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Mysids and euphausiids in the diet of *Scomber japonicus* Houttuyn, 1782 off the Canary Islands

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ABSTRACT

The trophic importance of mysids and euphausiids in the diet of chub mackerel Scomber japonicus *Houttuyn, 1782 caught between March 1988 and May 1989 off the Canary Islands was deduced from their stomach contents. Mysids constituted an unusually high proportion of the diet (in wet weight) of* S. japonicus *in the Canary Islands when compared with other areas of the world, and they had a much higher trophic importance than euphausiids. This is not in consonance with their relative abundance in the zooplankton around this archipelago reported by other authors.*

The cycle of the species of mysids in the stomach contents showed an alternation in their relative abundance. However, Anchialina agilis *G. O. Sars, 1877 was the predominant species, followed by* Gastrosaccus normani *G. O. Sars, 1877. Breeding females of* A. agilis *and* G. normani *with larvae in the marsupium were present in the diet nearly year-round.*

Euphausia *spp. was the most abundant euphausiid species of those identified in the stomach contents.*

Key words: Mysids, euphausiids, diet, *Scomber japonicus,* Canary Islands.

RESUMEN

Misidáceos y eufausiáceos en la dieta de *Scomber japonicus* Houttuyn, 1782 en las islas Canarias.

La importancia trófica de los misidáceos y eufausiáceos en la dieta del estornino Scomber japonicus *Houttuyn, 1782 en las islas Canarias fue determinada a partir de los contenidos estomacales de individuos capturados entre marzo de 1988 y mayo de 1989. Cuando se compara la dieta de* S. japonicus *en Canarias con la descrita en otras áreas mundiales para esta misma especie, se observa que los misidáceos representan una proporción inusualmente alta de la misma (en peso húmedo) y, contrariamente a lo esperado, tienen una importancia trófica mucho más alta que los eufausiáceos. Sin embargo, este aspecto no coincide con los datos de abundancia relativa en la comunidad zooplanctónica dados por otros autores para el archipiélago.*

Los contenidos estomacales muestran una alternancia en la abundancia relativa de las especies de misidáceos. Sin embargo, Anchialina agilis *G. O. Sars, 1877 fue la especie predominante seguida de* Gastrosaccus normani *G. O. Sars, 1877. Hembras de* A. agilis *y* G. normani *con larvas en el marsupio estuvieron presentes en la dieta durante prácticamente todo el año.*

De las especies de eufausiáceos identificados en los contenidos estomacales, el género Euphausia *fue el más abundante.*

Palabras clave: Misidáceos, eufausiáceos, dieta, *Scomber japonicus,* islas Canarias.

INTRODUCTION

Species of the orders Mysidacea and Euphausiacea are shrimp-like animals which occur in vast numbers in oceanic and coastal regions of the world. Despite their importance in many marine ecosystems, they have been little studied off the northwest coast of Africa (Baker, 1970; Mauchline, 1980; Vives, 1985). Mysids are often overlooked during sampling programmes because they are not sampled efficiently by either conventional benthic or pelagic sampling methods. However, euphausiids are more frequent in plankton samples, especially those taken in oceanic water, because they are a prominent part of the scattering layers (Baker, 1970).

According to acoustic estimates, chub mackerel *Scomber japonicus* Houttuyn, 1782 represents 52.0 % of the mid-sized pelagic fish off the Canary Islands (Pastor and Delgado de Molina, 1985). Since *Scomber japonicus* is an opportunistic planktivore (Collette and Nauen, 1983), stomach contents analyses may yield valuable information on euphausiids' and mysids' abundance, which could complement data obtained with traditional plankton nets.

MATERIALS AND METHODS

Specimens of chub mackerel *Scomber japonicus* were sampled from commercial catches taken from the fishing grounds off the island of Gran Canaria (28° 00' N - 15° 30' W) between March 1988 and May 1989 (figure 1). Most samples were obtained from purse-seine nets operating at nightfall, generally over the bathymetric zones of 30 to 80 m depth. The purse-seine nets employed by the Canary Islands' traditional fishing fleet work to a depth of 40-50 m, and fish are lured with light. Other samples, especially juvenile fish, were obtained from beach-seine nets, in the morning. Fish were selected for stomach content analysis according to season and the size-range of the species in the catches, independent of sex. Fish were classified as juvenile (1.5-13.5 cm Total Length (TL)), immature (13.6-22.5 cm TL) or adult (more than 22.6 cm TL), following criteria reported by Watanabe (1970) and Angelescu (1979) from Japanese and Argentinian waters.

