COMPARISON OF FOREGUT CONTENTS OF *Sergestes similis* OBTAINED FROM NET COLLECTIONS AND ALBACORE STOMACHS

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ABSTRACT

Sergestes similis, an oceanic shrimp, was taken at a number of locations in the eastern North Pacific, principally in the California Current region. The contents of foreguts from shrimp caught by net during the day and night and those of shrimp eaten by free-swimming fish were compared. In all three categories of foreguts the predominant prey were adult specimens of the larger, common calanoid copepods which typically inhabit the upper 200 to 300 m in the California Current region. However, because the diversity of calanoid species and the numbers of fish scales, calanoids, and euphausiids were appreciably greater in the foreguts of net-caught *S. similis* than in fish-caught samples, it appears likely that *S. similis* feeds in collecting nets under tow.

Sergestes similis Hansen is an abundant pelagic shrimp endemic to North Pacific waters of boreal-temperate influence (Pearcy and Forss, 1969; Judkins, unpublished data). Examination of its stomach contents indicates it is predaceous and feeds primarily on copepods and euphausiids (Renfro and Pearcy, 1966).

There is an expanding body of evidence that, in the freshwater environment, predation by planktivores is size selective and determines, in part, the composition of zooplankton communities (Brooks and Dodson, 1965; Brooks, 1968; Dodson, 1970; Hall, Cooper, and Werner, 1970). Size-selective feeding by an abundant oceanic carnivore such as *S. similis* may play an important role in limiting the abundance of an array of prey species within a size range and, hence, in determining the composition of the zooplankton community within its habitat. The first step in determining the impact of *S. similis* as a predator in the community is to identify and to enumerate the prey species it utilizes.

In this report we identify and enumerate the foregut contents of *S. similis* from net tows and albacore stomachs taken at a number of localities in the eastern North Pacific. To determine if the results were affected by feeding in the net or by diurnal changes in feeding intensity and diet, comparisons were made between three categories of specimens: day-net samples, night-net samples, and fish-stomach samples.

MATERIALS AND METHODS

About two thirds of the 270 foreguts with contents examined in this study were obtained from *S. similis* collected by nets, principally Isaacs-Kidd midwater trawls, over several seasons (Table 1). The remaining one third were obtained from troll-caught albacore taken in July-August 1968 (Laurs and Nishimoto, personal communication). With the exception of one net tow taken in the Gulf of California all of the collections were made in the northeast Pacific Ocean between lat 31° and 53° N (Table 1).

Carapace lengths (measured from the tip of the rostrum to the dorsal mid-point of the posterior margin) of the net-caught shrimp ranged from 6.5 to 17.0 mm, with a median of 11.3 mm. Carapace lengths of fish-caught shrimp ranged from 6.3 to 12.5 mm, with a median of 8.3 mm. Because many fish-caught shrimps were partially digested, it was necessary to estimate their carapace lengths from the lengths of their foreguts (Judkins, unpublished data).

The foreguts were removed intact from the specimens with fine forceps and placed on glass

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TABLE 1.—Material examined.

