EVIDENCE OF POSTCAPTURE INGESTION BY MIDWATER FISHES IN TRAWL NETS

The ingestion of food items by midwater fishes in trawl nets, if it occurs at appreciable levels, may pose serious bias problems for dietary studies based on stomach content analyses. In a recent discussion of "net feeding," Hopkins and Baird (1977) reviewed the available evidence and found that while it may occur to some degree, net feeding is probably not extensive. In an earlier field study, Hopkins and Baird (1975) used side-by-side nets that provided captured fishes with different levels of exposure to captured zooplankton. On one side the fish were allowed to enter the cod end of the net and mingle with the zooplankton concentrated there. In the adjacent net fishes were excluded from the cod end by an 11 mm mesh bag at its mouth. Their results from 19 intraspecific comparisons of 700 myctophid and gonostomatid fishes showed little significant data that indicated net feeding.

All of the evidence to date, both for and against postcapture ingestion, has been indirect. This is because there was no sure way to determine whether a food item had been ingested in the net. The following study was conducted in order to provide a more direct investigation of stomach content contamination.

Methods

Experiments were conducted by introducing bogus food items into the cod end of a net before launching it, and then examining the stomach contents of captured fishes after recovery. Eleven such hauls were made with Tucker-type midwater trawls in deep water off southern California (Table 1). The nets had a main scoop of 6 mm nylon mesh and a rear section of 0.333 mm plankton netting. The 9 m² net utilized an enclosed, bag-type cod end (Baker et al. 1973) on two hauls (10, 11) and a rigid closing cod end (Childress et al. 1978) on three hauls (7, 8, 9). Both of these cod ends are of the flow-through variety and allow the passage of water out the rear. The 2.3 m² net had a rigid, nonclosing, 3.7 l plastic jug cod end that restricted flow.

Prior to launching the trawl, approximately 100 ml (or about 3,000 pieces) of artificial prey were placed in the cod end. In all cases, the amount of bogus prey introduced was much less than the eventual catch of similarly sized zooplankton in the cod end. The material consisted of rubber band fragments and bits of filter paper, between 2 and 15 mm in greatest dimension. Their individual volumes ranged between 0.5 and 60 mm³, which falls within the size range of natural prey items. Upon recovery, the cod end samples were preserved initially in 10% formaldehyde then transferred to 50% isopropanol. In the laboratory, fish stomachs were removed from the body cavity before being opened for examination. Only material from intact stomachs was counted, material found in the mouth and esophagus was not recorded. Data from haul 23 are biased toward larger individuals because the smallest specimens in the catch were not examined. Percent net feeding represents the relative number of individuals of any species which had ingested at least one bogus prey item. It is necessarily a conservative representation because zooplankton from the cod end may also have been ingested after capture but could not be distinguished from naturally ingested prey.

TABLE 1.—Trawling data for the ingestion experiments at Santa Barbara (SB) and San Clemente (SC) Basins, and off Guadalupe Island (GI), Calif.

Haul no.	Date 1977	Location	Mouth opening (m²)	Day/ night	Depth (m)	Duration (min)
1	Apr. 12	SB	2.3	N	0-190	60
2	12	SB	2.3	N	0-130	50
3	13	SB	2.3	N	0-150	50
4	13	SB	2.3	D	0-500	95
5	14	SB	2.3	D	0-400	100
6	14	SB	2.3	D	0-590	145
7	Feb. 22	SC	9	D	0-425	80
8	22	SC	9	Evening	483-891	180
9	24	SC	9	D	526-634	165
10	Aug. 10	GI	9	D	450-480	90
11	13	GI	9	N	0-150	135

Results

A total of 1,211 specimens were examined, representing 15 midwater fish species. Fifty-nine individuals (5% of the total) from 10 species were found with artificial prey in their stomachs (Table 2). Most of the bogus prey ingested (92%) were small (0.5-6 mm³) and only four fish had swallowed artificial items >12 mm³. Generally, the average number per stomach was low (Table 2) but a few fish had their stomachs packed with artificial prey. Only 5 of the 59 fishes containing bogus prey had stomachs which were otherwise empty; all others also contained zooplankton, some portion of which may have been ingested in the cod end.

Notable differences in net feeding occurred both interspecifically and intraspecifically. The two

TABLE 2.—Occurrence of bogus prey items in the stomachs of midwater fishes. Sizes are standard lengths in millimeters.

Species	No. of fish	Mean size (range)	Fish that net fed: Number	Percent	Mean size	Mean no. bogus prey	% net fed night/day
Bathylagus wesethi	35	50(27-84)	0	—	—	—	—
Leuroglossus stilbius	20	60(45-100)	1	5.0	100	1.0	0/100
Cyclothone acclinidens	64	45(26-57)	1	1.6	56	1.0	—
C. signata	89	20(17-38)	0	—	—	—	—
Poromitra crassiceps	6	44(34-75)	1	16.7	75	3.0	—
Scopelogadus m. bispinosus	13	55(43-69)	0	—	—	—	—
Lampanyctus ritteri	14	77(39-100)	7	50.0	68	3.8	0/50
L. regalis	15	42(35-53)	0	—	—	—	—
Parvilux ingens	11	71(35-172)	0	—	—	—	—
Stenobrachius leucopsarus	138	52(24-82)	32	23.2	61	2.3	5/47
Symbolophorus californiensis	6	48(30-62)	2	33.3	60	3.5	0/67
Triphoturus mexicanus	742	56(19-67)	11	1.5	50	1.2	1/2
Ceratoscopelus townsendi	22	42(33-48)	2	9.1	44	19.5	0/100
Sternoptyx diaphana	20	29(14-37)	1	5.0	37	1.0	0/7
Idiacanthus antrostomus	16	175(63-318)	1	6.3	231	1.0	0/25
Total	1,211		59				

TABLE 3.—Haul by haul comparisons of postcapture ingestion by *Stenobrachius leucopsarus*. Measurements are standard lengths in millimeters.