The stomach content of 721 fish (139 juvenile, 431 immature and 151 adults) was removed immediately after landing and preserved in 70 % ethanol. All food items from the stomach were placed on filter paper to remove excess moisture, and weighed. Stomach fullness (*SF*) was calculated as:

$$SF = (\text{wet weight of the gut contents/wet weight of fish}) \times 100.$$

Prey items were identified to the lowest taxa possible. For each stomach examined, counts were made of the number of prey items in each prey category. An index of importance by number (*IN*) for each stomach was calculated as the mean for each prey category, where

$$IN = ((\%\ \text{composition by number}) \times \times (\%\ \text{occurrence}))^{1/2}$$

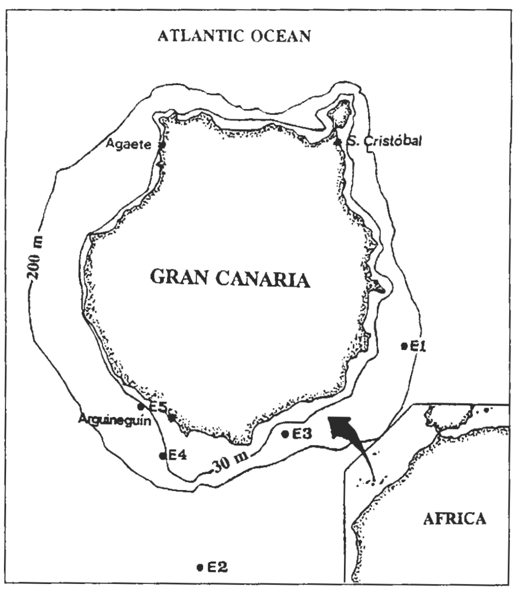

Figure 1. Geographical position of the island of Gran Canaria, landing points where the fish samples were collected and the stations (E1, E2, E3, E4 and E5) where the zooplankton samples were obtained during March 1991.

(Windell, 1968; Vesin, Legget and Able, 1981), in percentage. Where:

$$\text{number}\ (\%) = (\text{number species}_i/\text{total number of all prey}) \times 100$$

and the percentage of occurrence is the frequency of occurrence of a prey item in the stomach.

Wet weights were determined for each prey category for juvenile, immature and adult fish, and an index of the importance of each prey category by wet weight (*IM*) was calculated, where

$$IM = ((\%\ \text{wet weight}) \times (\%\ \text{occurrence}))^{1/2}$$

(Castro, 1993), and also in percentage. Where:

$$\text{weight}\ (\%) = (\text{wet weight species}_i/\text{total wet weight all prey}) \times 100.$$

On the other hand, two neustonic surveys were carried out from nightfall to midnight from 12-14 March 1991, with nets of 500 and 1000 µm (Schram, Svelle and Opsahl, 1981) on board the Spanish Coastguard vessels *Villa de Bilbao* and *Grosa* (figure 1). The neustonic nets were towed for 10 min at 1 knot, at three subsurface depths (0-50, 50-100 and 100-150 cm). The aim of these surveys was to capture fish larvae on the shelf of Gran Canaria. However, the large quantities of mysids that were caught enabled us to make some comparisons with the stomach content data.

