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The distribution of oceanic cirripedes in the North-east Atlantic in summer 1983 and the connotations of the results to the problems of Conchoderma fouling

Celia J. Ellis, D.S.M. Billett & M.V. Angel

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NATURAL ENVIRONMENT RESEARCH COUNCIL
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The distribution of oceanic cirripedes in the North-east Atlantic in summer 1983 and the connotations of the results to the problems of *Conchoderma* fouling

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INTRODUCTION

Oceanic pedunculate barnacles have long been known to pose fouling problems to shipping. One species in particular Conchoderma auritum (Linnaeus) is proving particularly intractable to prevention of fouling using antifouling paints. Dalley (1982) produced a report in which he reviewed the literature on the biology and ecology of the two species of Conchoderma. C. auritum has been recorded settled on ten species of whale, but most frequently on sperm (Physeter catodon) and humpback whales (Megaptera norvae-angliae). The barnacle does not appear able to settle directly on the skin of the whales, but normally occurs attached to another epibiont often a Coronula sp. (an acorn barnacle) or to teeth, jaws or baleen plates. Records of its occurrence on inanimate objects are not numerous, but Dalley and Crisp (1981) have highlighted the hazard it poses to shipping. Heavy settlements occur rather infrequently and in an apparently random and unpredictable fashion. A ship infested with these barnacles becomes totally uneconomic to run and has to be dry-docked for cleaning.

The other member of the genus, Conchoderma virgatum is found much more frequently on floating debris and moorings. It appears to settle in somewhat deeper water than other barnacles. For example, three current meter moorings were set out by the University of Liverpool in 1981 off the Northwest African coast in the vicinity of 22°N 18°W (Barton, personal communication). Two of the moorings had their subsurface buoyancy and shallowest current meters below 100m depth and no fouling was obvious. One mooring had the subsurface buoyancy and current meter at 50m and the next current meter at about 90m. On recovery both the buoyancy and the top two meters were fouled with Conchoderma virgatum. The size distribution clearly showed that there had been repeated settlements. The shallow meter stopped functioning at the end of January 1982, whereas the deeper meter stopped at the beginning of March. Around 22nd January the temperature record on the shallower current meter suggest that a front between two water masses (South Atlantic Central Water and North Atlantic Central Water) moved across the mooring position. Knowing the rapidity with which these barnacles can grow (a mooring set out for eleven days in March 1968 near 11°N 20°W had sexually mature C. virgatum settled on the nylon rope) it is possible that the initial settlement was associated with the front moving through.

C. virgatum has frequently been recorded settled on fish, usually on an intermediate the parasitic copepod Pennella. Dalley (1982) emphasises the ecological difference between the two Conchoderma species; C. virgatum is often found on Penella but never occurs on Coronula, whereas C. auritum settles on Coronula but not Pennella.

The Biological Department at the Institute of Oceanographic Sciences was commissioned by ROSCM to carry out a zoogeographical survey of the distribution of the cyprid larvae of stalked barnacles during Discovery cruise 140 off the Northwest coast of Africa. It was hoped to relate the distribution of the cyprids to surface water conditions such as minor thermal fronts using data collected by the ship's hull-mounted sensors. Plankton samples from greater depths were to be scanned for the presence of larvae. Any Conchoderma specimens found living either were to be kept alive and allowed to settle on a variety of substrates or were to be fixed for histological examination. If possible C. auritum cyprids were to be filmed or videoed in the act of settling.

METHODS

The track of Discovery cruise 140 is shown in figure 1. The original cruise programme allowed for more working time on the first leg in the Cape Verde Island region. However, at the last minute the Foreign and Commonwealth Office advised the Research Vessel Services that it was unwise to make the original mid-cruise port call at Tenerife . Consequently the mid-port call was rescheduled for Madeira and also had to be brought forward for logistic reasons. Hence the work carried out south of the Canaries was very much curtailed.

On leg 1, 29 samples were collected using a neuston net (figure 2). The neuston net (David, 1965) is towed from a boom mounted on the bow of the ship so that it tows outside the bow-wave of the vessel in undisturbed water (figure 3). The towing speed was normally 2 knots. Tow durations ranged from 5-30 minutes. The net is designed to sample the surface 30cm of water and filters about $60m^3$ every 5 minutes.

On leg 2, a further 60 neuston net samples were collected (figure 2). Towing durations were increased to 15-110 minutes. In addition eight RMT 1 tows (Baker, Clarke and Harris, 1973) were examined taken at depths down to 990m (figure 4).

SETTLEMENT

Settlement experiments were carried out on some of the cyprids caught. Two settlement chambers were tried. In type 1 the settlement chamber consisted of a 2.2ℓ container filled with surface sea water collected from the ship's non-toxic sea water supply and kept at laboratory temperature. 180 x 50cm settlement panels drilled and laced to circular, rigid PVC,end plates 100cm in diameter to form a rigid structure were placed inside the container (figure 5). The chamber was placed on a Gallenkamp stirrer so that a continuous flow was maintained over the panels. Five substrates were presented, expanded polystyrene, PTFE, perspex, rigid PVC and polypropylene. In type 2 eight cylinders of clear polycarbonate plastic 80cm high by 65cm in diameter enclosed at one end with RMT 1 netting (i.e. 320μm mesh) were placed in a plastic bath, raised above the bottom by a perforated plate (figure 6). Small cubes of the test substrates were inserted together with a cube of marine plywood. Fresh sea-water from the non toxic supply was run continuously through the bath, so that each chamber had a slow but steady exchange of water.

GEOGRAPHICAL DISTRIBUTION

The data for all the hauls examined are listed in Tables 1-3. The geographical distributions of the various species in the neuston net tows are illustrated in figures 7-9. Overall, cyprids of two Conchoderma and seven 'Lepas'-type species were found. Only two of the Lepas cyprids could be identified with certainty i.e. L. anatifera and L. pectinata. The remaining types have been designated by letter. Species 'F' was possibly L. fascicularis on the basis of the description by Bainbridge and Roskell (1966). The ventral and lateral views of all the cyprids are illustrated in figure 10, and their meristic characters listed in Table 4.

a. Conchoderma

Two types of cyprid were taken that were very similar in size and shape to the illustrations in Dalley (1982). One species, species A, was only taken in RMT 1 samples during leg 2 at 31°15'N, 21°23'W and 36°19'N, 22°52'W, at depths of 250-430m. It was characterised by the substantial protuberances of the carapace which overlay the large eyes. These protuberances were clearly to be seen when the specimens were viewed ventrally. The carapace was colourless but the underlying tissue was a chocolate-brown, except over the eyes where it was transparent. Species B was taken in two neuston net samples on leg 1 at 16°30'N, 20°23'W and 30°06'N, 17°48'W. The dorsal edge to its carapace was smoothly curved, in contrast to the angled curve in species A. Its general coloration was a pale greyish-violet, and there were only very slight carapace protuberations over the eyes. The meristic characters (Table 3) suggest this form was slightly larger than species A, but had smaller carapace height ÷ length and breadth ÷ length ratios.

Species A came from a region that lies almost in the centre of the very poorly productive (oligotrophic) current gyre. Whereas species B occurred in a region that can be reasonably productive at certain seasons. The general current drift is likely to be southerly under the influence of the Canary Current, but there are seasonal incursions of South Atlantic Central Water.

Although there is no firm evidence at present whereby an accurate species identification can be attributed to either of the Conchoderma larvae, there is some indirect evidence that hints that species B may be Conchoderma virgatum. When the towed fish which carries the transducers for the precision echo-sounder was raised for repairs during the second leg on 1 September, twelve dead specimens of C. virgatum ranging in length from 3-9mm were found attached to it. These barnacles probably settled towards the end of leg 1, when type B cyprids were taken in the neuston. The hull of the ship was scraped to see if any Conchoderma had settled there, but none were found amongst the Lepas anatifera that had settled in the strip above the anti-fouling paint.

b. Lepas anatifera

Cyprids of this species occurred in only one of the neuston net samples on Leg 1, but were frequently taken on leg 2 (figure 7). Rather surprisingly they were not taken in the RMT 1 hauls. This suggests that there may be quite distinct vertical zonation in the distributions of Lepas cyprids particularly in those not ready to settle and undergo metamorphosis. There is a marked contrast between the vertical distribution of this species and that of the second abundant species L. pectinata. Two single specimens of newly settled L. anatifera were taken in the neuston net samples both at around 32°-33°N.

c. Lepas pectinata

Cyprids of this species occurred in two neuston net samples on leg 1, and were abundant in some of the neuston net samples collected west of 24°N and between 30-35°N (figure 8). They were also extremely abundant in RMT 1 samples collected at depths ranging from 250-735m. This species with its characteristic carapace horns, is a familiar organism in mesopelagic plankton tows. It was extremely abundant in tows collected during Discovery cruise 120. During this cruise a major oceanic front was investigated, which probably marks one of the return flows of the Gulf Stream (Gould, in press). In May 1981 four vertical profiles were made with a Longhurst Hardy Plankton Recorder which divides an oblique plankton tow into a large number of depth horizons. Day profiles were observed on both sides of the front in typical Eastern Atlantic Water and typical Western Atlantic Water and both a day and a night profile within the frontal region itself. The position at which the observations were made (centred around 33½°N 33½°W to the S W of the Azores) were separated by only 100 nautical miles. Figure 11 illustrates the data for the barnacle cyprids and nauplii, all of which were ascribed to L. pectinata. These data were generously provided by Dr. R. Williams and Mr. D. Conway of IMER, Plymouth.

