PELAGIC ASSEMBLAGES AS DETERMINED FROM PURSE SEINE AND LARGE MIDWATER TRAWL CATCHES IN MONTEREY BAY AND THEIR AFFINITIES WITH THE MARKET SQUID, *LOLIGO OPALESCENS*

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ABSTRACT

The catches of large midwater trawls and commercial anchovy purse-seine hauls were analyzed for recurrent assemblages of pelagic organisms in Monterey Bay. In all, 71 samples, taken in the upper 50 fathoms using large (30-and 50-foot-mouth) midwater trawls aboard the R/V *Alaska* were examined. For the years 1968 to 1974, species composition data were obtained from California Department of Fish and Game records and the CalCOFI data report series. Original data were used in the 1975 and 1976 surveys. From similar depths and locations in 1975 and 1976, 29 commercial anchovy hauls were subsampled as they were being unloaded in Moss Landing Harbor. Due to the differences in sampling methods, data for individual taxa are presented only as presence or absence, relative abundance, and frequency of occurrence. Ranks of relative abundance for the dominant taxa are presented for both methods. In addition, catches were subjected to recurrent group analysis, and both methods showed similar assemblages despite the obvious differences in purpose of sampling and the type of gear employed. Catches taken over deeper water (more than 35 fathoms, or 64 m) were compared with those from shallower water, and the differences are discussed. In general, catches were dominated by *Loligo opalescens* and *Engraulis mordax*, but other frequently occurring organisms were *Sebastes* spp., *Merluccius productus*, scyphomedusae (*Pelagia* and *Chrysaora*), *Torpedo californica, Citharichthys sordidus, Porichthys notatus, Genyonemus lineatus, Peprilus simillimus,* and *Clupea harengus pallasii.*

INTRODUCTION

Although many studies have assessed various parameters of populations of commercially fished pelagic organisms such as anchovies, mackerels, and squid (Messersmith 1969, Mais 1974b), few have considered those organisms that commonly co-occur with these species. To adequately manage a commercially exploited species, it is important to consider the associated organisms comprising the biological component of its ecosystem, especially those involved in such important ecological interactions as predation and competition for food and space. It was this assumption, among others, that led Kato and Hardwick (1975) to propose that "research is needed on economics, population dynamics, distribution and life history of *Loligo opalescens* in order to expand the fishery with due regard to optimum sustainable yield, economic ramifications and the ecosystem." It is our objective in this paper to present preliminary studies on the biological ecosystem of the market squid population in Monterey Bay.

Techniques such as midwater trawling and purse seining can be useful in exploratory fishing (Blackburn and Thorne 1974), in assessing distribution and abundance patterns, in assessment of recurrent pelagic assemblages, and in identifying potential competitors and predators (Day and Pearcy 1968; Fager and Longhurst 1968). An additional benefit from such sampling techniques would be the determination of the non-target species that are captured but not utilized by a fishery employing these types of gear. Also, Kato and Hardwick (1975) have suggested that commercially "alternate fishing methods—such as bottom and midwater trawling—may prove to be fruitful in some areas or seasons, particularly with the non-spawning squid."

Preliminary subsampling of northern anchovy commercial purse seine operations out of Moss Landing, California, showed that catches included numerous other species, including *Loligo opalescens.* We decided that an assessment of pelagic assemblages would be possible by subsampling these catches at the offloading dock. In addition, the California Department of Fish and Game (CDFG) Sea Survey Program has been using large midwater trawls since 1966 to estimate northern anchovy population abundance and distribution. The data from these samples are available and can be used in determining which organisms tend to associate with each other and with the market squid in the pelagic waters off central California. Recently, the same gear has been used on several successive summer CDFG cruises to evaluate the market squid resource and to obtain specimens for further natural history studies (Ally 1974, 1976; Ally and Mais 1975).

Thus, using subsamples from commercial anchovy purse seine catches and from larger midwater trawl samples from the CDFG Sea Survey, coupled with three successive CDFG summer squid cruises using the same gear, we here attempt to characterize the pelagic nekton assemblages in Monterey Bay, especially with reference to their allegiance to the market squid, *Loligo opalescens,* in these samples.

MATERIALS AND METHODS

Commercial anchovy hauls from five different fishing boats were subsampled from September 1975 through March 1976. All sets were at night, using purse seines and lampara nets with mesh sizes ranging from ⅝-inch (16 mm) to ¾-inch (19 mm) square mesh and measuring from 165 feet (50.3 m) to 1,500 feet (454.5 m) in length. The methods of fishing followed those described in Messersmith (1969). Fishing intensity varied daily with the number of sets per night ranging from one to four and over the season sampled with four boats operating from September through November. Only one boat operated the remaining four months. Subsamples were taken as the boats were off-loading the total night's catch at either the Starkist or Santa Cruz Cannery docks in Moss Landing, California. The catches were brailed or sucked out of the boat's hold onto a conveyor belt heading toward the cannery for processing. As the catch was moving up the conveyor at a rate varying from ½ to 1 ton/minute, the organisms were visually inspected for alternate 5-ton intervals for the duration of the off-loading period. All organisms were identified to as low a taxon as possible and enumerated. Those species that were difficult to identify on sight were saved for later identification in the laboratory. In an attempt to quantify the visual inspection techniques, intermittent 5-gallon bucket samples (averaging 40 pounds of organisms) were taken at the end of the conveyor belt. The organisms contained in these samples were sorted, identified and enumerated, and conversion factors were calculated so that the numbers seen visually on the belt coincided with the numbers sampled in the buckets. Since it was necessary only to express abundances relatively (as percent by number and frequency of occurrence), estimates of density such as numbers per ton were not required and the sampling program as designed proved sufficient. In order to assess the effect of depth of the samples and their proximity to the Monterey Submarine Canyon, the sample depths were divided into those that were in waters deeper than 64 m (35 fathoms) and those shallower than 64 m.

