CSIRO
Division of Fisheries and Oceanography

REPORT 119

Observations on the Distribution of *Nyctiphanes australis* Sars (Crustacea, Euphausiidae) in Australian Waters

Maurice Blackburn

1980

COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION
DIVISION OF FISHERIES AND OCEANOGRAPHY
P.O. BOX 21, CRONULLA, NSW 2230

Reprint 1055

National Library of Australia Cataloguing-in-Publication Entry

Blackburn, Maurice.

Observations on the distribution of *Nyctiphanes australis* Sars (Crustacea, Euphausiidae) in Australian waters.

(Division of Fisheries and Oceanography report; no. 119)
Bibliography
ISBN 0 643 02569 3

1. *Nyctiphanes australis.* 2. Crustacea – Australia.
I. Title. (Series: Commonwealth Scientific and Industrial Research Organization. Division of Fisheries and Oceanography. Report; no. 119)

595.3'85'0994

Printed by CSIRO, Melbourne

80.144-600

OBSERVATIONS ON THE DISTRIBUTION OF *Nyctiphanes australis* SARS (CRUSTACEA, EUPHAUSIIDAE) IN AUSTRALIAN WATERS

Maurice Blackburn[1,2]

[1] Formerly of the Division of Fisheries and Oceanography, CSIRO, P.O. Box 21, Cronulla, NSW 2230.

[2] Present address: 741 Washington Way, Friday Harbor, Washington 98250, USA.

CSIRO Aust. Div. Fish. Oceanogr. Rep. 119 (1980)

Abstract

The range of *Nyctiphanes australis* in Australian waters is from 31° to 44°S latitude and 132° to 156°E longitude. It is abundant on most parts of the continental shelf and very scarce in deeper waters. Postlarvae, adolescents and adults are more abundant in the shelf water column by night than by day. They probably descend almost to the bottom in daytime and rise towards the surface at night. At certain seasons, particularly July-September off Victoria and Tasmania and February-April off New South Wales, they become relatively scarce in the upper water column even at night. This may be connected with reduced sexual activity at those periods. Another explanation, namely avoidance of high temperatures, could apply in New South Wales. During the season when *Nyctiphanes* migrate at night into the upper part of the water column over the shelf, their mean concentration there is about 5 m^{-3}. Extremely high concentrations can reach about 200 m^{-3}.

INTRODUCTION

The euphausiid crustacean *Nyctiphanes australis* Sars occurs in south-east Australian and New Zealand waters, where it is the only species of its genus. It is the principal euphausiid in the neritic (continental shelf) waters of south-eastern Australia, where other species are rare or absent (Sheard 1953; Blackburn 1957; Mauchline and Fisher 1969). *Nyctiphanes australis* eats diatoms, detritus including copepod faecal pellets, and copepods (Sheard 1953). It is an important food for several vertebrates of south-eastern Australian seas, including barracouta or snoek, *Thyrsites atun* (Blackburn 1957); southern bluefin tuna, *Thunnus thynnus maccoyii* (Serventy 1956); skipjack tuna, *Katsuwonus pelamis* (Blackburn and Serventy, unpublished data); Australian "salmon", *Arripis trutta* (Malcolm 1959); tiger flathead, *Neoplatycephalus macrodon* (Fairbridge 1951); and the short-tailed shearwater or mutton bird, *Puffinus tenuirostris* (Marshall and Serventy 1956).

Our knowledge of *Nyctiphanes* in Australian waters comes mainly from Sheard (1953), who was particularly concerned with its development and growth. His account of its distribution was incomplete. In 1952 I began a program of plankton collecting to obtain more information about the distribution of *N. australis*. The program was incomplete in several ways, especially because hauls could not be made at night in some areas. I was unable to continue the work after 1955. The data taken are now summarised here.

