GENERAL PATTERNS IN THE SUMMER DISTRIBUTION OF EARLY JUVENILE OMMASTREPHID SQUID OFF EASTERN AUSTRALIA (MOLLUSCA, CEPHALOPODA)

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CEPHALOPODA
OMMASTREPHIDAE
LARVAL SQUID
EASTERN AUSTRALIA
DISTRIBUTION

ABSTRACT. — Larval squid were sampled in three surveys off the eastern Australian coast in January, March and May 1983. Ommastrephid larvae were abundant and occurred at over 90 % of stations. Although identification to species level has not so far been possible for the majority of specimens, general patterns of distribution with respect to latitude and bottom depth are presented.

CEPHALOPODA
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RÉSUMÉ. — De jeunes Céphalopodes planctoniques ont été échantillonnés au large de la côte Est de l'Australie en janvier, mars et mai 1983. Les « larves » d'Ommastréphidés étaient abondantes et présentes dans plus de 90 % des stations. Bien que l'identification des spécimens au niveau de l'espèce n'ait pas été possible jusqu'ici, du moins pour la majorité des individus récoltés, quelques aspects généraux de la distribution des animaux en relation avec la latitude et la profondeur peuvent être dégagés.

INTRODUCTION

Eleven species of the commercially important squid family Ommastrephidae are known to occur off the eastern Australian coast (Nesis, 1979; Okutani, 1980; Lu & Dunning, 1982; Dunning & Brandt, 1985; Dunning, In Prep.). While the distribution and relative abundance of adults are now relatively well known, few studies have been directed at larval and early juvenile stages of these species in Australia waters.

Pelagic cephalopods collected by opportunistic plankton tows between the southern Great Barrier Reef and southeast Tasmania were described by Allan (1945). Ommastrephid larvae and early juveniles were outnumbered in the small collection only by "*Pyrgopsis pacificus* (Issel)" [probably *Leachia* spp.] and all were referred to the only ommastrephid species known from the east coast at that time, *Nototodarus gouldi* (McCoy, 1888). Because of the limited size of the collection, geographic and seasonal distribution patterns could not be described.

The study described here aimed to obtain preliminary information on the relative abundance of larval ommastrephid squid across the continental shelf and slope off central eastern Australia and to assess any changes in relative abundance with latitude and at different times during the summer. Because this area is dominated by a western boundary current, water mass associations were also expected to be important and detailed hydrographic information was sought.

Broad distributional patterns for species groups only are presented here; detailed species distributional patterns require identification of small larvae to lower taxonomic units than has so far been possible with this collection.

METHODS

Early juvenile cephalopods were collected during three eight-day surveys undertaken between 28° and 34°S off the eastern Australia coast in January, March and May 1983 (Fig. 1). Eight sampling stations were located along transects roughly perpendicular to the continental slope at each degree of latitude nominally at bottom depths of 50, 100, 200, 400, 1 000 and 2 000 metres and at stations 5 and 10 nautical miles east of the 2 000 m station. Concurrent 30 minute surface tows using 500 µm 50 cm paired Bongo nets and double oblique tows using a 500 µm 1 m bridleless larval tuna net (FAO, 1966) were undertaken at each station. Nominal towing speed was 1.5 m sec^{-1} (3 knots) with oblique tows to 150 m where bottom depths exceeded 200 m and to 10 m above the bottom in shallower water. Catches were standardized to numbers per 1 000 m^3 using Rigosha flowmeter counts from each net.

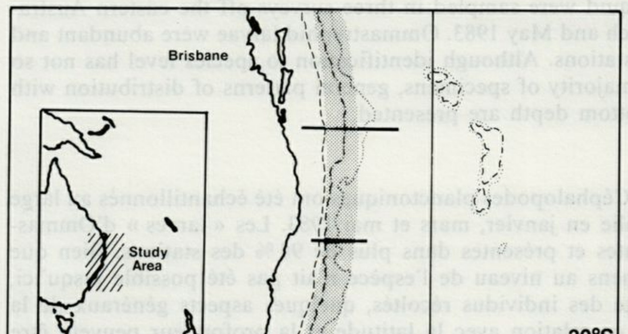


Fig. 1. — Study area showing the East Australian Current and the transects along each degree of latitude.

Unless otherwise indicated, standardized values are used throughout this paper.

