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Food Habits of Albacore, Bluefin Tuna, and Bonito In California Waters

By
Leo Pinkas
,
Malcolm S. Oliphant,
and
Ingrid L. K. Iverson
1971

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ACKNOWLEDGMENTS

The Food Habits Study of Organisms of the California Current System, (Project 6–7-R), was an investigation established under contract between the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service (formerly the Bureau of Commercial Fisheries) and the State of California as provided by the Commercial Fisheries Research and Development Act of 1964, Public Law 88–309.

Special acknowledgment and thanks are due John E. Fitch for his expertise in using otoliths to identify fish remains and his guidance of our staff in this technique. He organized and led the project in its formative stage, and his advice was keenly appreciated throughout the project's history.

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Herbert W. Frey, during his brief period of leading the project, contributed much to its organization and direction. Laura L. Richardson and her staff undertook the difficult task of converting rough drafts into a working manuscript. Paula Neff typed the final manuscript. The editorial staff of Herbert W. Frey, Patricia Powell, and Doyle E. Gates assisted in polishing and guiding this report through prepublication stages.

We owe a debt of gratitude and special thanks to Robert R. Bell; his fine hand and expertise appear and reappear throughout this report. He assumed leadership of a terminating project and brought loose ends together with polish and dispatch. He helped design and draft all figures except those of otoliths and cephalopod beaks. Under Bell's general editorship this paper was compiled, rewritten, and brought to fruition in time to meet a demanding schedule. Any errors or omissions, of course, are ours. Again our thanks.

Leo Pinkas
Malcolm S. Oliphant
Ingrid L. K. Iverson
June 1970

1. FOOD HABITS STUDY

LEO PINKAS
Marine Resources Region
California Department of Fish and Game

1.1. INTRODUCTION

The Food Habits Study of Organisms of the California Current System was undertaken to elucidate synoptically predator-prey relationships of economically significant fish inhabiting marine waters off California. Initial goals of the investigation were to provide answers to such questions as: 1. Why do albacore move through only a limited area off our coast when there are broad expanses where temperatures and other conditions are favorable? 2. Would shrimp fisheries improve if hake, tomcod, midshipmen, and other predators were utilized to a greater degree? 3. Would salmon fishing suffer if rockfishes were exploited more heavily, leaving fewer juveniles for forage? 4. Would considerably more exploitation of anchovies and sauries jeopardize summer runs of bluefin tuna, marlin, swordfish, yellowtail, or albacore?

These questions of course relate to many other considerations of concern to resource users and managers. For example, what are the effects of selective harvesting on the species being exploited, on its predators, its prey, and its competitors? The complex problem of intra-specific dynamics as a result of selective harvesting has been under investigation for many years in California and indeed throughout the world. Previous examinations of predator-prey relationships have been sporadic and usually only through a dominant predatory species. A reversal of this trend was initiated several years ago when the Institute of Marine Resources at Scripps Institution of Oceanography undertook a systematic investigation of energy transfer from the environment to and through lower planktonic organisms.

Economically desirable carnivors have been the objects of most food web studies since their obvious worth invokes greater interest and support. Albacore feeding behavior was investigated several times (Brock, 1943; Clemens and Iselin, 1962; Hart, 1942; Iverson, 1962; McHugh, 1952), sardines were studied at least three times (Hand and Berner, 1959; Hart and Wailes, 1932; and Lewis, 1929), and yellowtail once (Baxter, 1960), to name a few fish associated with California's coastal marine waters. Systematic broad based studies of larger carnivores have been lacking. The current food habits study was initiated to fill this obvious knowledge gap.

The investigation, launched in 1966, experienced a number of setbacks due to personnel and financial curtailment. These early difficulties, plus a 100 percent turnover in personnel by July 1967, necessitated a reevaluation of goals and objectives. A decision was made at that time to limit the study to 11 species: albacore, Thunnus alalunga; barracuda, Sphyraena argentea; bluefin tuna, Thunnus thynnus; bonito, Sarda chiliensis; white seabass, Cynoscion nobilis; California halibut, Paralichthys californicus; kelp bass, Paralabrax clathratus; sand bass, Paralabrax nebulifer; yellowtail, Seriola dorsalis; bocaccio, Sebastes paucipinis; and chilipepper, Sebastes goodei. A decision was made in the fall of 1969 to terminate the project on June 30, 1970.

Work had progressed to the point where we could report adequately on albacore, bluefin tuna, and bonito, as well as prepare a pictorial guide on cephalopod beaks.

Besides limitations mentioned above, other conditions reduced the overall effectiveness of our analysis. For example, regurgitation after capture is a well known phenomenon of tuna, and determination of time and frequency of feeding were beyond the project's capabilities. Continuing digestion between time of capture and preservation, usually a variable period, also was a limiting factor. We were unable to measure the extent or effect of these processes, yet they were evident as samples were processed. Volumetric measurement was perhaps the least reliable indicator of food quantities consumed since most ingested food was in an advanced stage of digestion, and presumably a significant amount of recently ingested food had been regurgitated by some fish. As a consequence, our results probably reflect a mixture of past as well as recent feedings.

Albacore, bluefin tuna, and bonito, the three fish reported here, are members of the same family (Scombridae), favor a pelagic environment, and are important to California sport anglers and commercial fishermen.

In season, these three fish inhabit the California Current System. Albacore are found in California Current oceanic waters; bluefin tuna travel closer to the mainland, congregating about islands and banks, and in general visiting waters under coastal influence. Bonito favor near shore habitats entering bays and harbors, as well as skirting islands and headlands. Considering the three species as a group, the area they cover while off California is from within casting distance of piers and breakwaters to several hundred miles offshore. To sample these fish is to sample thousands of cubic miles of feeding area, and to learn of their feeding preference is to discover much about the California marine environment.

1.2. METHODS

The procedures and methodology used in this investigation certainly were not the only ones available. Several factors had to be considered in designing our research activities, such as a scientific staff of three, a modest budget, and limited field equipment. The sport and commercial fishing fleets, in a sense, became our basic sampling tool. Seasonal help subsampled the sport and commercial catch for stomachs of project species. Scientific effort and talent were directed towards identification and analysis of stomach contents.

Dependence upon the commercial and sport fishing fleets for samples raised the question how to obtain stomach samples that were unbiased by the fishing operation. Bluefin tuna were no problem since the commercial fleet used purse seines exclusively in capturing these fish. The albacore fleet is divided between those vessels that use live anchovies for chum and those that only use artificial lures; our sampling efforts mainly were directed towards the latter. Bonito fishing provided two choices, a large pool of bait-biased samples from the sport fleet or fortuitous samples from a sporadic commercial purse seine fishery; again, we chose the latter as our prime sampling source.

The seasonal nature of each fishery forced us to accept samples as they became available. We could not predict when, where, or how many fish would be caught. The number of empty stomachs we would encounter also was an indeterminate factor. Sampling procedures, therefore, were designed to compensate for these factors. To assure an adequate volume of material for analysis, we arbitrarily decided to collect up to 20 stomachs per sample in 1968. In 1969 the number was reduced to 10 per sample with emphasis on catch localities. The few opportunities to fill data gaps were exploited to the fullest. For example, old unanalyzed collections of stomachs were examined, and various scientific and educational collecting operations were used to gather stomachs.

Stomachs were taken from fish landed at canneries prior to butchering. These were placed individually in plastic bags with coded identification numbers and frozen until examined in the laboratory. Catch location and date, boat name, gear, and fork length of each fish were recorded and the sample coded for identification.

At the laboratory, stomachs were thawed, opened with scissors, and their contents emptied into flat containers. The contents were separated into major forage categories, and excess moisture was removed by draining and then blotting with paper towels. Volumes of each category were determined by water displacement, using graduated cylinders. Volume, number of food items, and frequency of occurrence were determined.

We identified food items to the lowest possible taxon. Each food category posed different identification problems. Whole or slightly digested fish presented little difficulty. Partially and near totally digested fishes were identified by their otoliths (sagittae), using a reference collection of common species developed by the project (Figures [1 2 3]). Infrequently occurring species were identified by John E. Fitch, California Department of Fish and Game. We accepted the greatest number of either left or right otoliths in a stomach to calculate the number of ingested fish. When otoliths were so eroded that we could not determine left or right, the total was divided by two to establish minimum number of forage fish represented.

Cephalopods are quickly digested in scombrid stomachs. However, their beaks resist digestion and these may be used to identify species. We prepared a cephalopod beak collection from squid and octopus collected in California waters during Department cruises. We removed paired beaks from identified specimens, labeled, measured, and stored them in 40 percent isopropyl alcohol. Drawings of both juvenile and adult beaks were made for each species and these were used, together with preserved beaks, to identify those found in stomach contents. Whenever necessary, squid numbers were determined utilizing upper or lower beak counts in the same manner as the left and right otoliths.

Specific identification of crustaceans normally requires appendages be attached and intact. This is rarely the case in stomach contents because of rapid digestive action. We were able to establish the specific identity of some more well known crustaceans such as Pleuroncodes planipes and Sergestes similis through exoskeletal characteristics. Other crustaceans only could be designated to order, class, family, or sometimes genus. Numbers of certain crustaceans (euphausiids and sergestids) were sometimes established by counting pairs of eyes. In other cases (Pleuroncodes planipes) paired chelipeds could be counted.

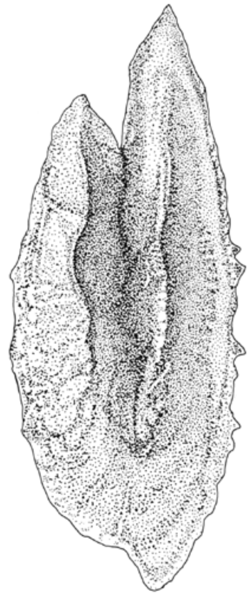

FIGURE 1. Left sagitta (otolith), 4.3 mm in length, of a northern anchovy, *Engraulis mordax.*

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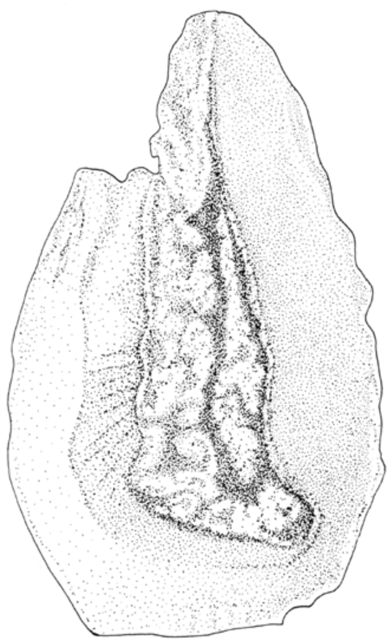

FIGURE 2. Left sagitta (otolith), 2.0 mm in length, of a Pacific saury, *Cololabis saira.*

FIGURE 2. Left sagitta (otolith), 2.0 mm in length, of a Pacific saury, Coloabis saira.

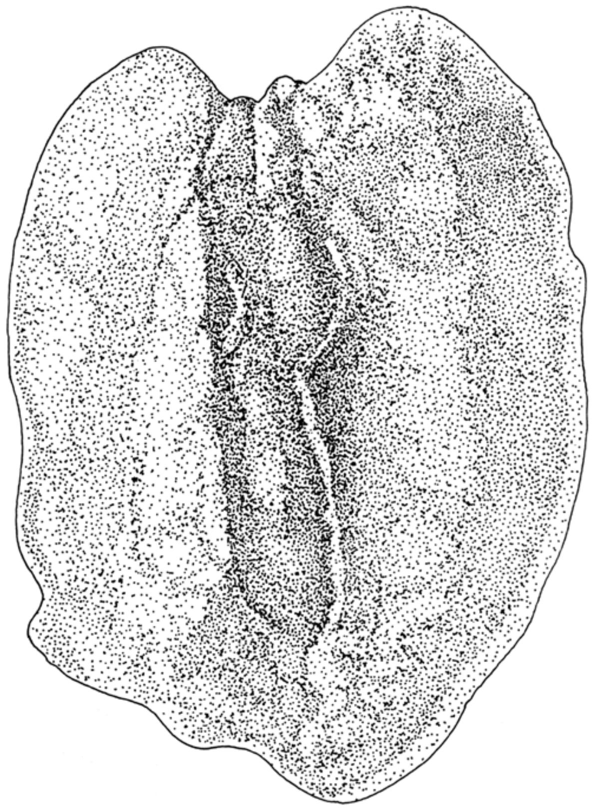

FIGURE 3. Left sagitta (otolith), 1.8 mm in length, of *Tarletonbeania crenularis.*

FIGURE 3. Left sagitta (otolith), 1.8 mm in length, of Tarletonbeania crenularis.

1.3. INDEX OF RELATIVE IMPORTANCE

Measurements of numbers, volume, and frequency of occurrence used traditionally in evaluating stomach contents of fish fall short of depicting true relative value. Numerous small organisms overshadow the importance of a few large ones. Differential digestive rates distort volumetric measurements. Frequency of occurrence tabulations are sensitive to sampling error. An ideal representative value would probably be one which integrates each of the above plus one for nutrition.

We developed an index of relative importance to assist in evaluating the relationship of the various food items found in stomachs knowing full well that it may fall short of some theoretical ideal. Our index of relative importance (IRI) was calculated by summing the numerical and volumetric percentage values and multiplying by the frequency of occurrence percentage value. Nutritional measurements, for example calories per unit volume, were beyond the project's capabilities.

$(N + V)F = IRI$

Where: N = Numerical percentage

V = Volumetric percentage

F = Frequency of occurrence percentage

IRI = Index of relative importance

1.4. SUMMARY OF FINDINGS

Results of this food habits study detail the relative importance of organisms used for food by albacore, bluefin tuna and bonito during 1968 and 1969. Perhaps our findings will be valid for decades, but change has taken place and we know conditions today are not those of 25, 50 or 100 years ago. Some marine organisms have found man's influence upon the marine environment inimical, others have found new opportunity. Current thinking among California scientists regards the latter to be the case with northern anchovy, Engraulis mordax.

Northern anchovies constitute 76 percent of the bonito's diet. Albacore have a mixed diet, particularly while offshore, but once in southern California waters 56 percent of their food is northern anchovy. Bluefin tuna while in Mexican and California waters depend on nothern anchovy for 80 percent of their diet. Thus, the role of the northern anchovy is singularly outstanding as the dominant food item for three important sport and commercial fish along the southern California coast.

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2. ALBACORE FOOD HABITS

INGRID L. K. IVERSON
Marine Resources Region
California Department of Fish and Game

2.1. LOCATION, NUMBER, AND SIZE OF SAMPLES

Most stomach samples were obtained from commercial vessels landing albacore, Thunnus alalunga, at San Pedro, California; a few came from truck loads originating at Oregon ports; and some were acquired from San Diego sport anglers.

The albacore were caught in three areas of the eastern Pacific Ocean: Region I, off southern California, between lat. 30° and 34° N, and long. 117° to 122° W; Region II, off central California, between lat. 34° 34' and 36° N, and long. 121° to 123° W; Region III, off Oregon and Washington between lat. 43° and 47° N and long. 125° to 127° W (Figures [4] and [5]). All samples came from 15 to 150 miles offshore.

We collected and examined 905 albacore stomachs. Sampling in 1968, July through November, provided 685 stomachs; 222 from Region I; 286 from Region II; and 177 from Region III. Sampling in 1969, July through September, provided 220 stomachs; 200 from Region I, none from Region II, and 20 from Region III.

The albacore sampled ranged in size from 522 to 932 mm (fork length). These samples included age groups I, II, III, IV, and V, with the majority in age groups II and III.

Pacific coast albacore are most aften caught with jigs and live bait; small numbers are caught with purse seines. About 20 percent of the commercial vessels from which we received samples fished with live bait (northern anchovy, Engraulis mordax) . We were able to determine the number of anchovies ingested as bait and not natural forage since little difficulty was experienced in distinguishing freshly ingested, whole, uniform sized bait from partially or completely digested forage fish. In 1968, bait constituted 52 percent of the anchovies ingested by volume and 7 percent numerically. In 1969, bait made up 57 percent by volume and 37 percent numerically of the anchovies ingested. Bait is excluded as a food item in all our discussions of volume, number, or frequency of occurrence.