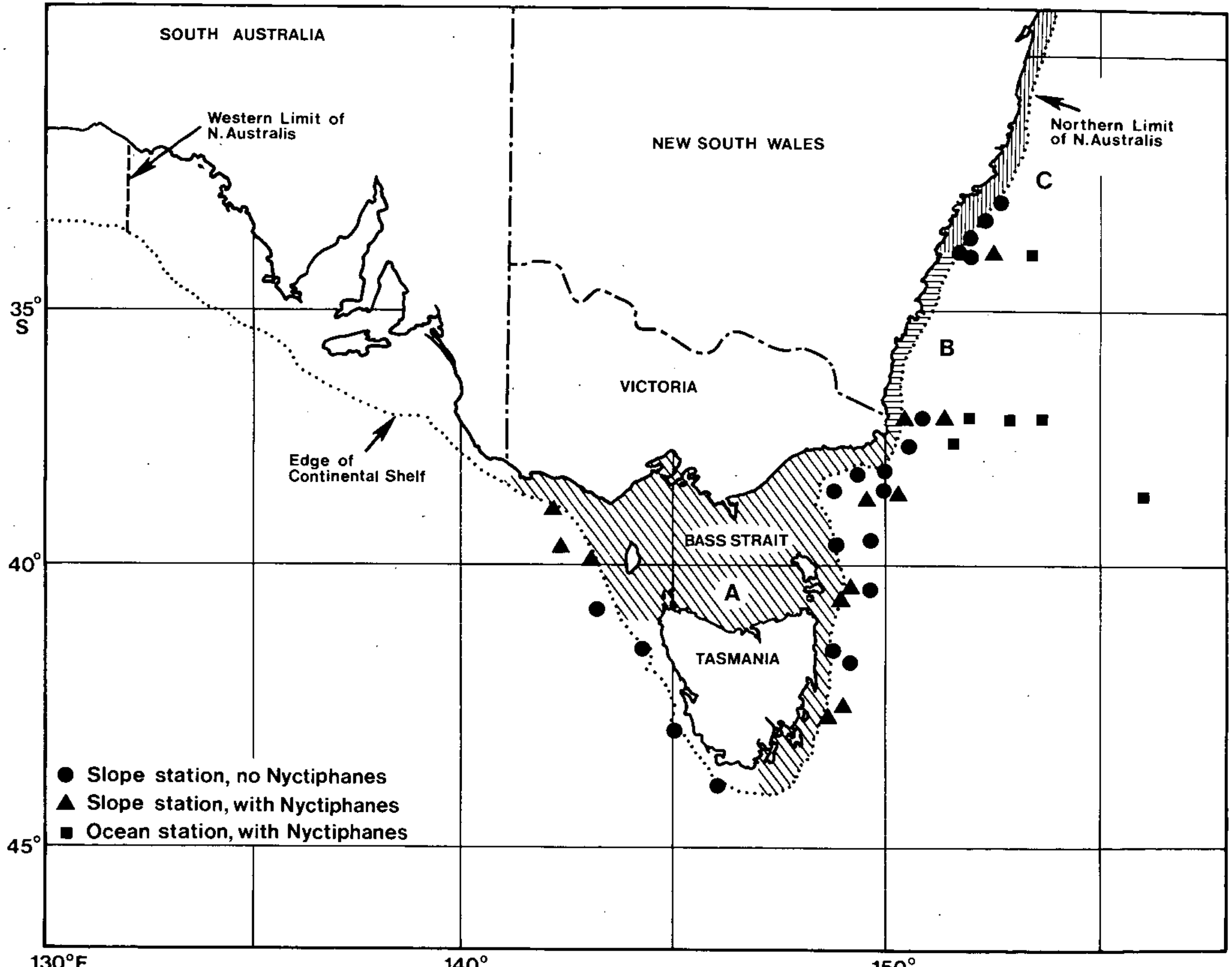

Fig. 1. South-eastern Australia, showing occurrences of *Nyctiphanes australis* discussed in text. Hatched areas A, B and C correspond to areas described in Table 1.