Information on organisms captured by midwater trawl was gathered in two ways. First, on three cruises during the summers of 1974, 1975, and 1976 (Ally 1974, 1976; Ally and Mais 1975), samples were taken using a large midwater trawl with a mouth opening 11.6 to 13.7 m (38 to 45 feet) (Mais 1974b) aboard the CDFG R/V *Alaska,* following methods described by Ally and Mais (1975). Tow durations ranged between 5 and 15 minutes, with most being between 5 and 7 minutes. Depths trawled ranged from 44 to 166 m and all were taken at night, usually between 2200 and 0300 hours. All organisms captured in these tows were sorted, identified to the lowest possible taxa, and enumerated. For those species that were not very abundant, all individuals were separated and counted. For the more numerous and usually smaller species, subsamples of the residue were taken, sorted, identified, and enumerated until the mean number per subsample agreed between one sample and the next and their standard deviations became minimal. These means were then raised by a factor to convert the sample numbers to total abundance in the tow, so that all species could then be ranked according to their proportionate number. Again, as with the anchovy haul subsamples, abundance was expressed as percent by number and frequency of occurrence, not as number per tow or minutes towed, due to the difficulty in obtaining the latter estimates.

The second source of midwater trawl information was the CDFG Sea Survey species composition and abundance data from midwater trawling surveys conducted from 1968 through 1975 and tabulated in the CalCOFI Data Reports (Mais 1971a-c, 1972, 1973, 1974a, 1975, 1976). Much of this information, especially for northern anchovy populations and acoustic monitoring, is summarized by Mais (1974b). However, as with the three summer cruises for squid, midwater trawl samples had been sorted to species and their relative abundances estimated. These data could then be retrieved from the CalCOFI Data Report for each year and location of interest. Data on all organisms captured in tows that were in the Monterey Bay vicinity (see Figure 3) were extracted and analyzed for species composition. The results were separated into summer tows that were either shallow (shallower than 64 m) or deep (deeper than 64 m) and winter tows, which were of mixed depths. To justify lumping data from both sources of midwater trawls, a species-by-species comparison between our data from both the three summer cruises and the particular CalCOFI Data Report for that year was made and indicated that the two were virtually identical. This enabled our trawl survey to cover a wide range of years, from 1958 through 1976.

The sufficiency of the number of samples was evaluated by plotting the cumulative number of species captured against the randomly-ordered number of subsamples both for anchovy hauls and midwater trawl hauls. These curves were visually inspected for the point at which more samples did not increase the cumulative number of species substantially. Since we were only interested in relative abundance and the presence or absence of a particular taxon, and since most taxa that were encountered toward the end of the cumulative curve were extremely rare, this method is sufficient to assess the minimum number of samples needed to evaluate species composition.

Abundances of the invididual taxa from all collection methods were expressed as percent frequency of occurrence (that proportion of samples containing the taxon) and percent by number (the numerical proportion of all organisms captured that were of a specific taxon). For the tables showing abundance, only those species that were "common" (having a numerical importance of at least 0.01) were included. In the case of the commerical anchovy hauls, northern anchovy counts were excluded from the calculations so that the relative proportions of other species would be detectable. The species composition of samples from commercial anchovy hauls and midwater trawls was then described using the total number of common species captured and the percent dominance (the sum of the individual percentages by numbers squared [Odum 1971]). Species similarity was compared among depths and methods using the equation $S = \frac{2C}{A + B}$ where C is the number of species common to both samples and A and B are the number of species found in samples A and B, respectively (Odum 1971).

In addition, for each of the methods and depths studied, recurrent group analysis was performed after Fager (1957) and Fager and McGowan (1963). In this analysis, the index of affinity (I) was calculated between each pair of species over all samples using the formula

$$I = [J/(N_A N_B)^{1/2}] - \tfrac{1}{2}(N_B)^{1/2}$$

where N_A and N_B are the numbers of occurrences of species A and B, and J is the number of joint occurrences of both species, and where N_B is larger than N_A. Using a minimum value of 0.5, a matrix of significant I values is generated that enables a process to resolve major groups of organisms that commonly occurred with each other. Finally, in order to identify potential interspecific relations, the index of affinity of each of the dominant organisms with *Loligo opalescens* was calculated.

RESULTS

Species Composition: Anchovy Hauls

Subsamples from anchovy hauls were taken from 6 deep and 23 shallow locations, representing approximately 557 tons, during September through March 1975 (Figure 1, Table 1). The cumulative species curve leveled off at around eight hauls and remained level until 16 hauls, when four new species occurred (Figure 2). These four, *Pleuronichthys decurrens, Sardinops caerulea, Alopias vulpinus* and *Psettichthys melanostictus,* were not representative of the species commonly occurring in these hauls, since single individuals were captured only once. Therefore, it appears that approximately eight hauls were sufficient to adequately represent the species composition of pelagic organisms from anchovy hauls. The total number of taxa found in anchovy samples was 22 (Figure 2).