2.2. RESULTS

of the 685 albacore stomachs taken during the 1968 season, 627 contained food, 48 were empty, and 10 contained only bait. We examined 220 stomachs from the 1969 season; 200 contained food, 17 were empty, and 3 had only bait. All organisms were identified to the specific level when possible and for analysis grouped into one of five categories: (A) anchovies, (B) sauries, (C) other fish and unidentified material, (D) cephalopods, and (E) crustaceans. Miscellaneous items (algae, paper, feathers) accounted for less than 0.1 percent by number, volume, and frequency. Food items in albacore stomachs included representatives of 21 fish families, 14 cephalopod families, and 3 crustacean subclasses (Tables 1 and 2).

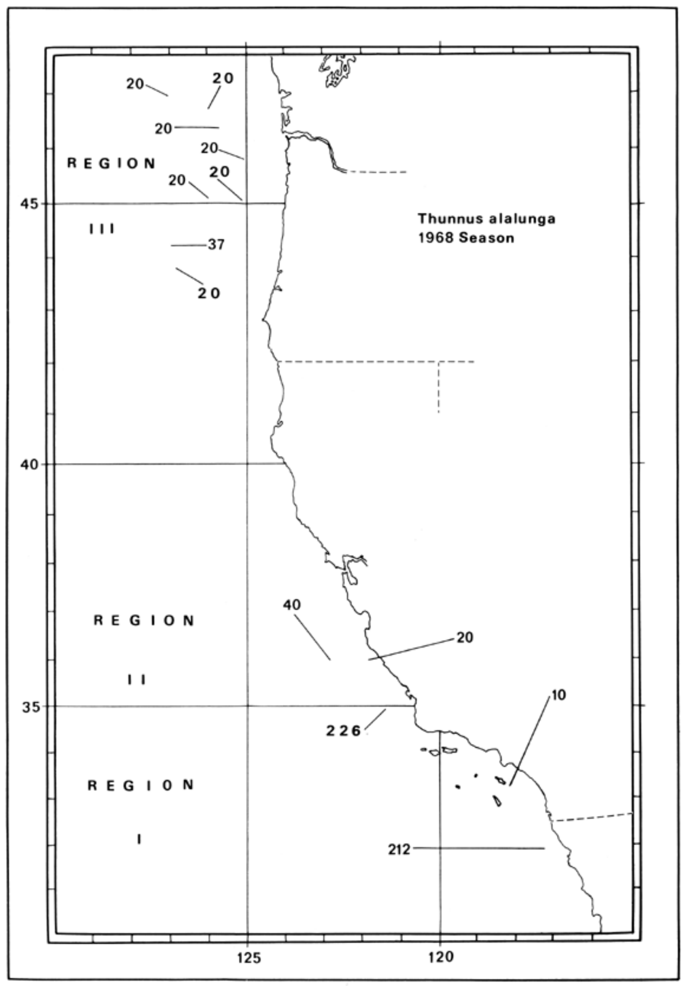

FIGURE 4. Number and location of albacore samples collected in 1968.

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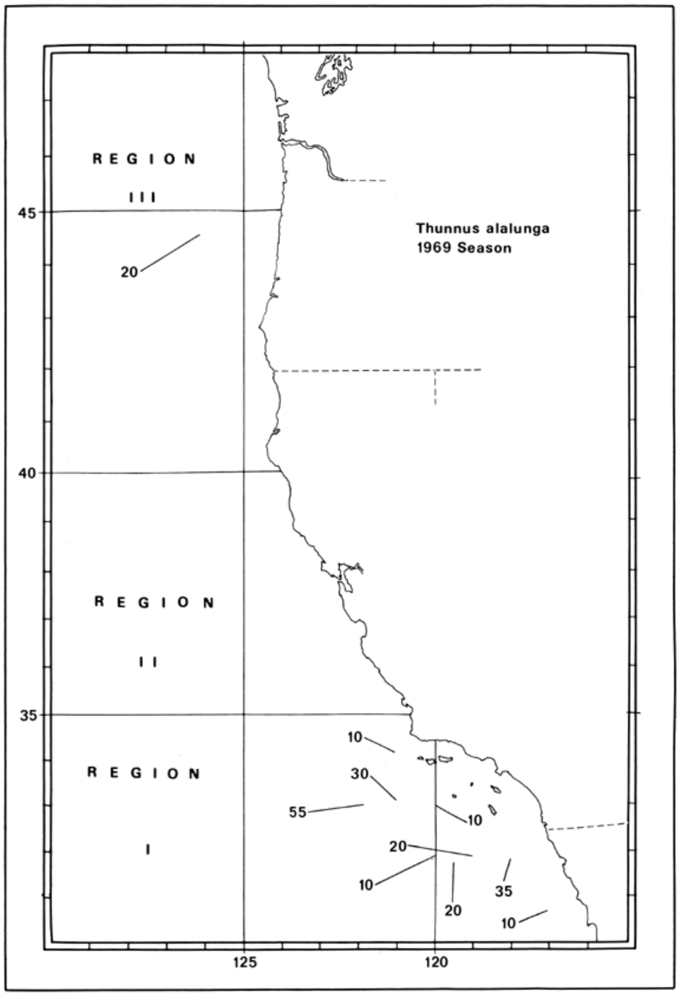

FIGURE 5. Number and location of albacore samples collected in 1969.

FIGURE 5. Number and location of albacore samples collected in 1969.

TABLE 1

Albacore Food, 1968—Regions I, II, III

Food items	Number of organisms			Volume of organisms			Frequency of occurrence	
	Number	Percent within subgroup	Percent of total	Milliliters	Percent within subgroup	Percent of total	Frequency	Percent of total
MOLLUSCA								
Cephalopoda								
Octopoda								
Argonautidae								
Argonauta sp. (*nouryi*)	1	<0.1	<0.1	tr			1	<0.1
Ocythoinae								
Ocythoe tuberculata	63	1.7	0.2	5.6	1.2	0.1	43	6.9
Octopodidae								
Octopus bimaculatus	336	9.1	1.1	17.3	3.8	0.2	69	11.0
Decapoda								
Loliginidae								
Loligo opalescens	250	6.8	0.8	48.5	10.7	0.4	61	9.7
Architeuthidae	1	<0.1	<0.1	<0.1	<0.1	<0.1	1	<0.1
Onychoteuthidae								
Onychoteuthis boreali-japonicus	1,202	32.7	3.8	95.2	20.9	0.8	236	37.6
Moroteuthis robusta	17	0.5	<0.1	9.5	2.1	0.1	10	1.6
Enoploteuthidae								
Abraliopsis felis	420	11.4	1.3	11.9	2.6	0.1	94	15.0
Octopodoteuthis sicula	272	7.4	0.9	16.4	3.6	0.1	124	19.8
Histioteuthidae								
Histioteuthis heteropsis	6	0.2	<0.1	<0.1	<0.1	<0.1	5	0.8
Gonatidae								
Gonatus anonychus	29	0.8	0.1	39.0	8.6	0.3	15	2.4
Gonatus sp.	493	13.4	1.5	42.8	9.4	0.4	77	12.3
Gonatus sp. (*fabricii*)	114	3.1	0.4	43.7	9.6	0.4	58	9.3
Gonatopsis sp.	55	1.5	0.2	0.2	<0.1	<0.1	28	4.5
Chiroteuthidae								
Mastigoteuthis dentata	266	7.2	0.8	<0.1	<0.1	<0.1	66	10.5
Cranchiidae								
Cranchia scabra	2	<0.1	<0.1	<0.1	<0.1	<0.1	2	<0.1
Leachia sp.	76	2.1	0.2	3.4	0.8	<0.1	35	5.6
Unidentified juvenile	25	0.7	0.1	0.1	<0.1	<0.1	16	2.6
Unidentified spp.	45	1.2	0.1	122.0	26.8	1.0	29	4.5
Subtotal	3,673	99.8	11.5	455.6	100.1	3.9	--	---

TABLE 1

Albacore Food, 1968—Regions I, II, III

CRUSTACEA								
Copepoda	12	0.1	<0.1	tr			1	<0.1
Cirripedia	1	<0.1	<0.1	0.1	<0.1	<0.1	1	<0.1
Malacostraca								
Stomatopoda—*Squilla* sp.	2	<0.1	<0.1	0.4	<0.1	<0.1	2	<0.1
Amphipoda								
Hyperiidae								
Unidentified spp. (2)	133	0.9	0.4	21.8	1.8	0.2	39	6.2
Phronima sedentaria	2,158	14.2	6.8	114.1	9.5	1.0	118	18.8
Grammaridae								
Unidentified sp.	2	<0.1	<0.1	tr			2	<0.1
Euphausiacea								
Euphausia pacifica	7,082	46.6	25.5	242.6	20.1	2.1	108	17.2
Gnathophausia gigas	2	<0.1	<0.1	16.0	1.3	0.1	2	<0.1
Decapoda								
Sergestes similis	5,684	37.4	14.6	417.9	34.8	3.5	60	9.6
Pleuroncodes planipes	69	0.5	0.2	150.9	12.5	1.3	20	3.2
Megalops crab larvae	20	0.1	<0.1	0.7	<0.7	<0.1	9	1.4
Unidentified	45	0.3	0.1	241.1	20.0	2.0	16	2.6
Subtotal	15,210	100.0	47.6	1,205.6	100.0	10.2	---	---
TUNICATA								
Thaliacea (salps)	15	0.1	<0.1	0.9	<0.1	<0.1	3	0.5
VERTEBRATES								
Fishes								
Engraulidae								
Engraulis mordax	7,932	61.2	24.9	5,147.3	50.7	43.6	175	27.9
Argentinidae								
Nansenia sp.	1	<0.1	<0.1	tr			1	0.2
Bathylagidae								
Leuroglossus stilbius	1	<0.1	<0.1	tr			1	0.2
Myctophidae								
Diaphus theta	11	0.1	<0.1	1.0	<0.1	<0.1	9	1.4
Lampanyctus ritteri	7	<0.1	<0.1	tr			7	1.1
Protomyctophum crockeri	4	<0.1	<0.1	tr			4	0.6
Stenobrachius leucopsarus	56	0.4	0.2	18.9	0.2	0.2	25	4.0
Tarletonbeania crenularis	634	4.9	2.0	578.5	5.7	5.0	74	11.8
Paralepididae								
Paralepis atlantica	51	0.4	0.2	377.7	3.7	3.2	28	4.5
Anotopteridae								
Anotopterus sp.	2	<0.1	<0.1	4.6	<0.1	<1.0	2	0.3

TABLE 1—Cont'd.

TABLE 1—Continued

Albacore Food, 1968—Regions I, II, III

Food items	Number of organisms			Volume of organisms			Frequency of occurrence	
	Number	Percent within subgroup	Percent of total	Milliliters	Percent within subgroup	Percent of total	Frequency	Percent of total
VERTEBRATES—Continued								
Fishes—continued								
Scomberesocidae								
Cololabis saira	752	5.8	2.4	3,392.3	33.4	28.7	150	23.9
Gadidae								
Merluccius productus	1	<0.1	<0.1	tr			1	0.2
Microgadus proximus	59	0.5	0.2	20.0	0.2	0.2	28	4.5
Melamphaidae								
Melamphaes lugubris	2	<0.1	<0.1	tr			2	0.3
Scopelogadus mizolepis bispinosus	66	0.5	0.2	tr			2	0.3
Carangidae								
Trachurus symmetricus	1	<0.1	<0.1	130.7	1.3	1.1	1	0.2
Scombridae								
Scomber japonicus	15	0.1	<0.1	tr			6	1.0
Scorpaenidae								
Sebastes spp.	3,189	24.6	10.0	308.5	3.0	2.6	224	35.7
Stromateidae								
Peprilus simillimus	1	<0.1	<0.1	17.0	0.2	0.1	1	0.2
Pleuronectiformes								
Unidentified juvenile flatfish	3	<0.1	<0.1	4.0	<0.1	<0.1	1	0.2
Unidentified fish	160	1.2	0.5	156.7	1.5	1.3	57	9.1
Subtotal	12,963	99.8	40.6	10,158.1	99.9	86.0	---	---
TOTAL	31,846	---	99.7	11,816.1	---	100.0	---	---

tr = Trace.

TABLE 1
Albacore Food, 1968—Regions I, II, III

TABLE 2

Albacore Food, 1969—Regions I, III

Food items	Number of organisms: Number	Number of organisms: Percent within subgroup	Number of organisms: Percent of total	Volume of organisms: Milliliters	Volume of organisms: Percent within subgroup	Volume of organisms: Percent of total	Frequency of occurrence: Frequency	Frequency of occurrence: Percent of total
MOLLUSCA								
Cephalopoda								
Octopoda								
Watasellidae (Vampyroteuthidae)								
Vampyroteuthis infernalis	1	<0.1	<0.1	tr			1	0.5
Cirroteuthidae								
Opisthoteuthis californiana	1	<0.1	<0.1	tr			1	0.5
Argonautidae								
Argonauta sp. (nouryi)	1	<0.1	<0.1	0.2	0.1	<0.1	1	0.5
Ocythoinae								
Ocythoe tuberculata	20	1.7	0.7	1.5	1.1	<0.1	17	8.5
Octopodidae								
Octopus bimaculatus	10	0.9	0.3	1.1	0.8	<0.1	6	3.0
Decapoda								
Loliginidae								
Loligo opalescens	31	2.7	1.0	0.3	0.2	<0.1	19	9.5
Onychoteuthidae								
Onychoteuthis boreali-japonicus	388	33.3	12.8	48.3	34.3	1.8	85	42.5
Moroteuthis robusta	13	1.1	0.4	0.4	0.3	<0.1	10	5.0
Enoploteuthidae								
Abraliopsis felis	324	27.8	10.7	5.8	4.1	0.2	68	34.0
Octopodoteuthis sicula	63	5.4	2.1	0.8	0.6	<0.1	33	16.5
Histioteuthidae								
Histioteuthis heteropsis	1	<0.1	<0.1	tr			1	0.5
Gonatidae								
Gonatus anonychus	15	1.3	0.5	9.0	6.4	0.3	5	2.5
Gonatus sp.	20	1.7	0.7	0.1	0.1	<0.1	12	6.0
Gonatus sp. (fabricii)	103	8.8	3.4	4.5	3.2	0.2	46	23.0
Gonatopsis sp.	29	2.5	1.0	1.7	1.2	<0.1	16	8.0
Ommastrephidae								
Dosidicus gigas	1	<0.1	<0.1	1.2	0.9	<0.1	1	0.5

TABLE 2

Albacore Food, 1969—Regions I, III

TABLE 2—Continued

Albacore Food, 1969—Regions I, III

Food items	Number of organisms			Volume of organisms			Frequency of occurrence	
	Number	Percent within subgroup	Percent of total	Milliliters	Percent within subgroup	Percent of total	Frequency	Percent of total
MOLLUSCA—Continued								
Cephalopoda—continued								
Octopoda—continued								
Chiroteuthidae								
Mastigoteuthis dentata	25	2.1	0.8	tr			9	4.5
Cranchiidae								
Leachia sp.	82	7.0	2.7	7.7	5.5	0.3	24	12.0
Unidentified juvenile	7	0.6	0.2	tr			4	2.0
Unidentified spp.	31	2.7	1.0	58.3	41.4	2.1	19	9.5
Subtotal	1,166	99.6	38.3	140.9	100.2	5.1	---	---
CRUSTACEA								
Malacostraca								
Mysidacea—Unidentified sp.	21	2.4	0.7	tr			8	4.0
Amphipoda								
Hyperiidae								
Unidentified spp. (2)	274	31.2	9.0	16.8	30.1	0.6	32	16.0
Phronima sedentaria	75	8.5	2.5	3.5	6.3	0.1	21	10.5
Euphausiacea								
Euphausia pacifica	374	42.6	12.3	25.0	45.0	0.9	37	17.6
Decapoda								
Sergestes similis	127	14.5	4.2	3.1	5.6	0.1	3	0.2
Pleuroncodes planipes	4	0.5	0.1	5.1	9.2	0.2	3	0.2
Unidentified	3	0.3	0.1	2.1	3.8	0.1	3	0.2
Subtotal	878	100.0	28.9	55.6	100.0	2.0	---	---
TUNICATA								
Thaliacea (salps)	19	1.9	0.6	3.1	0.1	0.1	5	2.5

TABLE 2
Albacore Food, 1969—Regions I, III

VERTEBRATES								
Fishes								
Engraulidae								
Engraulis mordax	293	29.4	9.6	1,211.8	47.2	43.9	44	22.0
Argentinidae								
Nansenia sp.	73	7.3	2.4	5.7	0.2	0.2	23	11.5
Opisthoproctidae								
Dolichopteryx sp.	1	0.1	<0.1	tr			1	0.5
Gonostomidae								
Vinciguerria lucetia	2	0.2	0.1	tr			2	1.0
Sternoptychidae								
Sternopthyx diaphana	1	0.1	<0.1	1.0	<0.1	<0.1	1	0.5
Melanostomiatidae								
Bathophilus flemingi	1	0.1	<0.1	tr			1	0.5
Scopelarchidae								
Scopelarchus sp.	4	0.4	0.1	tr			2	1.0
Myctophidae								
Ceratoscopelus townsendi	1	0.1	<0.1	tr			1	0.5
Diaphus theta	2	0.2	0.1	1.3	<0.1	<0.1	2	1.0
Lampanyctus ritteri	1	0.1	<0.1	tr			1	0.5
Protomyctophum crockeri	5	0.5	0.2	0.1	<0.1	<0.1	5	2.5
Stenobrachius leucopsaurus	3	0.3	0.1	tr			3	1.5
Tarletonbeania crenularis	20	1.9	0.6	3.2	0.1	0.1	8	4.0
Triphoturus mexicanus	1	0.1	<0.1	0.4	<0.1	<0.1	1	0.5
Paralepididae								
Paralepis atlanticus	12	1.2	0.4	21.0	0.8	0.8	7	3.5
Scomberesocidae								
Cololabis saira	269	27.0	8.9	1,237.4	48.2	44.8	85	42.5
Gadidae								
Microgadus proximus	13	1.3	0.4	tr			6	3.0
Melamphaidae								
Melamphaes lugubris	32	3.2	1.1	tr			11	5.5
Scopelogadus mizolepis bispinosus	5	0.4	0.1	0.1	<0.1	<0.1	4	2.0
Syngnathidae								
Syngnathus sp.	18	1.8	0.6	8.8	0.3	0.3	3	1.5
Embiotocidae								
Cymatogaster aggregata	1	0.1	<0.1	20.0	0.8	0.7	1	0.5
Scorpaenidae								
Sebastes spp.	155	15.5	5.1	16.4	0.6	0.5	38	19.0
Pleuronectiformes								
Unidentified juvenile flatfish	3	0.3	0.1	2.5	0.1	0.1	2	1.0
Unidentified fish	65	6.5	2.1	32.4	1.3	1.2	24	12.0
Subtotal	1,000	100.0	32.6	2,565.2	99.7	92.7	---	---
TOTAL	3,044	---	99.8	2,761.7	---	99.8	---	---

tr = Trace.