RESULTS

Mysid species found in the stomach contents of chub mackerel showed a peak of maximum abundance in number of specimens per fish during December, followed by a second peak in October and another of

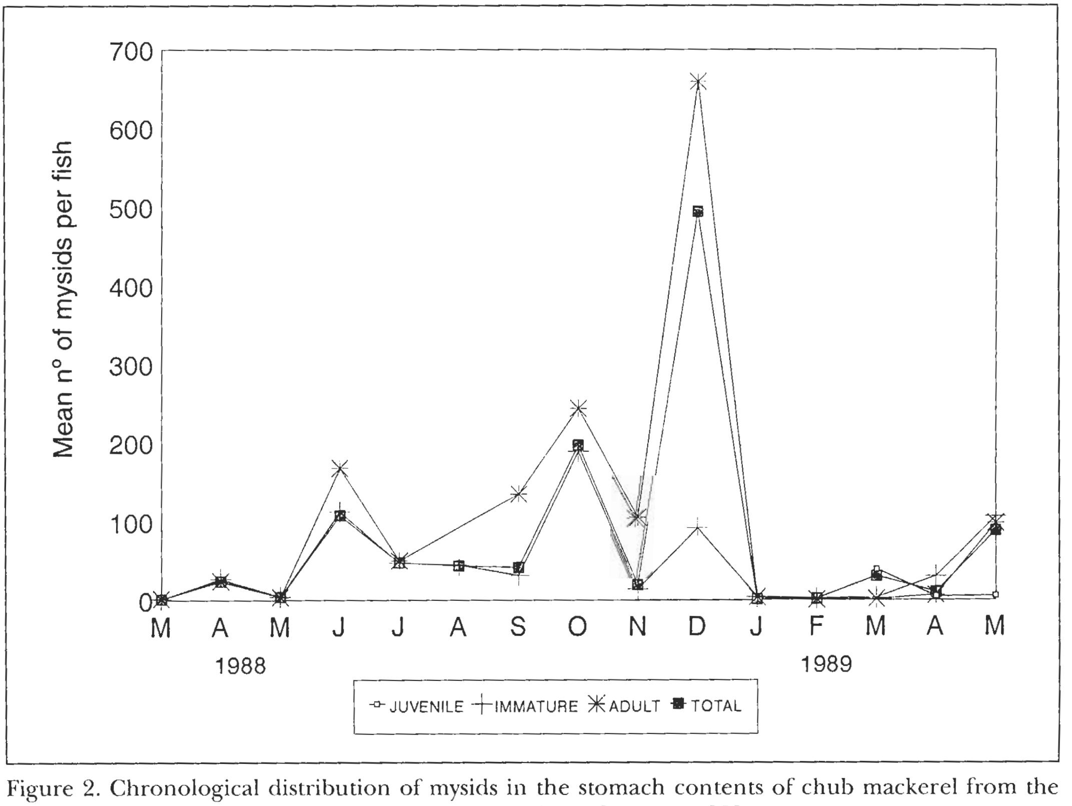

Figure 2. Chronological distribution of mysids in the stomach contents of chub mackerel from the Canary Islands, March 1988 to May 1989.

less importance in June (figure 2). However, there were no significant differences between the peaks of December and October (Mann-Whitney U-test, $P < 0.167$) (Siegel, 1990). The peak in December may be biased, because the number of mysids per fish was inflated by four adult fish (TL > 30 cm) whose stomachs were full of mysids ($\bar{x}$ = 4 071; *SD* = 1 163.7), caught off the north coast of the island with a beach seine in the morning. If the contribution of these four specimens caught in December is omitted, the main peak of mysids per fish was obtained in October, and there was an insignificant difference between the secondary peaks of December and June (Mann-Whitney U-test, $P < 0.823$). The lowest abundance of mysids in the stomach contents was recorded from January to April.

Euphausiid species showed two different non significant peaks of maximum abundance in number of specimens per fish, during May and August (Mann-Whitney U-test, $P > 0.05$), followed by two other secondary peaks in October and January (figure 3). Nonsignificant differences were also found between the secondary peaks ($P > 0.05$). No euphausiids were found in the stomach contents during April and July 1988 and March-April 1989. From 101 stomach contents analysed, only two euphausiids were collected in September and November 1988.

