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THE SERGESTID SHRIMP *LUCIFER* IN THE 1970 CICAR PLANKTON SAMPLES TAKEN BY H.M.S. "LUYMES", WITH NOTES ON THE AMAZON RIVER AS NUTRIENT SOURCE

DICK G. TROOST

ABSTRACT

In accordance with previous works, *L. faxoni* was found to be abundant and *L. typus* scarce in the changing environment of the coastal waters off northern South America. High numbers of *L. faxoni* were present in two types of water, viz. highly saline coastal waters with high primary productivity due to enrichment by subsurface water, and in low-salinity lenses, isolated from the Amazon outflow.

Low nutrient levels, as reported before from similar low-salinity lenses are presumed to be caused by increased mixing with infertile, though highly saline Guiana Current water, and depletion by primary producers which are consumed by the relatively large zooplankton standing stock in these lenses, of which *L. faxoni* comprised the bulk.

INTRODUCTION

Species of the genus *Lucifer* (Decapoda, Sergestidae) have been subject of several investigations, especially in the Atlantic. From these studies it is obvious that different species show varying preferences for neritic and oceanic waters. Bowman & McCain (1967) have described this phenomenon for the western North Atlantic. They found an association of *Lucifer typus* A. Milne Edwards, 1837, with highly saline and warm Florida Current water.

Vannucci & Queiroz (1963) observed the presence of *L. typus* in samples along the line of Fortaleza - Fernando de Noronha, and mentioned it as one of the species "whose optimum is an environment of high salinity or high temperature, or both".

As for *L. faxoni* Borradaile, 1915, the only other species occurring in the Atlantic, Bowman & McCain presumed that its tolerance towards oceanic water is limited. They quote several papers which report *L. faxoni* as very abundant in coastal waters along the Atlantic coast of North and South America, while *L. typus* was absent.

Of *L. faxoni* very large numbers were found by Calef & Grice (1967) in samples from low-salinity lenses off-shore northern South America. These lenses, some 600 miles north of the Amazon estuary and 100-250 miles off-shore, are isolated from the Amazon discharge, as can be concluded from their high silicate content (Ryther et al., 1967).

Cadée (1975) has studied the effect of the Amazon river outflow on the fertility and productivity (= rate of production) of the coastal area off Surinam and French Guiana. Measurements for that study, and material for the present one, were collected during the same CICAR cruises.

Preliminary results of the study of Luciferinae from certain 1970 samples taken by H.M.S. "Luymes" off-shore northern South America were already presented by Troost (1973), together with data on planktonic molluscs, and fish larvae. In the present paper, more elaborated results, based on all 1970 samples from H.M.S. "Luymes", are recorded. Moreover, the role of the Amazon river as a nutrient source is discussed.

MATERIAL AND METHODS

For data on all stations, one can refer to Van der Spoel & Koperdraat (1974).

From area 1, around the islands of Aruba, Curaçao, and Bonaire (67°40' - 69°50' W and 11°55' - 12°50' N), 75 samples taken at 53 stations were checked for the presence of *Lucifer*. Of these, 60 samples from 38 stations, were taken between 12 June and 22 July 1970 (cruises 13 and 14). Eight samples, from 8 stations, were obtained between 13 and 26 November (cruise 18). (Seven stations of cruise 19 provided very poor samples without any *Lucifer*, and have been disregarded, since another sampling method, which may have influenced the catch, was used during this cruise.)

From area 2, along the coast of the three Guianas and Venezuela as far as Carúpano (47°35' - 63°07' W and 04°48' - 12°21' N), 89 samples from 72 stations were investigated, all taken between 22 August and 4 November 1970 (cruises 15, 16, 17).

Only during cruises 16 and 17 data on salinity, current velocity (both at several depths), and primary productivity were obtained by scientists of the Netherlands' Institute of Sea Research, and the Royal Netherlands' Meteorological Institute. Plankton samples are available from 40 stations of these two cruises (fig. 3). Both temperature and salinity are known from 36 of these (fig. 4).