TABLE 2—Cont'd.

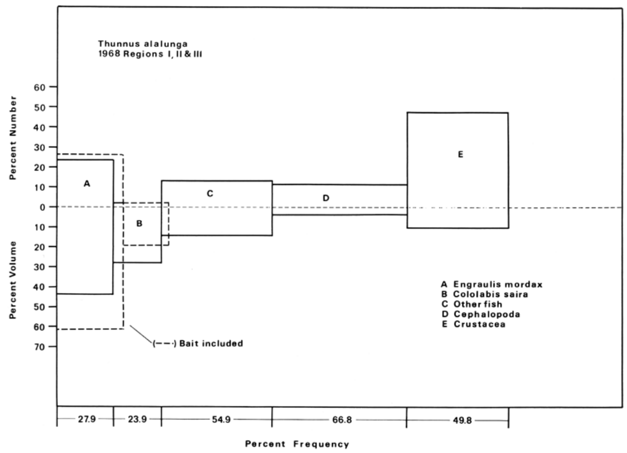

FIGURE 6. Percent composition by major food categories in number, volume, and frequency of occurrence; albacore 1968, all regions (southern California, central California, and Oregon-Washington).

FIGURE 6. Percent composition by major food categories in number, volume, and frequency of occurrence; albacore 1968, all regions (southern California, central California, and Oregon-Washington).

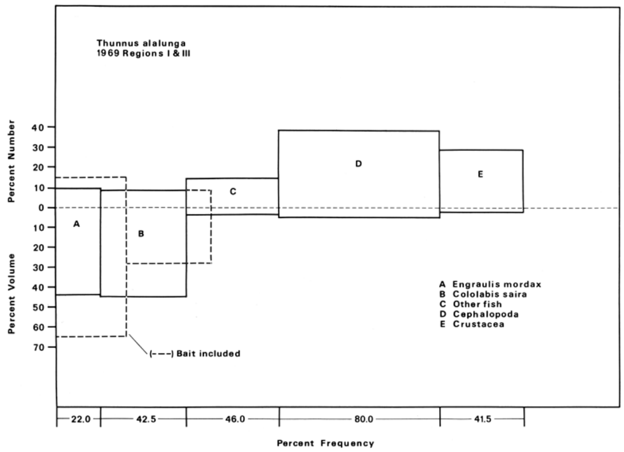

FIGURE 7. Percent composition by major food categories in number, volume, and frequency of occurrence; albacore 1969, all regions (southern California, central California, and Oregon-Washington).

FIGURE 7. Percent composition by major food categories in number, volume, and frequency of occurrence; albacore 1969, all regions (southern California, central California, and Oregon-Washington).

2.2.1. Analysis by Volume

Fish are the most important food in the albacore diet; they comprised by volume 86.0 percent of the stomach contents in 1968 and 92.7 percent in 1969. Two fish, northern anchovy, Engraulis mordax, and saury, Cololabis saira, contributed the greatest volume of all food sources, 43.6 percent and 28.7 percent respectively in 1968, and 43.9 percent and 44.8 percent in 1969 (Figures [6] and [7]).

In 1968, cephalopods contributed 3.9 percent of the total food volume and 5.1 percent in 1969 (Figures 6 and 7). We found few entire squid or octopus since they are digested rapidly leaving behind only chitinous beaks. However, many cephalopods are equal in volume to fish and the small volume we found cannot be considered a true representation of cephalopod importance as food for albacore.

Crustaceans contributed 10.2 percent of the total food volume for 1968, but only 2.0 percent for 1969 (Figures 6 and 7). The most important species were Phronima sedentaria, Euphausia pacifica, Sergestes similis, and Pleuroncodes planipes (Tables 1 and 2).

2.2.2. Analysis by Numbers

A numerical analysis of stomach contents does not illustrate the true importance of individual food items in albacore diet. Crustaceans appeared to be the greatest food source in 1968, accounting for 47.6 percent of all organisms by numbers (Figure 6); however, the volume of a single crustacean is negligible when compared to the volume of a fish or cephalopod. Analysis by volume more accurately describes albacore diet. Nevertheless, numbers were useful when looking at cephalopods and juvenile rockfish, two food items which occurred in many stomachs in large numbers, although their volumes were always reduced through digestion.

In 1968, cephalopods accounted for 11.5 percent of the total numbers of items and in 1969 their numbers were 38.3 percent (Figures 6 and 7). Onychoteuthis boreali-japonicus, Abraliopsis felis, and three species of gonatids were the most common decapods found, while pelagic juveniles of Octopus bimaculatus were the important octopod. Juvenile rockfish, represented by hundreds of otoliths, contributed 10.0 percent of the total items in 1968 and 5.1 percent in 1969 (Tables 1 and 2).

2.2.3. Analysis by Frequency of Occurrence

Analysis of frequency of occurrence also revealed that fish were the dominant forage. In 1968 we found 81.8 percent of the stomachs contained fish, and the frequency was 76.5 percent in 1969. Again the individual species of fish occurring most often were anchovies, 27.9 percent in 1968 and 22.0 percent in 1969; and sauries, 23.9 percent in 1968, and 42.5 percent in 1969 (Figures 6 and 7). Several undetermined species of juvenile rockfish occurred in a significant portion of the stomachs; 35.7 percent in 1968 and 19.0 percent in 1969 (Tables 1 and 2). We consistently found several species of deep water fish, especially myctophids (mostly Tarletonbeania crenularis) , but their numbers were few.

Cephalopods are easy prey for albacore, and occurred in a large percentage of the stomachs; 66.8 percent in 1968, and 80.0 percent in 1969 (Figures 6 and 7). Onychoteuthis boreali-japonicus was the most

TABLE 3

Ranking of Major Albacore Food Items Grouped by Regions, 1968 and 1969

Food items	Percent—1968 Number N	Percent—1968 Volume V	Percent—1968 Frequency F	Index of Relative Importance (N + V) F	Food items	Percent—1969 Number N	Percent—1969 Volume V	Percent—1969 Frequency F	Index of Relative Importance (N + V) F
REGION I—SOUTHERN CALIFORNIA									
Engraulis mordax	56.2	55.1	55.7	6,199	*Cololabis saira*	9.2	44.1	45.5	2,425
Cololabis saira	11.1	34.1	42.8	1,935	*Engraulis mordax*	10.1	44.9	23.5	1,293
Sebastes spp.	20.2	2.0	27.9	619	*Onychoteuthis boreali-japonicus*	13.4	1.8	44.9	683
Onychoteuthis boreali-japonicus	1.9	0.3	27.4	60	*Abraliopsis felis*	11.3	0.2	36.4	419
Pleuroncodes planipes	1.3	2.9	10.0	42	*Euphausia pacifica*	13.0	0.9	19.8	275
REGION II—CENTRAL CALIFORNIA									
Euphausia pacifica	43.1	5.9	38.9	1,906	No data for Region II				
Sebastes spp.	13.4	5.0	52.0	957					
Phronima sedentaria	14.5	2.8	40.0	692					
Onychoteuthis boreali-japonicus	7.1	1.9	58.5	527					
Cololabis saira	0.9	27.9	16.4	512					
REGION III—OREGON-WASHINGTON									
Sergestes similis	52.1	14.1	45.0	2,979	*Sergestes similis*	76.5	4.9	23.1	1,880
Engraulis mordax	40.1	57.1	26.5	2,584	*Cololabis saira*	2.4	75.7	15.4	1,203
Cololabis saira	0.3	19.7	12.6	252	*Gonatus anonychus*	9.0	14.1	38.5	889
Tarletonbeania crenularis	1.6	1.0	15.2	40	*Tarletonbeania crenularis*	5.4	tr	7.7	42
Gonatus sp. (*fabricii*)	0.3	1.2	15.2	23	*Onychoteuthis boreali-japonicus*	1.2	0.9	7.7	16
ALL REGIONS COMBINED									
Engraulis mordax	24.9	43.6	27.9	1,911	*Cololabis saira*	8.9	48.2	42.5	2,282
Cololabis saira	2.4	28.7	23.9	743	*Engraulis mordax*	9.6	43.9	22.0	1,177
Euphausia pacifica	25.5	2.1	17.2	475	*Onychoteuthis boreali-japonicus*	12.8	1.8	42.5	621
Sebastes spp.	10.0	2.6	35.7	450	*Abraliopsis felis*	10.7	0.2	34.0	371
Sergestes similis	14.6	3.5	9.6	174	*Euphausia pacifica*	12.3	0.9	17.6	232

TABLE 3

Ranking of Major Albacore Food Items Grouped by Regions, 1968 and 1969

common species, occurring in 37.6 percent of stomachs collected in 1968 and in 42.5 percent of those acquired in 1969 (Tables 1 and 2).

Crustaceans were the least common group, but we still found them in 49.8 percent of the stomachs for 1968 and 41.5 percent for 1969 (Figures 6 and 7). Phronima sedentaria, Euphausia pacifica, and hyperiid amphipods were the crustaceans most often encountered.

2.2.4. Analysis by Index of Relative Importance

Index of relative importance (IRI) calculations which attempt to coalesce the numerical, volumetric, and frequency of occurrence measurements into one value, enabled us to rank each species by region as well as for the entire eastern North Pacific Ocean (Table 3).

In the eastern North Pacific Ocean in 1968 the northern anchovy, with an IRI of 1,911, was the predominant food item of albacore. Saury were second (IRI 743) followed by euphasiids (IRI 475), Sebastes spp. (IRI 450) and Sergestes similis (IRI 174).

For 1969 the index of relative importance indicated that fish, as a group, were as dominant as in 1968; however, individual rankings shifted: saury were first (IRI 2,282) and anchovy second (IRI 1,177). Two cephalopods, Onychoteuthis boreali-japonicus, (IRI 621) and Abraliopsis felis (IRI 321) ranked third and fourth respectively displacing Euphausia pacifica (IRI 232) to fifth place from third in 1968. Sebastes spp., fourth in 1968 with an index of relative importance of 450, was reduced to seventh place in 1969 (IRI 106).

2.3. AREAL VARIATIONS

Analysis of the individual areas of sampling revealed distinct differences in predominant species and relative amount of organisms eaten although albacore in all three regions ate fish, cephalopods, and crustaceans. No samples came from Region II (central California) in 1969 and we received very few from Region III (Oregon and Washington) in 1969; therefore, areal variations are considered mostly for 1968 (Tables 4, 5, 6, 7, and 8).

2.3.1. Region I—Southern California

In Region I samples, fish comprised 96.0 percent of the stomach contents by volume; 55.1 percent were anchovies and 34.1 percent sauries (Figure 8). Frequencies of occurrence were impressive for these two fish; 55.7 percent for anchovies, and 42.8 percent for sauries. Juvenile rockfish contributed little by volume (2.0 percent), but they still occurred in 27.9 percent of the stomachs examined (Table 4).

Cephalopods, as a group, were second to fish in importance off southern California. They numerically contributed 7.6 percent of the total food ingested; however, the volume was low, registering only 1.0 percent. of the 12 species of cephalopods selected for food by albacore, Onychoteuthis boreali-japonicus was taken in the greatest numbers, 25.1 percent, followed by Octopus bimaculatus, 21.6 percent, Abraliopsis felis, 17.3 percent and Loligo opalescens, 11.8 percent.

Crustaceans contributed very little to the total volume of albacore food in Region I. One species, Pleuroncodes planipes, constituted almost the entire portion numerically, 1.3 percent, and volumetrically, 2.9 percent.

TABLE 4

Albacore Food, 1968—Southern California, Region I

Food items	Number of organisms			Volume of organisms			Frequency of occurrence	
	Number	Percent within subgroup	Percent of total	Milliliters	Percent within subgroup	Percent of total	Frequency	Percent of total
MOLLUSCA								
Cephalopoda								
Octopoda								
Ocythoinae								
Ocythoe tuberculata	3	0.7	0.1	tr			3	1.5
Octopodidae								
Octopus bimaculatus	86	21.6	1.6	11.6	22.1	0.2	32	15.9
Decapoda								
Loliginidae								
Loligo opalescens	47	11.8	0.9	7.9	15.1	0.2	27	13.4
Onychoteuthidae								
Onychoteuthis boreali-japonicus	100	25.1	1.9	15.1	28.8	0.3	55	27.4
Moroteuthis robusta	17	4.3	0.3	9.5	18.1	0.2	12	6.0
Enoploteuthidae								
Abraliopsis felis	69	17.3	1.3	1.6	3.1	<0.1	28	13.9
Octopodoteuthis sicula	31	7.8	0.6	tr			25	12.4
Histioteuthidae								
Histioteuthis heteropsis	4	1.0	0.1	tr			3	1.5
Gonatidae								
Gonatus sp. (1)	5	1.2	0.1	1.4	2.7	<0.1	4	2.0
Gonatus sp. (*fabricii*)	3	0.7	0.1	tr			3	1.5
Gonatopsis sp.	5	1.2	0.1	tr			5	2.5
Cranchiidae								
Leachia sp.	14	3.5	0.3	2.0	3.8	<0.1	2	1.0
Unidentified juvenile	tr	tr	tr	tr			tr	
Unidentified spp.	15	3.8	0.3	3.4	6.5	0.1	8	4.0
Subtotal	399	100.0	7.6	52.5	100.2	1.0	----	----

TABLE 4
Albacore Food, 1968—Southern California, Region I

TABLE 4—Continued

Albacore Food, 1968—Southern California, Region I

Food items	Number of organisms			Volume of organisms			Frequency of occurrence	
	Number	Percent within subgroup	Percent of total	Milliliters	Percent within subgroup	Percent of total	Frequency	Percent of total
CRUSTACEA								
Copepoda	12	11.4	0.2	tr			1	0.5
Malacostraca								
Stomatopoda—*Squilla* sp.	1	0.9	<0.1	0.2	0.1	<0.1	1	0.5
Amphipoda								
Hyperiidae								
Unidentified spp. (2)	1	0.9	<0.1	tr			1	0.5
Phronima sedentaria	7	6.6	0.1	0.7	0.5	<0.1	6	3.0
Euphausiacea								
Euphausia pacifica	3	2.8	<0.1	1.1	0.7	<0.1	1	0.5
Decapoda								
Pleuroncodes planipes	69	65.1	1.3	150.9	97.9	2.9	20	10.0
Megalops crab larvae	1	0.9	<0.1	tr			1	0.5
Unidentified remains	12	11.4	0.2	1.2	0.8	<0.1	7	3.5
Subtotal	106	100.0	1.8	154.1	100.0	2.9	----	----
VERTEBRATES								
Fishes								
Engraulidae								
Engraulis mordax	2,943	62.2	56.2	2,821.3	57.4	55.1	112	55.7
Gonostomatidae								
Vinciguerria lucetia	1	<0.1	<0.1	tr			1	0.5
Myctophidae								
Lampanyctus ritteri	1	<0.1	<0.1	tr			1	0.5
Stenobrachius leucopsaurus	28	0.6	0.5	18.9	0.4	0.4	3	1.5
Tarletonbeania crenularis	6	0.1	0.1	tr			3	1.5
Paralepididae								
Paralepis atlantica	8	0.2	0.2	56.7	1.2	1.1	8	4.0

TABLE 4
Albacore Food, 1968—Southern California, Region I

Scomberesocidae								
Cololabis saira	580	12.3	11.1	1,745.1	35.5	34.1	86	42.8
Gadidae								
Microgadus proximus	12	0.3	0.2	20.0	0.4	0.4	3	1.5
Carangidae								
Trachurus symmetricus	1	<0.1	<0.1	130.7	2.6	2.5	1	0.5
Scombridae								
Scomber japonicus	15	0.3	0.3	tr			6	3.0
Scorpaenidae								
Sebastes spp.	1,059	22.4	20.2	105.0	2.1	2.0	56	27.9
Stromateidae								
Peprilus simillimus	1	<0.1	<0.1	17.0	0.4	0.4	1	0.5
Unidentified fish	76	1.6	1.5	tr			10	5.0
Subtotal	4,731	100.0	90.3	4,914.7	100.0	96.0	----	----
TOTAL	5,236	----	99.7	5,121.3	----	100.6	----	----

tr = Trace.