In immature fish, mysids constituted the most important item by weight (32.2 %), ranking third by number (13.7 %). Euphausiids represented only 2.1 % and 4.2 % of the total by number and weight, respectively. Mysids were also the most important food items for adult *Scomber japonicus*, contributing 32.0 % by number and 36.2 % by weight of food ingested. Euphausiids accounted for only 3.9 % by number and 4.4 % by weight of the diet of adult fish. Juvenile *S. japonicus*, which are more coastal in their habits, showed a lower trophic

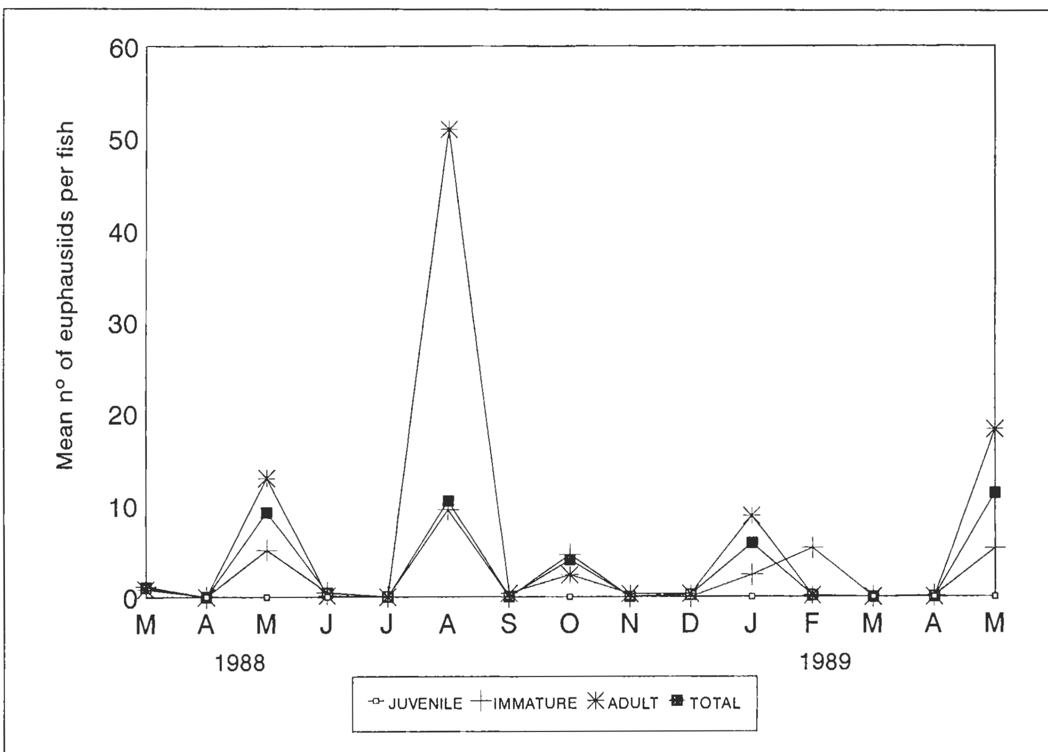

Figure 3. Chronological distribution of euphausiids in the stomach contents of chub mackerel from the Canary Islands, March 1988 to May 1989.

Table I. List of mysids and euphausiids species found in the stomach contents of chub mackerel.

Mysidacea		Code
Mysinae	*Paramysis* spp.	
	Hemimysis sp.	H
	Stilomysis sp. (*S. grandis* ?)	Sg
	Siriella sp.	S
	S. clausii G. O. Sars, 1877	
	S. norvegica G.O. Sars, 1869	
	S. thompsoni Milne Edwards, 1837	
	Gastrosaccus normani G. O. Sars, 1877	Gn
	Anchialina agilis G.O. Sars, 1877	Aa
	Paramblyops sp.	P
	Leptomysis sp. (*L. sardica* ?)	
Euphausiacea		**Code**
Euphausiidae	*Euphausia* sp.	E
	E. brevis Hansen, 1905	Eb
	E. krohnii Brandt, 1851	Ek
	Stylocheiron sp.	S
	Nyctiphanes sp.	N
	Thysanopoda subaequalis Hansen, 1905	Ts

dependence on mysids (*IN* = 8.6 % and *IM* = 14.7 %), while euphausiids constituted a merely anecdotical figure (*IN* = 0.1 % and *IM* = 0.2 %).