MATERIALS AND METHODS

This paper deals principally with numbers of *Nyctiphanes australis* counted from open vertical plankton hauls made on the continental shelf. Numbers from similar hauls in slope and ocean waters were much lower (zero in most hauls) and are mentioned only briefly. No other type of haul was routinely practicable with the facilities available.

The open vertical hauls were made with 'Discovery' N70V nets, constructed and used according to Kemp *et al.* (1929). Each haul was made in duplicate. Flowmeters were not used. In continental shelf waters the net was hauled from near the bottom to surface. The length of the net assembly from mouth to bottom sinker was about 4.4 m, so the practice was to pay out 5 m less wire than the depth of the water when lowering the mouth of the net below the sea surface. Thus the lowest 5 m of the water column was not sampled. The depth of the column that was sampled ranged from 20 to 110 m. Since the hauls were short and the vessel's freeboard low, wire angles were low even in rather rough weather. Hauls in continental slope and ocean waters were generally made from 100 m to surface and 500 m to surface.

Occasionally the closing mechanism of the N70V net was used to make separate hauls through the upper and lower halves of the water column on the shelf. Separate hauls were made also through 100 m sections of the column between 100 and 500 m at a few slope and ocean stations, but very few *Nyctiphanes* were taken. Closing-net hauls were not duplicated.

The few plankton hauls made on the continental shelf off South Australia during this study included some surface horizontal hauls as well as open vertical hauls. Further information is not required, because the observations on *Nyctiphanes* are used only to demonstrate its geographic range.

The data presented are on numbers of *Nyctiphanes* over 5 mm total length, measured from the front margin of the carapace to the rear of the telson (excluding telsonic spines) along the mid-dorsal line. This range of size includes postlarval, adolescent and adult stages, and excludes calyptopis and most furcilia stages (Sheard 1953). Measurements were made with an ocular micrometer. The largest specimen had a total length of 16 mm. The largest found in New Zealand by Bary (1956) measured 17 mm. All specimens over 5 mm in each entire plankton catch were counted. If another worker had removed an aliquot I scanned the remainder and increased my count proportionately.

The following groups of data are considered:

(1) Numbers of *Nyctiphanes* from 222 open vertical hauls, each made in duplicate, on the continental shelf off Victoria, northern Tasmania and eastern Tasmania (area A of Fig. 1). The approximate range of latitude in this area is 44° to 38°S. Results are given in Table 1. They cover the four quarters of the year (years 1952 to 1955 combined) and three diel periods. The diel periods are day (0800-1600), night (2000-0400) and crepuscular (0400-0800 and 1600-2000). This work was done from the CSIRO research vessel *Derwent Hunter*. The few hauls made on the shelf off western Tasmania are ignored here because they did not cover all quarters and periods, but some of the hauls were positive for *Nyctiphanes*.

(2) Numbers from 86 similar hauls, each made in duplicate on the continental shelf off New South Wales (areas B and C of Fig. 1). The approximate ranges of latitude are 37° to 34°S in area B (46 hauls) and 34° to 29°S in area C (40 hauls). The data are given in Table 1. They

Table 1. Number of *Nyctiphanes* taken in bottom-to-surface vertical hauls on the continental shelf, by time of day and season, data of the years 1952-55 combined. N, C and D stand respectively for night (2000-0400 hours), crepuscular (0400-0800 and 1600-2000) and day (0800-1600). Each *Nyctiphanes* number is the mean of numbers taken in duplicate hauls, with means such as n.5 rounded alternately to n+1 and n in each column. Numbers in parentheses are frequencies greater than 1 at which *Nyctiphanes* numbers occurred. Hauls means number of hauls (excluding duplicates) and mean is mean number of *Nyctiphanes* per haul