TABLE 4—Cont'd.

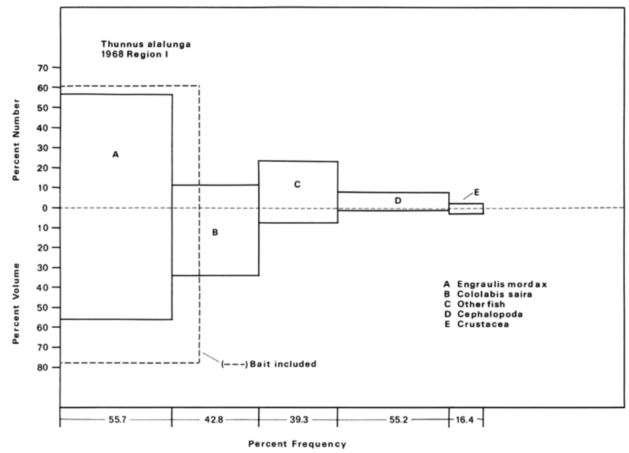

FIGURE 8. Percent composition by major food categories in number, volume, and frequency of occurrence; albacore 1968, Region I (southern California).

FIGURE 8. Percent composition by major food categories in number, volume, and frequency of occurrence; albacore 1968, Region I (southern California).

TABLE 5

Albacore Food, 1969—Southern California, Region I

Food items	Number of organisms			Volume of organisms			Frequency of occurrence	
	Number	Percent within subgroup	Percent of total	Milliliters	Percent within subgroup	Percent of total	Frequency	Percent of total
MOLLUSCA								
Cephalopoda								
Octopoda								
Watasellidae (Vampyroteuthidae)								
Vampyroteuthis infernalis	1	0.1	<0.1	tr			1	0.5
Cirroteuthidae								
Opisthoteuthis californiana	1	0.1	<0.1	tr			1	0.5
Argonautidae								
Argonauta sp. (*nouryi*)	1	0.1	<0.1	0.2	0.2	<0.1	1	0.5
Ocythoinae								
Ocythoe tuberculata	19	1.7	0.7	1.5	1.2	0.1	16	8.6
Octopodidae								
Octopus bimaculatus	10	0.9	0.3	1.1	0.8	<0.1	5	2.8
Decapoda								
Loliginidae								
Loligo opalescens	31	2.7	1.1	0.3	0.2	<0.1	19	10.2
Onychoteuthidae								
Onychoteuthis boreali-japonicus	386	33.8	13.4	47.7	36.8	1.8	84	44.9
Moroteuthis robusta	13	1.1	0.5	0.4	0.3	<0.1	10	5.3
Enoploteuthidae								
Abraliopsis felis	324	28.3	11.3	5.8	4.5	0.2	68	36.4
Octopodoteuthis sicula	63	5.5	2.2	0.8	0.6	<0.1	33	17.6
Histioteuthidae								
Histioteuthis heteropsis	1	0.1	<0.1	tr			1	0.5
Gonatidae								
Gonatus sp. (1)	19	1.7	0.7	0.1	0.1	<0.1	11	5.3
Gonatus sp. (*fabricii*)	101	8.8	3.5	4.5	3.5	0.2	44	23.5
Gonatopsis sp.	28	2.4	1.0	1.7	1.3	0.1	13	7.0
Ommastrephidae								
Dosidicus gigas	1	0.1	<0.1	1.2	0.9	<0.1	1	0.5

TABLE 5
Albacore Food, 1969—Southern California, Region I

TABLE 5—Continued

Albacore Food, 1969—Southern California, Region I

Food items	Number of organisms			Volume of organisms			Frequency of occurrence	
	Number	Percent within subgroup	Percent of total	Milliliters	Percent within subgroup	Percent of total	Frequency	Percent of total
MOLLUSCA—Continued								
Cephalopoda—continued								
Octopoda—continued								
Chiroteuthidae								
Mastigoteuthis dentata	25	2.2	0.9	tr			9	4.8
Cranchiidae								
Leachia sp.	82	7.2	2.9	7.7	5.9	0.3	24	12.8
Unidentified juvenile	7	0.6	0.2	tr			3	1.6
Unidentified spp.	30	2.6	1.0	56.8	43.8	2.1	18	9.6
Subtotal	1,143	100.0	39.7	129.8	100.1	2.1	----	----
CRUSTACEA								
Malacostraca								
Mysidacea—unidentified sp.	21	2.8	0.8	tr			8	4.3
Amphipoda								
Hyperiidae								
Unidentified 2 spp.	274	36.5	9.5	16.8	32.0	0.6	33	17.6
Phronima sedentaria	74	9.9	2.6	3.5	6.7	0.1	20	10.7
Euphausiacea								
Euphausia pacifica	374	49.9	13.0	25.0	47.6	0.9	37	19.8
Decapoda								
Pleuroncodes planipes	4	0.5	0.1	5.1	9.7	0.2	3	1.6
Unidentified remains	3	0.4	0.1	2.1	4.0	0.1	3	1.6
Subtotal	750	100.0	26.1	52.5	100.0	1.9	----	----
TUNICATA								
Thaliacea (salps)	19	1.9	0.7	3.1	0.1	0.1	5	2.7

TABLE 5

Albacore Food, 1969—Southern California, Region I

VERTEBRATES								
Fishes								
Engraulidae								
Engraulis mordax	291	29.6	10.1	1,210.5	48.1	44.9	44	23.5
Argentinidae								
Nansenia sp.	73	7.4	2.5	5.7	0.2	0.2	23	12.3
Opisthoproctidae								
Dolichopteryx sp.	1	0.1	<0.1	tr			1	0.5
Gonostomatidae								
Vinciguerria lucetia	2	0.3	0.1	tr			1	0.5
Sternoptychidae								
Sternoptyx diaphana	1	0.1	<0.1	1.0	<0.1	<0.1	1	0.5
Melanostomiatidae								
Bathophilus flemingi	1	0.1	<0.1	tr			1	0.5
Scopelarchidae								
Scopelarchus sp.	4	0.4	0.1	tr			2	1.1
Myctophidae								
Diaphus theta	2	0.3	0.1	1.3	<0.1	<0.1	2	1.1
Lampanyctus ritteri	1	0.1	<0.1	tr			1	0.5
Protomyctophum crockeri	5	0.5	0.2	0.1	<0.1	<0.1	5	2.7
Stenobrachius leucopsarus	3	0.3	0.1	tr			3	1.6
Tarletonbeania crenularis	11	1.1	0.4	3.2	0.1	0.1	8	4.3
Triphoturus mexicanus	1	0.1	<0.1	0.4	<0.1	<0.1	1	0.5
Paralepididae								
Paralepis atlantica	12	1.2	0.4	21.0	0.8	0.8	7	3.7
Scomberesocidae								
Cololabis saira	265	26.9	9.2	1,189.1	47.3	44.1	85	45.5
Gadidae								
Microgadus proximus	13	1.3	0.5	tr			6	3.2
Melamphaidae								
Melamphaes lugubris	32	3.3	1.1	tr			11	5.9
Scopelogadus mizolepis bispinosus	5	0.5	0.2	0.1	<0.1	<0.1	5	2.7
Syngnathidae								
Syngnathus sp.	18	1.8	0.6	8.8	0.3	0.3	3	1.6
Embiotocidae								
Cymatogaster aggregata	1	0.1	<0.1	20.0	0.8	0.7	1	0.5
Scorpaenidae								
Sebastes spp.	155	15.7	5.4	16.4	0.7	0.6	38	20.3
Pleuronectiformes								
Unidentified juvenile flatfish	3	0.3	0.1	2.5	0.1	0.1	2	1.1
Unidentified fish	65	6.6	2.3	32.4	1.3	1.2	tr	
Subtotal	984	100.0	34.1	2,515.6	99.8	93.6	----	----
TOTALS	2,877	----	99.9	2,697.9	----	100.3	----	----

tr = Trace.

TABLE 5—Cont'd.

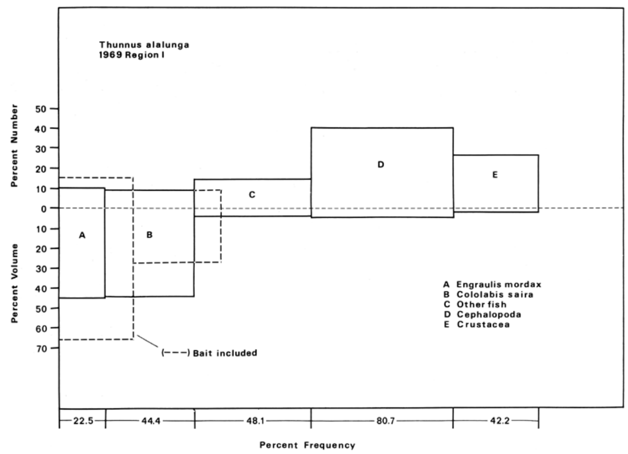

FIGURE 9. Percent composition by major food categories in number, volume, and frequency of occurrence; albacore 1969, Region I (southern California).

FIGURE 9. Percent composition by major food categories in number, volume, and frequency of occurrence; albacore 1969, Region I (southern California).

Index of relative importance computations for Region I, 1968, indicated that fish ranked one, two and three: anchovy (IRI 6,199); saury (IRI 1,935); and rockfish species (IRI 619). The squid Onychoteuthis boreali-japonicus (IRI 60) was fourth followed by the crustacean Pleuroncodes planipes (IRI 42) (Table 3).

In 1969 the rankings changed: saury (IRI 2,425) became the number one food item; anchovies (IRI 1,293) were second and Onychoteuthis boreali-japonicus (IRI 683) was third, up from fourth in 1968. The crustacean, Euphausia pacifica (IRI 275) was fifth (Table 5 and Figure 9).

2.3.2. Region II—Central California

The volume of fish in stomachs from Region II samples was also substantial, 77.7 percent. The contribution of anchovies, 19.9 percent, was considerably less than in Region I; saury importance was slightly less, 27.9 percent; while other fish increased in importance: Tarletonbeania crenularis (13.7 percent), Paralepis atlantica (8.0 percent), and Sebastes spp. (5.0 percent). Sauries occurred in 16.4 percent of the stomachs examined and Paralepis atlantica were in 6.5 percent, while Sebastes spp. occurred in 52.0 percent of the stomachs (Table 6).

In Region II, crustaceans replaced cephalopods as the second-most important group of food organisms; numerically comprising 59.9 percent and volumetrically 16.3 percent (Figure 10) . Despite their small size, Euphausia pacifica contributed a significant fraction of the total food ingested in the area, numerically 43.1 percent, volumetrically 5.9 percent and by frequency of occurrence 38.9 percent. Phronima sedentaria was, despite a low volume of 2.8 percent, of some significance contributing 14.5 percent by number and 40.0 percent by frequency of occurrence. Both these species are common inhabitants of California waters (Boden, Johnson and Brinton, 1955).

Albacore cropped off at least 17 different species of cephalopods in Region II, yet they were third in importance. The frequency of occurrence of Onychoteuthis boreali-japonicus, 58.5 percent, established it as first within the group followed by an unknown species of Gonatus, then by Octopodoteuthis sicula.

Index of relative importance computations for Region II revealed that the individual species rankings were different from the group ratings, plus illustrating marked differences between areas. Euphausia pacifica, with an IRI of 1,906, was first; rockfish (IRI 957) were second and the crustacean Phronima sedentaria (IRI 692) was third. Onychoteuthis boreali-japonicus (IRI 527) ranked fourth and saury (IRI 512) a close fifth (Table 3).

2.3.3. Region III—Oregon-Washington

Fish consumed by albacore in Region III during 1968 constituted 79.3 percent of the total food volume. Anchovies were dominant, providing 57.1 percent of the total (mostly juveniles approximately 30 to 40 mm in length), with sauries contributing 19.7 percent (Figure 11) . In frequency of occurrence anchovies and sauries predominated but neither in any overwhelming percentage of stomachs. Anchovies were found in 26.5 percent of the stomachs and sauries in 12.6 percent, followed by Sebastes spp., 17.2 percent, and Tarletonbeania crenularis, 15.2 percent (Table 7).

TABLE 6

Albacore Food, 1968—Central California, Region II

Food items	Number of organisms			Volume of organisms			Frequency of occurrence	
	Number	Percent within subgroup	Percent of total	Milliliters	Percent within subgroup	Percent of total	Frequency	Percent of total
MOLLUSCA								
Cephalopoda								
Octopoda								
Argonautidae								
Argonauta sp. (*nouryi*)	1	<0.1	<0.1	tr			1	0.4
Ocythoinae								
Ocythoe tuberculata	18	0.6	0.1	tr			14	5.1
Octopodidae								
Octopus bimaculatus	248	8.7	1.7	5.7	2.4	0.1	36	13.1
Decapoda								
Loliginidae								
Loligo opalescens	123	4.3	0.8	2.4	1.0	0.1	21	7.6
Architeuthidae								
Unidentified sp.	1	<0.1	<0.1	tr			1	0.4
Onychoteuthidae								
Onychoteuthis boreali-japonicus	1,056	37.0	7.1	75.5	31.1	1.9	161	58.5
Enoploteuthidae								
Abraliopsis felis	262	9.2	1.8	3.6	1.5	0.1	50	18.2
Octopodoteuthis sicula	228	8.0	1.5	16.4	6.8	0.4	90	32.7
Histioteuthidae								
Histioteuthis heteropsis	2	0.1	<0.1	tr			2	0.7
Gonatidae								
Gonatus anonychus	3	0.1	<0.1	tr			2	0.7
Gonatus sp. (1)	416	14.6	2.8	8.9	3.8	0.2	61	22.2
Gonatus sp. (*fabricii*)	79	2.8	0.5	10.9	4.5	0.3	32	11.6
Gonatopsis sp.	47	1.6	0.3	0.2	0.1	<0.1	24	8.7
Chiroteuthidae								
Mastigoteuthis dentata	261	9.2	1.8	tr			62	22.5

TABLE 6
Albacore Food, 1968—Central California, Region II

Cranchiidae								
Cranchia scabra	2	0.1	<0.1	tr			2	0.7
Leachia sp.	61	2.1	0.4	1.4	0.6	<0.1	32	11.6
Unidentified juvenile	25	0.9	0.2	0.1	<0.1	<0.1	16	5.8
Unidentified sp.	18	0.6	0.1	117.4	48.4	2.9	12	4.4
Subtotal	2,851	99.9	19.1	242.5	100.2	6.0	----	----
CRUSTACEA								
Cirripedia	1	<0.1	<0.1	0.1	<0.1	<0.1	1	0.4
Malacostraca								
Stomatopoda—*Squilla* sp.	1	<0.1	<0.1	0.2	<0.1	<0.1	1	0.4
Amphipoda								
Hyperiidae								
Unidentified—2 spp.	127	1.4	0.9	21.4	3.2	0.5	36	13.1
Phronima sedentaria	2,149	24.2	14.5	113.4	17.2	2.8	110	40.0
Euphausiacea								
Euphausia pacifica	6,379	71.8	43.1	238.3	36.2	5.9	107	38.9
Gnathophausia gigas	1	<0.1	<0.1	5.0	0.8	0.1	1	0.4
Decapoda								
Sergestes similis	214	2.4	1.4	41.0	6.2	1.0	1	0.4
Megalops crab larvae	4	<0.1	<0.1	0.1	<0.1	<0.1	3	1.1
Unidentified remains	11	0.1	<0.1	239.7	36.4	6.0	4	1.5
Subtotal	8,887	99.9	59.9	659.2	100.0	16.3	----	----
TUNICATA								
Thaliacea (salps)	15	0.5	0.1	0.9	<0.1	<0.1	3	1.1
VERTEBRATES								
Fishes								
Engraulidae								
Engraulis mordax	216	7.0	1.5	803.9	25.7	19.9	23	8.4
Argentinidae								
Nansenia sp.	1	<0.1	<0.1	tr			1	0.4
Bathylagidae								
Leuroglossus stilbius	1	<0.1	<0.1	tr			1	0.4
Myctophidae								
Diaphus theta	10	0.3	0.1	1.0	0.1	<0.1	8	2.9
Lampanyctus ritteri	5	0.2	<0.1	tr			5	1.8
Protomyctophum crockeri	1	<0.1	<0.1	tr			1	0.4
Stenobrachius leucopsarus	26	0.8	0.2	tr			21	7.6
Tarletonbeania crenularis	437	14.2	3.0	551.9	17.6	13.7	46	16.7

TABLE 6—Cont'd.