	Collection number	Gear	Date	Position		Time (local)	Depth	Sample size
				Latitude (N)	Longitude (W)			
							m	
Night-net	Northern Holiday 10	IKMT[1]	11 Aug. 1951	43° 08′	150° 00′	2130-2320	175	10
	CalCOFI 6204-H 60.60	IKMT	26-27 Mar. 1962	37° 37′	123° 37′	2024-0005	1,873	9
	60.90	IKMT	28 Mar. 1962	36° 34′	125° 46′	0012-0147	298	10
	80.55	IKMT	16 Mar. 1962	34° 18′	120° 48′	1930-2135	296	10
	80.60	IKMT	17 Mar. 1962	34° 07′	121° 08′	0100-0236	300	10
	100.40	IKMT	17 Apr. 1962	31° 21′	117° 27′	0229-0414	298	3
	Ursa Major 10	IKMT	16 Aug. 1964	47° 01′	155° 00′	0327-0416	245	10
	24-Shallow	BMOC[2]	28 Aug. 1964	47° 38′	155° 00′	2216-2238	100-75	4
	Fazor II Birch 4	Tucker T[3]	14 Feb. 1966	48° 12′	148° 37′	0622-0656	450	10
	MV 68-I-73	IKMT	20 Jan. 1968	29°	113°	2245-0507	1,000	10
	Total							86
Day-net	Northern Holiday 13	IKMT	18 Aug. 1951	53° 35′	146° 05′	1345-1655	450	6
	CalCOFI 6204-H 60.70	IKMT	27 Mar. 1962	37° 07′	124° 25′	0613-0750	298	4
	60.100	IKMT	28 Mar. 1962	36° 17′	126° 31′	0809-1226	1,863	3
	80.70	IKMT	17 Mar. 1962	33° 54′	121° 50′	0948-1424	1,863	5
	Ursa Major 25-Deep	BMOC	29 Aug. 1964	46° 15′	155° 02′	1640-1809	300-400	10
	Fazor II Birch 3	Tucker T	14 Feb. 1966	47° 54′	148° 23′	1519-1553	--	10
	SIO 67-101	IKMT	9 June 1967	35° 16′	122° 16′	0827-1534	2,200	10
	SIO 67-102	IKMT	10 June 1967	35° 19′	123° 06′	0705-1403	2,200	9
	SIO 67-113	IKMT	14 June 1967	37° 20′	123° 42′	0558-1150	2,200	8
	Total							65
Twilight-net	CalCOFI 6204-H 90.60	IKMT	6 Apr. 1962	32° 28′	120° 06′	0450-0620	148	10
	SIO 66-51	IKMT	21-22 May 1966	40° 35′	125° 52′	2003-0643	1,125	11
	SIO 67-47	IKMT	20 Apr. 1967	31° 36′	117° 54′	1508-1923	4,000	10
	Total							31
Fish stomachs	AO 68 Stomach 216	Troll	16 July 1968	~36°	~125°	1815		11
	233		17 July 1968	~34°	~124°	--		2
	241		18 July 1968	~35°	~126°	1213		24
	248		18 July 1968	~36°	~126°	1800		10
	92		19 July 1968	~39°	~127°	--		17
	179		20 July 1968	~42°	~127°	--		2
	140		21 July 1968	~44°	~127°	--		4
	58		2 Aug. 1968	~44°	~135°	--		5
	9		12 Aug. 1968	~45°	~124°	0555		15
	234		18 Aug. 1968	~36°	~125°	0615		10
	Total							100

[1] Isaacs and Kidd, 1953.
[2] McGowan and Brown, 1966.
[3] Tucker, 1951.

microscope slides where their contents were emptied into 100% glycerol. All observations were made with aid of a stereomicroscope or a compound microscope at various magnifications as needed from 16× to 1000×.

The contents were examined to identify and enumerate all particles. Several drops of lactic acid tinted with chlorozol Black E were added to the glycerol to facilitate identification of the components. Lactic acid aids in clearing the preparation. The tint stains the components and is especially useful for arthropod cuticle. The identity of crustacean prey was often established from the morphology of mandibles, genital segments, fifth legs, or other diagnostic features.

In Table 1, collection numbers grouped by the designation "night-net" represent a set of 10 samples varying in number from 3 to 10 shrimp each and collected by nets that were towed exclusively between sunset and sunrise. Collection

numbers designated "day-net" comprise a set of nine samples of from 3 to 10 shrimp each and collected by nets that were towed exclusively between sunrise and sunset. "Twilight-net" collection numbers represent three samples collected by nets which were actually towed at sunset or sunrise. Collection numbers designated "fish stomachs" represent 10 samples of 2 to 24 shrimp taken from stomachs of albacore. The albacore were taken during daylight hours by trolling lines; exact times of capture were not available for five of the specimens.