Area	July-Sept.			Oct.-Dec.			Jan.-Mar.			Apr.-June		
	N	C	D	N	C	D	N	C	D	N	C	D
A. Tasmania &	0(6)	0(8)	0(22)	0(4)	0(12)	0(12)	0(2)	0(7)	0(13)	0(4)	0(10)	0(20)
Victoria	1	2	1	2(2)	1(2)	1(4)	1	1(4)	1(2)	1(2)	1(5)	1(2)
(44°-38°S)	2(2)	19	3	3(2)	5	4	5(3)	2	3	2(2)	2(2)	2(2)
	3			4	7	6	6	5(2)	4	4	3	3
	4			5	17	11	9	8(2)	7	5	7	5
	11(2)			6			11	30		10	8	
	12			11			17	39		20	13	
	13			12			19			21	15	
	16			17			29			37	254	
				18			38			43		
				24						47		
				25						51		
				39						89		
				1325						275		
Hauls	16	10	24	19	17	19	13	18	18	19	23	26
Mean	4.7	2.1	0.2	78.7	1.8	1.3	11.2	5.6	0.9	32.0	13.4	0.5
B. New South			0(11)			0(5)			0(3)			0(22)
Wales			1						1			
(37°-34°S)			2						16			
			3									
Hauls			14			5			5			22
Mean			0.4			0.0			3.4			0.0
C. New South			0(10)			0(7)			0(8)			0(15)
Wales												
(34°-29°S)												
Hauls			10			7			8			15
Mean			0.0			0.0			0.0			0.0

cover the four quarters of the year (years 1952 to 1954 combined) but all are for the daytime period. The work was done from small vessels, hired for daytime work on other investigations.

(3) Numbers from closing vertical hauls through the upper and lower halves of the water column at 16 stations in area A. The data are given in Fig. 2. Similar hauls at an additional 21 stations yielded no *Nyctiphanes* from either half of the water column and are ignored here.

(4) Numbers from open vertical hauls made in slope and ocean waters as discussed above. These numbers are so small that they are not individually listed, but means per haul are given in the text. Figure 1 shows the 32 station positions at which hauls were made on the continental slope (5 to 40 nautical miles from the shelf edge), distinguishing those positions at which *Nyctiphanes* was taken. The number of slope stations was 65, since some positions were occupied on two or three separate occasions. An additional 98 stations were occupied farther offshore in ocean waters, in an area bounded approximately by 34°S, 156°E and 43°S. *Nyctiphanes* were found at only six of these stations, at positions shown in Fig. 1. Closing vertical hauls were made at a few of these slope and ocean stations.

Times given in this paper are local (Australian Eastern Standard Time).

RESULTS AND DISCUSSION

Distribution by Time of Day and Season

Data groups 1, 2 and 3 of Material and Methods, which all refer to continental shelf waters, are utilised here.

Inspection of the original data of Table 1, area A, showed that numbers of *Nyctiphanes* in duplicate hauls at the same station were generally low and not very different in the daytime, whereas they were higher and sometimes quite different at night. An analysis of variance was performed on the data for stations occupied in the diel period 2000-2400 and a similar one for the period 0000-0400, using stations and haul order as criteria of classification. Stations with zero numbers in both hauls were ignored. The remaining numbers were distributed more or less normally when transformed by adding 1 and taking logarithms, and the analysis was made on the transformed data.

Station differences were significant as expected ($P<0.01$). Haul order was significant at the period 2000-2400 ($P<0.01$) but not at 0000-0400. The difference at the former period was that the second haul usually contained more *Nyctiphanes* than the first. The most likely explanation is carryover of specimens from first to second haul, as a result of incomplete washing down of the net after the first haul. The persons who made hauls after midnight may have washed down more thoroughly. In subsequent work the arithmetic mean of the *Nyctiphanes* numbers in the duplicate hauls was used. Table 1 gives numbers of hauls made (excluding duplicates) and mean numbers of *Nyctiphanes* per haul (mean of the means for duplicates).