	Nighttime hauls		Daytime hauls		
Item	1	2	4	5	6
Number of fish examined	48	25	21	26	13
Mean size (range)	46(26-68)	50(30-81)	60(32-79)	53(34-70)	51(36-69)
Number net fed	3	1	12	10	6
Percent net fed	6.3	4.0	57.1	38.5	46.2
Mean size net fed	54	59	64	59	60
Number of fish ≥51 mm	23	15	19	17	11
Percent fish ≥51 mm net fed	13.0	6.7	63.2	58.8	54.5
Mean number bogus prey/stomach	1.3	1.0	2.0	3.4	1.7
Number of fish net fed/hour	3.0	1.25	7.5	5.9	2.5

most abundant fishes in the collection, myctophids *Stenobrachius leucopsarus* and *Triphoturus mexicanus*, showed a large difference in the percentage of individuals which had ingested the bogus prey items (23.2% vs. 1.5% respectively). In 8 of the 10 species that showed net feeding, larger-than-average individuals were more likely to contain artificial prey than smaller ones.

A haul by haul comparison of data on *S. leucopsarus* (Table 3) shows a greater degree of net feeding in daytime hauls than at night; although the average size of specimens in nighttime hauls is smaller (t-test, $P<0.001$). If we consider only those specimens which were equal to or larger than the smallest individual found with bogus prey in its stomach (51 mm), the trend for greater daytime net feeding still holds. All other species also showed a higher incidence of daytime net feeding (Table 2).

Discussion

The ingestion of bogus prey items by midwater fishes is direct evidence that the contamination of stomach contents can and does occur in the cod ends of midwater trawls. The degree to which it occurs, and thus the seriousness of the bias imparted to dietary studies, is apparently variable. Within a collection of midwater fishes, our data and that of Hopkins and Baird (1975, 1977) indicate that overall the bias may be low. However, the data from the present study showed that important levels of contamination can occur within some species. Hopkins and Baird (1975) based their low estimates of net feeding on intraspecific comparisons of their paired net data. The same data, when examined interspecifically, reveals that in 14 of 19 comparisons (700 fish from 11 species), fishes prevented from reaching the cod end had a lower average number of prey items in their stomachs than fishes which had entered the cod end. The probability of finding no difference in the number of prey items between these samples (i.e., no net feeding) is <10% (Wilcoxon matched pair signed rank test); thus their data indicating net feeding is significant to at least the 90% level of confidence.

Several factors may be responsible for the observed variations in degree of net feeding. The condition and viability of captured fishes is certainly a key factor; hardy species such as *S. leucopsarus* and *Symbolophorus californiensis* commonly survive capture and arrive at the surface alive and active. The survival of other fishes (e.g., *T. mexicanus, Cyclothone acclinidens, C. signata, Sternoptyx diaphana*) is usually quite low. Obviously a dead fish cannot swallow cod end material while a stressed but living fish may. The survival factor may have caused some of the differences between our results and those of Hopkins and Baird (1975); off California the survival rate of trawled specimens is relatively high (Childress et al. 1978) while in the Gulf of Mexico it is very low (T. L. Hopkins and R. C. Baird, pers. commun.). Survival rate is probably influenced by haul duration, the depth and temperature range sampled, cod end design, and net construction.

It is also apparent that specimen size can influence the degree of net feeding. It is not clear whether this is due to the greater survival rate of larger individuals or to their larger mouth size. Within the limits of survival rate and size variables, the degree of exposure to prey in the cod end is a function of haul duration, the depth strata sampled, and the amount of time a fish spends in the cod end. Discrete-depth hauls probably decrease the degree of exposure by limiting the number and diversity of prey items while oblique hauls increase exposure. The data also indicate that small prey are more readily ingested in cod ends than large prey. Accordingly, the bias imparted to stomach content analyses by net feeding would be toward the smaller prey items.

Postcapture ingestion is a complex problem and no clear-cut conclusions can be drawn from the available data except that it occurs to a varying degree and that the extent of its occurrence is subject to fish survival, fish size, and exposure. To gain a predictive capability it will be necessary to investigate these factors further.

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INHIBITORY EFFECT OF THE ALGA *PAVLOVA LUTHERII* ON GROWTH OF MUSSEL, *MYTILUS EDULIS*, LARVAE

The culture of bivalve larvae sometimes appears to be more of an art than a science. Many factors can influence the growth and survival of larvae and it is usually difficult to assign a cause to the failure of a particular culture. In one instance we had set up a large experiment with mussel, *Mytilus edulis*, larvae and noticed after 5-8 days that the larvae had ceased to grow in all of our treatments but that they remained alive and active. During this experiment one factor was known to have been changed: Previously we had been feeding the larvae a mixture of the algae *Isochrysis galbana* and *Pavlova lutherii*, while in this experiment only *P. lutherii* was available.

There has been one account in the literature (Fretter and Montgomery 1968) of *P. lutherii* being toxic; yet Bayne (1965) found *P. lutherii* to support normal growth in *M. edulis* larvae. Davis and Guillard (1958) found *P. lutherii* to be as good as *I. galbana* (and about as good as a mixture of the two) when fed to larvae of *Crassostrea virginica* and *Mercenaria mercenaria*. The results of Wilson (1978) show that *P. lutherii* is as satisfactory as other algae as food for *Ostrea edulis* larvae. In order to determine whether our *P. lutherii* cultures were to blame for the lack of growth we observed, we set up an experiment to compare the growth of mussel larvae when fed several diets of algae.