TABLE 6—Continued

Albacore Food, 1968—Central California, Region II

Food itms	Number of organisms			Volume of organisms			Frequency of occurrence	
	Number	Percent within subgroup	Percent of total	Milliliters	Percent within subgroup	Percent of total	Frequency	Percent of total
VERTEBRATES—Continued								
Fishes—continued								
Paralepididae								
Paralepis atlantica	39	1.3	0.3	321.0	10.3	8.0	18	6.5
Anotopteridae								
Anotopterus sp.	2	0.1	<0.1	4.6	0.1	0.1	2	0.7
Scomberesocidae								
Cololabis saira	133	4.3	0.9	1,122.4	35.9	27.9	45	16.4
Gadidae								
Merluccius productus	1	<0.1	<0.1	tr			1	0.4
Microgadus proximus	47	1.5	0.3	tr			26	9.5
Melamphaidae								
Melamphaes lugubris	1	<0.1	<0.1	tr			1	0.4
Scopelogadus mizolepis bispinosus	66	2.2	0.4	tr			2	0.7
Scorpaenidae								
Sebastes spp.	1,988	64.8	13.4	200.2	6.4	5.0	143	52.0
Pleuronectiformes								
Unidentified juvenile flatfish	3	0.1	<0.1	4.0	0.1	0.1	1	0.4
Unidentified fish	75	2.4	0.5	120.4	3.8	3.0	39	14.2
Subtotal	3,067	99.7	20.7	3,130.3	100.0	77.7	3	1.1
TOTAL	14,805	----	99.7	4,032.0	----	100.0	----	----

tr = Trace.

TABLE 6

Albacore Food, 1968—Central California, Region II

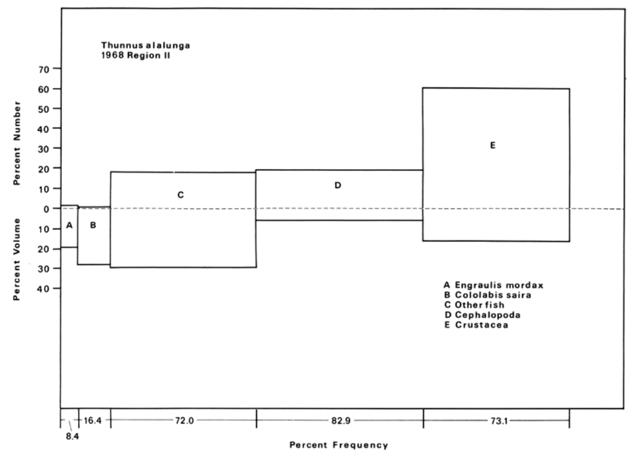

FIGURE 10. Percent composition by major food categories in number, volume, and frequency of occurrence; albacore 1968, Region II (central California).

FIGURE 10. Percent composition by major food categories in number, volume, and frequency of occurrence; albacore 1968, Region II (central California).

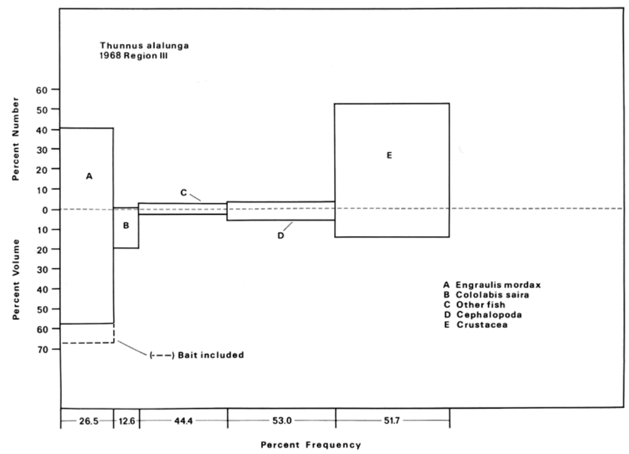

FIGURE 11. Percent composition by major food categories in number, volume, and frequency of occurrence; albacore 1968, Region III (Oregon-Washington).

FIGURE 11. Percent composition by major food categories in number, volume, and frequency of occurrence; albacore 1968, Region III (Oregon-Washington).

Crustaceans contributed significantly, 14.7 percent, to the contents of albacore stomachs collected in Region III, ranking the group second as in Region II. Sergestes similis was responsible for 96.1 percent of this volume and occurred in 45.0 percent of all stomachs. It had significant occurrence only in this region. off central California the same species contributed only 6.2 percent of the total crustacean volume and none off southern California.

We found the distribution of cephalopods, through their presence in albacore stomachs, varied little between regions. While they did not contribute substantially to volume, 6.0 percent, or by number, 3.6 percent, the species variety and frequency of occurrence still rated them as a significant group.

No one octopus or squid stood out for this area in 1968. The common squid, Loligo opalescens, Gonatus sp. (fabricii) , and Gonatus anonychus, were perhaps the three most important species off Oregon and Washington. The latter was found in 8.6 percent of the stomachs during 1968 while in 1969 38.5 percent of the albacore sampled contained this squid (Table 8 and Figure 12), an expected phenomena since this squid's distribution is northern and does not extend into southern California (Pearcy and Voss, 1963). Abraliopsis felis and Octopodoteuthis sicula occurred in albacore stomachs taken from all three regions. The octopod Ocythoe tuberculata occurred most frequently in the north, decreasing in importance as a food item in the southern regions covered by our study. Octopus bimaculatus showed the opposite trend, occurring more often in the stomachs from albacore sampled in the south and found less frequently in stomachs collected to the north.

In Region III during 1968 the species rankings, as revealed by the index of relative importance, were Sergestes similis (IRI 2,979); Engraulis mordax (IRI 2,584) a strong second and Cololabis saira (IRI 252) a weak third. A fish, Tarletonbeania crenularis, (IRI 40) and a squid, Gonatus sp. (fabricii) , (IRI 23) were fourth and fifth respectively.

In 1969 Sergestes similis was still dominant (IRI 1,880); however, saury (IRI 1,203) replaced anchovies in second place following the pattern set in southern California. The cephalopod, Gonatus anonychus, (IRI 889) made a strong third while Tarletonbeania crenularis (IRI 42) was again fourth and Onychoteuthis boreali-japonicus (IRI 16) was fifth.

Albacore stomachs examined by National Marine Fisheries Service (formerly U.S. Bureau of Commercial Fisheries) personnel, La Jolla, California, contained many cephalopods (Michael Laurs, personal communication). We examined beaks from these stomachs and our identifications, correlated with sample locations, closely followed distribution patterns reported in the literature (Berry, 1912; Pearcy and Voss, 1963; McGowan and Okutani, 1968; Talmadge, 1968; McGowan, 1967). Onychoteuthis boreali-japonicus occurred almost exclusively south of Cape Blanco, Oregon, lat. 43° N. Abraliopsis felis occurred mostly south of San Francisco; one albacore stomach from central Oregon contained a pair of Abraliopsis felis beaks. Gonatus anonychus was found in stomachs from albacore caught within 100 miles offshore

TABLE 7

Albacore Food, 1968—Oregon-Washington, Region III

Food itmes	Number of organisms			Volume of organisms			Frequency of occurrence	
	Number	Percent within subgroup	Percent of total	Milliliters	Percent within subgroup	Percent of total	Frequency	Percent of total
MOLLUSCA								
Cephalopoda								
Octopoda								
Ocythoinae								
Ocythoe tuberculata	42	9.9	0.4	5.6	3.5	0.2	26	17.2
Octopodidae								
Octopus bimaculatus	1	0.3	<0.1	tr			1	0.7
Decapoda								
Loliginidae								
Loligo opalescens	78	18.4	0.7	38.2	23.8	1.4	11	7.3
Onychoteuthidae								
Onychoteuthis boreali-japonicus	48	11.3	0.4	4.6	2.9	0.2	23	15.2
Enoploteuthidae								
Abraliopsis felis	91	21.5	0.8	5.7	4.2	0.3	16	10.6
Octopodoteuthis sicula	13	3.1	0.1	tr			9	6.0
Gonatidae								
Gonatus anonychus	26	6.1	0.2	39.0	24.3	1.5	13	8.6
Gonatus sp. (1)	72	17.0	0.6	32.5	20.2	1.2	10	6.6
Gonatus sp. (*fabricii*)	32	7.6	0.3	32.8	20.4	1.2	23	15.2
Gonatopsis sp.	2	0.5	<0.1	tr			2	1.3
Chiroteuthidae								
Mastigoteuthis dentata	5	1.2	<0.1	tr			4	2.6
Cranchiidae								
Leachia sp.	1	0.3	<0.1	tr			1	0.7
Unidentified sp.	12	2.8	0.1	1.2	0.7	<0.1	8	5.3
Subtotal	423	100.0	3.6	160.6	100.0	6.0	----	----
CRUSTACEA								
Malacostraca								
Amphipoda								
Hyperiidae								
Unidentified sp.	5	0.1	<0.1	0.4	0.1	<0.1	3	2.0
Phronima sedentaria	2	<0.1	<0.1	tr			2	1.3
Grammaridae								
Unidentified sp.	2	<0.1	<0.1	tr			2	1.3

TABLE 7
Albacore Food, 1968—Oregon-Washington, Region III

Euphausiacea								
Euphausia pacifica	18	0.3	0.2	3.2	0.8	0.1	2	1.3
Gnathophausia gigas	1	<0.1	<0.1	11.0	2.8	0.4	1	0.7
Decapoda								
Sergestes similis	6,152	99.0	52.1	376.9	96.1	14.1	68	45.0
Megalops crab larvae	15	0.2	0.1	0.6	2	<0.1	5	3.3
Unidentified spp.	22	0.4	0.2	0.2	<0.1	<0.1	4	2.6
Subtotal	6,217	100.0	52.6	392.3	100.0	14.7	----	----
VERTEBRATES								
Fishes								
Engraulidae								
Engraulis mordax	4,773	92.4	40.4	1,522.1	72.0	57.1	40	26.5
Myctophidae								
Diaphus theta	1	<0.1	<0.1	tr			1	0.7
Lampanyctus ritteri	1	<0.1	<0.1	tr			1	0.7
Protomyctophum crockeri	3	0.1	<0.1	tr			3	2.0
Stenobrachius leucopsarus	2	<0.1	<0.1	tr			1	0.7
Tarletonbeania crenularis	191	3.7	1.6	26.6	1.3	1.0	23	15.2
Paralepidae								
Paralepis atlantica	4	0.1	<0.1	tr			2	1.3
Scomberesocidae								
Cololabis saira	39	0.8	0.3	524.8	24.8	19.7	19	12.6
Melamphaidae								
Melamphaes lugubris	1	<0.1	<0.1	tr			1	0.7
Scorpaenidae								
Sebastes spp.	142	2.7	1.2	3.3	0.2	0.1	26	17.2
Unidentified fish	8	0.2	0.1	36.3	1.7	1.4	4	2.6
Subtotal	5,165	100.0	43.6	2,113.1	100.0	79.3	----	----
Total	11,805	----	99.8	2,666.0	----	100.0	----	----

Tr — Trace.

TABLE 7—Cont'd.

TABLE 8

Albacore Food, 1969—Oregon-Washington, Region III

Food items	Number of organisms			Volume of organisms			Frequency of occurrence	
	Number	Percent within subgroup	Percent of total	Milliliters	Percent within subgroup	Percent of total	Frequency	Percent of total
MOLLUSCA								
Cephalopoda								
Octopoda								
Ocythoinae								
Ocythoe tuberculata	1	4.5	0.6	tr			1	7.7
Decapoda								
Onychoteuthidae								
Onychoteuthis boreali-japonicus	2	9.1	1.2	0.6	5.4	0.9	1	7.7
Gonatidae								
Gonatus anonychus	15	68.3	9.0	9.0	81.1	14.1	5	38.5
Gonatus sp. (1)	1	4.5	0.6	tr			1	7.7
Gonatus sp. (*fabricii*)	2	9.1	1.2	tr			2	15.4
Unidentified sp.	1	4.5	0.6	1.5	13.5	2.4	1	7.7
Subtotal	22	100.0	13.2	11.1	100.0	17.4	----	----
CRUSTACEA								
Malacostraca								
Amphipoda								
Hyperiidae								
Phronima sedentaria	1	0.8	0.6	tr	tr	tr	1	7.7
Decapoda								
Sergestes similis	127	99.2	76.5	3.1	100.0	4.9	3	23.1
Subtotal	128	100.0	77.1	3.1	100.0	4.9	----	----

TABLE 8

Albacore Food, 1969—Oregon-Washington, Region III

VERTEBRATES								
Fishes								
Engraulidae								
Engraulis mordax	2	12.5	1.2	1.3	2.6	2.0	2	15.4
Myctophidae								
Ceratoscopelus townsendi	1	6.2	0.6	tr			1	7.7
Tarletonbeania crenularis	9	56.3	5.4	tr			1	7.7
Scomberesocidae								
Cololabis saira	4	25.0	2.4	48.3	97.4	75.7	2	15.4
Subtotal	16	100.0	9.6	49.6	100.0	77.7	----	----
TOTALS	166		99.9	63.8		100.0	----	----

tr = Trace.

TABLE 8—Cont'd.

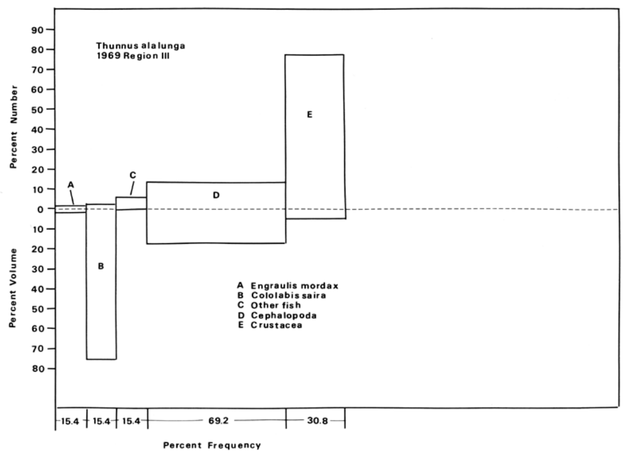

FIGURE 12. Percent composition by major food categories in number, volume, and frequency of occurrence; albacore 1969, Region III (Oregon-Washington).

FIGURE 12. Percent composition by major food categories in number, volume, and frequency of occurrence; albacore 1969, Region III (Oregon-Washington).

of Cape Mendocino, California. Gonatus fabricii (probable identification) occurred offshore Oregon, and Ocythoe tuberculata was found in stomachs from albacore taken close to shore from San Francisco north to central Oregon.