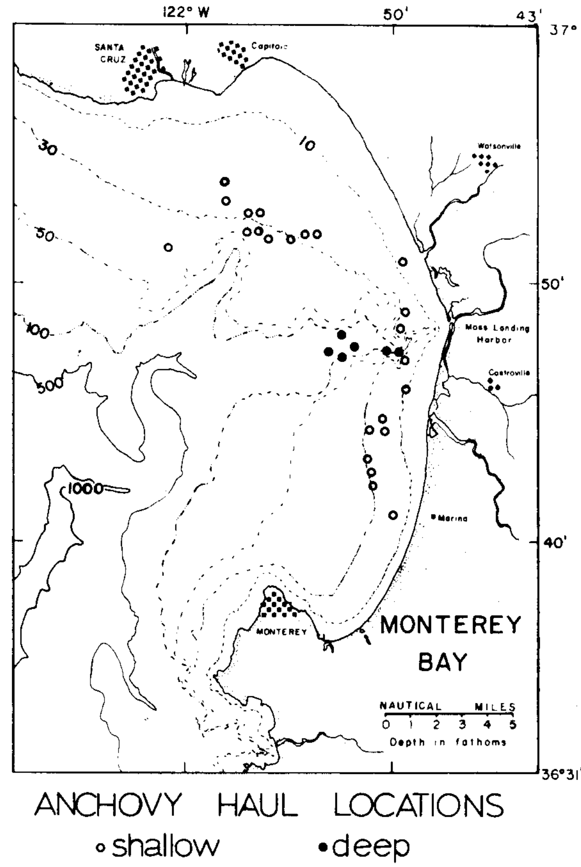

Figure 1. Map showing locations of commercial anchovy hauls in Monterey Bay during 1975 and 1976. Dark circles indicate deep samples (more than 64 m) and open circles indicate shallow samples.

In the 29 commercial anchovy haul samples, 19 common taxa were noted, and they were not surprisingly dominated by the northern anchovy, *Engraulis mordax* (Table 1). When ranked by frequency of occurrence, *E. mordax* was followed by the market squid, *Loligo opalescens* (90%), scyphomedusae (76%), *Torpedo californica* (62%), *Citharichthys sordidus* (41%), *Porichthys notatus* (38%), *Genyonemus lineatus* (35%), and *Clupea harengus pallasii* (31%). Other species occurred in trace amounts (see Table 1). When *E. mordax* was included, the percent domination was 99.8%, while without *E. mordax* it was only 59.0%.

Species Composition: Midwater Trawls

During the summer, 27 shallow and 24 deep tows were analyzed that had captured 73,572 individuals and 64,852 individuals, respectively, with a total of 21 common taxa (Figure 3, Table 2). The cumulative number of these taxa for both deep and shallow midwater tows leveled off at around eight to ten tows, with only slight increases continuing to occur, especially for the deep tows (Figure 4). Again, these increases were caused by rare species that occurred only once. The total number of taxa captured in

TABLE 1
Abundance, Frequency of Occurrence, and Index of Affinity (I) with *Loligo opalescens* of Pelagic Organisms Caught in Anchovy Hauls

	Overall % Frequency	Overall % by Number*	Affinity (*I*) Shallow	Deep
Engraulis mordax	100	99.9	0.87	0.61
Loligo opalescens	90	76.1	n/a	n/a
Scyphomedusae	76	2.9	0.74	0.45
Pelagia sp.	(50)	–	–	–
Chrysaora sp.	(58)	–	–	–
Aurelia sp.	(17)	–	–	–
Torpedo californica	62	0.2	0.76	0.25
Citharichthys sordidus	41	1.0	0.58	–
Porichthys notatus	38	6.3	0.61	–
Genyonemus lineatus	35	0.5	0.58	–
Clupea harengus pallasii	31	8.1	0.43	0.62
Peprilus simillimus	18	0.3	0.38	–
Atherinopsis californiensis	17	0.6	0.38	–
Octopus sp.	17	1.8	0.38	–
Cololabis saira	7	0.6	0.20	–
Merluccius productus	7	0.01	0.20	–
Trachurus symmetricus	7	0.01	0.20	–
Spirinchus starksi	7	2.3	0.20	–
Myliobatis californica	7	0.02	0.20	–
Salps	7	0.01	0.20	–

Total Number Hauls Sampled: 29
Total Tonnage Sampled 557
*All other species calculated without *Engraulis mordax.*

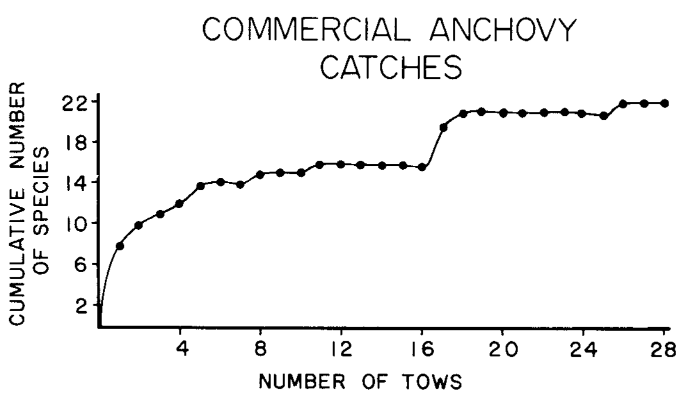

Figure 2. The cumulative number of species subsampled from commercial anchovy catches plotted against randomly-ordered number of hauls.