In all profiles the nauplii were concentrated just below the seasonal thermocline close to where the chlorophyll maximum occurred. The night profile in the front suggested that a small proportion of the population migrated up into the surface 20m at night. The upward shift in the main population maximum of the nauplii is interpreted here not as an upward migration, but as a response to changes in the temperature structure and hence the chlorophyll maximum. The chlorophyll maximum occurs close to, but not necessarily coincidental with the production maximum, and the abundance of the nauplii within a relatively narrow depth zone reflects the vertical distribution of available food. The cyprids which are reported to be non-feeding occur in very low numbers down through the water column to depths of 330-440m. Maximum abundances were about $3.m^{-3}$

in the Eastern Atlantic Water profile. Total integrated population estimates for nauplii were 8.9-116.4 per m^2 of sea surface, but were much higher for cyprids $152.4\text{-}321.6.m^{-2}$. The differences between the day and night profiles are hard to interpret. They could arise because of the patchy nature of the organisms in a physically very heterogeneous zone. They could also be interpreted as illustrating a reverse diel migration by the cyprids. A portion of the population observed at night may have moved up into the surface few centimetres by day where the sampling will not have been adequate, However, in this context it is sufficient to record the surprising depths to which the cyprids descend. This observation of the occurrence of Lepas cyprids at depth is not unique, and abundant material has been collected during previous Discovery cruises supporting the conclusion that this is a normal phenomenon. Because settlement occurs on objects floating at the surface, the stimulus that sets off upward migration back to the surface prior to settlement is of key interest, particularly as Conchoderma cyprids were also found to occur at depths.

d. Other Lepas species

Five other types of 'Lepas' cyprids were encountered. Species D and E occurred in the neuston net samples on Leg 1. Single individuals of species F and species G were taken by the neuston net on leg 2. Species C and G were only caught in small numbers in RMT 1 samples, but species E occurred in substantial numbers in two RMT 1 samples at 450-700m. The identification of a total of seven species of 'Lepas' cyprid is puzzling as only five species are known from the N Atlantic:- L. hilli and L. anserifera in addition to the three mentioned above (Zullo, 1979). Therefore two of the cyprids possibly belong to other genera, possibilities include Alepas which has been recorded as settled on the scyphomedusan Pelagia in the region, and some of the Coronulid barnacles, such as Coronula reginae, C. diadema, and Xenobalanus globicipitis which all occur as epibionts o ectoparasites on whales, or Stomatobalanus elegans which occurs on turtles.

e. Metamorphosed Lepas

Newly settled Lepas specimens attached to lumps of fuel oil or plastic debris were only taken in the neuston net on leg 2. At 30-35°N the majority of the specimens were L. pectinata. In addition two specimens of L. anatifera were found, one attached to the same piece of plastic as three L. pectinata. North of 40°N a number of colonies of L. fascicularis were caught and some well-grown specimens of L. pectinata were found attached to the shells of L. fascicularis. At present there is not much known about the pattern of oceanic currents in this region of the N E Atlantic, but the change in the barnacle communities may be associated with the southern boundary of strong winter mixing of the surface few hundred metres of the water column. This, in other oceans is termed the subtropical convergence, but most of the characteristics of this convergence are absent from the N E Atlantic.

SETTLEMENT EXPERIMENTS

The settlement experiments were not very successful. Two of the Conchoderma type A cyprids were placed in a type 1 settlement container. After five days the cyprids had failed to settle. Nine cyprids of L. anatifera were placed in a similar but unstirred chamber. After three days one had settled, not on any of the substrates provided but on the bottom edge of the container.

In the type 2 chambers, trials were carried out with the same two Conchoderma larvae, a number of L. anatifera and L. pectinata and single specimens of the type 'C' and 'F' larvae. With the exception of the L. anatifera none of the cyprids settled. The L. anatifera that did settle once again ignored the substrates provided and chose instead the junction between the cylinders and the netting base.

DISCUSSION

Dalley (1982) states that 'the cyprid is unable to feed, and relies on a large store of food in the form of oil-globules to sustain it whilst it searches for a suitable place to attach and settle.' While this statement may be fully correct for littoral species, it does not appear to be consistent with the observed vertical distributions of the oceanic cyprids. The cyprids are unlikely to be searching for suitable settlement sites at depths of 400m or more, and their lack of clear migratory behaviour into the surface layers suggests their presence at mesopelagic depths is the result of some other phenomenon.

One possibility is that the cyprids are in a state of diapause. Diapause is a familar phenomenon in temperate calanoid copepods. For example the stage V copepodites of Calanus finmarchicus overwinter in a state of diapause in deep water. They become non-feeding, their guts regress, they convert all their reserves into lipids (i.e. they become very oily), and their metabolic activity becomes very low. Diapause is similar to hibernation in various terrestrial animals living at high latitudes. In the profiles observed to the S W of the Azores, the integrated numbers of nauplii were consistently lower than the numbers of cyprids, yet there is no reason to believe that this is a sampling artefact. Nauplii are continually being released by adult barnacles once they have reached maturity. The nauplii grow and develop relatively quickly but are subjected to predation. So if the duration of the naupliar and cyprid stages were similar, nauplii would be expected to substantially outnumber the cyprids. Therefore, the observed greater abundance of cyprids implies that the cyprid stage is greatly extended which is again consistent with their entering a state of diapause.

In the settlement experiments the only cyprids that settled (L. anatifera) were from neuston net tows, whereas all the other cyprids were taken in the RMT 1 at depth. If these latter animals were in a state of diapause, then in the absence of the appropriate stimulus to break this state, they would not be expected to settle.

The function of the diapause is likely to be to hold the cyprid economically at a depth of relative safety, so that ultimately when an appropriate environmental stimulus occurs there is a mass migration back to the surface. The stimulus is likely to be related to when there is a high chance of encountering suitable settlement substrates. In the case of Lepas species, this would occur at convergences which physically aggregate floating debris suitable for settlement. The stimulus to break diapause would therefore be expected to be a form of chemical or physical signal that a front might generate (at a depth of 450m in the case of L. pectinata).

In the case of Conchoderma, the ecology of their normal whale hosts may provide hints as to their possible behaviour and distribution. Humpback whales migrate to high latitudes during the polar summers and return to low latitudes during the winters. In the case of sperm whales the bulls perform a similar migration but the cows tend to be non-migratory.

The pattern of migration is six months out-of-phase between the two hemispheres. Clarke (1966) records that 97.8% of humpbacks from the Antarctic, South Africa and the North Pacific are infected with C. auritum whereas only 0.2-0.3% of blue, fin and sei whales were infected. The incidence on sperm whales is intermittent ranging from around 2% in bulls to 4% in cows. At present the stocks of humpback whales in the North-west Atlantic are estimated at 1800 compared with 4700 in 1865 (Mitchell and Reeves, 1983). The overwintering grounds for this stock is off the West Indies. In the North-east Atlantic the overwintering grounds for humpbacks is off the Cape Verdes, but there are few data as to the size of the stock. In the South Atlantic the humpback stocks are small and even historically very few humpbacks were taken in the Western Indian Ocean (Wray and Martin, 1983), what few early records of humpbacks from the Indian Ocean there are occurred around Madagascar and Mozambique.

Estimated stocks of sperm whale in the N W Pacific have declined from 300,000 in 1910 to 200,000 in 1982 (Donovan, 1983), and in the Atlantic from 70,000 (in 1905) to 58,000 (in 1981) (Donovan, 1982). Thus despite the greater infection rate of humpbacks, the greater abundance of sperm whales in most oceans is likely to result in the latter being the main source of Conchoderma larvae, certainly in the Atlantic and Indian Oceans. This effect will be reinforced by the non-migratory behaviour of sperm whale cows and calves.

The early whaling records probably provide the best indication of where sperm whales occur throughout the year, and so where fouling may be expected to be most intense. In the Indian Ocean, Wray and Martin (1983) have described the main whaling grounds and the seasons during which whaling was most active (figure 12). This is likely to be the best guide as to where and when Conchoderma settlement is most likely to be troublesome.