2.4. DISCUSSION

The composition of stomach contents differed in albacore sampled from southern California and those from the north. In southern California, anchovies and sauries predominated, cephalopods followed next in importance, and crustaceans occurred occasionally. In central California, fish were significant food items in stomachs, but the importance of anchovies and sauries decreased with a corresponding increase in myctophids, paralepids, and rockfish. Cephalopods and crustaceans also became more important in this region. In Oregon and Washington, anchovies were the most important food fish in 1968, but in 1969 we found sauries most often in albacore stomachs. Other fish contributed little either year. Cephalopods contributed a small amount in 1968 but were of considerable importance in 1969. Crustaceans contributed significantly both years in northern waters. A comparison of the 2 years sampled showed similar contributions by fish for both years in southern California. However, cephalopods and crustaceans were more important in 1969 than in 1968. We found anchovies and sauries were the most important forage of albacore in the eastern Pacific Ocean in 1968 and 1969.

Albacore sampled from Washington and Canada reveal feeding habits similar to those from southern California waters. Hart (1942) noted that albacore from Washington and Canada feed on a wide variety of organisms such as anchovies, sauries, myctophids, squid, and euphausiids. He also found pieces of bark, gravel, seaweed, feathers, and barnacles in albacore stomachs. Hart and Hollister (1947) found much the same in northern albacore stomachs with the addition of octopus and rockfish. McHugh (1952) observed Pacific saury was by far the most important food item in stomachs from California and Baja California (50 percent by volume). He found squid were next (12 percent), followed by Pleuroncodes planipes (11 percent), and euphausiids (7 percent), while anchovies contributed little (4 percent). Laurs' study of albacore from waters off California, Oregon, and Washington revealed sauries as the principal food item. He found Sergestes similis the most important crustacean. Although Laurs' samples were collected in 1968, the first year of our study, there was a difference between the two studies in more important food items. Laurs' samples, containing mostly sauries and few anchovies, came from more than 180 miles offshore while our samples came from 15 to 150 miles offshore. Our results closely compare with those of Clemens and Iselin (1962). Their samples, from California and Baja California fishing areas, contained anchovies, sauries, rockfish, jack mackerel, and myctophids as well as squid, euphausiids, amphipods, and heteropods.

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3. BLUEFIN TUNA FOOD HABITS

LEO PINKAS
Marine Resources Region
California Department of Fish and Game

3.1. LOCATION, NUMBER, AND SIZE OF SAMPLES

Purse seine caught bluefin tuna, Thunnus thynnus, were sampled intensively for stomachs in 1968 and 1969 at San Pedro, California, canneries. The bulk of sampling effort was distributed from June through September to coincide with the principal fishing season off southern California and Baja California. A sample was collected from a January 1969 catch off Guadalupe Island, representing a small off-season fishery that develops annually with few exceptions.

In 1968 the commercial purse seine fleet caught 6,466 tons of bluefin tuna between Magdalena Bay and the Channel Islands of California with a preponderance of the catch originating from Cedros Island northward. The slightly larger 1969 catch of 7,617 tons also was caught within the same overall geographical boundaries; however, the fish were found in two areas in approximately equal abundance: off southern Baja California, and off northern Baja California.

The 1968 sampling effort resulted in 45 samples comprised of 766 bluefin tuna stomachs. These samples represented catches in July, August, September, and October. The sampled fish ranged from 574 mm to 1,272 mm in fork length and averaged 747 mm. The areas of catch ranged from Uncle Sam Bank, lat. 25° 37' N, long. 113° 23' W, to Santa Catalina Island, approximate lat. 33° 20' N. long. 118° 20' W (Figure 13) .

Selective sampling in 1969 yielded 36 samples of 368 stomachs from fish caught in January, April, June, July, August, and September. These fish ranged from 531 mm to 1,360 mm in fork length and averaged 757 mm. The area of catch ranged between Magdalena Bay, approximate lat. 24° 30' N, long. 112° 30' W, and the Channel Islands, approximate lat. 34° 00' N, long. 120° 30' W (Figure 14) .

Sampling error (i.e., no catch information, record keeping errors, etc.) caused us to discard 61 stomachs leaving a total of 1,073 for analysis. On completing the laboratory analysis, we found that 423 or 39.5 percent of the stomachs were devoid of food. The remaining 650 stomachs contained one or more food items and form the basis of this report. of these stomachs, 447 were collected in 1968 and 203 in 1969.

3.2. RESULTS

Fish are the predominant food of bluefin tuna during their summer sojourn in the eastern North Pacific Ocean. Numerically they contribute 91.8 percent of organisms ingested (1968–1969 combined). Fish composed 93.1 percent of the total volume of all consumed food, and one or more species of fish were found in 88.0 percent of the stomachs containing food (frequency of occurrence).

Mollusks and crustaceans, the other major animal groups found in bluefin tuna stomachs, were of minor significance when compared to fish. Crustaceans were slightly more important than cephalopods: numerically 4.2 as opposed to 3.9 percent, volumetrically 4.6 compared to 2.2 percent, and by frequency of occurrence 16.5 compared to 14.8 percent (Table 9).

The northern anchovy, Engraulis mordax, was the primary food of bluefin tuna in 1968 and 1969. It overshadowed all other ingested species, singularly or in any combination. Combined data for 1968–1969 clearly illustrate the anchovy's importance. Numerically anchovies provided 86.6 percent of the bluefin diet, volumetrically 80.0 percent, and we found them in 72.0 percent of the bluefin stomachs (Figure 15) .

The red swimming crab, Pleuroncodes planipes, was the second most important animal species preyed upon by bluefin tuna: numerically 3.7 percent, volumetrically 4.5 percent, and by frequency of occurrence 13.5 percent. Saury, Cololabis saira, ranked third: numerically 1.9 percent, volumetrically 2.5 percent, and frequency of occurrence 11.9 percent.

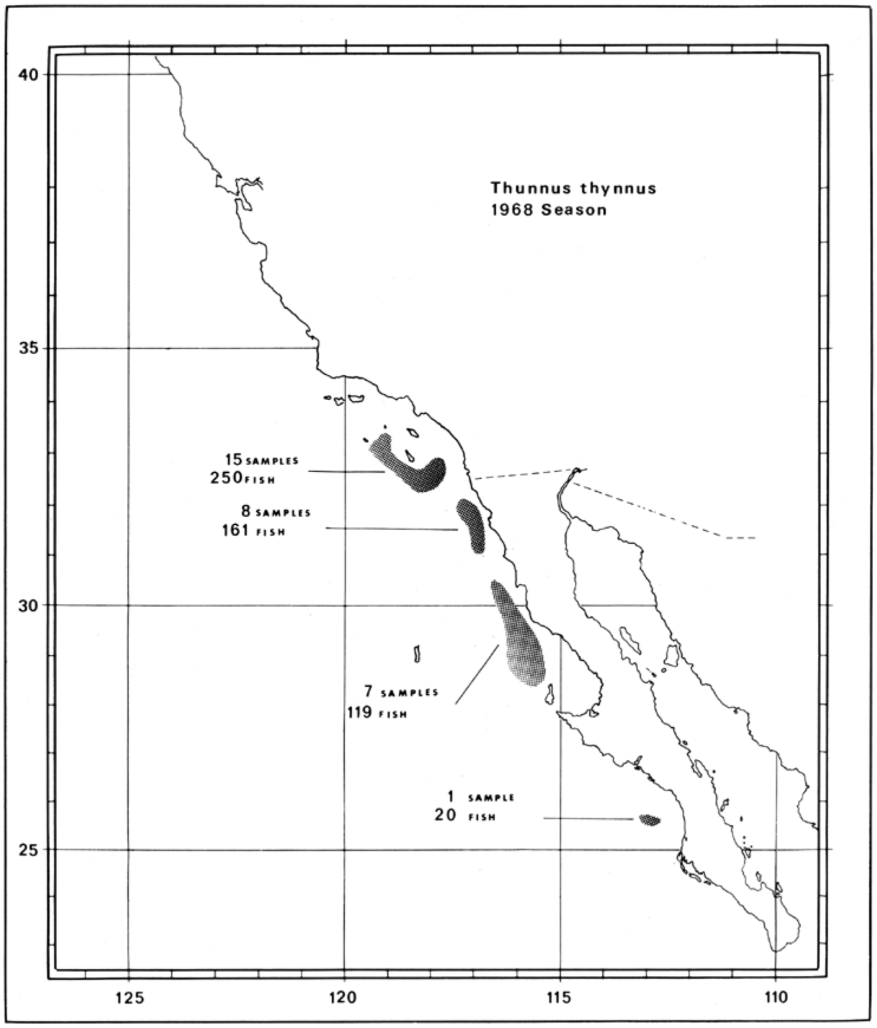

FIGURE 13. Number and general catch localities of bluefin tuna collected in 1968.

FIGURE 13. Number and general catch localities of bluefin tuna collected in 1968.

There were 36 identifiable animals at the specific, generic, familial, or orderinal levels eaten by bluefin tuna (1968 and 1969 combined). Cephalopods were the most prevalent group of animals with at least 15 species being eaten by bluefin. This number may be larger since the Gonatus group probably consists of 3 or 4 species. At least 12 species of fish were preyed upon by bluefin tuna. Again this number may be greater since we could not identify rockfish (Family—Scorpaenidae) to the specific level.

The number of species comprising the bluefin tuna's diet varied by year with 23 species being represented in 1968 and 26 in 1969. The species ratio Cephalopoda : Pisces changed from 7 : 10 in 1968 to 13 : 8 in 1969. While this ratio is biologically interesting and may be economically significant, the paucity of data signals caution in drawing conclusions.

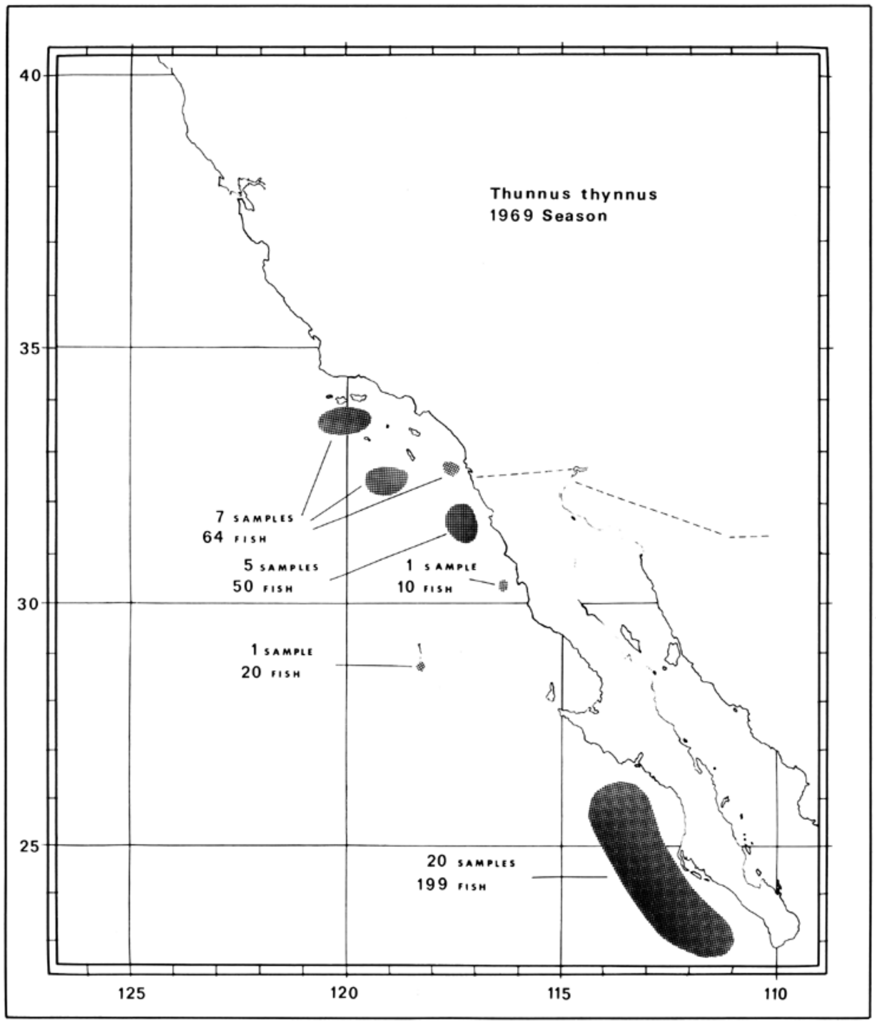

FIGURE 14. Number and general catch localities of bluefin tuna samples collected in 1969.

FIGURE 14. Number and general catch localities of bluefin tuna samples collected in 1969.

TABLE 9

Bluefin Tuna Food Items, 1968 and 1969—Eastern North Pacific Ocean

Food items	Number of organisms				Volume of organisms (ml)				Frequency of occurrence			
	1968	1969	Total	Percent	1968	1969	Total	Percent	1968	1969	Total	Percent
Number of stomachs	447	203	[1]650		447	203	[1]650		447	203	[1]650	
MOLLUSCA												
Cephalopoda												
Octopoda												
Argonauta nouryi		2	2	0.01		20.0	20.0	0.06		2	2	0.31
Octopus bimaculatus	62		62	0.26	6.5		6.5	0.02	18		18	2.77
Ocythoe tuberculata	4	1	5	0.02		tr	tr		2	1	3	0.46
Octopoda sp.	30		30	0.13	tr		tr		10		10	1.54
Decapoda												
Loligo opalescens	304	42	346	1.46	345.0	146.3	491.3	1.58	31	15	46	7.08
Gonatus sp.	58	5	63	0.27		tr	tr		11	2	13	2.00
Onychoteuthis boreali-japonicus	21	1	22	0.09	0.4	tr	0.4		12	1	13	2.00
Octopodoteuthis sicula	3	2	5	0.02		tr	tr		3	2	5	0.77
Onychoteuthis sp.		50	50	0.21		2.0	2.0	0.01		6	6	0.92
Abraliopsis felis		297	297	1.26		5.1	5.1	0.02		9	9	1.39
Cranchia scabra		4	4	0.02		tr	tr			1	1	0.15
Dosidicus gigas		1	1			100.0	100.0	0.32		1	1	0.15
Gonatopsis sp.		3	3	0.01		tr	tr			2	2	0.31
Enoploteuthidae		4	4	0.02		tr	tr			1	1	0.15
Leachia sp.		6	6	0.03		tr	tr			3	3	0.46
Unidentifiable remains	7	13	20	0.09	30.2	15.0	45.2	0.15	8	9	17	2.62
Gastropoda												
Atlanta sp.	4		4	0.02	tr		tr		3		3	0.46
CRUSTACEA												
Isopoda		1	1			tr	tr			1	1	0.15
Copepoda	1		1		tr		tr		5		5	0.77

TABLE 9

Bluefin Tuna Food Items, 1968 and 1969—Eastern North Pacific Ocean

Amphipoda												
Grammaridea	6		6	0.03					1		1	0.15
Hyperiidea												
Phronima sp.	6	46	52	0.22		11.7	11.7	0.04	5	6	11	1.69
Mysidacea		33	33	0.14		tr	tr			5	5	0.77
Euphausiacea	2	18	20	0.09	tr	10.0	10.0	0.03	2	1	3	0.46
Decapoda												
Pleuroncodes planipes	228	655	883	3.73	425.8	972.0	1,397.8	4.50	36	52	88	13.54
Natantia shrimp		1	1			1.0	1.0			1	1	0.15
Unidentifiable remains		1	1			1.0	1.0					
VERTEBRATA												
Fishes												
Engraulis mordax	15,611	4,888	20,499	86.62	21,012.0	3,857.0	24,869.0	79.99	336	132	468	72.00
Bathylagus sp.	1		1						1		1	0.15
Myctophidae	1	1	2	0.01	0.3		0.3		1	1	2	0.31
Paralepis atlantica		1	1		tr		tr			1	1	0.15
Cololabis saira	421	33	454	1.92	648.3	133.0	781.3	2.51	71	6	77	11.85
Hirundichthys rondeleti	3		3	0.01	70.0		70.0	0.23	1		1	0.15
Scomber japonicus	28		28	0.12	4.0		4.0	0.01	16		16	2.46
Sebastes spp.	176	40	216	0.91	2.7	tr	2.7	0.01	17	3	20	3.08
Trachurus symmetricus	7	25	32	0.14		653.4	653.4	2.10	3	9	12	1.85
Merluccius productus	253	18	271	1.15		tr	tr		31	9	40	6.15
Peprilus simillimus		1	1			40.0	40.0	0.13		1	1	0.15
Porichthys myriaster	1		1		tr		tr		1		1	0.15
Unidentifiable remains	168	54	222	0.94	2,321.0	195.5	2,516.5	8.01	83	14	97	14.92
PLANTS	4	6	10	0.04	13.3	tr	13.3	0.04	5	3	8	1.23
UNIDENTIFIABLE REMAINS	3		3	0.01	46.1	1.5	47.6	0.15	29	1	30	4.62
TOTALS	17,413	6,253	23,666		24,925.6	6,164.5	31,090.1		742	301	1,043	
Recapitulation by Major Groups												
MOLLUSCA	493	431	924	3.90	382.1	288.4	670.5	2.16	63	33	96	14.77
CRUSTACEA	243	755	998	4.22	425.8	995.7	1,421.5	4.57	46	61	107	16.46
VERTEBRATA	16,670	5,061	21,731	91.82	24,058.3	4,878.9	28,937.2	93.08	421	151	572	88.00
PLANTS	4	6	10	0.04	13.3	tr	13.3	0.04	5	3	8	0.01
UNIDENTIFIABLE REMAINS	3		3	0.01	46.1	1.5	47.6	0.15	29	1	30	0.05
TOTALS	17,413	6,253	23,666	99.99	24,925.6	6,164.5	31,090.1	100.00	564	249	813	

[1] All analyzable stomach samples, including those with specified as well as unspecified areas of capture.
tr = Trace.