Sampling was undertaken on each occasion from south to north to counter the possibility of towing in the same water mass in the southward flowing current. On transects at 34°, 32°, 30° and 28°S on the January and March surveys, paired day and night samples were taken at each of the eight stations during the same 24 hour period. Information on temperature, salinity, phosphates, nitrates, silicates and oxygen along each transect was obtained using expendable bathythermographs and a Neil Brown CTD with rosette sampler.

Larval ommastrephid squid are characterized by the fusion of the tentacles into a proboscis, persisting from hatching to "metamorphosis" at between 5 and 10 mm ML. Further identification was undertaken using the following characters :

1) the diameter of the lateral suckers on the proboscis tip;

2) the location and size of light organs on the ventral surface of the eyes and intestine;

3) the length of the proboscis relative to mantle length until the commencement of splitting to form the tentacles;

4) the length of the tentacles just prior to splitting relative to longest arm length.

Larvae with mantle lengths greater than 4 mm could generally be identified at least to genus using the above characters. However, the vast majority of the specimens collected during the study were less than 3 mm ML and these specimens have been separated into three major species groups as shown in the following table :

	Sucker diameters	Proboscis length	Species included
Group 1	≠	⩾ ML	*Ommastrephes bartrami* *Ornithoteuthis volatilis* *Nototodarus hawaiiensis*
Group 2	=	⩾ ML	*Sthenoteuhis spp.*
Group 3	=	⩽ ML	*Eucleotheuthis luminosa* *Nototodarus gouldi* *Todaropsis eblanae* *Todarodes pacificus*

Larvae of *Todarodes filippovae* would fall into Group 3 morphologically but the known distribution of mature adults (Dunning & Brandt, 1985) makes it unlikely that this species is represented in the collections. No specimens of *Hyaloteuthis pelagica* (which have light organs present on the eyes and intestine from 1.5 mm [Harman & Young, 1985, this vol.]) were represented among the specimens less than 3 mm ML.

RESULTS

Oceanographic patterns

Throughout the sampling period, the area was dominated by the East Australian Current (EAC) (Hamon, 1965; Boland & Church, 1981), carrying tropical Coral Sea water southward along the offshore edge of the continental shelf to a point between 31° and 32°S where it turned eastward to form the Tasman Front (Stanton, 1981). During the January and March surveys, the EAC was evident at the slope as far south as 32° but in May, had moved away from the slope just to the north of 31°S. A temperature profile throught the current at 32°S in March is shown in figure 2. Anticyclonic warm core 'eddies' pinched off from the EAC often occur south of 32°S but were not encountered during the sampling period in the area surveyed.

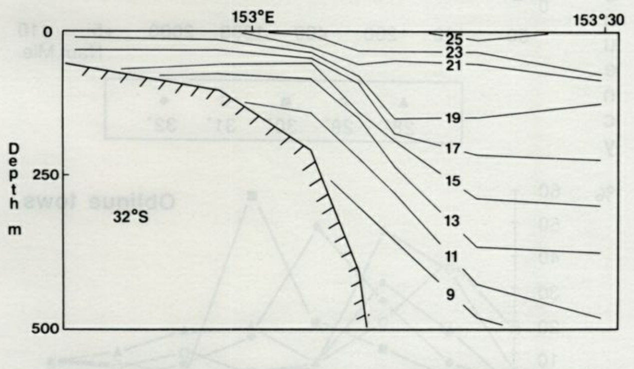


Fig. 2. — Temperature profile through the EAC at 32 °S, March 1983.

Surface currents were strongest in all three surveys at the edge of the continental shelf (400-1 000 m bottom depth) and decreased in velocity both shoreward and seaward. These southerly currents as measured by ship's drift reached 1.6 m sec^{-1} in January at 33°S, 2.05 m sec^{-1} in March at 31°S and 1.35 m sec^{-1} in May at 30°S. Between 30° and 32°S, especially during January, surface currents recorded at 50 and 100 m depth stations were typically northwest to northward at less than 0.5 m sec^{-1}.

Surface water temperatures varied by approximately 6 °C from north to south during each survey, with the major change at the temperature front to the south of the EAC at the point where it turned east. In March, a change of 4.7 °C was recorded over 1 nautical mile at the shelf edge at 32°S. The highest temperature recorded was 26.9 °C at the shelf edge at 28°S in March and the lowest, 19.6 °C on the shelf at 32°S in March.