Several species of mysids were indentified in the stomach contents of chub mackerel (table I). The contribution of these species in the stomach content showed a temporal alternation in abundance. *Anchialina agilis* G. O. Sars, 1877 was dominant, followed by *Gastrosaccus normani* G. O. Sars, 1877 (table II).

Mysid larvae and breeding females of *Anchialina agilis* and *Gastrosaccus normani* with larvae in the marsupium were present in the stomach contents nearly year-round. There were two peaks of presence of mysid larvae in the stomach contents, one during spring (May-June) and the other during the winter (December) (figure 4).

We were unable to classify under any species category the majority of the euphausiids found in the stomach contents of chub mackerel. *Euphausia* spp. (*E. krohnii* (Brandt, 1851) and *E. brevis* Hansen, 1905) were the species of euphausiids most frequently found in the stomach contents (table III). Euphausiid larvae were present

Table II. Number of fish sampled per month, averages of mysids per fish sampled and, in columns, number of mysids per species found in the stomach contents of chub mackerel during the sampling period (March 1988-May 1989). (N): number of fish sampled per month; (n+): number of stomachs with presence of mysids per month; (%): percentage of stomachs with presence of mysids in relation to the total fish sampled per month; ($\bar{x}$): average of mysids in relation with the total fish sampled by month; (σ): standard deviation; (Mx): maximum number of mysids found in a single stomach each month; (UN): unidentified species. See other codes in table I.

	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M
N	54.0	66.0	37.0	67.0	39.0	48.0	50.0	55.0	51.0	24.0	108.0	22.0	39.0	38.0	23.0
n+	23.0	44.0	16.0	62.0	37.0	40.0	40.0	52.0	24.0	23.0	19.0	10.0	33.0	15.0	19.0
%	42.6	66.7	43.2	92.5	94.9	83.3	80.0	94.5	47.0	95.8	17.6	45.4	84.6	39.5	82.6
$\bar{x}$	1.5	24.0	9.9	107.9	47.8	43.8	41.5	196.9	19.2	493.0	0.9	1.6	30.4	10.1	88.3
σ	2.6	44.9	36.2	104.7	58.1	42.4	75.3	184.6	48.3	1001.0	3.9	3.3	41.8	22.5	148.2
Mx	13.0	235.0	32.0	336.0	275.0	177.0	380.0	769.0	205.0	4588.0	36.0	14.0	181.0	94.0	640.0
Aa	63	1505	197	932	1285	1344	1743	7147	59	2721	84	30	285	0	244
Gn	0	0	0	379	151	126	83	3249	911	1420	6	2	380	0	243
S	0	16	14	204	151	21	21	0	0	0	0	0	237	371	1280
H	0	31	0	0	0	0	0	0	0	0	0	0	142	0	0
P	0	0	0	0	0	0	0	0	0	7573	0	0	12	0	0
Sg	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
UN	16	32	154	1399	2192	610	228	433	10	119	8	1	131	12	265