The sperm whales tend to aggregate within frontal systems particularly in the front associated with the shelf break. Production at shelf-break fronts tends to be higher and the structure of the physical current system allows organisms with the appropriate life cycle characteristic of ontogenetic migration combined with diapause to stay within the system.

This has been shown for the copepod Calanoides carinatus in the Somali Current upwelling system (Smith, 1982).

However, the historical importance of humpback whale populations can be expected to have had an influence on the evolution of barnacles. So in Conchoderma the movement of cyprids back to the surface prior to settlement and the breaking of diapause (if this hypothesis is correct) would be most likely to coincide with the return of the whales to their overwintering grounds. Hence it would occur in October/November in the Northern Hemisphere and in April/May in the Southern Hemisphere. The newly settled larvae would then have time to grow, mature and reproduce before the end of the season.

It is important to bear in mind Dalley's (1982) statement that 'laboratory studies indicate that although C. auritum will survive at temperatures <10°C, it is inactive below 16°-18°C and shows greatest activity at 25°-30°C.' This lends support to the hypothesis that the cyprids caught at depths of 400m at water temperatures of 12°-14°C are probably inactive. It also emphasises that Conchoderma is essentially a subtropical/tropical organism and hence is unlikely to settle at latitudes higher than 30-40°. It is also an oceanic animal and so is unlikely to occur in shallow coastal seas particularly in the Persian (Arabian) Gulf because a) its normal whale host do not enter the Gulf b) the high temperatures and salinities in the Gulf are likely to be inimicable to both adults and larvae.

CONCLUSIONS

1. Two species of Conchoderma cyprids were identified from N E Atlantic plankton samples which could be easily separated morphologically, but could not be ascribed to species.

2. Seven other cyprids were collected, two of which were identified as Lepas anatifera and L. pectinata. Another cyprid possibly belonged to L. fascicularis. Because only five Lepas species are known from the N E Atlantic, two of the cyprids possibly belonged to other epibiontic barnacles, some of which are associated with whales.

3. The abundance of records of cyprid larvae at depth which are non-feeding and very oily suggests that cyprids are in a state of diapause. The recovery of Conchoderma larvae from depths of >200m suggests that these too may enter diapause. The inability to persuade cyprids collected at depth to settle together with the relative ease of persuading cyprids collected in the neuston (i.e. at the ocean surface) supports this theory that the cyprids enter diapause.

4. Consideration of the ecology of the normal hosts of Conchoderma, the sperm and humpback whales, suggests that settlement is likely to be associated with oceanic fronts particularly shelf break fronts. Furthermore, settlement is likely to be maximum in late autumn or early winter, and to differ by six months in the two Hemispheres.

5. Future work should be aimed at investigating a) the hypothesis that the cyprids enter a state of diapause and the environmental stimulus which breaks the diapause. b) the investigation of plankton communities in the vicinity of shelf-break fronts in the tropics and subtropics, to look for high concentrations of Conchoderma cyprids, c) the re-examination of fouling incidents to examine whether there is evidence of a seasonality with peaks in intensity occurring six months apart in the different Hemisphere, and whether there is any correlation between fouling incidents and the routeing of vessels along the shelf break.

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REFERENCES

BAINBRIDGE, V. and J. ROSKELL 1966. A re-description of the larvae of *Lepas fascicularis* Ellis and Solander with observations on the distribution of *Lepas* nauplii in the North-eastern Atlantic. Pp. 67-88 In: *Some contemporary studies in marine science*, H. Barnes (Ed.). London: Allen and Unwin.

CLARKE, R. 1966. The stalked barnacle *Conchoderma* ectoparasitic on whales. *Norsk Hvalfangst-Tidende*, **8**, 153-168.

DALLEY, R. 1982. The oceanic pedunculate barnacle *Conchoderma* as a fouling hazard. Unpublished Report for ROSCM, 32pp.

DALLEY, R. and D.J. CRISP 1981. *Conchoderma*: a fouling hazard to ships underway. *Marine Biology Letters*, **2**, 141-152.

DONOVAN, G.P. (Ed.) 1982. *Report of the International Whaling Commission*, 32.

DONOVAN, G.P. (Ed.) 1983. *Report of the International Whaling Commission*, 33.

GOULD, W.J. (in press) Physical oceanography of the Azores Front. *Progress in Oceanography*, **13**.

MITCHELL, E. and R.R. REEVES 1983. Catch history, abundance and present status of Northwest Atlantic humpback whales. *Report of the International Whaling Commission*, Special Issue 5, 153-212.

SMITH, S.L. 1982. The north western Indian Ocean during the monsoons of 1979; distribution, abundance and feeding of zooplankton. *Deep-Sea Research*, **29**, 1331-1353.

WRAY, P. and K.P. MARTIN 1983. Historical whaling records for the Western Indian Ocean. *Report of the International Whaling Commission*, Special Issue 5, 213-241.

ZULLO, V.A. 1979. Marine flora and fauna of the Northeastern United States. Arthropoda: Cirripedia. *NOAA Technical Report* NMFS, 425, 28pp.

Table 1. Cyprids in neuston net samples taken on leg 1. Asterisks denote night hauls. *Lepas* 'A' ≡ *L. anatifera*; B ≡ *L. pectinata*.

Haul No.	Date 1983	Start Time h	Duration min.	Start Position N	Start Position W	*Conchoderma* B	*Lepas* A	*Lepas* B	*Lepas* D	*Lepas* E
1	7.viii	1340	5	14°33'	17°46'	.	.	.	3	.
2*		1930	5	14°48'	17°43'	.	.	.	.	.
3	8.viii	1800	5	14°49'	18°50'	.	.	.	.	.
4*		2130	5	14°50'	19°04'	.	.	.	.	.
5	9.viii	0930	5	14°47'	20°32'	.	.	.	.	.
6		1620	5	14°58'	20°59'	.	.	.	.	.
7*		1930	5	15°02'	21°07'	.	.	.	.	.
8	10.viii	0930	5	16°20'	20°23'	.	.	.	1	.
9		1410	5	16°30'	20°23'	1	.	.	.	.
10*		2030	5	16°53'	20°14'	.	.	.	3	.
11	11.viii	1015	5	17°57'	19°45'	.	.	.	.	.
12		1050	5	17°56'	19°45'	.	.	.	.	.
13		1430	10	17°57'	19°59'	.	.	.	1	.
14*		2110	10	17°58'	20°10'	.	.	.	.	.
15	17.viii	1030	10	20°44'	20°44'	.	.	.	.	1
16		1515	10	20°59'	20°41'	.	.	.	.	1
17		1600	20	21°00'	20°40'	.	.	.	.	.
18		1915	20	21°19'	20°34'	.	1	1	.	.
19*		2015	20	21°22'	20°33'	.	.	.	.	.
20	18.viii	1900	20	23°39'	19°56'	.	.	.	.	.
21	19.viii	0930	20	25°20'	19°18'	.	.	.	.	.
22		1300	20	25°40'	19°11'	.	.	.	.	.
23		1500	20	25°44'	19°10'	.	.	.	.	.
24*		2000	15	26°14'	19°02'	.	.	.	.	.
25	20.viii	1350	20	28°08'	18°31'	.	.	.	.	.
26		1500	30	28°10'	18°30'	.	.	.	.	.
27	21.viii	0800	30	30°06'	17°48'	1	.	.	.	.
28		0900	30	30°08'	17°48'	.	2	.	.	.
29		1615	30	30°50'	17°33'	.	.	.	.	.

Table 2. Cyprids and metamorphosed barnacles taken by the neuston net on leg 2. Asterisks denote night tows. Lepas 'A' ≡ *L. anatifera*; B ≡ *L. pectinata*; metamorphose Lepas F ≡ *L. fascicularis*; metamorphose Lepas H ≡ *L. pectinata* settled on *L. fascicularis*.