Most samples came from various depths between 1 and 6 m. During cruises 13 and 14 tows at 10 and 18 m were also made. All nets had meshes of 56 µm. The numbers of the two species were computed for a standard collecting time of two hours drift.

No flowmeters were used, and data on direction and velocity of wind and current are incomplete. Therefore the volume of water filtered during each tow cannot be computed. This makes no difference in the case conclusions were based on the comparison of the abundance of the two species in the same samples. But comparisons of numbers of the same species from different stations are less reliable. Therefore such comparisons are only, tentatively, made when numbers of specimens from several stations together are notably higher.

Animals belonging to the genus *Lucifer* can easily be recognized by their long head parts. Using a dissecting microscope the two species concerned can be easily distinguished by the length of the eyestalk. The stalks are short in *L. faxoni* (fig. 1a) and long in *L. typus* (fig. 1b).

TABLE I

PERCENTAGES AND TOTAL NUMBERS OF *L. TYPUS* AND *L. FAXONI*

code	area	number of stations studied	max. coll. depth (m)	coll. period (1970)	*L. typus* % (total)	*L. faxoni* % (total)
A	1	8	18	June/July	55.8 (332)	44.2 (262)
B	1	8	06	do.	45.9 (173)	54.1 (204)
C	1	23	02	November	4.7 (3)	95.3 (57)
D	2	51	05	Aug.-Sept.	0.2 (16)	99.8 (7149)

RESULTS

Distribution and abundance

Numbers of *L. typus*, and *L. faxoni* within consecutive ranges are marked for area 1 and 2 in figs. 2 and 3, respectively. At most stations in area 1 both species were found in similar, relatively small numbers. At a few stations in area 2, however, *L. faxoni*, with very high abundance, significantly outnumbered *L. typus*. In table I percentages and total numbers are listed. Since the samples from area 2 come from depths up to 5 m only, they are more reliably compared with the catches from the upper layer in area 1, which are therefore separately given in line B (table I). The numbers from the November samples in area 1 are given in line C. Although these numbers are small, the high abundance of *L. faxoni* as compared with *L. typus* is obvious. The percentages approximate those found in area 2 (line D). The difference is not due to the difference in maximum collecting depths as has been concluded from comparisons between the June/July samples from several depths (unpublished data).

Primary production, and temperature/salinity

As stated above, productivity measurements were made only at certain stations of the cruises 16 and 17. Isopleths of in situ primary productivity estimations (mg C/m^2/day), are incorporated in fig. 3. They are comparable with those given by Cadée (1975, fig. 5e). Productivity is found highest in two symmetrical wedges, 16-50 miles off-shore. Relatively high numbers of *L. faxoni* were found at three (Sts. 157, 177, 178) of the five stations in the western wedge. In the samples from two of these five (Sts. 156, 157) huge numbers of the diatom *Coscinodiscus* spec. were found, while also groups as Chaetognatha, Crustacea, and fish larvae were relatively well represented in the last two samples. Several specimens of *L. faxoni* in the sample from St. 177 were carrying eggs.

Zooplankton was sampled at only two stations (159 and 160) in the eastern wedge of high productivity. Only few specimens of *L. faxoni* were found in these samples.

Samples with high numbers of *L. faxoni* came from the Sts. 180-182 with relatively low salinity values.

The aforementioned high abundances are not due to vertical migration. Besides that the samples in question were taken at various times of the day, the average number of *L. faxoni* of all daytime samples did not differ much from that of all night-time samples investigated in the present study.

Temperature as well as salinity were measured during plankton sampling at 36 of the 40 stations of the cruises 16 and 17 from which plankton samples were available. The temperature-salinity diagram (fig. 4) is based on data from the top 0.5 m of the surface layer. In this figure the abundance of *L. faxoni* is represented by the same marks as used in fig. 3. Isopleths of the water density ar` marked as well.

The surface layer at all five stations situated in the highly productive western wedge has a density of more than 23.00 g/l. By comparison the density of the surface layer at the other three *L. faxoni*-rich stations (180-182) is much lower: 16.47-19.06 g/l. Because the variations in temperature are small, the density is almost entirely due to salinity.