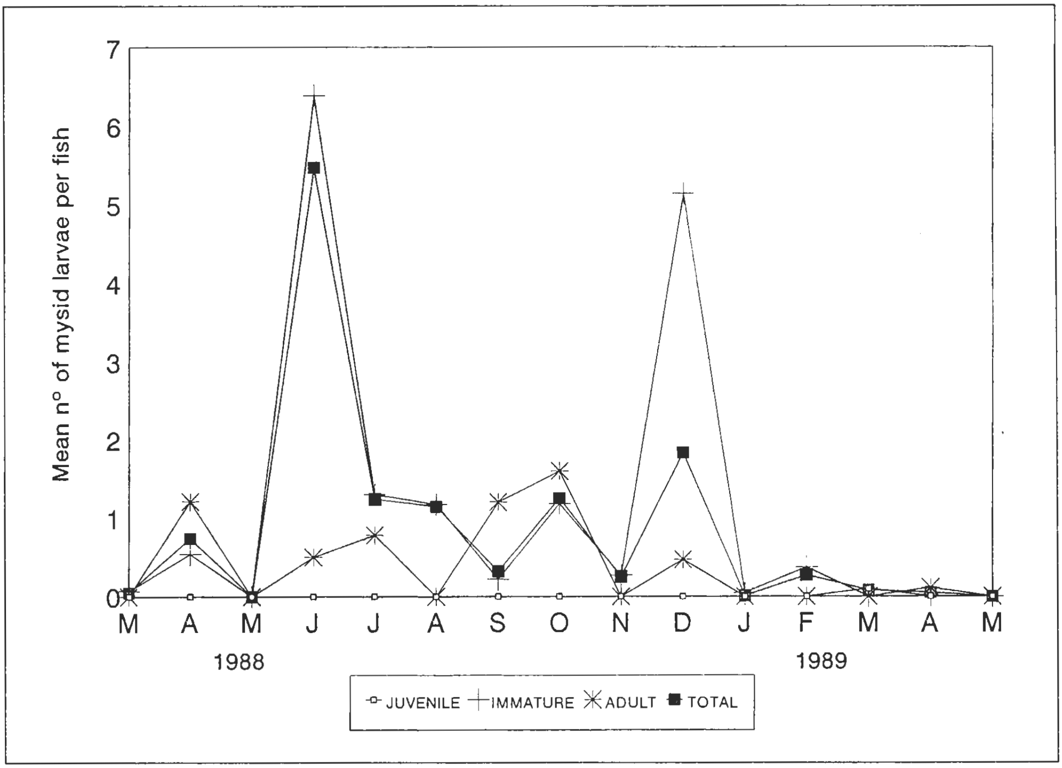

Figure 4. Chronological distribution of the mean number of mysid larvae per fish.

Table III. Number of fish sampled per month, averages of euphausiids per fish sampled and, in columns, number of euphausiids per species found in the stomach contents of chub mackerel during the sampling period (March 1988-May 1989). (N): number of fish sampled per month; (n+): number of stomachs with presence of euphausiids; (%): percentage of stomachs with presence of euphausiids in relation to the total fish sampled per month; ($\overline{x}$): average of euphausiids per stomach analysed and month; (σ): standard deviation; (Mx): maximum number of euphausiids found in a single stomach each month; (UN): unidentified. See other codes in table I.

	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M
N	54.0	66.0	37.0	67.0	39.0	48.0	50.0	55.0	51.0	24.0	108.0	22.0	39.0	38.0	23.0
n+	15.0	0.0	7.0	11.0	0.0	12.0	1.0	21.0	2.0	2.0	9.0	4.0	0.0	1.0	16.0
%	27.8	0.0	18.9	40.7	0.0	25.0	2.0	38.2	3.9	8.3	8.3	18.2	0.0	2.6	69.5
$\overline{x}$	1.1	0.0	9.2	0.4	0.0	10.5	0.0	2.9	0.1	0.2	5.9	0.2	0.0	0.0	11.3
σ	2.1	0.0	40.2	1.5	0.0	30.1	0.3	6.1	0.3	0.9	53.7	0.4	0.0	0.2	24.8
Mx	8.0	0.0	240.0	10.0	0.0	165.0	2.0	77.0	1.0	4.0	558.0	1.0	0.0	1.0	111.0
Ts	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ek	0	0	7	0	0	271	0	15	0	0	0	0	0	0	0
Eb	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
E	0	0	17	1	0	0	0	0	0	0	0	0	0	0	0
S	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
UN	53	0	318	29	0	234	2	208	2	6	663	4	0	1	261