Haul No.	Date 1983	Start Time h	Duration min.	Start Position N	Start Position W	Lepas cyprids A	B	E	F	Lepas metamorphosed A	B	F	H
30	25.viii	0755	20	31°34'	20°15'	.	.	.	.	.	.	.	.
31		1418	65	31°25'	20°51'	.	.	.	.	.	.	.	.
32*		2100	15	31°16'	21°22'	.	.	.	.	.	.	.	.
33*		2300	15	31°18'	21°19'	.	.	.	.	.	.	.	.
34*	26.viii	0120	15	31°10'	21°39'	.	.	.	.	.	.	.	.
35		0830	25	30°51'	22°43'	2	.	.	.	.	.	.	.
36		0900	25	30°52'	22°42'	5	.	.	.	.	.	.	.
37*		1950	20	30°44'	23°16'	.	.	.	.	.	.	.	.
38*		2218	20	30°46'	23°12'	.	.	.	.	.	.	.	.
39	27.viii	0824	30	30°20'	24°41'	4	.	1	.	.	.	.	.
40		0930	30	30°23'	24°41'	5	.	.	.	.	.	.	.
41		1344	30	30°28'	24°42'	2	.	.	.	.	.	.	.
42	28.viii	0800	30	30°15'	26°45'	2	.	.	.	.	.	.	.
43		0830	30	30°17'	26°44'	1	.	.	.	.	.	.	.
44		0900	30	30°18'	26°43'	9	.	.	.	.	.	.	.
45		1100	25	30°21'	26°41'	1	.	.	.	.	.	.	.
46		1413	30	30°23'	26°54'	9	.	.	.	.	.	.	.
47		1445	45	30°24'	26°54'	4	1	.	.	.	.	.	.
48		1550	70	30°27'	26°53'	7	.	.	.	.	.	.	.
49*		2115	30	30°31'	27°07'	4	.	.	.	.	.	.	.
50*		2200	15	30°32'	27°09'	11	.	.	.	.	.	.	.
51	29.viii	1100	30	30°02'	28°27'	.	8	.	.	.	31	.	.
52		1130	30	30°01'	28°28'	1	16	.	.	.	29	.	.
53		1300	45	30°00'	28°29'	2	8	.	.	.	71	.	.
54*		2124	35	30°18'	28°36'	1	.	.	.	.	.	.	.
55	30.viii	0830	40	31°43'	28°08'	1	14	.	.	.	147	.	.
56		0910	110	31°43'	28°07'	4	10	.	.	.	~160	.	.
57		1130	45	31°46'	28°00'	3	.	.	.	.	~200	.	.
58*		2120	60	32°26'	27°39'	2	10	.	.	1	.	.	.
59	31.viii	0835	40	33°30'	26°27'	5	1	.	.	.	.	.	.
60		1030	45	33°32'	26°21'	1	.	.	.	.	.	.	.
61		1540	30	30°41'	26°08'	.	.	.	.	.	.	.	.
62		1630	40	33°42'	26°09'	1	.	.	.	1	3	.	.
63*		1955	50	33°47'	26°16'	.	.	.	.	.	34	.	.
64	1.ix	1100	60	34°44'	25°10'	.	.	.	.	.	2	.	.
65		1740	40	35°14'	24°32'	.	.	.	.	.	5	.	.
66*		2100	60	35°18'	24°23'	.	.	.	.	.	.	.	.
67	2.ix	0954	60	36°20'	22°51'	13	.	.	.	.	.	.	.
68	3.ix	1130	35	37°50'	21°16'	10	.	.	.	.	.	.	.
69		1200	60	37°51'	21°16'	14	.	.	1	.	.	.	.
70		1800	60	38°15'	20°43'	10	.	.	.	.	.	.	.
71		1900	20	38°17'	20°42'	9	.	.	.	.	.	.	.
72*		2100	50	38°20'	20°41'	3	.	.	.	.	.	.	.
73*		2150	40	38°22'	20°41'	8	.	.	.	.	.	.	.
74	4.ix	0810	60	39°12'	19°05'	6	.	.	.	.	.	.	.
75		0910	50	39°15'	19°06'	.	.	.	.	.	.	.	.
76		1650	35	39°32'	18°51'	.	.	.	.	.	.	.	.
77*		2110	15	39°43'	18°34'	1	.	.	.	.	.	.	.
78	5.ix	1100	60	40°39'	16°35'	.	.	.	.	.	.	.	.
79		1900	25	40°52'	15°53'	.	.	.	.	.	.	.	.
80	6.ix	0755	60	41°39'	14°10'	.	.	.	.	.	.	9	3

Table 2 contd.

81		0855	60	41°40'	14°09'	.	.	.	.	.	.	1	.
82		0955	60	41°41'	14°07'	.	.	.	.	.	.	.	.
83		1425	70	41°52'	13°45'	.	.	.	.	.	.	.	.
84		1615	90	41°53'	13°41'	.	.	.	.	.	.	12	1
85		1745	45	41°54'	13°37'	.	.	.	.	.	.	.	.
86*		1930	50	41°59'	13°25'	.	.	.	.	.	.	.	.
87	7.ix	1300	60	42°48'	11°48'	.	.	.	.	.	.	17	11
88		1400	60	42°50'	11°48'	.	.	.	.	.	.	6	5
89	8.ix	1035	80	42°46'	11°51'	.	.	.	.	.	.	3	7

Table 3. Cyprids taken in RMT 1 tows on leg 2. Lepas 'B' ≡ L. pectinata.

Station	Date 1983	Depth (m)	Time	Start Position N	Start Position W	Conchoderma A	Lepas B	Lepas C	Lepas E	Lepas G
10899	25.viii	490-600	0849-0949	31°35'	20°16'	.	19	.	390	.
10900	25.viii	740-990	1445-1545	31°26'	20°50'	.	.	.	.	.
10901	25.viii	290-430	2022-2122	31°15'	21°23'	2	136	1	.	.
10904	26.viii	450-700	1936-2106	30°44'	23°16'	.	616	4	304	.
10913	29.viii	250-280	1313-1412	30°00'	28°30'	.	920	.	.	1
10917	30.viii	540-735	1557-1657	32°07'	27°56'	.	155	.	.	.
10925	2.ix	250-300	0915-1015	36°19'	22°52'	3	.	.	.	.
10938	6.ix	150-400	1930-2142	41°59'	13°25'	.	.	.	.	.

Table 4. Meristic characters of the Conchoderma and 'Lepas' cyprids. Lepas 'A' ≡ *L. anatifera* B ≡ *L. pectinata*.

		Conchoderma		Lepas						
Species		A	B	A	B	C	D	E	F	G
No.		5	2	20	20	5	6	20	1	1
Length mm	average	1.49±0.062	1.59	1.31±0.085	1.53±0.080	1.57±0.136	1.48±0.188	1.14±0.109	1.42	1.26
	range	1.40-1.54	1.53-1.65	1.13-1.43	1.40-1.66	1.34-1.70	1.17-1.66	0.93-1.34	-	-
Height mm	average	0.60±0.032	0.59	0.54±0.035	0.45±0.049	0.66±0.062	0.62±0.113	0.62±0.094	0.65	0.57
	range	0.55-0.63	0.57-0.62	0.46-0.57	0.38-0.52	0.57-0.74	0.42-0.72	0.45-0.83	-	-
Breadth mm	average	0.57±0.46	0.47	0.42±0.047	0.77±0.050	0.51±0.073	0.41±0.089	0.55±0.070	0.49	0.45
	range	0.51-0.63	0.46-0.49	0.33-0.49	0.69-0.86	0.40-0.59	0.26-0.49	0.39-0.66	-	-
$\frac{\text{Height}}{\text{Length}} \times 100$	average	40.43	37.42	40.97	29.15	42.28	41.47	53.79	45.8	45.2
	range	39.2-42.5	37.3-37.6	37.4-43.9	24.2-34.8	40.9-43.5	35.9-43.8	45.4-58.3	-	-
$\frac{\text{Breadth}}{\text{Length}} \times 100$	average	38.38	29.88	31.8	50.47	32.36	27.33	31.84	34.5	35.7
	range	36.4-40.9	29.7-30.1	28.2-36.6	45.7-53.3	29.8-34.7	22.2-30.3	28.4-36.6	-	-