From these means for area A in Table 1, it is clear that abundance of *Nyctiphanes* in the sampled water column decreases from night to day and from warm to cold season. The means for each quarter-year are highest at night and lowest in the daytime, the latter ranging from 1.6 to 8.0 percent of the former. The means for each diel period are with one exception less in July-September, the coldest season, than in the other three seasons. The differences in such means between the three warmer seasons are of doubtful significance. Most of the variation would disappear if the three very high *Nyctiphanes* numbers (1325, 275 and 254) were ignored, although the altered means

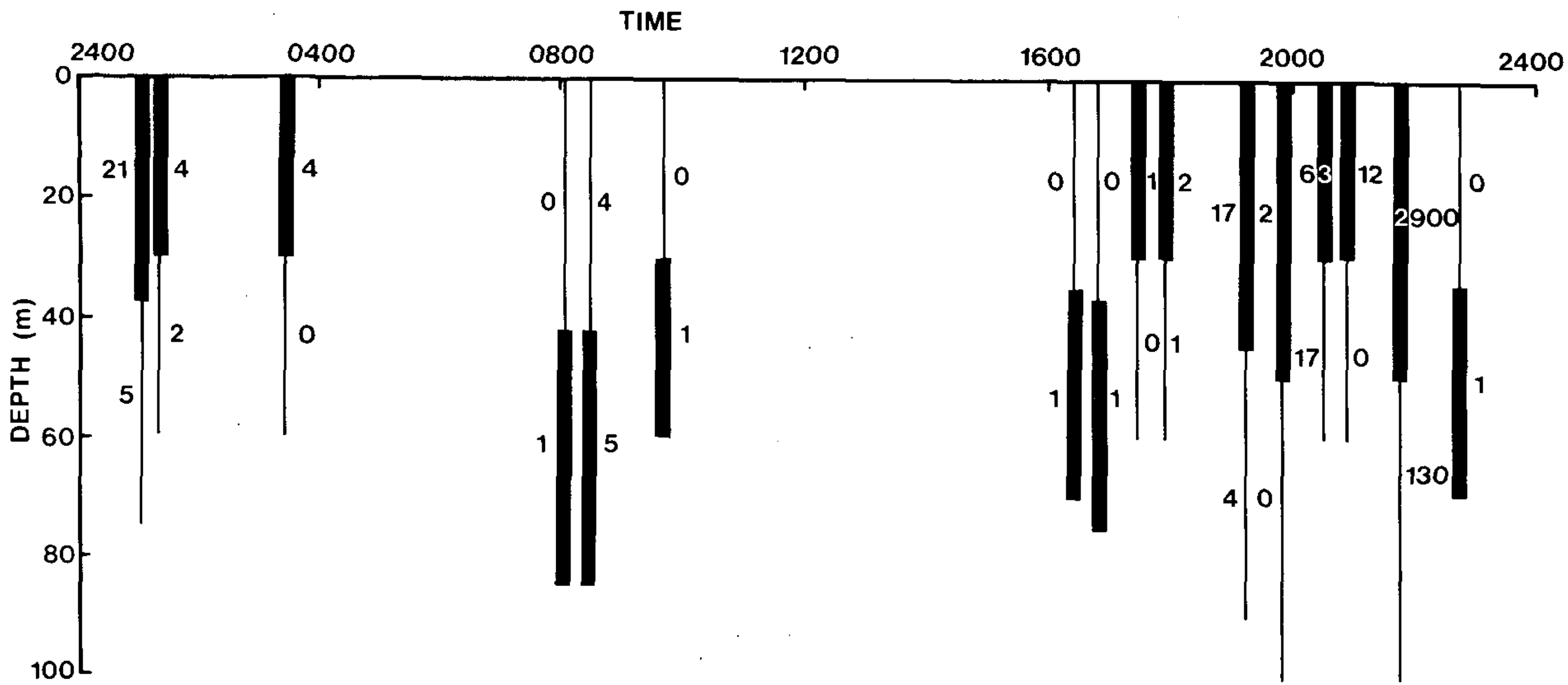

Fig. 2. Numbers of *Nyctiphanes australis* in the upper and lower halves of the sampled water column at 16 plankton stations on the continental shelf. The halves of the columns with the larger numbers are drawn thick. Stations are shown in order of diel time.

would still be higher than those for the same diel periods in July-September.