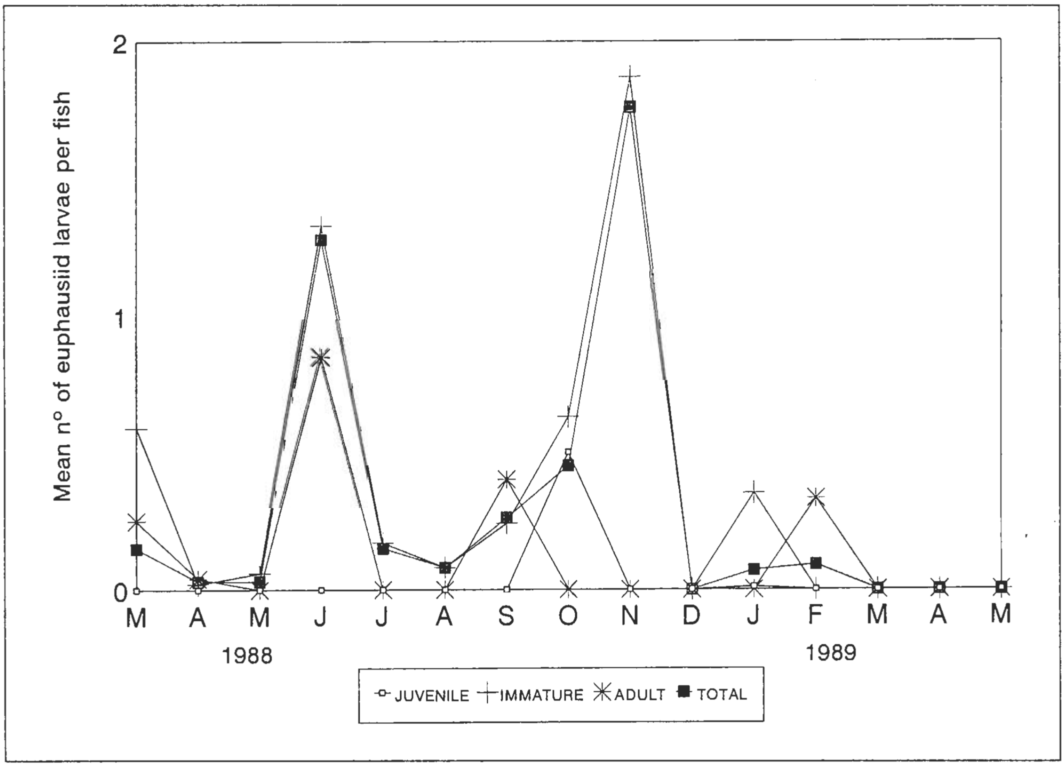

Figure 5. Chronological distribution of the mean number of euphausiid larvae per fish.

in the stomach contents nearly year-round, except in December 1988 and March-May 1989. There were two peaks in the presence of euphausiid larvae in the stomach contents, one in June and the other, the highest, in November (figure 5).

Table IV shows the number of mysids caught with neuston nets at five stations in the most important fishing ground off Gran Canaria (March, 1991). No euphausiids were present in the neustonic samples. The mysid *Gastrosaccus normani* was the most abundant species in the samples of zooplankton, followed by *Anchialina agilis.* At station 4, 1 888 specimens were collected in a single neustonic sample. In this sample, the proportions of *G. normani* and *A. agilis* were similar (56.9 % and 42.0 %, respectively).

DISCUSSION

Data obtained from the stomach contents of *Scomber japonicus* leave many ques-

Table IV. Number of mysids obtained with neuston nets off Gran Canaria in March 1991.

Station	E 1	E 2	E 3	E 4	E 5	Total	$\bar{x}$	σ
Date (March 1991)	12th	12th	12th	14th	14th			
Depth (m)	80	2 150	60	45	30			
No mysids/sample	23	0	4	1 888	399	2 314	462.8	814.4
Siriella clausi	8	–	4	19	4	35	7.0	7.3
Gastrosaccus normani	11	–	0	1 076	363	1 450	290.0	466.1
Anchialina agilis	0	–	0	793	32	825	165.0	351.3
Paramblyops sp.	4	–	0	0	0	4	0.8	1.8

tions unanswered, but it is obvious that mysids, and specially those species with pronounced migration patterns, have a more important role to play in the Canary Islands area than previously believed. Curiously, they have been overlooked during sampling programmes relating to the zooplankton communities around this archipelago (Baker, 1970; Corral, 1970; Corral and Genicio, 1970; Foxton, 1970; Mingorance, 1983; Hernández and Lozano, 1984; Santamaría, 1984; Fernández de Puelles, 1987; Hernández-León, 1988a, 1988b; Fernández de Puelles and Braun, 1989; Santamaría *et al.*, 1989; García-Ramos *et al.*, 1991; among many others). Probably, this is due to inadequate sampling methods for this species, which has very specific patterns of behaviour (many species are associated with the seabed) (Mauchline, 1980; Fossa, 1985, 1986; Kaartvedt, 1985). It is possible that *Scomber japonicus* feeds on swarms of mysids, taking advantage of the positive phototactic response of mysids to weak light sources (Mauchline, 1980), such as occurs with purse seiners which use light to lure mackerel at night (Bas *et al.*, 1995).