FIGURES

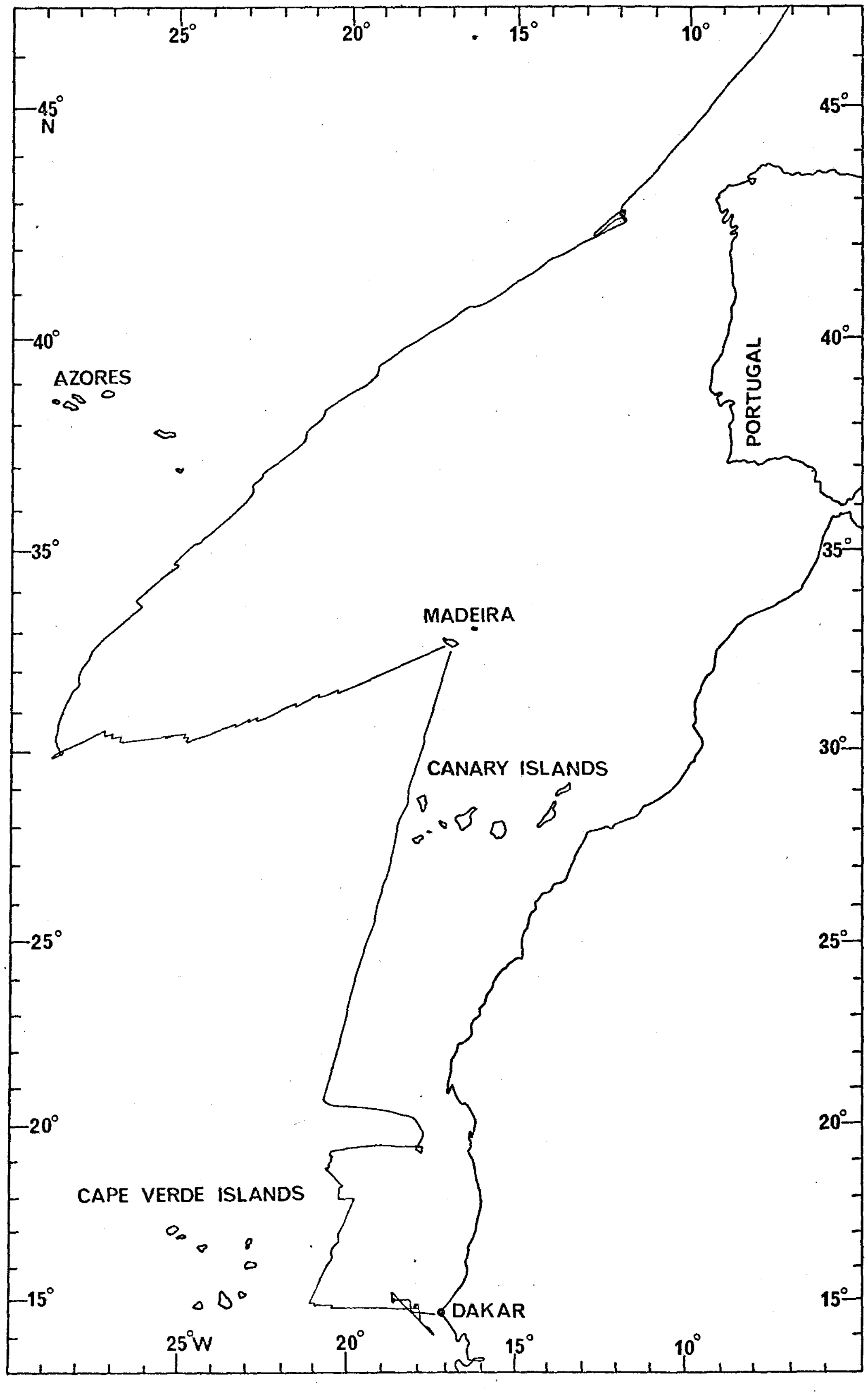

Fig. 1. Track chart for Discovery cruise 140

FIGURE 2.

Postitions at which neuston net samples were collected during the cruise.

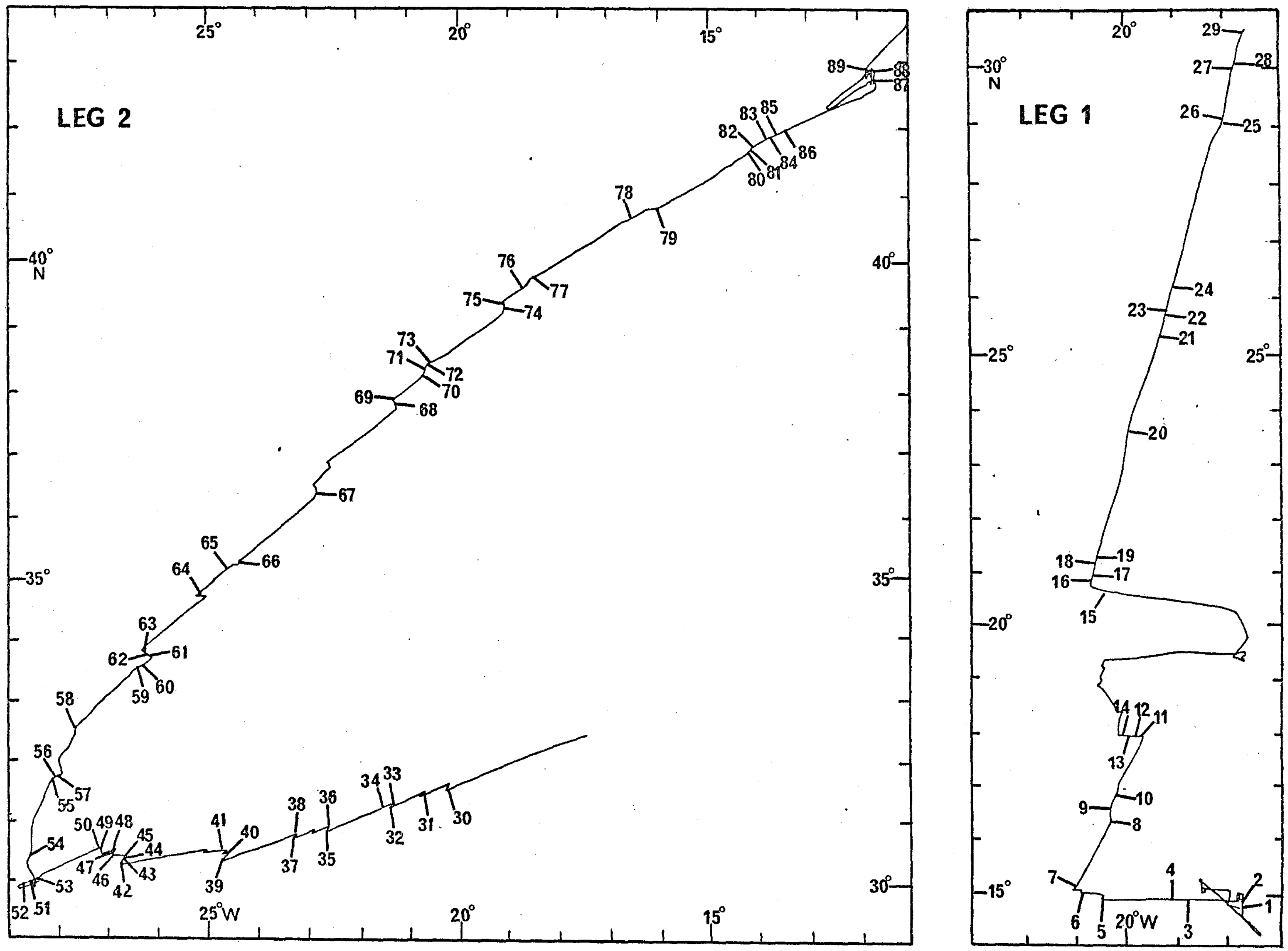

Fig. 2. Position of neuston net samples along the track chart.

FIGURE 3

a. The neuston net during a tow

b. RRS Discovery at sea

FIGURE 4.

Positions of RMT 1 samples which were collected and examined for cirriped larvae.