Evidently *Nyctiphanes* becomes much less catchable in the sampled water column by day than by night. This could occur by the animals avoiding the net more successfully in the daytime than at night, or by them aggregating by day in the unsampled zone within 5 m of the bottom, and moving upwards at night. The first explanation is improbable by itself, because large catches of *Nyctiphanes* have sometimes been made in daytime horizontal tows of the same net at the same speed at the sea surface. The second explanation is probable, because the species has been taken in daytime horizontal net tows near the bottom (Sheard 1953) and also frequently in the stomachs of the bottom-living tiger flathead, *Neoplatycephalus macrodon* (Fairbridge 1951). Moreover, the same pattern of diel vertical migration has been found in the related species *Nyctiphanes couchii* and *Meganyctiphanes norvegica*, which live close to the bottom by day and rise towards the sea surface at night (Mauchline and Fisher 1969).

Further indications of such movement are given by counts of *Nyctiphanes* in the upper and lower halves of the water column on the continental shelf in area A (Fig. 2). At stations occupied from 0800 to 1700 *N. australis* was more abundant in the lower half of the column than in the upper; at stations occupied from 1800 to 0400, with one exception, the situation was opposite. The exception is the station on the extreme right of Fig. 2, with one *Nyctiphanes* in the lower half and none in the upper, which is not a serious discrepancy.

The low numbers for each diel period in the July-September quarter indicate a great reduction in the entire population of *Nyctiphanes* or in the portion of the population making vertical migrations, at that season. The former possibility may be rejected because Fairbridge (1951) found euphausiids more or less uniformly throughout the year in stomachs of *Neoplatycephalus macrodon* taken on the bottom in east Tasmanian shelf waters. He did not name the euphausiid species but specimens were identified by Sheard as *N. australis*, and no other species occurs abundantly in the area. It is concluded that the bulk of the *Nyctiphanes* population at sizes over 5 mm remains near the bottom in winter in Victorian and Tasmanian shelf waters, without making diel vertical migrations. This might be connected with sexual activity or with food. Sheard (1953, Table 13) showed from records of ovigerous females that sexual activity must be minimal for the year in June and July. Food would be available near the bottom in the form of detritus, which is eaten by *N. australis* and other euphausiids (Sheard 1953; Mauchline and Fisher 1969), and perhaps little food is available in the rest of the water column in winter. The optimal temperature range for the species is about 12° to 18°C, although adults can tolerate 11° to 22°C (Sheard 1953). According to the charts of Gorshkov (1974) mean monthly surface temperatures are within the optimum range all year in most waters off Victoria and Tasmania, and temperatures at 50 m and 100 m can be up to 1° lower than surface in the same area and month, although bottom temperatures of 10°C have been recorded in our investigations. Thus the winter bottom-dwelling phase is probably not a response to temperature.

