*C. sicula* was present in equally low abundance in the summer at stations 1 and 2, while a 10-fold increase occurred at station 3, the center of abundance in summertime (Table I). No specimens were taken at stations 4 and 5. In winter the center of abundance occurred at station 4 where captures were slightly greater than the summertime abundance at station 3. No material was taken at station 2; the catches at stations 3 and 5 were negligible. Therefore, the center of abundance of *C. sicula* appears to shift from the Tyrrhenian Sea in the summer eastward to the Ionian Sea in winter.

4. *Onychoteuthis banksi*, the most abundant cephalopod captured during the Mediterranean studies, was also the only cephalopod that was captured at every station both summer and winter. A total of 104 specimens was captured in the closing net, 84 in the summer and 20 in the winter. In the summer during the day an average rate of capture of 1.7 specimens per hour (0.8-5.0) was made between 50 and 800 m; 46% of the captures was concentrated at 50-100 m and 38% at 750 m. At night an average catch of 4.5 spec./hr (0.8-24.0) was attained between 0 and 300 m, with only one capture at 300 m and the rest at 100 m or less; 49% of the captures occurred at 50 m and 37% at 100 m. In the winter an average of 1.2 spec./hr (1.0-1.3) was captured during the day, one specimen each at 75 m and 375 m. At night during the winter an average of 4.1 spec./hr (1.0-12.0) was taken between 0 m and 150 m; 83% of the captures was concentrated at 25-75 m (50% at 25 m).

*O. banksi* clearly has a broad vertical range, particularly during the daytime (summer), but heaviest concentrations occur in the upper 100 m both day and night. The range is more restricted at night when nearly the entire population occurs at 25-100 m. As strong, active swimmers the larger juveniles and the adults are able to make occasional excursions to depths of 600-800 m during the day, apparently returning toward the surface waters at night. Winter captures, less numerous than those of summer, occur over a more restricted range of depths (0 - 375 m).

*O. banksi* was present at all 5 stations during the summer, with maximum abundance at station 3,

followed by station 2; it was least abundant at station 1 (Table I). In winter the center of abundance of the sample population occurred at station 4 where the species was three times more abundant than at station 3. Captures at stations 2 and 5 were very low.

*O. banksi*, therefore, is distributed throughout the area of study both summer and winter, but is concentrated in the central basins. The site of greatest abundance occurs in the Tyrrhenian Sea (station 3) in summer and shifts eastward to the Ionian Sea (station 4) in winter.

#### SUMMARY

The cephalopods collected during the Mediterranean Biological Studies Program exhibit several different types of diel vertical distributions, four of which are: 1) *Heteroteuthis dispar* shifts up toward the surface at night but retains a significant zone of overlap of day and night distributions. 2) *Pyroteuthis margaritifera* exhibits strong diel vertical movements of at least 200-500 m in extent with no overlap. 3) *Onychoteuthis banksi* is distributed

broadly throughout the water column to about 800 m but is concentrated in the upper 100 m. 4) *Ctenopteryx sicula* is very restricted in vertical range, limited to the upper 150 m.

Seasonal differences also occur. In general, relative abundance of a species is considerably lower in winter than in summer. A general trend exists for the displacement of the bulk of the population of each species toward the eastern basins in wintertime. Station 3 was most productive in the summer, while station 4 was most productive in the winter.

#### Acknowledgements

I wish to thank the following for support during the Mediterranean Biological Studies Program: biologists of the Smithsonian Institution, University of Rhode Island, Naval Oceanographic Office, (Washington) and Underwater Systems Center (New London); Office of Naval Research (Contract No. N00014-67-A-399-0007); officers and crew of the research vessels TRIDENT and SANDS. I am especially grateful to M. J. Sweeney and R. D. Gatton for preparing specimens and data for analysis.