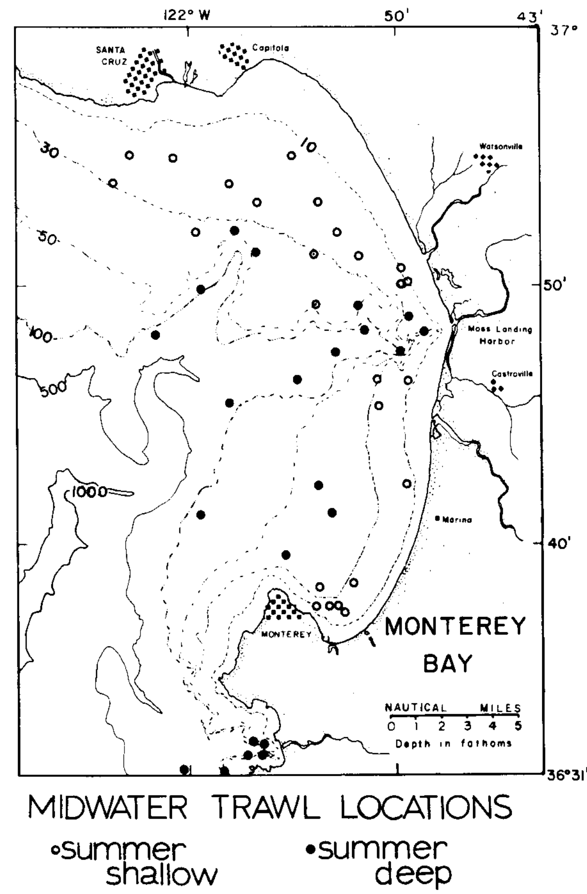

Figure 3. Map showing locations of large midwater trawl samples in and around Monterey Bay during summers from 1968 to 1976. Dark circles indicate deep samples (more than 64 m), while open circles indicate shallow tows. The two circles with a dot inside of them represent duplicate locations at both depths.

the shallow tows was 45, while that for the deep tows was 62 (Figure 4). The difference in total taxa was due to an increase in midwater organisms associated with the Monterey Submarine Canyon.

In the 27 summer shallow midwater trawls, 20 common taxa were noted, with the dominance relatively low (34%), shared numerically by *Loligo opalescens,* juvenile *Sebastes* spp., ctenophores, and euphausiids. Other relatively frequent taxa were *Porichthys notatus, Engraulis mordax, Pelagia* sp., *Torpedo californica, Merluccius productus, Peprilus simillimus, Citharichthys sordidus,* and *Clupea harengus pallasii.*

In the 24 summer deep midwater trawls, 21 common taxa occurred, again with relatively low dominance (46%), led numerically by euphausiids (66%) and followed by *E. mordax, Merluccius productus,* juvenile *Sebastes* spp., *Citharichthys sordidus,* and *Loligo opalescens* (Table 2.) Other species that occurred frequently but not necessarily with high numbers were *Pelagia* sp., *Porichthys notatus,* ctenophores, juvenile *Sebastes paucispinis* and *S. jordani,* and unidentified flatfishes.

The 20 tows taken during the winer produced 2,595 individuals of 19 taxa (Table 3). These tows had a high dominance (56%), led by the northern anchovy, *E. mordax,* with *C. sordidus* and *C. stigmaeus, L. opalescens,* and euphausiids also occurring relatively frequently. The remainder of the total list of taxa closely resembled those caught during the summer, and most of these were low, both in numerical importance and in their frequency of occurrence.

In general, the species composition from the anchovy hauls was quite similar to that found in the large midwater trawl samples. In both, catches were dominated by *E. mordax,* and *L. opalescens,* with other taxa such as

Porichthys notatus, Citharichthys sordidus, and scyphomedusae ranking high (see Tables 1-3). The species similarity index was highest between shallow and deep summer midwater trawl samples (98%). The index was less for the other comparisons, with the summer shallow midwater trawls having an index of 61% with the anchovy hauls and the winter midwater trawls having lower indices when compared with shallow summer midwater trawls (55%), deep summer midwater trawls (54%), and anchovy hauls (52%).

Recurrent Groups

Recurrent group analysis revealed similar groupings of organisms for both methods of sampling. In the shallow anchovy hauls, a major group consisting of *Engraulis mordax, Loligo opalescens, Torpedo californica, Porichthys notatus,* and *Genyonemus lineatus* was resolved (Figure 5). This main group shared affinities with four other taxa, *Citharichthys sordidus* and scyphomedusae (with three out of the five taxonomic pairs having significant indices of affinity), *Clupea harengus pallasii* (with two having significant *I* values) and *Atherinopsis californiensis* (with only a tendency to associate with the taxa in the main group; Figure 5). When only deep samples were considered, the three more demersal taxa dropped out leaving only one major group comprised of *E. mordax, L. opalescens,* and *C. harengus pallasii.* Two of these three taxa had a significant index of affinity with scyphomedusae.

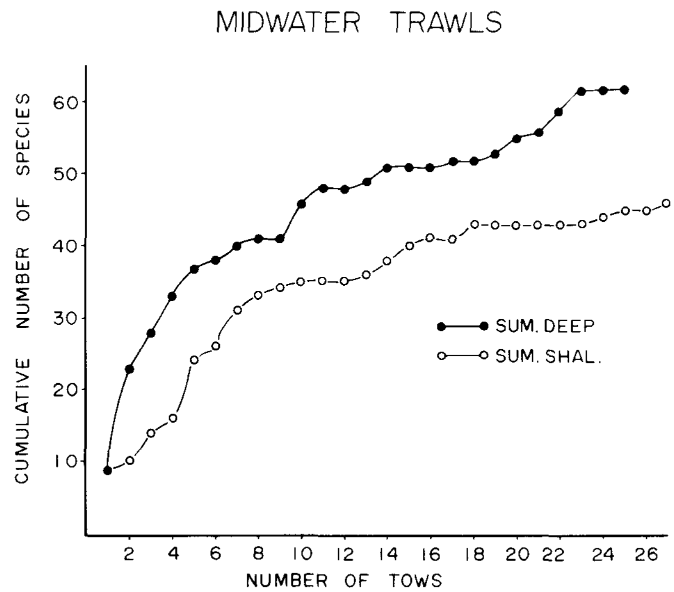

Figure 4. The cumulative number of species caught in large midwater trawl samples plotted against randomly ordered number of tows. The upper curve (dark circles) is for deep (64-91 m) summer tows, while the lower curve (open circles) is for shallow summer tows.