TABLE 9—Cont'd.

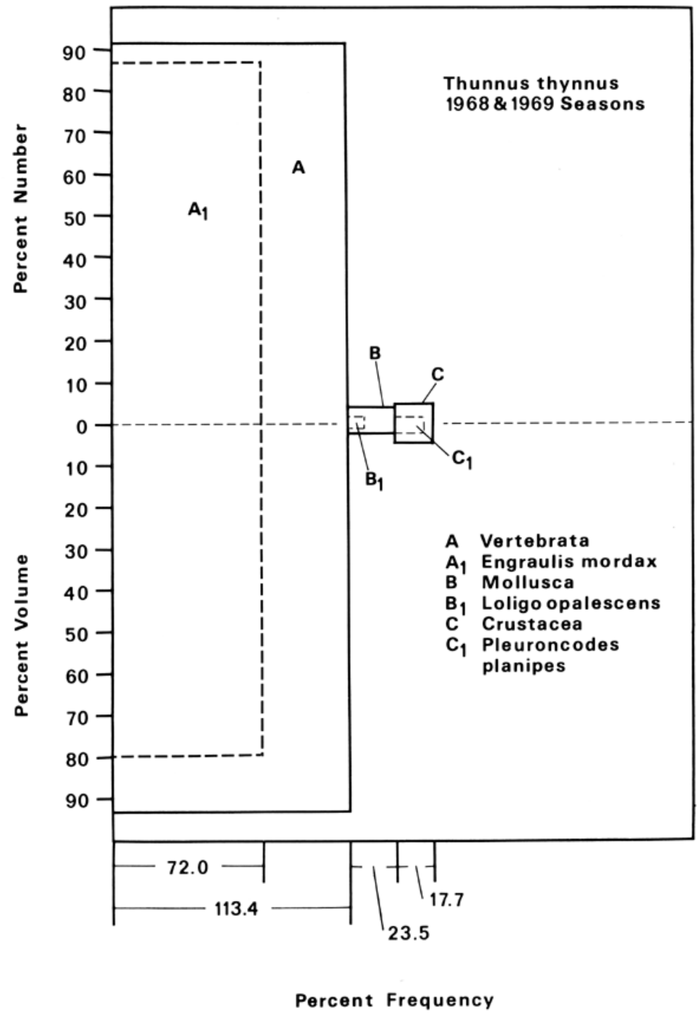

FIGURE 15. Percent composition of major food categories in number, volume, and frequency of occurrence of bluefin tuna; 1968 and 1969 combined.

FIGURE 15. Percent composition of major food categories in number, volume, and frequency of occurrence of bluefin tuna; 1968 and 1969 combined.

Small chunks of kelp were found occasionally, but their infrequent occurrence, small size, and low number suggests fortuitous ingestion rather than a component of the steady diet.

3.2.1. 1968 Season

Fish were the dominant food group eaten by bluefin tuna during 1968. Numerically, fish provide 95.7 percent of the bluefin diet, volumetrically 96.5 percent, and by frequency of occurrence 94.1 percent.

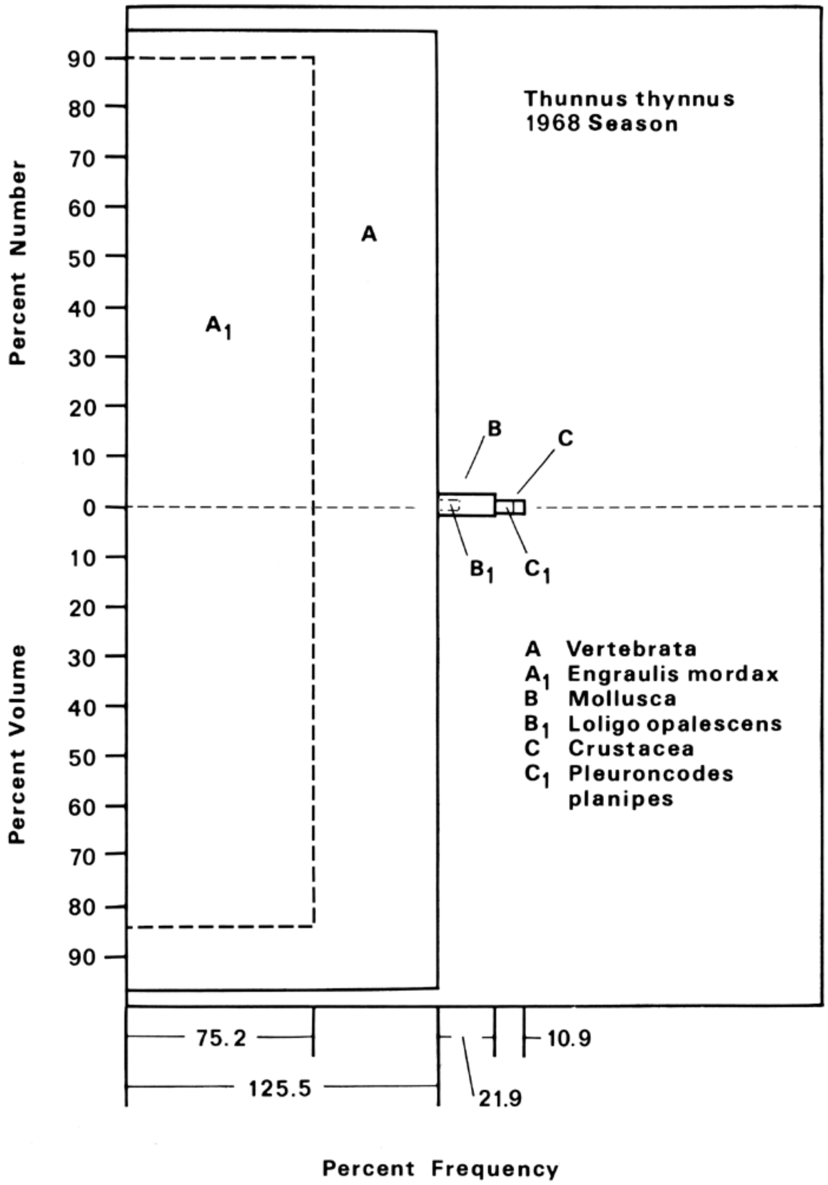

FIGURE 16. Percent composition of major food categories in number, volume, and frequency of occurrence; bluefin tuna 1968.

FIGURE 16. Percent composition of major food categories in number, volume, and frequency of occurrence; bluefin tuna 1968.

The northern anchovy alone accounted for 89.7 percent by number of the total organisms ingested. Other fish consisted of saury, hake, Merluccius productus, and rockfish, Sebastes spp.

The common squid, Loligo opalescens, and the red swimming crab were each a major factor within their respective categories, and provided 1.8 and 1.3 percent of the food items by number (Figure 16).

3.2.2. 1969 Season

Northern anchovy, with a contribution of 78.2 percent by number, 62.6 percent of volume, and 65.0 percent by frequency of occurrence, again was the most common food item in the bluefin tuna diet in 1969. Our observations indicated that fish composed 80.9 percent by number of all food ingested, provided 79.2 percent volumetrically, and occurred in 74.4 percent of the stomachs we examined.

Red swimming crabs contributed 10.5 percent by number of food items ingested, and placed the crustacean category second in importance. Cephalopods were third with no single species being a dominant contributor; nevertheless, as a group they contributed 6.9 percent by number of the total food consumed (Figure 17).

Bluefin feeding patterns did not change significantly from 1968 to 1969. The greatest change occurred in southern California waters where anchovies declined numerically from 94 percent in 1968 to 31 percent in 1969. Conversely the common squid increased numerically from 0.9 percent in 1968 to 15 percent in 1969. In southern Baja California a reverse shift occurred, from 47 percent anchovies (numerically) in 1968 to 85 percent in 1969. Squid also changed markedly from 29 percent occurrence in 1968 to only 0.02 percent in 1969.

3.3. REGIONAL FEEDING BEHAVIOR

To test whether or not there were geographical differences in bluefin tuna feeding patterns, the samples were grouped by several clearly discernable regions: southern California, northern Baja California, central Baja California, and southern Baja California. Although these areas were not sharply defined, the 1968 and 1969 samples could be segregated by regions without overlapping. The 1969 Guadalupe Island sample was unique since it was geographically and seasonally (winter as opposed to summer) isolated.

Initial summarization revealed gaps in the area data. For example, only one sample consisting of 18 stomachs with food came from southern Baja California in 1968, whereas 20 samples of 131 stomachs were secured in 1969. The central Baja California area also was represented weakly because no samples with food were obtained in 1969 compared to 79 stomachs in 1968. To compensate for these inadequacies, yearly regional groupings of stomachs with food were combined to construct a composite picture of bluefin tuna feeding behavior.

Northern anchovy was the dominant feature of bluefin tuna feeding in each of the geographical regions in 1968 and 1969. Items of secondary importance, such as red swimming crab, saury, rockfish, or squid, alternated in ranking from region to region and year to year (Tables 10, 11, 12, 13, 14 and 15).

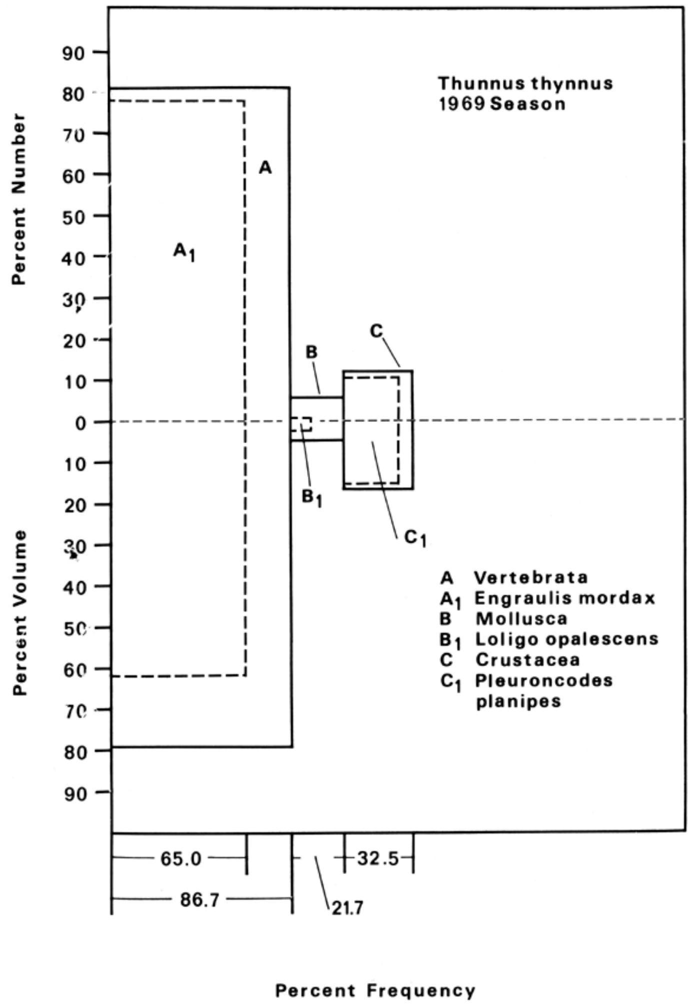

FIGURE 17. Percent composition of major food categories in number, volume, and frequency of occurrence; bluefin tuna 1969.

FIGURE 17. Percent composition of major food categories in number, volume, and frequency of occurrence; bluefin tuna 1969.

The ingestion of red swimming crabs was consistent during both years with their greatest contribution to the bluefin diet occurring in the Magdalena Bay area off southern Baja California and declining northward. Numerically they provide 13 percent of the bluefin food in this area but only 0.05 percent in southern California. Sauries made a relatively fair contribution to the bluefin tuna's diet in southern California and northern Baja California waters, numerically 2.1 and 6.6 percent, but were absent in southern portions of the fishing grounds. In 1968 the common squid was important off southern California and declined southward; however, in 1969 the situation reversed itself. Rockfish and hake made minor contributions to the bluefin diet. In general, rockfish were relatively important off southern California, 2.3 percent by number; of minor ranking off central Baja California, 0.3 percent by number; and absent off northern Baja California and southern Baja California. Hake otoliths were found fairly frequently, numerically 6 percent, in the stomachs from southern Baja California and were of lesser importance to the north.

Mesopelagic fish, such as myctophids and bathylagids occurred sporadically and in low numbers.

3.3.1. Southern California

Northern anchovy (Index of Relative Importance 4,811), saury (IRI 20), squid (IRI 8), and rockfish (IRI 6) were the most important food items of bluefin tuna in southern California waters. Together they accounted for over 97 percent by number of all food ingested; anchovy alone constituted 92 percent of the total. Other food consisted of six fish species, four cephalopods, and three crustaceans. Red swimming crabs occurred in only three stomachs and rank as a trace item (Tables 10 and 11).

3.3.2. Northern Baja California

Northern anchovy (IRI 4,913), saury (IRI 261), and Pacific mackerel (IRI 5) were the most significant food items of bluefin when in northern Baja California waters. Numerically anchovies contributed 88 percent of the food items we found in bluefin stomachs collected in this area. Mysids (IRI 4), the molluscan decapod, Onychoteuthis sp., (IRI 3), the common squid (IRI 2), and red swimming crab (IRI 2) were numerically and by frequency of occurrence of approximately equal but low value (Tables 10 and 12).

3.3.3. Central Baja California

Numerically over 98 percent of the food eaten by bluefin tuna in central Baja California waters was composed of northern anchovy (IRI 8,386), red swimming crab (IRI 15), and Gonatus sp. (IRI 10). At least five other species of fish led by the rockfish complex (IRI 2) and three cephalopods also were consumed (Table 10 and 13).

3.3.4. Southern Baja California

Bluefin tuna fed on anchovy (IRI 6,029), red swimming crab (IRI 537), squid (IRI 13), and hake (IRI 8) in the waters off southern Baja California. These four species comprised over 99.7 percent of all food eaten. Animals registering at the trace level included a flying fish, Hirundichthys rondeleti, an amphipod, a euphausiid, and four cephalopod species (Tables 10 and 14).