DISCUSSION

From the data in area 2 (off-shore the three Guianas and Venezuela as far as Carúpano), the tolerance of *L. faxoni* for high as well as low salinities is clear. The scarcity of *L. typus* in the same area is another indication of its "aversion" for coastal waters, being a changing environment where low salinities may occur. The environmental changes, including salinity drops, occuring in area 1 (around the islands of Aruba, Curaçao, and Bonaire) during the month of November as compared with the stability during June/July (cf. Gade, 1961) may have caused the relative scarcity of *L. typus* in the November samples from this area. This in contrast to the slightly higher number of this species as compared with *L. faxoni* in the June/July samples.

In area 2, relatively large numbers of *L. faxoni* were found in two types of water (figs. 3 and 4). In the near-shore wedge high values for primary productivity, salinity, and density were measured. Consequently, only two of the three nutrient sources mentioned by Cadée (1975) for the whole area are contributing here, viz. upwelling, and mineralization of terrestrial organic detritus.

The second type of water with large numbers of *L. faxoni* was sampled at three stations between 45 and 110 miles off-shore. Two of these were located in, and the other near the centre (S < 30 ‰) of a low-salinity lens, originating from the Amazon river (cf. Ryther et al., 1967). The freshened surface layer (S < 36 ‰) was from 17 to 45 m thick, and current speed at 1 m depth is about 31 cm/sec. Primary productivity was not measured in this lens, but is presumed by the present author to be lower due to consumption of phytoplankton (see below).

Huge numbers of *L. faxoni* were already found by Calef & Grice (1967) in low-salinity lenses farther away from the mouth of the Amazon river. The hydrography and nutrient chemistry of these and the surrounding areas were previously described by Ryther et al. (1967). While Vannucci & Queiroz (1963) recorded *L. typus* from stations south-west of the Amazon river mouth, they did not mention the presence, let alone high abundance, of Luciferinae in the relatively rich plankton samples from just outside and north of the river mouth, "where the fertilizers brought by the same are dragged by the current ....". Consequently, it appears that the large populations of *L. faxoni* developed within these lenses, which may also be the case with the large populations of the phyllopod *Evadne tergestina* found by Calef & Grice (1967). It is obvious that this has required a large phytoplankton supply as food, and consequently nutrients. From the foregoing and the following, it is presumed by the present author, that the Amazon river, the third nutrient source given by Cadée (1975), is the major if not the only nutrient contributor for such low-salinity lenses.

According to Ryther et al. (1967), the Amazon river as source of nutrients for the ocean into which it flows is negligible but significant according to Cadée (1975). It has to be said, however, that Cadée mainly based his conclusions on results from stations (including Sts. 159 and 160 of the present study) within 80 miles from the shore on the continental shelf.

Unpublished data of CICAR cruises 16 and 17 show that here thickness of the freshened surface layer (S < 36 ‰) can be relatively small (5.5-7.0 m), values for salinity highly variable, and current speeds high (up to 196 cm/sec at 1 m depth). Hence, the above findings point in the direction that all three nutrient sources given by Cadée (1975), viz. upwelling, mineralization and Amazon outflow, are contributing. The low numbers of *L. faxoni* from Sts. 159 and 160, located in the eastern wedge with high primary productivity (fig. 3), may have been caused by these exceptional environmental characteristics. By comparison, the two *L. faxoni*-rich low-salinity lenses (S < 36 ‰) investigated by Ryther et al. (1967) were found over deep waters with their centres (S < 30 ‰) 150 miles and more off-shore. The thickness of the freshened surface layer (S < 36 ‰) of the lens found during October-November 1964, could be deduced from Hulbert & Corwin (1969; fig. 7, section D) and was up to about 60 m.