TABLE 2
Abundance, Frequency of Occurrence, and Index of Affinity (*I*) with *Loligo opalescens* of Pelagic Organisms Caught in Summer Midwater Trawls.

	Shallow			*Deep*		
	% F.O.	% N.	*I*	% F.O.	% N.	*I*
Loligo opalescens	89	11.0	n/a	67	1.0	n/a
Sebastes spp.	63	16.0	0.64	63	6.0	0.33
Porichthys notatus	63	0.01	0.49	42	0.01	0.19
Engraulis mordax	52	6.0	0.61	38	10.0	0.29
Pelagia sp.	52	0.01	0.55	46	0.01	0.33
Torpedo californica	52	0.01	0.66	13	0.01	0.16
Merluccius productus	48	0.01	0.58	54	7.0	0.50
Peprilus simillimus	48	0.01	0.63	17	0.01	0.38
Citharichthys sordidus	37	0.01	0.41	40	2.0	0.25
Clupea harengus pallasii	33	3.0	0.51	8	0.01	-
Ctenophora	30	53.0	0.48	29	0.01	0.25
Sebastes paucispinis	19	0.01	0.35	33	0.01	0.23
Pleuronectiformes	19	0.01	0.35	29	0.01	0.16
Clupeidae	19	0.01	0.26	4	0.01	-
Ophiodon elongatus	19	0.01	0.35	8	0.01	-
Euphausiacea	15	11.0	0.31	29	66.0	0.16
Sebastes jordani	15	4.0	0.31	17	0.01	0.13
Octopoda	15	0.01	0.19	13	0.01	0.31
Citharichthys spp.	15	0.01	0.31	8	0.01	0.23
Leuroglossus stilbius	-	-	-	10	0.01	0.32
Icichthys lockingtoni	4	0.01	-	17	0.01	0.25
Spirinchus starksi	-	-	0.25	-	-	-
Polyorchis sp.	-	-	0.25	-	-	-
Trachurus symmetricus	-	-	0.19	-	-	-
Scyphomedusae	-	-	0.19	-	-	-
Tarletonbeania crenularis	-	-	-	-	-	0.25
Symbolophorus californiensis	-	-	-	-	-	0.23
Parophrys vetulus	-	-	-	-	-	0.23
Total Number Hauls		27			24	
Total Number Individuals		73,572			64,852	

TABLE 3
Abundance, Frequency of Occurrence, and Index of Affinity (*I*) of Pelagic Organisms from Winter Midwater Trawls.

	% F.O.	% N.	*I*
Engraulis mordax	75	74.0	0.47
Citharichthys sordidus	40	2.0	0.12
Citharichthys stigmaeus	35	2.0	0.15
Loligo opalescens	35	1.0	n/a
Euphausiacea	35	1.0	0.27
Porichthys notatus	20	1.0	0.03
Peprilus simillimus	20	1.0	0.00
Torpedo californica	20	0.01	0.38
Ctenophora	20	0.01	0.03
Decapoda	20	0.01	-
Syngnathidae	20	0.01	0.19
Clupea harengus pallasii	15	6.0	0.03
Diaphus theta	15	6.0	-
Chrysaora sp.	15	0.01	0.19
Sebastes sp.	15	0.01	0.08
Salpidae	15	0.01	0.03
Pteropoda	15	0.01	0.03
Thetys vagina	15	0.01	0.03
Total Number Hauls	20		
Total Number Individuals	2,595		

The midwater trawls produced similar but more complex recurrent groups (Figure 6). In the 27 shallow tows, two large interconnected recurrent groups emerged, one with *L. opalescens, Clupea harengus pallasii,* and juvenile *Sebastes* spp. included and the other with *Porichthys notatus, Torpedo californica,* and *Pelagia* sp. Five of the nine taxonomic pairs between these two groups had significant indices of affinity. Two additional main groups occurred, one comprised of *Merluccius productus* and *Peprilus simillimus* and the other having only the northern anchovy, *E. mordax.* The first groups had two out of the possible six taxonomic pairs with significant indices of affinity with the two main groups, while *E. mordax* had a significant association with at least one taxon in each of the main groups. Several other groups appeared in these shallow tows. One group was composed of *Sebastes jordani* juveniles, *Octopus* spp., ctenophores, and unidentified flatfishes. Two other taxa had significant affinity with this group, *Ophiodon elongatus* and *Polyorchis* sp. Since these species all had relatively low frequencies of occurrence (Table 2), their significant affinities were based on a low number but a high proportion of co-occurrences, thus placing them in a recurrent group individually that had slight affinity with one of the main groups. Nevertheless, out of 27 tows, they did co-occur sufficiently to warrant separate groups. Another small group consisted of two species of the cephalopod genus *Gonatus,* both too uncommon to appear in Table 2, but having an index of affinity high enough to warrant their assemblage.

In the deep midwater trawls, similar species generally occurred in the recurrent groups (Figure 6), but their positioning differed slightly and association among them was not as evident. One main group was comprised of *Loligo opalescens* and *Merluccius productus;* another of *Citharichthys stigmaeus, Microstomus pacificus,* and *Chrysaora* sp.; and a third of *Porichthys notatus, Citharichthys* spp., and juvenile *Sebastes* spp. This third group had an affinity with *Pelagia* sp. One additional group occurred in these samples, comprised of three midwater animals that commonly occupy the Monterey Submarine Canyon (Anderson 1977). These were the zoarcid fish *Lycodapus mandibularis* and the two prawns, *Pasiphaea pacifica* and *Sergestes similis.* Since the tows were taken at night, these species were captured in shallower waters during their nocturnal vertical migrations from the midwater region.