Seasonal and latitudinal distribution of larvae

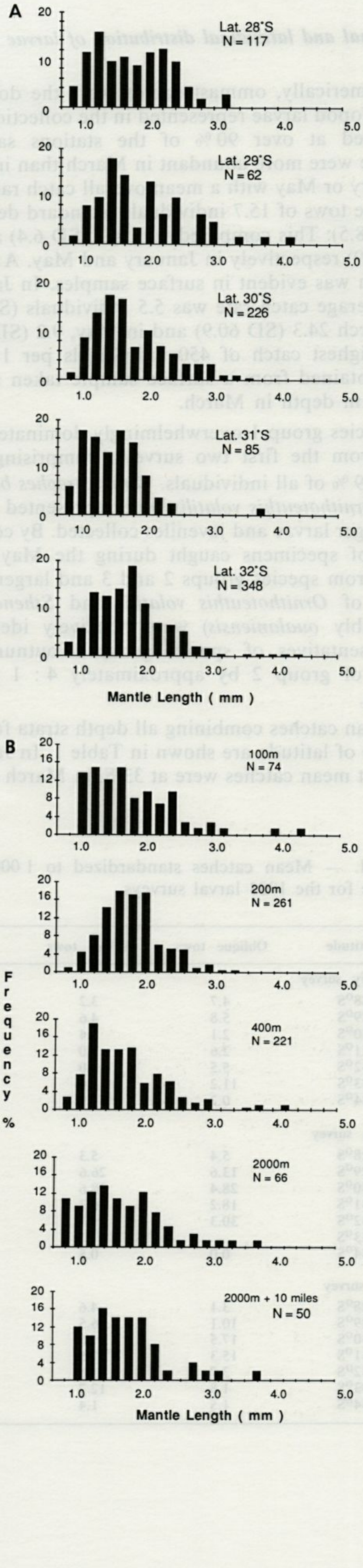
Numerically, ommastrephids were the dominant cephalopod larvae represented in the collections and occurred at over 90 % of the stations sampled. Larvae were more abundant in March than in either January or May with a mean overall catch rate from oblique tows of 15.7 individuals (standard deviation [SD] 28.5). This compared with 4.3 (SD 6.4) and 7.5 (SD 8.9) respectively in January and May. A similar pattern was evident in surface samples. In January, the average catch rate was 5.5 individuals (SD 8.4), in March 24.3 (SD 60.9) and in May, 9.2 (SD 13.9). The highest catch of 450 individuals per 1 000 m^3 was obtained from a surface sample taken at 32°S in 100 m depth in March.

Species group 1 overwhelmingly dominated samples from the first two surveys, comprising more than 99 % of all individuals. *Ommastrephes bartrami* and *Ornithoteuthis volatilis* were represented among the larger larvae and juveniles collected. By contrast, 44 % of specimens caught during the May cruise were from species groups 2 and 3 and larger specimens of *Ornithoteuthis volatilis* and *Sthenoteuthis* (probably *oualaniensis*) were positively identified. Representatives of species group 3 outnumbered those of group 2 by approximately 4 : 1 in this survey.

Mean catches combining all depth strata for each degree of latitude are shown in Table 1. In January, highest mean catches were at 33°S, in March at 32°S

Table I. — Mean catches standardized to 1 000 m^3 by latitude for the 1983 larval surveys.

Latitude	Oblique tows	Surface tows	Total
January survey			
28°S	4.7	3.2	4.0
29°S	5.8	4.6	5.2
30°S	2.1	1.4	1.7
31°S	2.6	2.0	2.3
32°S	5.5	11.0	8.3
33°S	11.2	18.0	14.6
34°S	0.7	2.9	1.8
March survey			
28°S	5.4	5.3	5.4
29°S	13.6	26.6	20.1
30°S	28.4	28.6	28.5
31°S	18.2	30.3	24.2
32°S	30.3	55.7	43.0
33°S	—	—	—
34°S	0.0	0.5	0.2
May survey			
28°S	3.1	4.6	3.9
29°S	10.1	6.5	8.3
30°S	17.5	21.6	19.6
31°S	15.3	17.5	16.4
32°S	3.7	1.1	2.4
33°S	1.8	12.7	7.2
34°S	1.5	1.4	1.4



and in May at 30°S. Lowest catches in all surveys were taken at 34°S.