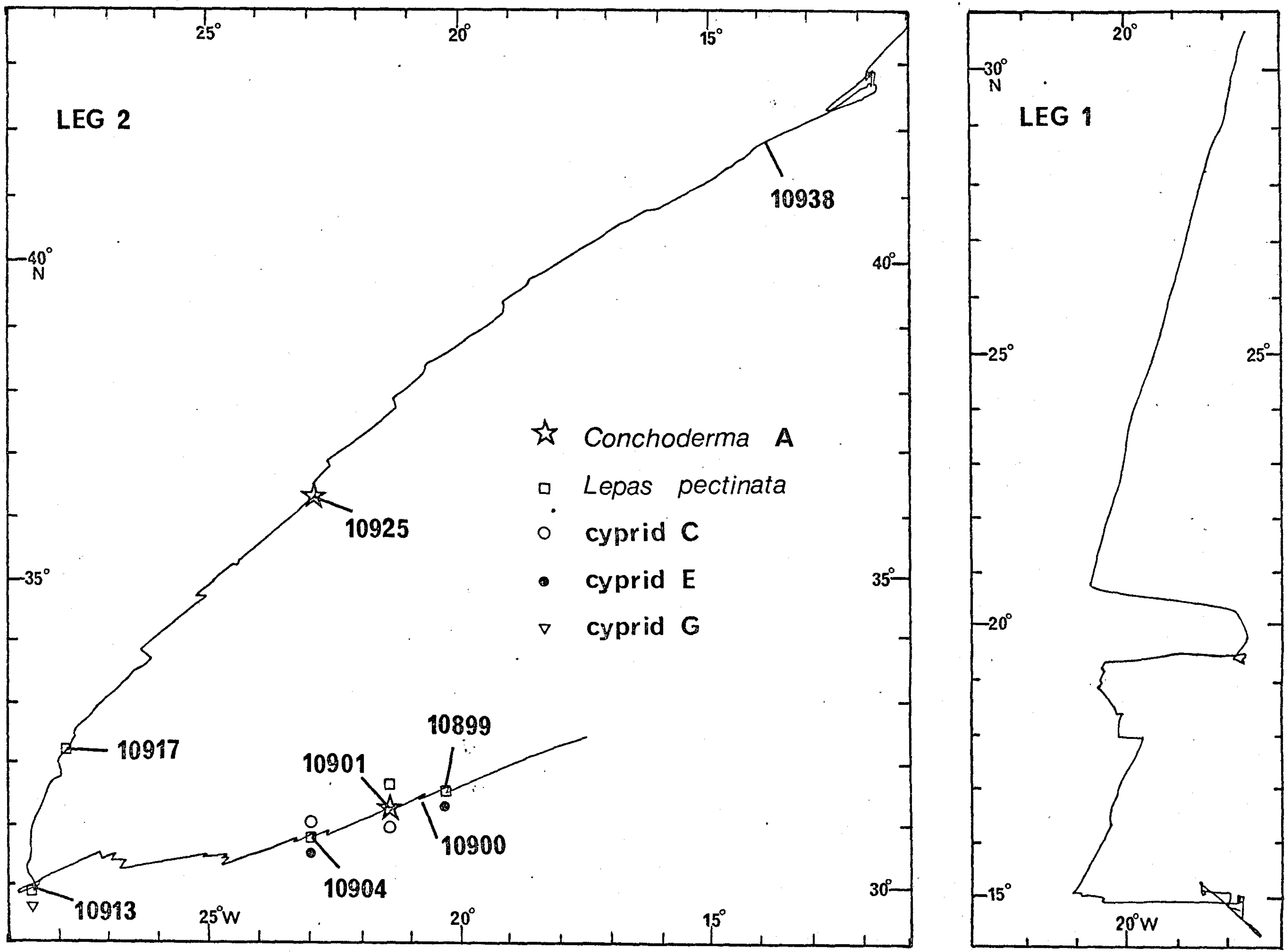

Fig. 4. Positions of RMT 1 hauls and occurrences of cyprids

FIGURE 5.

Settlement chamber type 1 drawing and photograph.

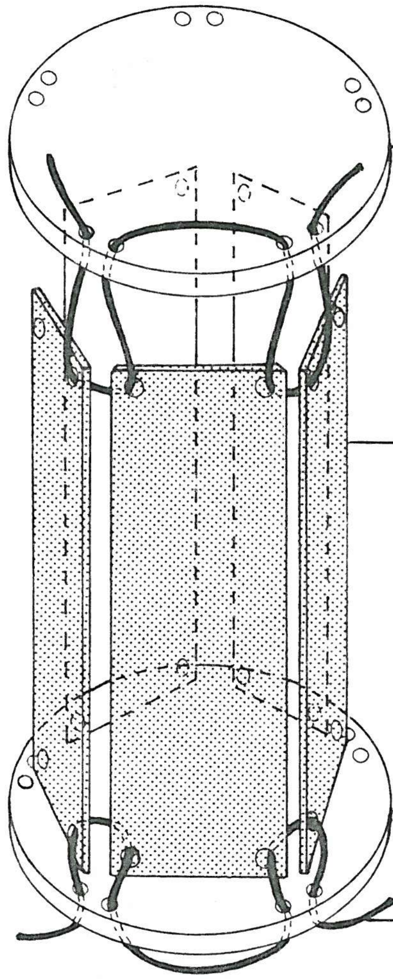

Fig. 5. Settlement chamber type 1

FIGURE 6.

Settlement chamber type 2 drawing and photograph.

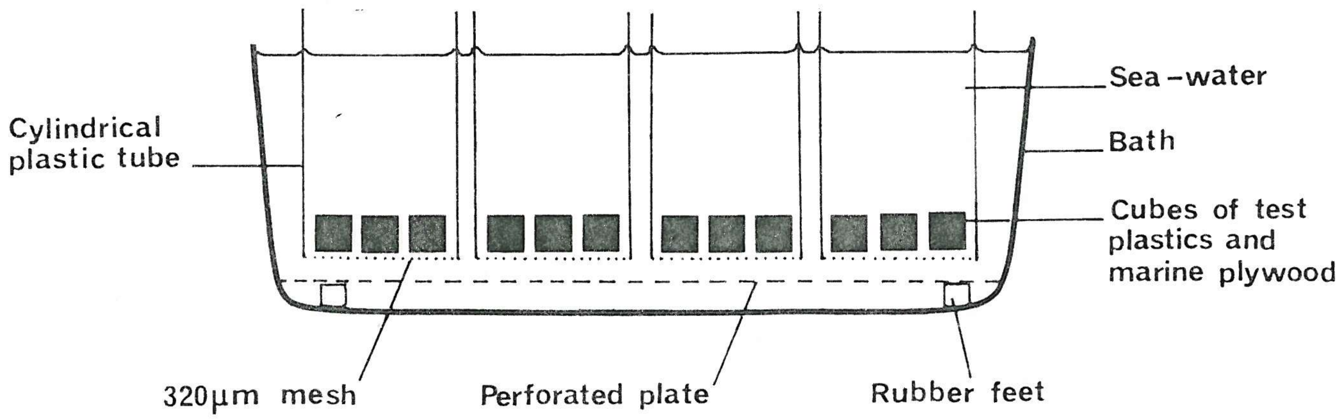

Fig. 6. Settlement chamber type 2

FIGURE 7.

Distribution of Lepas anatifera cyprids in the neuston net hauls.

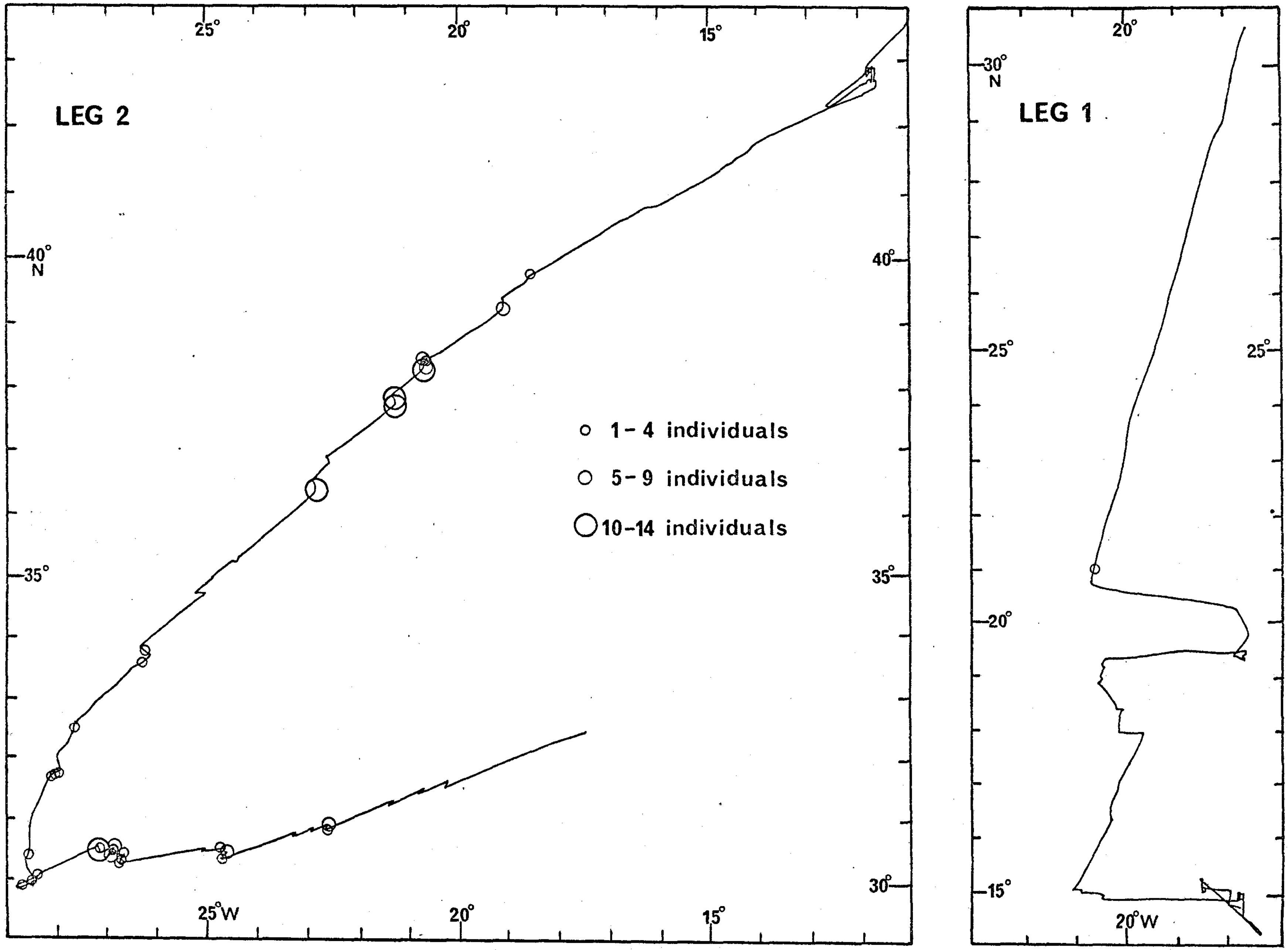

Fig. 7. Occurrences of *Lepas anatifera* in neuston net hauls

FIGURE 8.