Included in statistical analyses were all classes of food occurring in 10% or more of any of the sets of night-net, day-net, and fish samples. Calanoid genera occurring in 10% or more of any of the sets of samples were considered separately. The small number of twilight-net samples was not included in statistical comparisons of the sampling categories, but the details of this set are given in Table 2. Overall means (no. prey/foregut) and frequencies (%) were calculated for the three sets of samples that were compared. In addition, means were calculated for each night-net, day-net, and fish sample. The Mann-Whitney *U*-Test, a test designed to estimate the significance of differences in median values of two samples was used to compare median sample means between day- and night-net samples and between combined day- and night-net samples and fish samples.

RESULTS

Ingested items included euphausiids, ostracods, amphipods, chaetognaths, and fish scales, but the principal identifiable components in all sampling categories were adult calanoid copepods (Table 2). The composition of foregut contents from different geographical regions (North Pacific Subarctic, North Pacific Drift, and the California Current) were very similar and hence were not considered separately. The diversity of calanoids was much greater in all categories of net samples than in fish samples: 42 species were identified in net samples, but only 7 were found in fish samples.

Foregut contents varied widely in the extent of maceration by digestion and mastication.

TABLE 2.—List of organisms and their frequency of occurrence in the foreguts of *Sergestes similis*.

	Night-net	Day-net	Twilight-net	Fish
Copepoda				
Aetidiopsis rostrata	4	--	--	--
Aetidiopsis	1	--	--	--
Aetidius	1	3	--	--
Calanus cristatus	--	--	1	--
Calanus pacificus	20	1	3	--
Calanus plumchrus	--	--	2	--
Calanus	18	9	3	--
Candacia bipinnata	--	--	2	10
Candacia	--	--	1	7
Chirundina	--	1	--	--
Clausocalanus furcatus	1	--	--	--
Clausocalanus parapergens	5	3	--	--
Clausocalanus	3	2	--	--
Corycaeus	1	--	--	--
Corycella	--	--	--	1
Eucalanus bungii	5	2	2	--
Eucalanus	4	5	--	--
Euchaeta propinqua	--	1	--	--
Euchaeta	8	7	4	1
Euchirella pulchra	1	2	--	--
Euchirella rostrata	--	--	1	--
Gaetanus	1	1	--	--
Gaidius pungens	2	1	--	--
Gaidius	4	3	--	--
Gaussia	2	--	--	--
Heterorhabdus abyssalis	2	1	2	--
Heterorhabdus	2	2	--	--
Lucicuta flavicornis	--	1	--	--
Lucicutia	--	--	1	--
Metridia brevicauda	--	1	--	--
Metridia pacifica	17	18	5	22
Metridia	20	11	--	2
Oncaea	3	1	2	1
Oithona	1	1	--	--
Paracalanus parvus	1	--	--	--
Paracalanus	4	--	--	--
Pareuchaeta	2	--	--	--
Phyllopus	--	1	--	--
Pleuromamma abdominalis	7	--	2	--
Pleuromamma borealis	1	1	1	1
Pleuromamma gracilis	2	--	--	--
Pleuromamma xiphias	1	1	1	--
Pleuromamma	11	6	4	1
Pseudocalanus	6	1	2	--
Rhincalanus nasutus	13	1	--	--
Rhincalanus	7	4	--	--
Racovitzanus	--	1	--	--
Scaphocalanus curtis	--	1	--	--
Scaphocalanus magnus	1	--	--	--
Scolecithricella abyssalis	--	--	1	--
Scolecithricella dentata	--	1	--	--
Scolecithricella minor	6	3	--	--
Scolecithricella ovata	3	1	--	--
Scolecithricella	--	3	1	--
Scottocalanus	1	--	--	--
Spinocalanus	1	2	--	--
Undeuchaeta intermedia	--	--	--	1
Undeuchaeta bispinosa	--	--	1	--
Undeuchaeta	2	--	--	1
unidentified calanoid	14	14	1	11
aegisthid harpacticoid	--	--	1	--
Euphausiacea				
Thysanoessa	12	--	--	--
unidentified	19	16	6	2
Ostracoda				
Conchaecia	--	2	--	1
unidentified	6	--	8	5
Amphipoda				
unidentified	5	9	--	6
Chaetognatha				
unidentified	12	1	--	2
Fish scales	17	16	3	--
Fish eggs	1	--	--	--
Foraminiferan, unidentified	--	2	--	--
Radiolarian, unidentified	--	1	--	1
Molluscan radula	1	--	1	--
Larvacean, unidentified	1	--	--	--
Cirriped cyprid	--	--	--	1
Unidentified debris	30	22	10	42
Total number foreguts with contents	86	65	31	88