Affinities with Loligo opalescens

During the course of assembling recurrent groups, indices of affinity of the various taxa captured with *Loligo opalescens* were calculated, and these are presented in

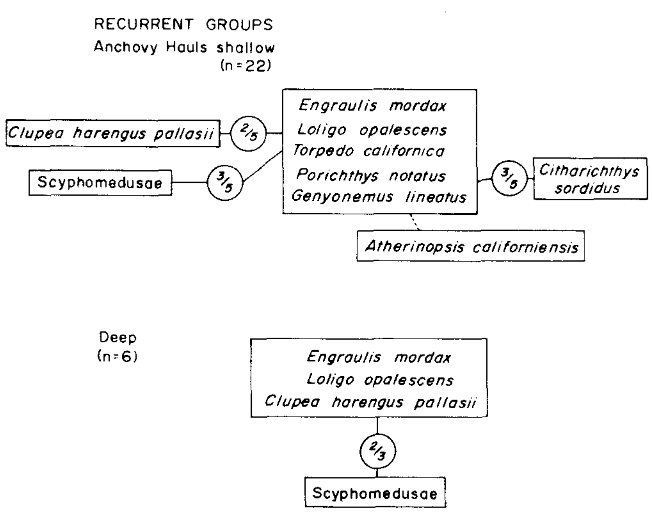

Figure 5. Recurrent groups of pelagic organisms taken in 22 shallow (less than 64 m) and 6 deep commercial anchovy hauls in Monterey Bay. Ratios in parentheses indicate the number of significant (i.e. over 0.50) affinities of species between recurrent groups.

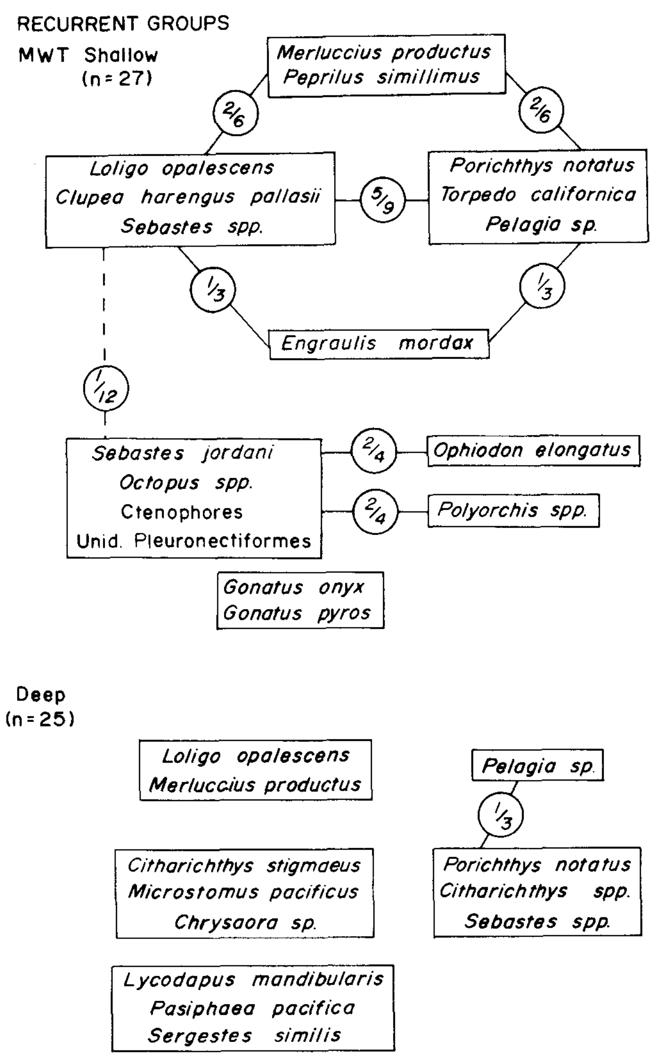

Figure 6. Recurrent groups of pelagic organisms taken in 27 shallow (less than 64 m) and 25 deep (61-91 m) midwater-trawl samples taken in Monterey Bay.

Tables 1, 2, and 3. In the anchovy hauls, those taxa having significant affinity with *L. opalescens* were *Engraulis mordax*, scyphomedusae, *Torpedo californica, Citharichthys sordidus, Porichthys notatus, Genyonemus lineatus*, and *Clupea harengus pallasii* (Table 1). For the summer midwater trawls, all of the above species except *Citharichthys sordidus, Genyonemus lineatus*, and *Porichthys notatus* had significant affinities with *Loligo* (Table 2). In addition, juvenile *Sebastes* spp., *Merluccius productus*, and *Peprilus simillimus* were associated with *Loligo* in these trawls. During the winter, none of the taxa captured in midwater trawls had significant affinities with *Loligo*.

DISCUSSION

In evaluating these results, it is essential that we evaluate the applicability of the analytical tools employed. We originally considered using Fager's (1957) recurrent group analysis because we had presence and absence data on our pelagic organisms and because it had been used by several other investigators for such groups as marine phytoplankton (Venrick 1971), marine zooplankton (Fager and McGowan 1963), midwater animals (Ebeling et al. 1970), and demersal fishes (Fager and Longhurst 1968). However, Boesch (1977) recently warned investigators about the value of using recurrent group analysis due to the arbitrary nature of setting the affinity index levels. Since then, a more recent evaluation of the technique by Hayes (1978) indicated that " the index . . . errs on the conservative side and one can put considerable confidence in the reality of recurrent species groups that are derived through its application," especially "if a large number of sites are sampled." Therefore, throughout this discussion, caution should be exercised in interpreting the results due to the nature of the sampling, the application of the recurrent group analysis techniques, and in some cases, due to limited sampling effort.