For the March survey, size distribution along the latitudinal gradient was examined. Figure 3 A shows a possible indication of larger larvae north of 30°S. Larvae of 1.0 mm ML and less, sizes close to that at hatching for several ommastrephids, occurred throughout the area from 28° to 33°S during all surveys.

Distribution with respect to bottom depth

Larval abundance with respect to eight bottom depth strata was examined for the March survey.

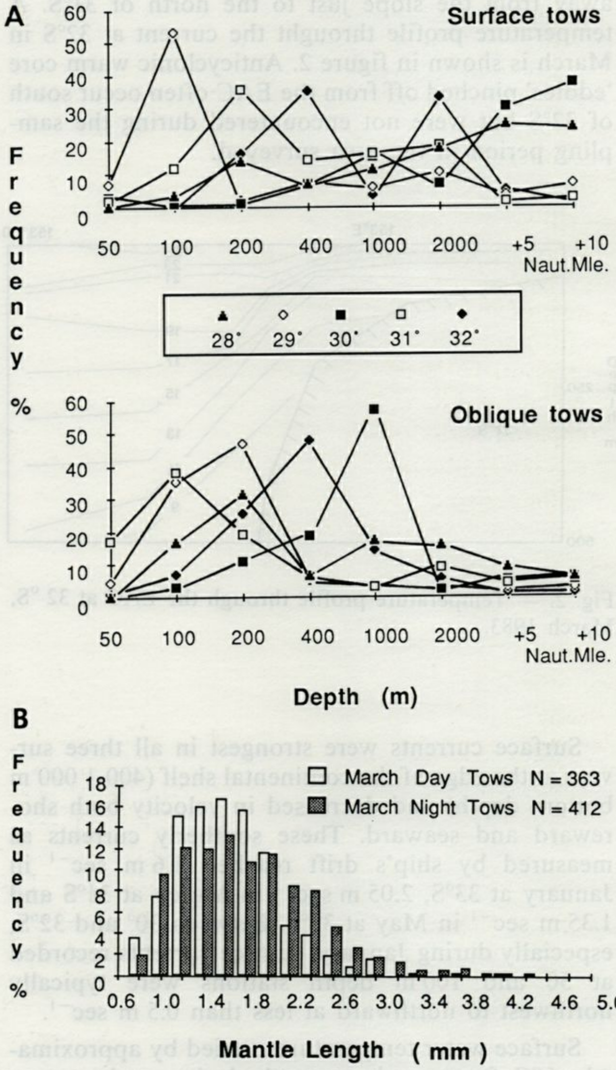


Fig. 4. — A, Larval abundance in relation to bottom depth, surface and oblique tows, March 1983; B, Size distribution, day and night oblique tows, March 1983.

Fig. 3. — A, Size distribution of larvae in relation to latitude, oblique tows, March 1983. B, Size distribution in relation to bottom depth, oblique tows, March 1983.

Figure 4 A shows that although the pattern for each transect differs, catches were generally lower in oblique tows over depths greater than 2 000 m in contrast to surface tows which sometimes showed higher catches here. Both showed low catches at 50 m stations.

A broad spectrum of size classes was present at all depth strata examined with no clear relationship between size and bottom depth at the sampling station (Fig. 3 B). At stations deeper than 1 000 m and at 100 m, there is a slight indication of a higher proportion of larvae smaller than 1.5 mm ML.

Day — night comparisons

Size distribution of all specimens collected during the day in March versus those caught at night is presented in Figure 4 B. The distribution of specimens caught at night shows a slightly higher proportion of larger size classes than does that for specimens from day samples suggesting that differential net avoidance may be occurring.

Of the 32 stations from all surveys where comparisons could be made for oblique tows, 14 showed day catches higher than night catches (44 %). Day catches exceeded night catches in 7 of 23 surface tow comparisons (30 %). Day surface tows were less successful in January yielding higher catches than the comparable night tow on only 9 % of occasions compared with 50 % in March. Day tows were not undertaken in May.

Comparisons of mean catches for day and night samples from both the January and March surveys are shown below :

Survey	Oblique		Surface	
	Day	Night	Day	Night
January	2.07	5.2	1.3	6.8
March	15.1	15.5	30.9 (9.9*)	20.5

* Mean if catch of 450 individuals taken at the 100 m station is excluded.