Specimens in the same sample frequently varied from one another, and the degree of decomposition in each specimen usually was not uniform. Lightly digested prey were largely intact, and their internal organs still visible. Moderately digested prey contained obviously macerated tissue and were often incompletely fragmented. Prey in an advanced state were highly fragmented, and soft tissues were absent. Digestion of foregut contents tended to be less advanced in night-net than in day-net samples. However, most foreguts in both categories contained material in an advanced state of digestion.

Five groups of ingested material, calanoids, euphausiids, chaetognaths, fish scales, and unidentifiable matter, occurred in 10% or more of at least one of the three sampling categories (Figure 1). Unidentifiable material consisted primarily of crustacean fragments and matted aggregations of fibrous and granular debris. Of identifiable groups, calanoids were usually most abundant in all three categories (Table 3). The four identifiable groups of prey organisms appeared in higher numbers in net samples than in fish samples, differences between the median values, with the exception of chaetognaths, being significant at $P \leqslant 0.05$.

Frequencies, overall means, and median sample means of calanoids and euphausiids in day-net samples were less than were those in night-net samples. However, differences between the day and night median values of the four identifiable groups were not significant ($P > 0.50$). Twilight-net samples do not appear to differ appreciably from day- and night-net samples.

Calanoid genera occurring in more than 10% of the three categories (Figure 2) were *Metridia*

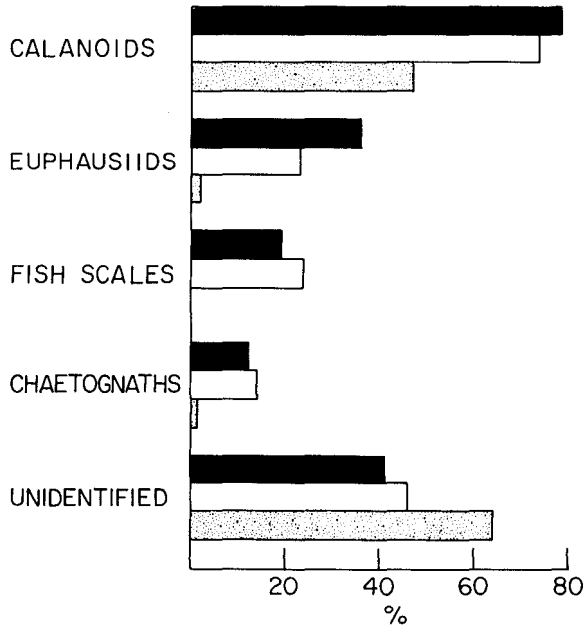

FIGURE 1.—Frequencies of ingested items occurring in 10% or more of night-net (black), day-net (open) and fish (strippled) samples.

(principally *pacifica*), *Calanus* (principally *pacificus*), *Pleuromamma* (principally *borealis*), *Rhincalanus* (all *nasutus*), *Euchaeta*, *Eucalanus* (principally *bungii*), *Scolecithricella*, and *Candacia* (principally *bipinnata*). These genera have been found typically in the uppermost 200 to 300 m of the California Current region (Fleminger, unpublished data).

The overall mean number of *Calanus* in day- and night-set samples are notably different (Table 4). In night-net samples *Calanus* ranked with *Metridia*, the two dominating the list of

TABLE 3.—Median of sample means and overall mean of number of prey per foregut.