In general, it appears that recurrent groups of organisms do occur in the pelagic water of Monterey Bay but that they can vary somewhat, depending on location, time of year, and type of gear fished. Nevertheless, the market squid (*Loligo opalescens*) and one of its main associates, the northern anchovy (*Engraulis mordax*), do appear to play a major role in these recurrent assemblages. It is the purpose of this discussion to characterize these assemblages, while interpreting the major differences found among locations, time, and type of gear used. The discussion will center on the predominant species, *L. opalescens*, and will take into account various aspects of the life histories of the associated pelagic and demersal species involved.

In the anchovy haul samples which were dependent on the activity of the fishing fleet, it was not altogether possible to separate seasonal from depth variation. Most of the shallow sets (19 out of 23) were taken in September through October, while the "deep" water samples (over the Monterey Submarine Canyon) were taken in January through March. However, as a first approach to understanding the species associations involved, it is interesting to examine the recurrent groups from these anchovy hauls more closely. Four species associated with *Loligo opalescens* in shallow water do not remain in close association in the samples from deeper water. This could be due to seasonal variation, ability to escape capture by swimming downward in deep water before the purse seine is closed, or simply due to the fact that they do not occur over deep water. We do not believe that this resulted from seasonal variation, since all four species either occurred in the midwater trawl samples over the year or were present in bottom trawls that are taken intermittently throughout the year (Cailliet, unpublished data). The second and third possibilities are certainly to be considered. Anchovy nets are more effective in capturing northern anchovies in shallow water of 30 fathoms or less (Messersmith 1969), where they are able to touch bottom and prevent fish from swimming out from under them. Therefore, this possibility could affect the capture of such demersal fishes as *Citharichthys sordidus, Genyonemus lineatus*, and *Porichthys notatus*. The third possibility that these fish do not occur over deep water needs to be examined more carefully for the four species under consideration. Both *Torpedo californica* and *P. notatus* occurred frequently and showed numerous significant joint occurrences with other species in the shallow midwater trawls. However, only *P. notatus* retained high frequencies and significant joint occurrences in the deep midwater trawls. It appears, then, that *T. californica* is restricted to more inshore areas, at least in midwater at night, whereas *P. notatus* can occur over deep water at least during the summer months. Indeed, a recent paper by Bray and Hixon (1978) found that adult *T. Californica*, which usually are not seen during the day in nearshore kelp beds off southern California, are very active preying on fishes in the midwater off these kelp beds at night. In addition, our data corroborate earlier reports that *P. notatus* is a vertical migrator, moving off the bottom in search of prey at night (Lavenberg and Fitch 1966; Hart 1973). Our lack of spring samples precludes investigating its documented migration inshore during spring and early summer to spawn in shallow water (Fitch and Lavenberg 1971). *Citharichthys sordidus*, a very common demersal flatfish, cannot be excluded from the deep midwater areas. It showed high frequencies of occurrence in all comparisons except the deep-water anchovy hauls. However, *C. sordidus* showed the lowest percent by number and no significant joint occurrences in the shallow summer midwater trawls, suggesting that it may only leave the bottom near canyons or deep-water areas. Stomach-content analyses of this species (Cailliet,unpublished data) indicate that it commonly feeds on nektonic organisms such as euphausiids, especially near the edge of the Monterey Submarine Canyon. Therefore, it either comes off the bottom to feed on these pelagic organisms or the prey come very close to the bottom during the downward portion of their vertical migration pattern. In contrast to the above three species, *Genyonemus lineatus* was markedly absent from all midwater trawl samples. Since *G. lineatus* is usually caught in water shallower than 100 feet (Frey 1971), they probably occurred in the shallow-water anchovy hauls because the seines scraped the bottom and were effective at catching them.

The other associates of *Loligo opalescens,* especially those such as *Clupea harengus pallasi* and scyphomedusae which occurred in anchovy haul samples in shallow and deep water, are more pelagic in habit and probably do regularly contribute to the pelagic assemblages in the area. Both associates also occurred in recurrent groups from the midwater trawl samples. The occurrence of *Atherinopsis californiensis* in the shallow anchovy haul recurrent groups may be an artifact of sampling, since that was the only time that they were significantly associated with any of the pelagic organisms under consideration.

The strong association between *Loligo opalescens* and *Engraulis mordax* in the anchovy hauls does not appear as strong in summer or winter midwater trawl catch analysis. Here, although both species appear commonly, they do not occur in the same recurrent groups during the summer, with *L. opalescens* associating more with *Clupea harengus pallasii,* juvenile *Sebastes* spp., and *Merluccius productus.* Indeed, in the winter midwater trawls, which were a combination of an equal number of deep and shallow trawls that had to be lumped due to poor cumulative species plots and small sample size, *L. opalescens* lacked significant associate species and had a low frequency of occurrence and relative abundance. This can be explained either by sampling strategy, the unavailability of squid in large numbers during the winter survey, or low availability in midwater of squid associated more with the bottom during these months. Certainly, sampling strategy could be a factor, since the winter CDFG Sea Survey cruises were primarily after anchovies, but if *L. opalescens* truly is an associate of *E. mordax,* it would have shown up more convincingly. Studies on another loliginid squid, *L. pealei,* indicate that they are vertical migrators, moving off the bottom at night during winter months (Roper and Young 1975). If *L. opalescens* behave in this fashion, they should have been in the water column during these trawls, yet they were not that commonly caught. Commercial landings of squid in Monterey Bay, during the winter months under consideration, may reflect availability (Fields 1965). During the two months of the midwater trawl survey (February 1968 and October 1969), squid landings in Monterey Bay were almost nonexistent (Heimann and Carlisle 1970; Pinkas 1970). In light of this, it would seem likely that during these months *L. opalescens* was simply not available in the bay to this kind of fishing gear. Perhaps squid are simply so randomly dispersed during the winter months that they are unavailable in large numbers to midwater trawls. The lack of associate species, other than *M. productus* in the deep summer trawls where *L. opalescens* was still abundant and frequently occurring, suggests a more random dispersion of other organisms captured in these trawls in relation to *L. opalescens,* thus making their co-occurrence less likely.