Table II and fig. 5 are illustrative for the significance of nutrient input into the sea by the Amazon discharge. At Sts. 1 and 6, located in the estuary, values for nitrogen, phosphorus, and silicate were on the average higher than at the river Sts. 2-5. At St. 465, just outside the river mouth, and obviously influenced by river water, the value for nitrogen was 37.8, for phosphorus 13.8, and for silicate 34.6 times higher than those for St. 461, also just outside the river mouth but located in highly saline water. The cause of the 5.7 times higher value of total dissolved phosphorus at St. 465 as compared with St. 6 is not understood, but does not alter the general picture. At St. 492, 600 miles northwest of the river mouth, 1 part river water is mixed with 8 times more sea-water of 36 ‰ S than at St. 465. The low nutrient values at this station, situated in the centre of a low-salinity lens, are presumed to be the result of depletion of the nutrients by primary producers which served as food for the large zooplankton standing stock, mainly composed of *L. faxoni* and *E. tergestina* (cf. Calef & Grice, 1967), found in these lenses.

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DICK G. TROOST
Unesco Regional Office for
Science and Technology
Tromolpos 273/JKT
Jakarta - Indonesia

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TABLE II

Salinity and some dissolved constituents in the Amazon river/estuary (Sts. 1-6; after Williams, 1968)[1]), outside the river mouth (Sts. 465 and 461; after Ryther et al., 1967)[2]), and 600 miles NW of the river mouth in a low-salinity lens (St. 492; do.)[2])

stations	2	4	5	3	1	6 [3])	465	461	492
salinity ‰	0	0	0	0	0	> 0	12.9	36.3	29.5
river water % [4])	100	100	100	100	100	< 100	64.3	0	18.2
NO_3-N (µg-at/l)	2.21	8.07	9.99	3.93	9.64	8.57	5.30	0.14	0.08
PO_4-P (µg-at/l)	0.01	0.05	0.40	0.18	0.35	0.70	----	0.07	0.01
P (µg-at/l)	0.08	0.22	0.52	0.24	0.41	0.72	4.16	0.30	0.16
SiO_3-Si (µg-at/l)	0.89	3.52	11.4	0.43	7.90	62.1	83.8	2.42	18.5

[1]) sampled during September 1967

[2]) sampled during October-November 1964

[3]) only station among Sts. 1-6 with "appreciably saline waters"

[4]) assuming the salinity of sea-water, and river water as 36.0 and 0.0 ‰, respectively

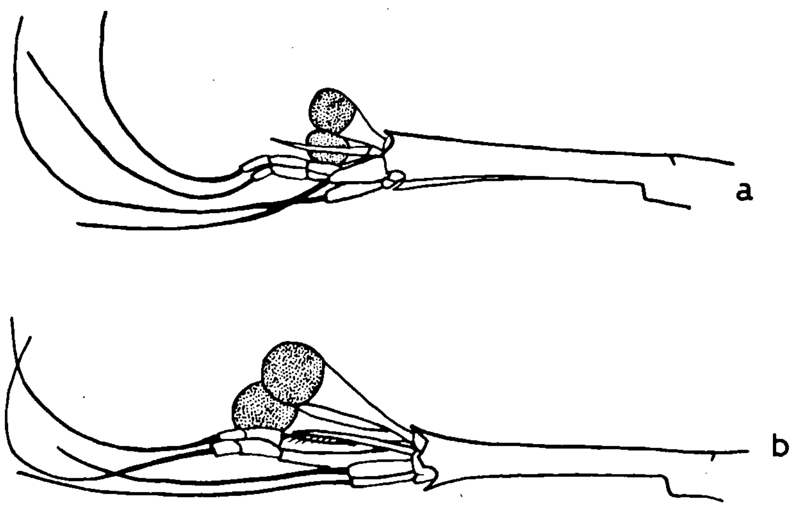

Fig. 1 Cranial parts of *L. faxoni* (a) and *L. typus* (b)