DISCUSSION

Ommastrephid squid larvae were abundant and broadly distributed in East Australian Current waters from midsummer to early autumn but were less abundant in shelf and slope waters immediately to the south of the point where the current turns east (generally at or about 32°S near the shelf edge). Catches, both from surface and oblique tows were higher in March than in either January or May, corresponding to times of highest surface water temperatures and current velocities.

Larval ommastrephids were caught at more stations and in greater abundance in this study than reported by Sato (1973), Yamamoto & Hamada (1981) and Matsuda et al. (1972) for waters between Taiwan and southern Japan where similar ommastrephid species assemblages are present. Using 2 m nets, Matsuda *et al.* (1972) collected larvae at 31.5 % of stations sampled. A mean catch from midlayer tows of approximately 2.9 individuals was obtained and a maximum of 19 per 1 000 m^3 collected compared with 14.4 and 450 in this study.

In the western Arabian Sea in an area of significant upwelling, Nesis (1974) obtained ommastrephid larvae (83 % *Sthenoteuthis*) at less than 54 % of stations sampled compared with more than 90 % in this study. The mean catch rate was, however, higher than obtained from eastern Australian waters — 16.6 per 1 000 m^3 compared with a maximum of 15.7 for oblique samples taken in March 1983.

Little difference was evident in the size distribution of larvae caught in March either latitudinally or across the shelf from 50 m depth to 10 nautical miles east of the 2 000 m bottom depth contour. Larvae close to the expected size at hatching were evident throughout the EAC area in all surveys.

Significantly more ommastrephid larvae were caught at night than during the day in both surface and oblique tows during the January and March surveys. Diel vertical migration is unlikely to be a major contributing factor to this difference at stations in depths of less than 200 m where tows sample the entire water column. Evidence from other studies (Nesis, 1977; Nesis & Nigmatullin, 1979) suggests that even in deeper water, larval and early juvenile ommastrephids are predominantly found in the upper 200 m. Together with the difference in size composition between day and night samples observed, these data suggest that larval squid even at these small sizes are able to avoid plankton nets.

Available information on the seasonal and geographic distribution of juveniles and mature adults from the region is limited (Dunning & Brandt, 1985) and provides little corroboration of tentative identifications. Mature adults and small juveniles of *Ommastrephes, Sthenoteuthis oualaniensis, Ornithoteuthis, Hyaloteuthis* and *Eucleoteuthis* together with mature adults of *Nototodarus hawaiiensis and N. gouldi, Sthenoteuthis* sp., *Todaropsis* and *Todarodes pacificus* have been recorded between 27° and 35°S during March and April in previous years and many appear to have extended spawning seasons in east coast waters. The presence of juvenile specimens in all bimonthly trawl samples from off the northwest Australian coast in 1982-83 suggests that the population of *N. hawaiiensis* there spawns throughout the year (Dunning, in prep.) and this species may behave similarly off the east coast. In a series of 12 midwater trawl samples taken in late March 1981 in waters of from 200 to 800 m bottom depth near

34°30'S, juveniles of six genera were represented in the following abundances :

Ornithoteuthis....	279	*Sthenoteuthis....*	16
Eucleoteuthis......	32	*Hyaleuthis.......*	2
Ommastrephes....	24	*Todaropsis........*	1

If these genera are represented in similar relative abundances in the 1983 larval samples, it is probable that Group 1 is dominated by *Ornithoteuthis* larvae and Group 3 by *Eucleoteuthis luminosa* although *Nototodarus gouldi* may be more abundant in shallower shelf waters.

The larval species assemblage present in the 1983 summer catches changes late in the season with an increase in relative abundance of species groups 2 and 3. Combining positive identifications made from the material with the published data on adult and juvenile abundance, this change probably reflects an increase in the abundance of *Sthenoteuthis* spp., *Eucleoteuthis* and *N. gouldi* with group 1 species — *Ornithoteuthis, Ommastrephes* and perhaps *N. hawaiiensis* — increasing in abundance from January to March and then decreasing to a similar level in May as in January. Further clarification of species differences in larval abundance awaits identification of the 1983 collections to lower taxonomic levels than has so far been possible.

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