Obviously, since the anchovy hauls were seeking anchovies, these fish co-occur with every other species, oftentimes significantly. However, in the more randomly scheduled midwater trawls during the summer months, there was no target species, and perhaps a clearer picture of the relationship between squid and their closest associate, *Engraulis mordax,* may result. Since these two species were only associated in shallow summer trawls, association in deeper waters is perhaps not strong. In addition, using the numerous, more random, summer midwater trawl samples, a clearer picture of the association between *Loligo opalescens* and its other associates is possible. In the shallow summer hauls, associates with significant indices of affinity were numerous, including *Clupea harengus pallasii* and *Sebastes* spp. (which were both in the same recurrent group as *L. opalescens, Merluccius productus,* and *Peprilus simillimus* [in a closely-related group]), *Porichthys notatus, Torpedo californica,* and *Pelagia colorata* (in another closely-related group) and *E. mordax* (by itself; Figure 6).

Miller and Schmidtke (1956) reported that *Clupea harengus pallasii* is not abundant in Monterey Bay during April through November; this is reflected in our results by an increased frequency of occurrence during summer months, at least in the shallow samples. Since they occurred much less frequently in the summer deep tows, it suggests a more inshore, shallow distribution for herring. *Peprilus simillimus* occurred only in the shallow-water anchovy hauls and midwater trawls, closely agreeing with the published information on this species (Fitch and Lavenberg 1971). It is difficult to explain the association between *P. simillimus* and *Merluccius productus* during the summer months, except that they both feed upon planktonic organisms. Large numbers of juvenile rockfishes were taken in the summer midwater trawls, ranging from 39 to 65 mm standard length in the shallow-water stations to 76 to 153 mm standard length in the deep samples. As many as 10,000 individuals were taken in a single haul, with larger numbers caught nearer the kelp bed areas. The pronounced absence of these juveniles from the anchovy commercial hauls can be simply explained by a lack of samples from near kelp bed areas. Miller and Geibel (1973) found, in a study of juvenile rockfish in the Monterey Bay area, that "concentrations of these fish appeared in April and May each year and remained densely aggregated in the kelp bed areas ...." This implies that juvenile rockfishes occur in these trawls seasonally and, therefore, only became pelagic associates with these other organisms during their juvenile stages.

Adult *Merluccius productus* were reported by Alverson and Larkin (1969) to undergo northward and inshore summer migrations. They also reported acoustic results indicating that this species undergoes a diel vertical migration paralleling the vertical migration pattern of the euphausiid, *Thysanoessa spinifera.* Alton and Nelson (1970) showed that the vertically migrating euphausiids *T. spinifera* and *Euphausia pacifica* were the leading food of *M. productus* both in frequency of occurrence and by weight, off Washington and Oregon. In Monterey Bay, it appears that the same is true (G.V. Morejohn, personal communication). Coincidentally, Karpov and Cailliet (in press) have shown that these two species of euphausiids dominated the diet of *Loligo opalescens* taken in the Monterey Bay area. When this information is combined with the fact that *Loligo opalescens* and *M. productus* were the only two species to remain associated in both the shallow and deep summer midwater trawls, it suggests that this association reflects utilization, perhaps competition, for the same resource. Certainly, this is conjectural, since euphausiids could not be included in the recurrent group analysis due to the mesh size; nor were stomach contents analyzed in all of these samples. However, this association warrants further investigation. Additionally, Karpov and Cailliet (1978) reported that peak feeding *L. opalescens* during summer months is at midday, while Alton and Nelson (1970) suggested that peak feeding in *M. productus* occurred during night hours.

While this analysis of recurrent groups of pelagic organisms from Monterey Bay has certain limitations, it does point out certain associations among organisms and suggests reasons for these associations. The primary organizing factor could be food source. The main members of recurrent groups in the pelagic waters of Monterey Bay, whether determined by commercial anchovy haul or winter and summer midwater samples, tend to feed upon the same kind of macroplankton euphausiids (G.V. Morejohn, personal communication). This euphausiids "link" may well be the reason that species such as *Loligo opalescens, Merluccius productus, Porichthys notatus, Clupea harengus pallasii,* juvenile rockishes (*Sebastes* spp.), *Peprilus simillimus, Citharichthys stigmaeus,* and *C. sordidus* variously come out in recurrent groups together. The association of these species with the northern anchovy, *Engraulis mordax*, is not quite as easy to explain. However, since *E. mordax* feeds on microplankton that live in the same general area of the pelagic ecosystem, it is not unreasonable to expect them to co-occur with such predatory organisms as squid. Indeed, young anchovies probably contribute to at least a portion of the diet of larger squid (Karpov and Cailliet, in press) .Despite the major problems inherent in trawling studies and in recurrent group analysis, there appears to be ample evidence that recurrent assemblages of pelagic species do occur in Monterey Bay waters and that both *L. opalescens* and *E. mordax* play very important roles in influencing the nature of these assemblages.

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