Prey	Night-net			Day-net			Fish		
	Median	Range	Mean	Median	Range	Mean	Median	Range	Mean
Calanoids	2.40	0-12.50	4.23	2.25	0.67-5.70	2.68	0.63	0-3.20	0.96
Euphausiids	.33	0- 2.90	.66	.10	0-1.50	.32	0	0- .12	.02
Fish scales	.10	0- 1.00	.31	.23	0-3.00	.37	0		0
Chaetognaths	.20	0- .30	.15	.16	0- .33	.14	0	0- .50	.02
Number samples	10			9			10		
Total number foreguts	86			65			88		

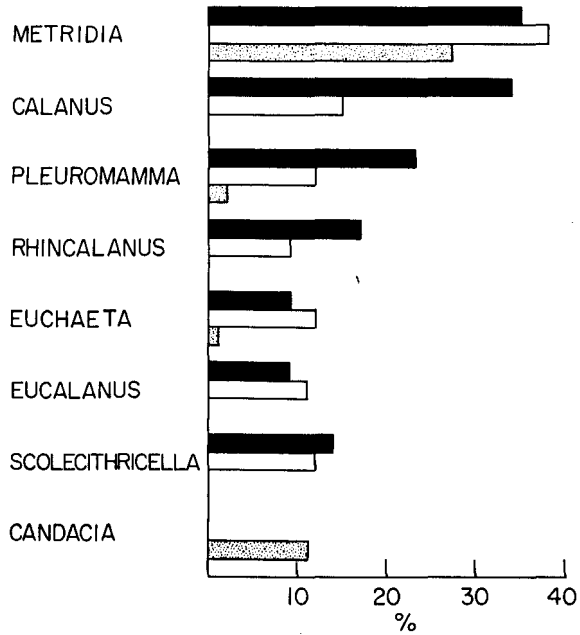

FIGURE 2.—Frequencies of calanoid genera occurring in 10% or more of night-net (black), day-net (open), and fish (strippled) samples.

calanoid prey. In day-net samples *Calanus* numbers are considerably below those of *Metridia* which remained high. However, the difference between the median sample means of *Calanus* in day- and night-net samples is not significant ($P > 0.20$). This is also true of the other seven genera.

Metridia was numerically dominant in fish samples, although it occurred in lower numbers than in net samples. Differences between the median sample means of *Metridia* in net and fish samples, however, are not significant ($P > 0.40$). Differences between net-and-fish-caught *S. similis* in the median values of *Eucalanus, Euchaeta,* and *Rhincalanus* are significant at P values falling between 0.10 and 0.20. Differences among the remaining calanoid genera are significant at P values between 0.02 and 0.10.

DISCUSSION

Metridia pacifica, Calanus pacificus, Pleuromamma abdominalis, Rhincalanus nasutus, Eucalanus bungii californicus, and *Candacia bipinnata* are among the 24 most abundant and frequently occurring of 176 calanoid species found in zooplankton samples collected on CalCOFI Cruises 5804, 5807, 5810, and 5901 (Fleminger, 1967). Significantly, these are also the principal species of six of the eight genera most frequently occurring in the foreguts examined in the present study. Adults of these species exceed 3 mm in length. It appears, then, that the principal prey of *S. similis* are the more abundant, relatively large, adult copepods inhabiting the uppermost 200 to 300 m in the California Current region.

Additional items found in both net and fish samples are euphausiids, chaetognaths, ostracods, amphipods, and radiolarians. Of these,

TABLE 4.—Median of sample means and overall mean in calanoid genera occurring in more than 10% of foreguts. [Means expressed as number of prey per foregut.]

Prey	Night-net			Day-net			Fish		
	Median	Range	Mean	Median	Range	Mean	Median	Range	Mean
Metridia	0.30	0-4.10	0.95	0.56	0-1.60	0.78	0.36	0-2.90	0.69
Calanus	.40	0-5.90	1.16	0	0- .80	.17	0		0
Pleuromamma	.30	0-1.10	.36	.10	0- .80	.15	0	0- .09	.02
Rhincalanus	.20	0-2.00	.35	0	0- .30	.09	0		0
Euchaeta	.10	0- .20	.10	0	0- .40	.14	0	0- .06	.01
Eucalanus	0	0- .30	.10	0	0- .50	.11	0		0
Scolecithricella	.10	0- .40	.13	.10	0- .30	.12	0		0
Candacia	0		0	0		0	.10	0- .50	.11
Number samples	10			10			10		
Total number foreguts	86			65			88		

only euphausiids were reported in a previous study on the diet of *S. similis* (Renfro and Pearcy, 1966).