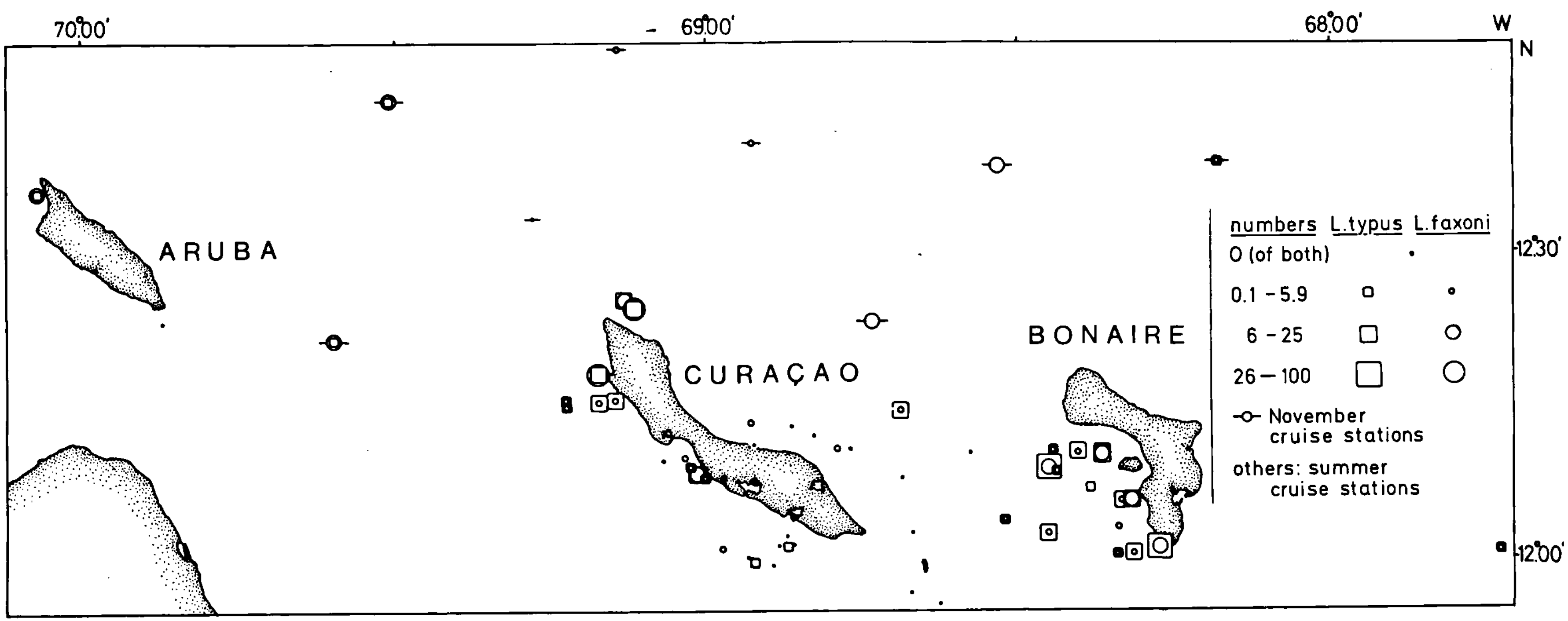

Fig. 2 Numbers of *L. typus*, and *L. faxoni* found in area 1 (computed for a standard collecting time of 2 hours).