Distribution of metamorphosed *Lepas fascicularis* (which were all adult) and *L. pectinata* cyprids in neuston net hauls.

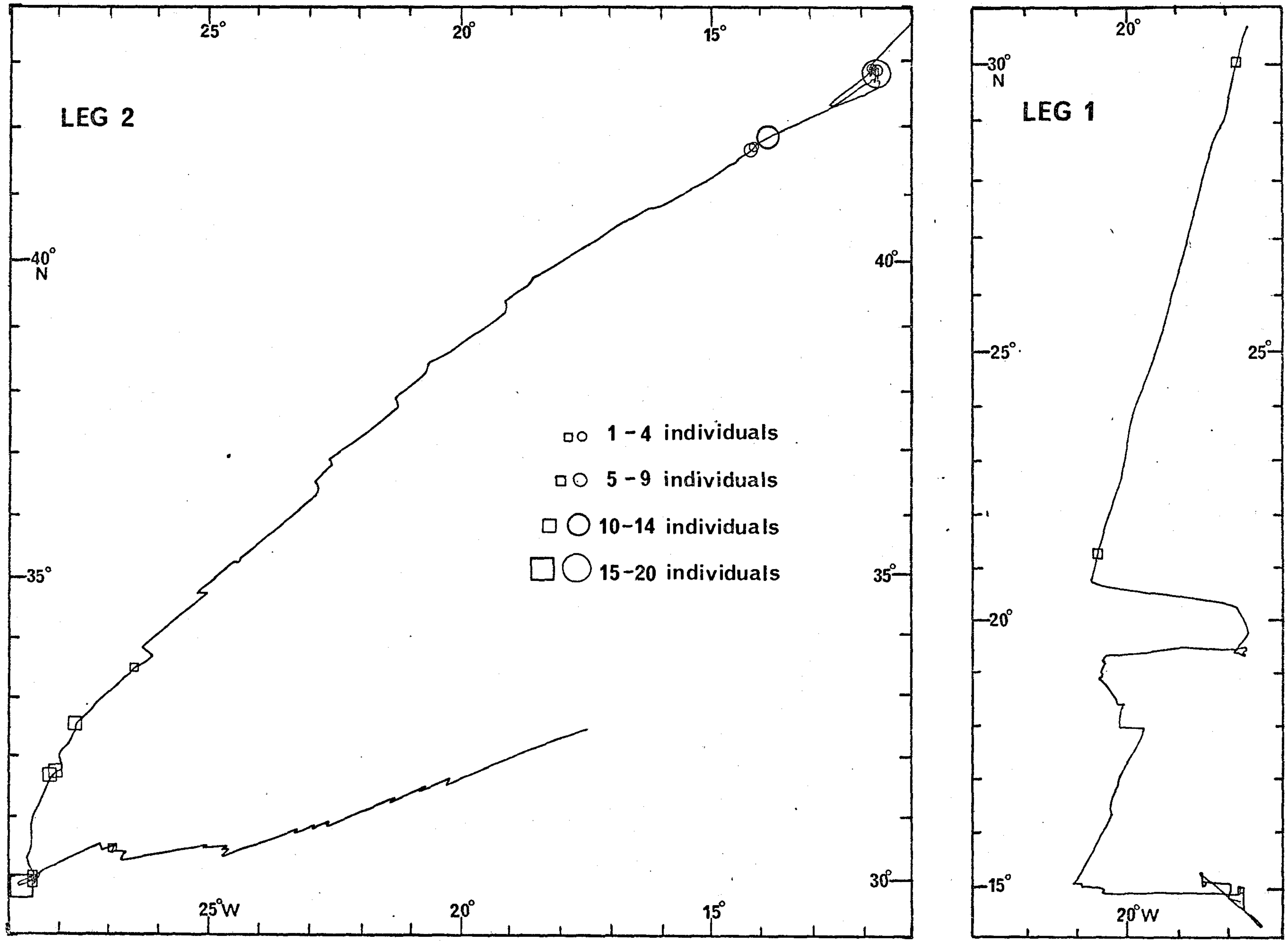

Fig. 8. Occurrences of *Lepas pectinata* cyprids (squares) and adults of *Lepas fascicularis* (circles) in neuston net hauls

FIGURE 9.

Distribution of unidentified types of *Lepas* cyprids in neuston net hauls and *Conchoderma* 'B'.

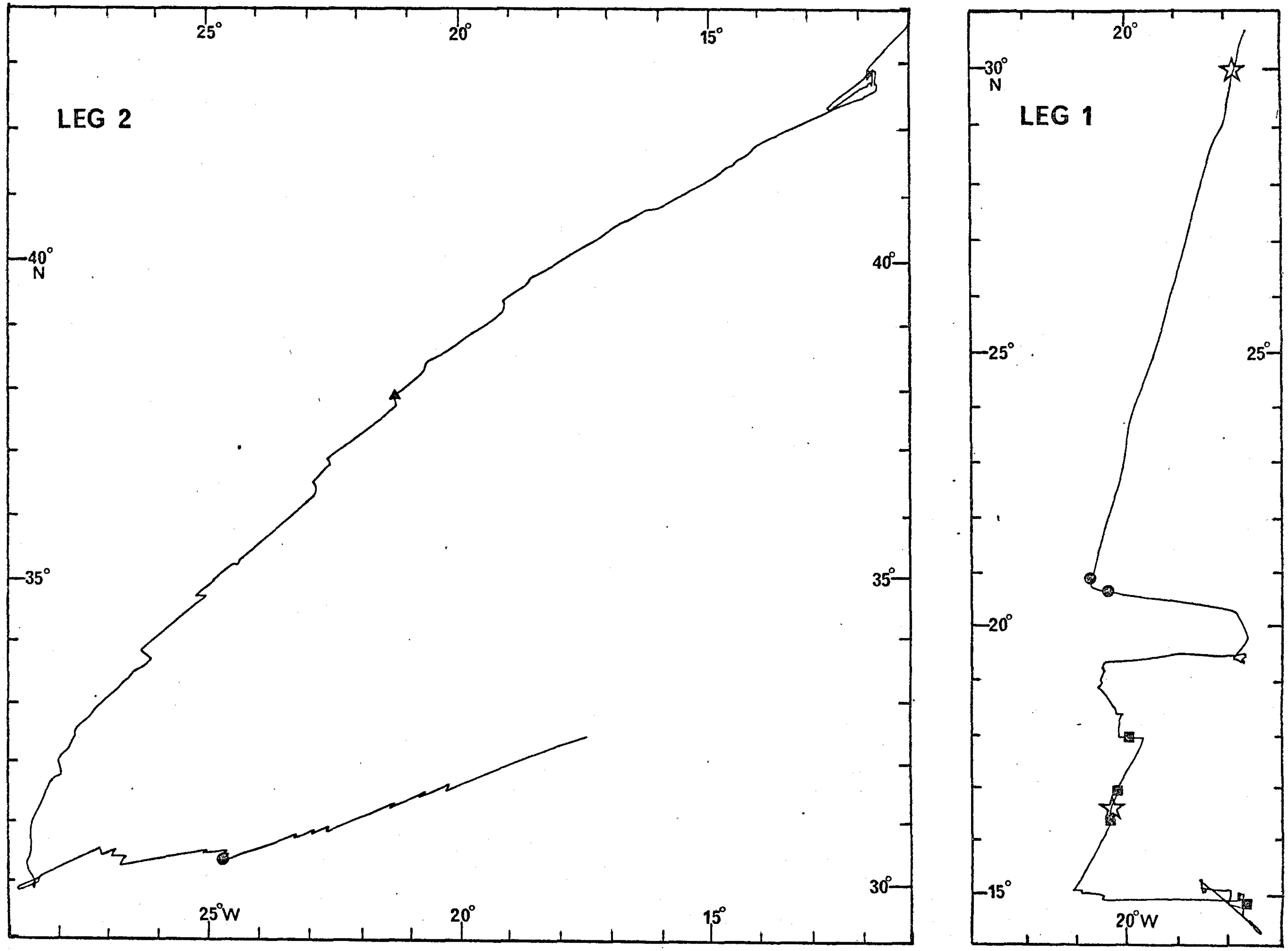

Fig. 9. Occurrences of other cyprids in neuston net hauls: ☆ - *Conchoderma* B, ■ - cyprid D, ● cyprid E, ▲ - cyprid F.