A large percentage of shrimp of all sampling categories contained mixtures of granular and fibrous debris. The unidentifiable state of this material may not be entirely the result of digestive processes, but of the decomposed nature of the material at the time of its ingestion. *Sergestes similis*, like *S. lucens* (Omori, 1969), may scavenge decomposing dead material in addition to taking living prey. Another possibility is that this material represents the remains of prey stomach contents, e.g., those of euphausiids.

There is a tendency for day-net overall means to be less than those of night-net samples (Table 3). This and the trend toward less advanced digestion in night-net samples suggest more intense feeding activity at night, as was reported for *S. lucens* (Omori, 1969). The lesser average number of calanoids per foregut in day-net samples may be attributed primarily to the notably fewer *Calanus* in that category (Table 4).

Although the median values are not statistically different, day and night differences in overall mean numbers of the two calanoid species most frequently occurring in net samples, *Metridia pacifica* and *Calanus pacificus*, are notable in that they agree with differences in the vertical distributions of these two species. In the California Current region south of lat 33° N, *Calanus pacificus* usually concentrates in and near the thermocline during the day and disperses throughout the mixed layer at night. *M. pacifica*, on the other hand, occurs in the vicinity of the thermocline at night and disperses downward during the day (Fleminger, unpublished data). Studies have shown *S. similis* to be concentrated between the surface and 200 m at night and between 250 and 500 m during the day (Barham, 1957; Pearcy and Forss, 1966). The diurnal vertical range of *M. pacifica*, then, seems to correspond more closely with that of *S. similis* than does the diurnal range of *C. pacificus*. *Sergestes similis* probably has access to quantities of *M. pacifica* during both day and night. Most likely, *S. similis* encounters and feeds upon concentrations of *C. pacificus* primarily at night after the sergestid has ascended to shallower depths. However, without knowledge of digestive rates, these considerations are speculative.

The large numbers of fish scales in net samples and their complete absence in fish-stomach samples strongly suggest that feeding in the net has occurred. Although the source of these scales cannot be ascertained, it seems probable that they are the highly deciduous scales of lanternfish captured in the net with the shrimp. The significantly greater numbers of euphausiids and chaetognaths and the higher diversity of calanoids in net samples may also be indicative of feeding after capture. Many preserved net-caught *S. similis* have been observed by one of us (Judkins) to have fish scales, chaetognaths, and small crustaceans packed into their mouthparts and sometimes gripped in their mandibles.

Special conditions under which fish-caught shrimp might have been feeding before capture (related perhaps to time or depth) may also have contributed to the observed disparities between net and fish samples. Albacore are thought to feed primarily during daylight hours and probably most intensively in the early morning and early evening (Iversen, 1962). Time of capture by trolling of the albacore that we examined is available for only about half of the specimens. Of these about half were taken in morning daylight hours and the remainder were from the late afternoon and early evening. If all of the fish-caught shrimp were captured during the day, the relatively small quantities of identifiable components might reflect less intensive feeding by the shrimp at the time they were ingested by the albacore.

The generally smaller size of fish-caught specimens is probably not a factor; small net-caught shrimp (carapace length less than 10 mm) contained numbers of fish scales, euphausiids, and chaetognaths proportionally as high as larger net-caught individuals. Differences amongst sergestid specimens in the length of time spent in an albacore stomach also appear to be a negligible factor. Foregut contents of nearly intact fish-caught shrimp do not differ appreciably from those of extensively decomposed shrimp.

In general, the various samples of foreguts from adult *S. similis* that were analyzed provide

vide a coherent pattern of prey organisms consisting principally of the larger, commoner species of calanoid copepods inhabiting the uppermost 200 to 300 m of the California Current region. However, it is likely that feeding by *S. similis* in the net while it is being towed may explain the greater number and diversity of prey items in net-caught shrimp.

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