The data for areas B and C in Table 1 are only for daytime. Most hauls in area B were negative for *Nyctiphanes*, as was the case for daytime hauls in area A. Daytime means per haul for all quarters combined are comparable in the two areas, namely 0.5 in B and 0.7 in A. The means per haul are higher than daytime means for area A in July-September and January-March, and lower (zero) in the other two quarters. The months in which *Nyctiphanes* was obtained were August, September and January. There is additional information on months of occurrence in the water column at the north end of area B (34°S) from other authors. Sheard (1949) took the species in each month of the year with highest number of adults in May-July, September-November and January. Dakin and Colefax (1940) made hauls in all months but found *Nyctiphanes* only in June-September. Park and Williams (unpublished data) found it abundant in January and February and scarce in March and April, but most of their specimens were larvae. There is obviously a tendency for the larger *N. australis* to be most abundant in the water column from winter to summer in area B, instead of spring to autumn as in area A. There could again be a connection with sexual activity, which is minimal (no ovigerous females) from February to July in area B (Sheard 1953, Table 12). There could also be a connection with temperature. The upper limit of the optimum temperature range for adults is about 18°C as mentioned above. From the mean temperature charts of Gorshkov (1974), surface temperatures at 18° or less occur at 34°S only from June to September; however temperatures at 50 and 100 m do not exceed 18° at that latitude at any time. Thus *Nyctiphanes* adults could live all year at the northern end of area B, but would not be expected in abundance above the bottom in late spring, summer and autumn. From Sheard's (1949) data, however, they can be abundant as late as January. Possibly the animal must continue to visit the upper part of the water column in summer, in order to breed under favorable conditions for its larvae.

For area C, between 34° and 29°S latitude on the New South Wales coast, all hauls listed in Table 1 are negative. The only records of *Nyctiphanes* from that area are a few listed by Sheard (1953) as far north as 31°S. Beyond that latitude temperatures are over 18° all year even at 50 and 100 m. That condition presumably is not suitable for *N. australis*, which is replaced on the shelf by *Pseudeuphausia latifrons* (Sheard 1953).

Occurrences in Slope and Ocean Waters

As mentioned earlier, there were 65 slope stations with four open vertical hauls at each. Half of these hauls were made from 100 m and half from 500 m. Some *Nyctiphanes* were taken in each quarter-year and diel period. The total however was only 18, an average of 0.07 per haul. From Table 1 the means for all available hauls in areas A and B were much higher, 12.8 for A (all diel periods) and 0.5 for B (daytime only). Evidently *Nyctiphanes* is relatively rare in slope waters. Closing hauls were made at a few slope stations and some of them yielded single specimens at depths to 400-500 m below surface. Thus the species can occur at least as deep as 400 m.

A total of 392 similar hauls were made at the 98 ocean stations. The total number of *Nyctiphanes* taken was 37, so the average per haul was 0.09 which is similar to that for the slope. Proportionately more of the ocean hauls were negative, however. Ocean occurrences of *Nyctiphanes* undoubtedly represent individuals swept offshore in currents and eddies. In slope and ocean waters other euphausiids, which are normally rare on the shelf, replace *N. australis*. The principal species are *Thysanoessa gregaria*, *Euphausia recurva* and (south of 37°S) *Euphausia lucens*. *Nyctiphanes couchii* of Europe is virtually restricted to shelf waters in the same way as *N. australis* in Australia (Einarsson 1945).

Occurrences in South Australian Waters

Two cruises were made in the waters of eastern South Australia during 1953, one in March-April and a short one in August. *Nyctiphanes australis* was taken at various places on the continental shelf to 132°E longitude, which is the western limit of the species as at present known. The data were not quantitative. Sheard

(1950) implied that the species was fairly numerous in summer.

Estimates of Concentration

From Table 1, *Nyctiphanes* is most abundant in the water column at night from october to June in area A. The mean number per haul is then 44.5. The mean height of the water column sampled by those hauls was 62 m, and from Fig. 2 one can estimate that 90 percent of *Nyctiphanes* would have been in the top half. The mouth of the N70V net measures 0.3848 m^2 in area. Assuming a filtration coefficient (water acceptance) of 0.9, the volume of the upper half of the mean sampled water column is $0.3848 \times 31 \times 0.9 = 10.74\ m^3$. The mean number of *Nyctiphanes* in that volume of water is estimated as $44.5 \times 0.9 = 40.00$, yielding a concentration estimate of 3.7 animals per m^3. This is probably too low because of net avoidance and escapement through the large meshes in the upper part of the net. A reasonable estimate of mean concentration of *Nyctiphanes* in their night habitat from October to June (area A) is about 5 per m^3. If they all descend in daytime to the bottom 5 m of the water column as I concluded earlier, the mean concentration there would be about 30 per m^3.