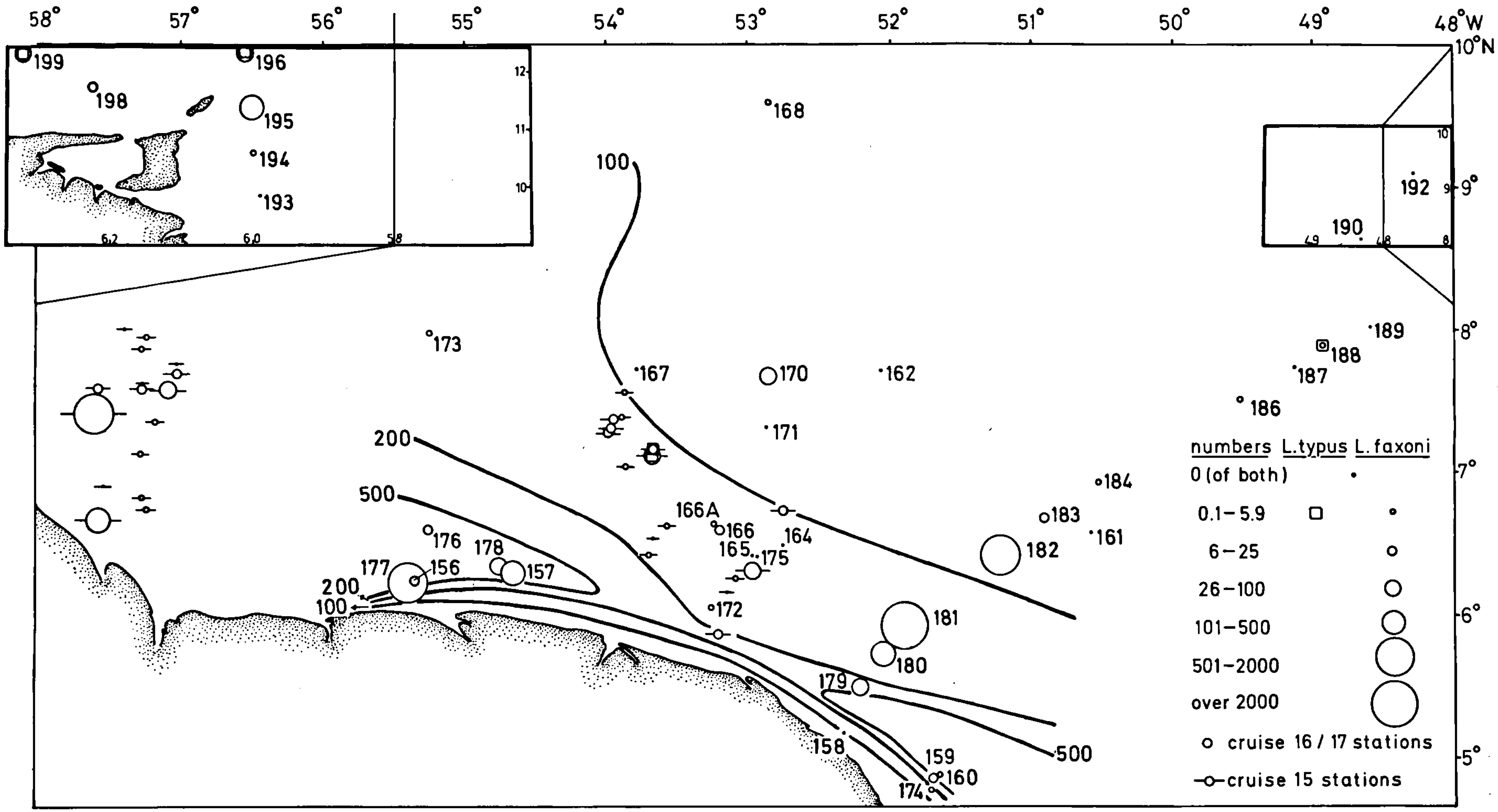

Fig. 3 Computed numbers of *L. typus*, and *L. faxoni* found in area 2. In situ primary productivity isopleths (mg C/m² /day) inserted; measurements based on cruises 16 and 17 up to St. 178 (based on Cadée, 1975).