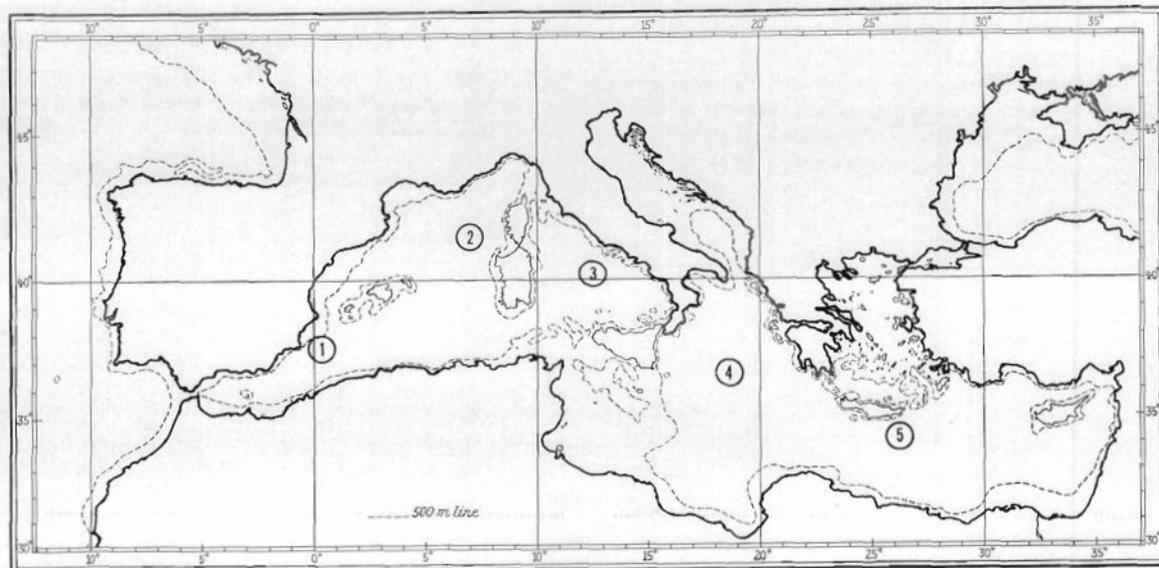


Figure 1. Location of collecting stations in the Mediterranean Sea.

TABLE I. Total number of specimens captured per hour of trawling (all sampling devices included).

| Station No.   | <i>H. dispar</i> | <i>P. margaritifera</i> | <i>O. banksi</i> | <i>C. sicula</i> |
|---------------|------------------|-------------------------|------------------|------------------|
| <b>Summer</b> |                  |                         |                  |                  |
| 1.            | 0.00             | 0.00                    | 0.06             | 0.02             |
| 2.            | 0.36             | 0.00                    | 0.36             | 0.02             |
| 3.            | 0.34             | 0.13                    | 0.52             | 0.20             |
| 4.            | 0.00             | 0.00                    | 0.26             | 0.00             |
| 5.            | 0.02             | 0.03                    | 0.15             | 0.00             |
| TOTAL AVERAGE | 0.21             | 0.05                    | 0.32             | 0.07             |
| <b>Winter</b> |                  |                         |                  |                  |
| 1.            | Not Sampled      |                         |                  |                  |
| 2.            | 0.00             | 0.00                    | 0.00+            | 0.00             |
| 3.            | 0.00             | 0.00                    | 0.13             | 0.01             |
| 4.            | 0.11             | 0.11                    | 0.42             | 0.21             |
| 5.            | 0.11             | 0.09                    | 0.02             | 0.00+            |
| TOTAL AVERAGE | 0.04             | 0.03                    | 0.07             | 0.02             |

+Fewer than 0.01 spec./hr.

## LITERATURE CITED

- Aron, W., N. Raxter, R. Noel, and W. Andrews. 1964. A description of a discrete depth plankton sampler with some notes on the towing behavior of a 6-foot Isaacs-Kidd midwater trawl and a one-meter ring net. *Limnol. and Oceanog.* 9 (3), pp. 324-333.
- Gibbs, R. H., Jr. 1972. Mediterranean Biological Studies. Part 1. Gear, sampling methods, and biological sample processing. Smithsonian Inst. Rep. July, 1972, 1, pp. 5-25.
- Gibbs, R. H., Jr. and C. F. E. Roper. 1971. Ocean Acre: preliminary report on vertical distributions of fishes and cephalopods. *In* Proceedings of an International Symposium on Biological Sound Scattering in the Ocean. U.S. Navy, Maury Center Report 005, pp. 120-135.
- Gibbs, R. H., Jr., C. F. E. Roper, D. W. Brown, and R. H. Goodyear. 1971. Biological studies of the Bermuda Ocean Acre. I. Station data, methods, and equipment for cruises 1 through 11, October, 1967 — January, 1971. Smithsonian Inst. Rep. September, 1971, 49 pp., 14 figs.
- Roper, C. F. E. 1972. Mediterranean Biological Studies. Part 5. Ecology and vertical distribution of Mediterranean pelagic cephalopods. Smithsonian Inst. Rep. July, 1972, 1, pp. 282-346.