The highest concentration encountered was in the haul shown second from right in Fig. 2. It had 2900 individuals in the upper half of a sampled water column of 100 m. The mean concentration was therefore at least 167.4 per m^3. It is safe to assume that concentrations of 200 per m^3 occurred within the range of that haul.

ACKNOWLEDGMENTS

The writer received support from CSIRO as a visiting scientist in the Division of Fisheries and Oceanography, which enabled him to complete this study. Brian Griffiths, Garth Murphy and David Tranter read a draft of the paper and made useful comments.

REFERENCES

Bary, B.M. (1956). Notes on ecology, systematics and development of some M sidacea and Euphausiacea (Crustacea) from New Zealand. *Pac. Sci.* 10, 431-467.

Blackburn, M. (1957). The relation between the food of the Australian barracouta, *Thyrsites atun* (Euphrasen), and recent fluctuations in the fisheries. *Aust. J. Mar. Freshwater Res.* 8, 29-54.

Dakin, W.J. and Colefax, A.N. (1940). The plankton of the Australian coastal waters off New South Wales. Part I. University of Sydney, Department of Zoology Monograph No. 1, 215 pp. E

Einarsson, H. (1945). Euphausiacea. I. Northern Atlantic species. Dana-Rep. Carlsberg Found. 27, 1-191.

Fairbridge, W.S. (1951). The New South Wales tiger flathead, *Neoplatycephalus macrodon* (Ogilby). I. Biology and age determination. *Aust. J. Mar. Freshwater Res.* 2, 117-178.

Gorshkov, S.G. (1974). *ed.* 'World ocean atlas. Volume 1. Pacific Ocean'. (In Russian with English introductory text). (Pergamon Press: Oxford) 302 charts.

Kemp, S., Hardy, A.C. and Mackintosh, N.A. (1929). Objects, equipment and methods. *Discovery Rep.* 1, 141-232.

Malcolm, W.B. (1959). The populations of Australian "salmon", *Arripis trutta* (Bloch and Schneider), in Australian waters. *Aust. J. Mar. Freshwater Res.* 10, 22-29.

Marshall, A.J. and Serventy, D.L. (1956). The breeding cycle of the short-tailed shearwater, *Puffinis tenuirostris* (Temminck), in relation to trans-equatorial migration and its environment. *Proc. Zool. Soc. London* 127, 489-510. M

Mauchline, J. and Fisher, L.R. (1969). The biology of euphausiids. *Adv. Mar. Biol.* 7, 1-454.

Serventy, D.L. (1956). The southern bluefin tuna, *Thunnus thynnus maccoyii* (Castelnau) in

Australian waters. *Aust. J. Mar. Freshwater Res.* 9, 1-43.

Sheard, K. (1949). Plankton characteristics at the Cronulla onshore station, New South Wales, 1943-46. CSIRO Aust. Bull. No. 246, 1-23.

Sheard, K. (1950). Factors in the behaviour of pelagic fish shoals in South Australia and New South Wales. CSIRO Aust. Bull. No. 251, 72-74.

Sheard, K. (1953). Taxonomy, distribution and development of the Euphausiacea (Crustacea). Rep. B.A.N.Z. Antarct. Res. Exped. (Ser. B) 8(1), 1-72.

CSIRO
Division of Fisheries and Oceanography

HEADQUARTERS
202 Nicholson Parade, Cronulla, NSW
P.O. Box 21, Cronulla, NSW 2230

NORTHEASTERN REGIONAL LABORATORY
233 Middle Street, Cleveland, Qld
P.O. Box 120, Cleveland, Qld 4163

WESTERN REGIONAL LABORATORY
Leach Street, Marmion, WA 6020
P.O. Box 20, North Beach, WA 6020