FIGURE 10.

Lateral and ventral outlines of all the cirriped cyprids collected during Discovery cruise 140.

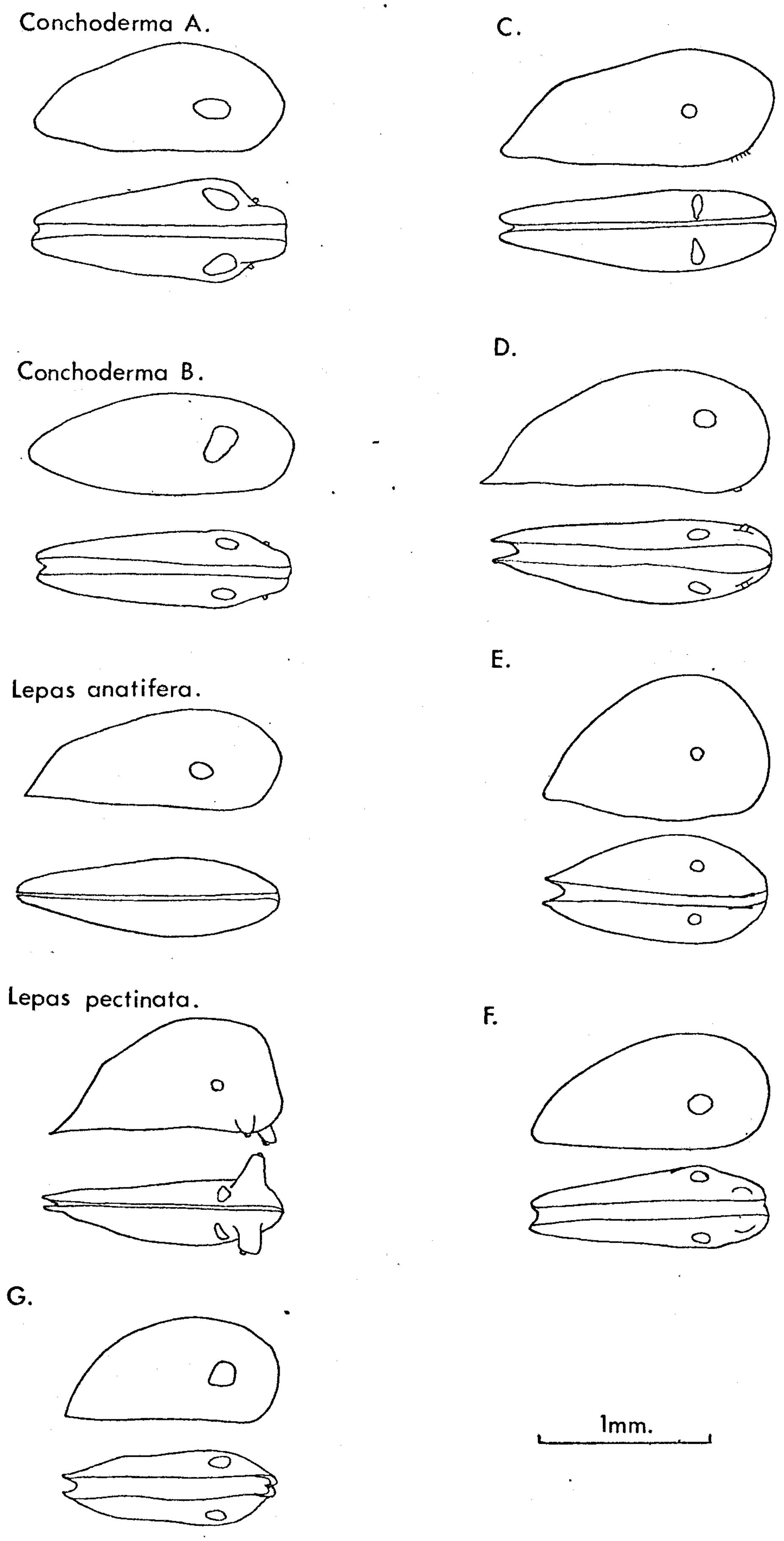

Fig. 10. Lateral and ventral outlines of the cyprids

FIGURE 11.

Vertical profiles of numbers/m^3 of L. pectinata nauplii and cyprids at three stations from the vicinity of the Azores front. Within the front itself a day and a night profile are shown together with the temperature profile. Daytime profiles are shown for the two main water masses; the Western Atlantic Water which is much warmer than the Eastern Atlantic Water. Note the nauplii are concentrated within the shallow thermocline close to the deep chlorophyll maximum. Figures given at the base of the profiles give the total number of cyprids as nauplii in the water column per m^2 of sea surface.

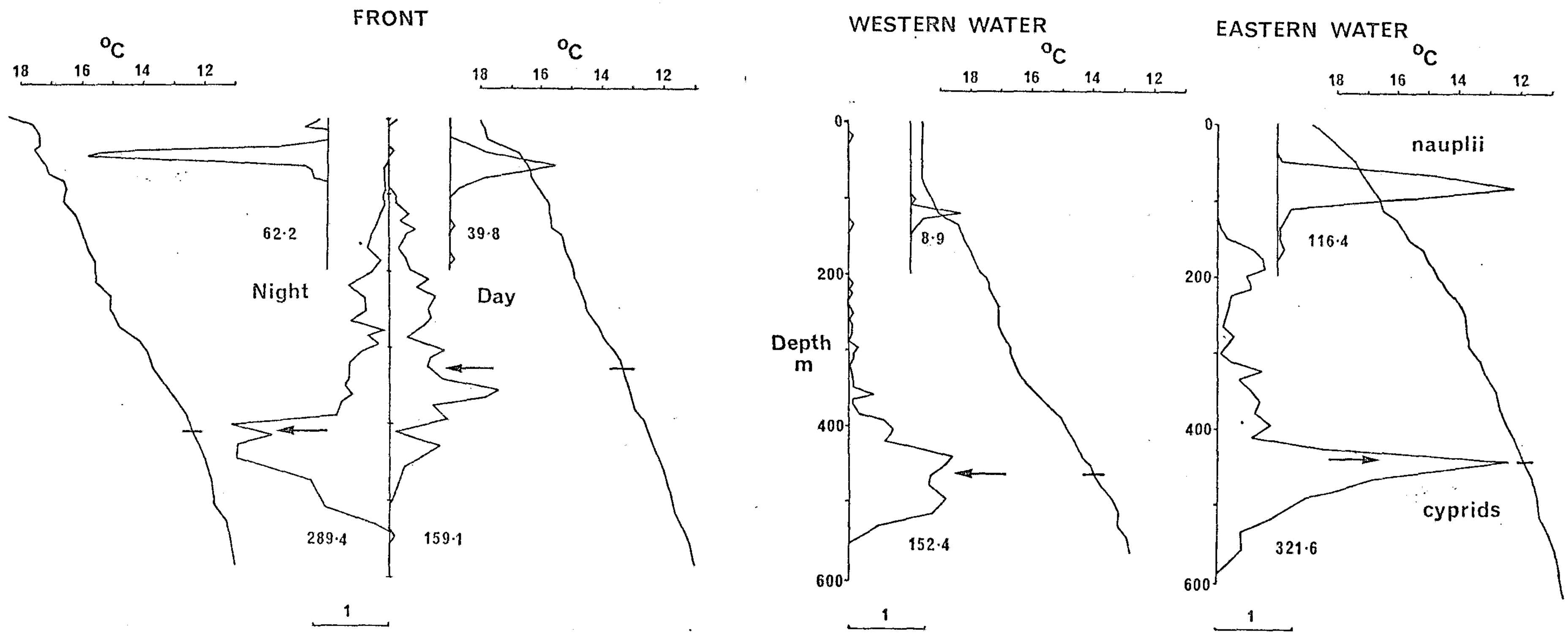

Fig. 11. Vertical profiles of *Lepas pectinata* cyprids and nauplii near Azores front

FIGURE 12.

The old whaling grounds in the Western Indian Ocean where mainly sperm whales were caught, with a calendar showing month by month when the main whaling activity took place. Note for example that whales occurred in the Arabian sector during the season of south-west monsoon, and so this is the season when the risk of Conchoderma fouling might be expected to be maximum (modified from Wray and Martin 1983).