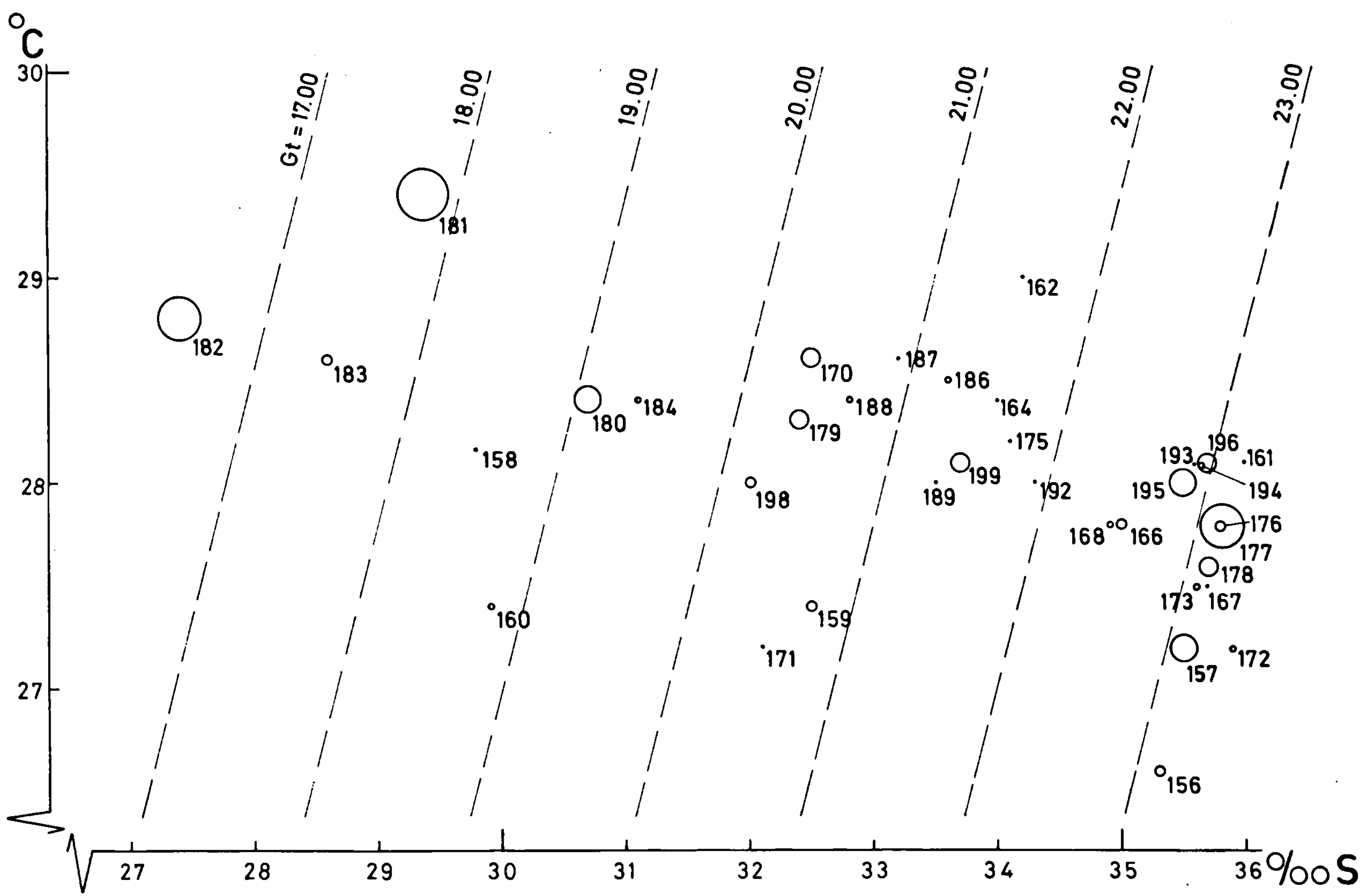

Fig. 4 Temperature/Salinity/Plankton-diagram for *L. faxoni* sampled during cruises 16 and 17. Isopleths of the water density are inserted. See fig. 3 for explanation of symbols.

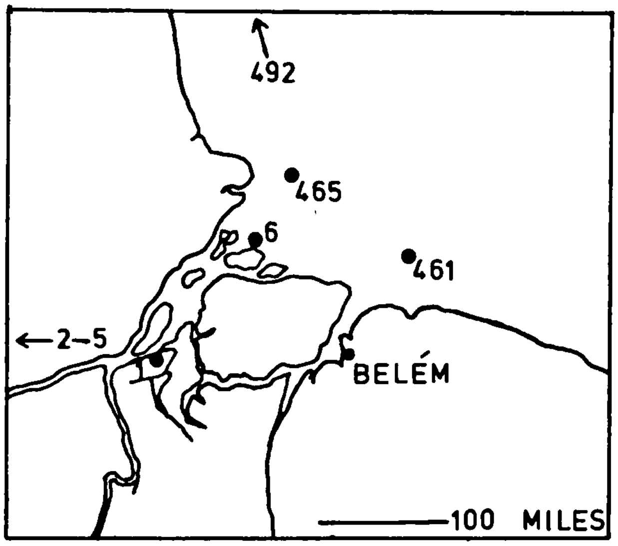

Fig. 5 Mouth of Amazon river with positions of stations listed in table II.