On the other hand, Hatanaka *et al.* (1957) and O'Connell and Zweifel (1972) reported that to maintain its rhythm of growth in nature, *Scomber japonicus* needs to consume daily more than 8 % of its body weight in food when its diet is based exclusively on crustaceans (euphausiids), but only more than 2.5 % when this is based exclusively on fish (anchovy). From this empirical daily consumption, we were able to make an approximate assessment of the mysids and euphausiids biomass consumed by chub mackerel in the Canary Islands. If we assume that the *S. japonicus* in the Canary Islands consumes daily over 5 % of its body weight in food because of its mixed diet (crustaceans, principally mysids) and fish (pilchard) (Castro, 1993), it is possible to estimate that the stock of chub mackerel living off the Canary Islands (38 000 tons according to acoustic estimates (Pastor and Delgado de Molina, 1985)) consumes annually more than 242 000 tons of mysids. However, the amount of euphausiids consumed annually is only 12 % (29 000 tons) of the mass of mysids ingested. This data clarifies the important role of mysids in the diet of *Scomber japonicus* and, therefore, their importance to the pelagic fish community which feeds and grows on the shelf slope of the Canary Islands.

Mysids found in the stomach contents of *Scomber japonicus* reflect a temporal alternation in the relative abundance of species during the annual cycle. *Anchialina agilis* is the predominant species, and the most important from the point of view of the trophic habits of chub mackerel. This species's presence in the stomach contents is marked from June to October, and reaches maximum abundance during December (table II). In the autumn and towards the end of winter, *A. agilis* is replaced in importance by *Gastrosaccus normani*, which is most abundant in the contents during this period (table II). This coincides with Furnestin's data (1959), which classified *G. normani* as a winter species, often to be found to the south of Morocco. *Siriella clausi* G. O. Sars, 1877 and *S. norvegica* G.O. Sars, 1869 are species with a significant presence in the stomach contents of chub mackerel during the spring (table II). However, the factors involved in the aggregation of some species of the genera *Siriella* and *Gastrosaccus normani* are not very clear (Mauchline, 1980).

Euphausia krohnii was the species that had been identified most frequently in stomach contents. Near the island of Fuerteventura, Baker (1970) found that *E. krohnii* was also the most abundant species, and together with *E. brevis* concentrates at or near the surface at night. However, when the diet of *Scomber japonicus* in the Canary Islands area is compared with the diets of this species in other areas of the world (Hatanaka and Takahashi, 1960; Takahashi, 1966; Habashi and Wojciechowski, 1973; Baird, 1978; Angelescu, 1979; Konchina, 1983; Schaefer, 1980), it can be observed that in the Canary Islands, euphausiids have been replaced in importance by mysids. Takano (1954) reported similar trophic habits for the *S. japonicus* populations in the Archipelagos of Oshima and Izu (Japan) to those described for the Canary Islands. In these areas, the mysid *Gastrosaccus vulgaris* constituted the major proportion of the chub mackerel diet. The physical oceanographic characteristics of these archipelagos are similar to those of the Canary Islands (i.e. an important oceanic current flowing between the islands, and narrow shelves). A narrow shelf, shown by the close proximity of the 30 and 200 m isobaths (figure 1), makes the schools of chub mackerel keep much closer to the shore, and mysids could be more accessible (table IV), while on the continental shelf areas mackerel live near the slope, far from the shore, where euphausiids are more abundant than mysids. Therefore, despite the fact that swarms of euphausiids are abundant offshore (Baker, 1970), they are not important in the diet of chub mackerel, perhaps because schools of *Scomber japonicus* do not move far away from neritic waters.

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