TABLE 10

Ranking of Major Bluefin Tuna Food Items Grouped by Subareas 1968 and 1969 Combined

Food items	Percent			Index of relative importance (N + V) F
	Number N	Volume V	Frequency F	
Southern California				
Engraulis mordax	92.02	84.82	52.28	9,245
Cololabis saira	2.10	2.78	9.42	46
Loligo opalescens	1.27	3.26	6.38	29
Trachurus symmetricus	0.17	5.12	1.52	8
Sebastes spp.	2.34	tr	2.74	6
Northern Baja California				
Engraulis mordax	87.89	56.24	55.86	8,051
Cololabis saira	6.58	7.00	39.64	538
Pleuroncodes planipes	0.24	1.68	9.01	17
Loligo opalescens	0.44	0.76	4.51	5
Scomber japonicus	0.51	tr	9.91	5
Central Baja California				
Engraulis mordax	93.43	97.65	89.87	17,172
Pleuroncodes planipes	4.01	2.28	3.80	24
Gonatus spp.	1.37	tr	7.60	10
Sebastes spp.	0.26	tr	7.60	2
Octopus bimaculatus	0.15	tr	6.33	1
Southern Baja California				
Engraulis mordax	81.66	64.07	73.83	10,759
Pleuroncodes planipes	12.99	31.53	33.56	1,494
Loligo opalescens	2.45	tr	5.37	13
Merluccius productus	1.51	tr	6.04	9
Octopus bimaculatus	0.56	0.21	6.04	5
Unspecified Catch Area				
Engraulis mordax	76.95	52.56	74.65	9,668
Pleuroncodes planipes	3.51	10.96	28.17	408
Merluccius productus	8.86	tr	28.17	250
Loligo opalescens	4.03	tr	11.23	45
Octopus species (Unident)	0.80	tr	8.45	7
All Areas				
Engraulis mordax	86.62	79.99	72.00	11,996
Pleuroncodes planipes	3.73	4.50	13.54	111
Cololabis saira	1.92	2.51	11.85	53
Loligo opalescens	1.46	1.58	7.08	22
Merluccius productus	1.15	tr	6.15	9

tr = Trace.

TABLE 10

Ranking of Major Bluefin Tuna Food Items Grouped by Subareas 1968 and 1969 Combined

3.3.5. Guadalupe Island

The small sample of bluefin tuna stomachs, collected from Guadalupe Island in January 1969, was not large enough for definitive conclusions; however, the contents of the 11 stomachs were sufficiently different from those observed in stomachs collected in other areas to warrant comment.

Cephalopods, represented by at least eight species, stand out since no other sample contained as many. Three decapods, Abraliopsis felis, Cranchia scabra, and a member of the family Enoploteuthidae, appear here and nowhere else. The common squid, Loligo opalescens, was about as important, numerically and volumetrically, in the diet of these fish as in bluefin in other areas.

TABLE 11

Bluefin Tuna Food, 1968 and 1969—Southern California Region

Food items	Number of organisms				Volume of organisms (ml)				Frequency of occurrence			
	1968	1969	Total	Percent	1968	1969	Total	Percent	1968	1969	Total	Percent
Number of stomachs	198	131	329		198	131	329		198	131	329	
MOLLUSCA												
Cephalopoda												
Decapoda												
Loligo opalescens	77	32	109	1.27	306	108	414	3.26	10	11	21	6.38
Gonatus sp.		4	4	0.05		tr	tr			1	1	0.30
Onychoteuthis boreali-japonicus	2		2	0.01	tr		tr		2		2	0.61
Dosidicus gigas		1	1	0.01		100	100	0.79		1	1	0.30
Leachia sp.		2	2	0.02		tr	tr			1	1	0.30
Unidentifiable remains	4	1	5	0.06	6	tr	6	0.05	1	1	2	0.61
Gastropoda												
Atlanta sp.	4		4	0.05	tr		tr		3		3	0.91
CRUSTACEA												
Amphipoda												
Grammaridea	6		6	0.07	tr		tr		1		1	0.30
Hyperiidea, *Phronima* sp.	6	4	10	0.12	tr	tr	tr		5	1	6	1.82
Decapoda												
Pleuroncodes planipes	3	1	4	0.05	4	2	6	0.05	2	1	3	0.91
VERTEBRATA												
Fishes												
Engraulis mordax	7,847	70	7,917	92.02	10,394	371	10,765	84.82	161	11	172	52.28
Bathylagus sp.	1		1	0.01	tr		tr		1		1	0.30
Myctophidae		1	1	0.01	tr		tr			1	1	0.30
Cololabis saira	149	32	181	2.10	287	66	353	2.78	26	5	31	9.42
Scomber japonicus	6		6	0.07	4		4	0.03	4		4	1.22
Sebastes spp.	161	40	201	2.34	tr	tr	tr		6	3	9	2.74
Trachurus symmetricus		15	15	0.17		650	650	5.12		5	5	1.52
Peprilus simillimus		1	1	0.01		40	40	0.32		1	1	0.30
Porichthys myriaster	1		1	0.01	tr		tr		1		1	0.30
Unidentifiable remains	109	13	122	1.42	197	140	337	2.66	13	4	17	5.17
PLANTS	2	6	8	0.09	5	tr	5	0.04	3	3	6	1.82
UNIDENTIFIABLE REMAINS	4		4	0.04	11		11	0.01	4		4	1.52
TOTALS	8,380	223	8,604	100.00	11,214	1,477	12,691	99.89	--	--	--	--

tr = Trace.

TABLE 11

Bluefin Tuna Food, 1968 and 1969—Southern California Region

TABLE 12

Bluefin Tuna Food, 1968 and 1969—Northern Baja California Region

Food items	Number of organisms				Volume of organisms (ml)				Frequency of occurrence			
	1968	1969	Total	Percent	1968	1969	Total	Percent	1968	1969	Total	Percent
Number of stomachs	92	19	111		92	19	111		92	19	111	
MOLLUSCA												
Cephalopoda												
Octopoda												
Octopus bimaculatus	13		13	0.32	tr		tr		3		3	2.70
Octopoda sp.	5		5	0.12	tr		tr		2		2	1.80
Decapoda												
Loligo opalescens	16	2	18	0.44	39.0	tr	39.0	0.76	3	2	5	4.51
Gonatus sp.	1		1	0.02	tr	tr	tr		1		1	0.90
Onychoteuthis boreali-japonicus	3		3	0.07	0.4		0.4	0.01	3		3	2.70
Onychoteuthis sp.		45	45	1.09		2.0	2.0	0.04		3	3	2.70
Octopodoteuthis sicula	2	2	4	0.10	tr	tr	tr		2	2	4	3.60
Gonatopsis sp.		3	3	0.07		tr	tr			2	2	1.80
Unidentifiable remains	2	7	9	0.22	tr	tr	tr		2	2	4	3.60
CRUSTACEA												
Amphipoda												
Hyperiidea, *Phronima* sp.		12	12	0.29		3.0	3.0	0.06		2	2	1.80
Mysidacea		33	33	0.80		tr	tr			5	5	4.51
Decapoda												
Pleuroncodes planipes	7	3	10	0.24	74.7	12.0	86.7	1.68	8	2	10	9.01
VERTEBRATA												
Fishes												
Engraulis mordax	3,259	362	3,621	87.88	1,586.4	1,315.0	2,901.4	56.24	49	13	62	55.86
Cololabis saira	271		271	6.58	361.3		361.3	7.00	44		44	39.64
Scomber japonicus	21		21	0.51	tr		tr		11		11	9.91
Sebastes spp.	1		1	0.02	02.7		2.7	0.05	1		1	0.90
Trachurus symmetricus		1	1	0.02		tr	tr			1	1	0.90
Merluccius productus	5		5	0.12	tr		tr		2		2	1.80
Unidentifiable remains	15	27	42	1.02	1,733.0	tr	1,733.0	33.59	29	3	32	28.83
UNIDENTIFIABLE REMAINS					29.3		29.3	0.57	16		16	14.41
TOTALS	3,621	497	4,118	99.93	3,826.8	1,332.0	5,158.8	100.00	--	--	--	--

tr = Trace.

TABLE 12

Bluefin Tuna Food, 1968 and 1969—Northern Baja California Region

TABLE 13

Bluefin Tuna Food, 1968—Central Baja California Region *

Food items	Number of organisms 1968	Number of organisms Percent	Volume of organisms (ml) 1968	Volume of organisms (ml) Percent	Frequency of occurrence 1968	Frequency of occurrence Percent
Number of stomachs	79		79		79	
MOLLUSCA						
Cephalopoda						
Octopoda						
Octopus bimaculatus	5	0.15	tr		5	6.33
Octopoda sp.	8	0.23	tr		2	2.53
Decapoda						
Loligo opalescens	2	0.06	tr		2	2.53
Gonatus sp.	47	1.37	tr		6	7.60
Onychoteuthis boreali-japonicus	1	0.03	tr		1	1.27
Unidentifiable remains	1	0.03	tr		1	1.27
CRUSTACEA						
Euphausiacea	1	0.03	tr		1	1.27
Decapoda						
Pleuroncodes planipes	138	4.01	201.0	2.28	3	3.80
VERTEBRATA						
Fishes						
Engraulis mordax	3,214	93.43	8,592.4	97.65	71	89.87
Myctophidae	1	0.03	.3		1	1.27
Scomber japonicus	1	0.03	tr		1	1.27
Sebastes spp.	9	0.26	tr		6	7.60
Trachurus symmetricus	1	0.03	tr		1	1.27
Merluccius productus	1	0.03	tr		1	1.27
Unidentifiable remains	10	0.29	5.7	0.07	10	12.66
TOTALS	3,440	100.01	8,799.4	100.00	--	--

* The 1969 stomach samples from this area were empty.
tr = Trace.

TABLE 13

Bluefin Tuna Food, 1968—Central Baja California Region

A natantian shrimp occurred in Guadalupe Island bluefin stomachs and nowhere else. Jack mackerel, Trachurus symmetricus, were relatively important numerically while the northern anchovy was conspicuously absent, and a deepwater fish, Paralepis atlantica, occurred in the Guadalupe Island stomachs and nowhere else (Tables 10 and 15).

3.4. DISCUSSION

Our 1968–1969 studies indicate that bluefin tuna feed primarily on northern anchovy and secondarily on either common squid or red swimming crabs, depending on the area.

Bell (1963), summarizing an unpublished study by Clarkson E. Blunt, California Department of Fish and Game, reported that northern anchovy comprised 70 percent of the bluefin's diet; a finding not inconsistent with ours.

Blunt's samples were collected in 1957, a period when the preponderance of the catch was made close to shore (Clarkson E. Blunt, personal communication). In his study, the stomach contents reflect the near shore feeding activity of bluefin. For example, of the 14 species of fish

TABLE 14

Bluefin Tuna Food, 1968 and 1969—Southern Baja California Region

Food items	Number of organisms				Volume of organisms (ml)				Frequency of occurrence			
	1968	1969	Total	Percent	1968	1969	Total	Percent	1968	1969	Total	Percent
Number of stomachs	18	131	149		18	131	149		18	131	149	
MOLLUSCA												
Cephalopoda												
Octopoda												
Argonauta nouryi		1	1	0.02		tr	tr			1	1	0.67
Octopus bimaculatus	28		28	0.56	6.5		6.5	0.21	9		9	6.04
Decapoda												
Loligo opalescens	123		123	2.45	tr		tr		8		8	5.37
Gonatus sp.		1	1	0.02		tr	tr			1	1	0.67
Onychoteuthis boreali-japonicus	2		2	0.04	tr		tr		2		2	1.34
Unidentifiable remains		1	1	0.02		tr	tr			1	1	0.67
CRUSTACEA												
Isopoda		1	1	0.02		tr	tr			1	1	0.67
Copepoda	1		1	0.02	tr		tr		5		5	3.36
Amphipoda												
Hyperiidea												
Phronima sp.		1	1	0.02		tr	tr			1	1	0.67
Euphausiacea	1	18	19	0.38	tr	10	10.0	0.33	1	1	2	1.34
Decapoda												
Pleuroncodes planipes	6	647	653	12.99	7.5	950	957.5	31.53	3	47	50	33.5
Unidentifiable remains		1	1	0.02		1	1.0	0.03				
VERTEBRATA												
Fishes												
Engraulis mordax	198	3,907	4,105	81.66	4.5	1,941	1,945.5	64.07	12	98	110	73.83
Hirundichthys rondeleti	3		3	0.06	70.0		70.0	2.31	1		1	0.67
Merluccius productus	60	16	76	1.51	tr	tr	tr		9	8	17	11.41
Unidentifiable remains		11	11	0.22	46.0		46.0	1.52	7	4	11	7.38
TOTALS	422	4,605	5,027	100.01	134.5	2,902	3,036.5	100.00	--	--	--	--

tr = Trace.

TABLE 14

Bluefin Tuna Food, 1968 and 1969—Southern Baja California Region

TABLE 15

Bluefin Tuna Food, 1969—Guadalupe Island Region *

Food items	Number of organisms		Volume of organisms (ml)		Frequency of occurrence	
	1969	Percent	1969	Percent	1969	Percent
Number of stomachs	11		11		11	
MOLLUSCA						
Cephalopoda						
Octopoda						
Ocythoe tuberculata	1	0.29	tr		1	9.09
Decapoda						
Loligo opalescens	8	2.32	38.3	27.40	2	18.18
Onychoteuthis boreali-japonicus	1	0.29	tr		1	9.09
Onychoteuthis sp.	5	1.45	tr		3	27.73
Abraliopsis felis	297	86.09	5.1	3.65	9	81.82
Cranchia scabra	4	1.16	tr		1	9.09
Enoploteuthidae	4	1.16	tr		1	9.09
Leachia sp.	4	1.16	tr		2	18.18
Unidentifiable remains	4	1.16	15.0	10.73	5	45.45
CRUSTACEA						
Decapoda						
Pleuroncodes planipes	4	1.16	8.0	5.72	2	18.18
Natantia shrimp	1	0.29	1.0	0.72	1	9.09
VERTEBRATA						
Fishes						
Paralepis atlantica	1	0.29	tr		1	9.09
Coloabis saira	1	0.29	67.0	47.93	1	9.09
Trachurus symmetricus	9	2.61	3.4	2.43	3	27.27
Unidentifiable remains	1	0.29	0.5	0.36	2	18.18
UNIDENTIFIABLE REMAINS			1.5		1	9.09
TOTALS	345	100.01	139.8	98.94	--	--

* No samples in 1968.
tr = Trace.

TABLE 15

Bluefin Tuna Food, 1969—Guadalupe Island Region

identified, 5 were near shore, shallow water types: jacksmelt, Atherinopsis californiensis, white croaker, Genyonemus lineatus, queenfish, Seriphus politus, white seaperch, Phanerodon furcatus, and Pacific sanddab, Citharichthys sordidus. The differences between Blunt's findings and ours are essentially the shallow water species. It would be premature to speculate as to causative factors since sampling error alone easily could account for the differences.

Thunnus thynnus of the eastern Pacific and Thunnus orientalis of the western Pacific Ocean are one and the same species. Early comparative morphological and taxonomic studies strongly suggested the tie (Godsil and Holmberg, 1950; Yamanaka et staff, 1963; Collette and Gibbs, 1963). Conclusive proof came in 1963 with the first trans-Pacific Ocean tag recovery 300 miles south of Tokyo, Japan. This bluefin tuna, at liberty over 5 years, was initially released off Guadalupe Island, Mexico in 1958 (Orange and Fink, 1963). Subsequent tag recoveries have demonstrated additional east-west migrations as well as west-east movement (Robert R. Bell, California Department of Fish and Game, personal communication).

Germane to a single ocean wide bluefin tuna population is a comparison of east-west feeding patterns. Yamanaka (1963) briefly summarized the pertinent Japanese reports of bluefin tuna feeding off Japan. He also presented some data from an unpublished manuscript by Watanabe as well as some of Yokota's (1961) findings. The consensus of these studies is that bluefin tuna feed on anchovies, common squid, "... followed by smaller fishes of various species, Crustaceans, and so forth."

Studies reported by Yokota et al. (1961) indicate that other fishes consisted of kibinago, three species of mackerel, a scad, and mesopelagic types such as myctophids. According to Okada (1966), kibinago is a small schooling fish closely related to sardines and anchovies. None of the reports specifically identified the fish, the common squid, or the composition of the crustacean group.

Despite the lack of specifics, it appears that bluefin tuna feeding patterns are the same whether they are occupying the eastern or western portions of the North Pacific Ocean, the dominant feature being anchovy and squid. Their feeding preferences when migrating are unknown.

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4. PACIFIC BONITO FOOD HABITS

MALCOLM S. OLIPHANT
Marine Resources Region
California Department of Fish and Game

4.1. LOCATION, NUMBER, AND SIZE OF SAMPLES

Pacific bonito, Sarda chiliensis, stomachs were obtained from commercial vessels landing fish at San Pedro from January 1968 through September 1969. In all we collected 1,498 stomachs; 645 in 1968, and 853 in 1969.

In 1968, all samples came from nearshore waters of southern California and adjacent offshore islands (Figure 18) . The 1969 samples were from the same area with an additional 80 stomachs from fish caught off Baja California, Mexico : 50 from the Uncle Sam Bank area,

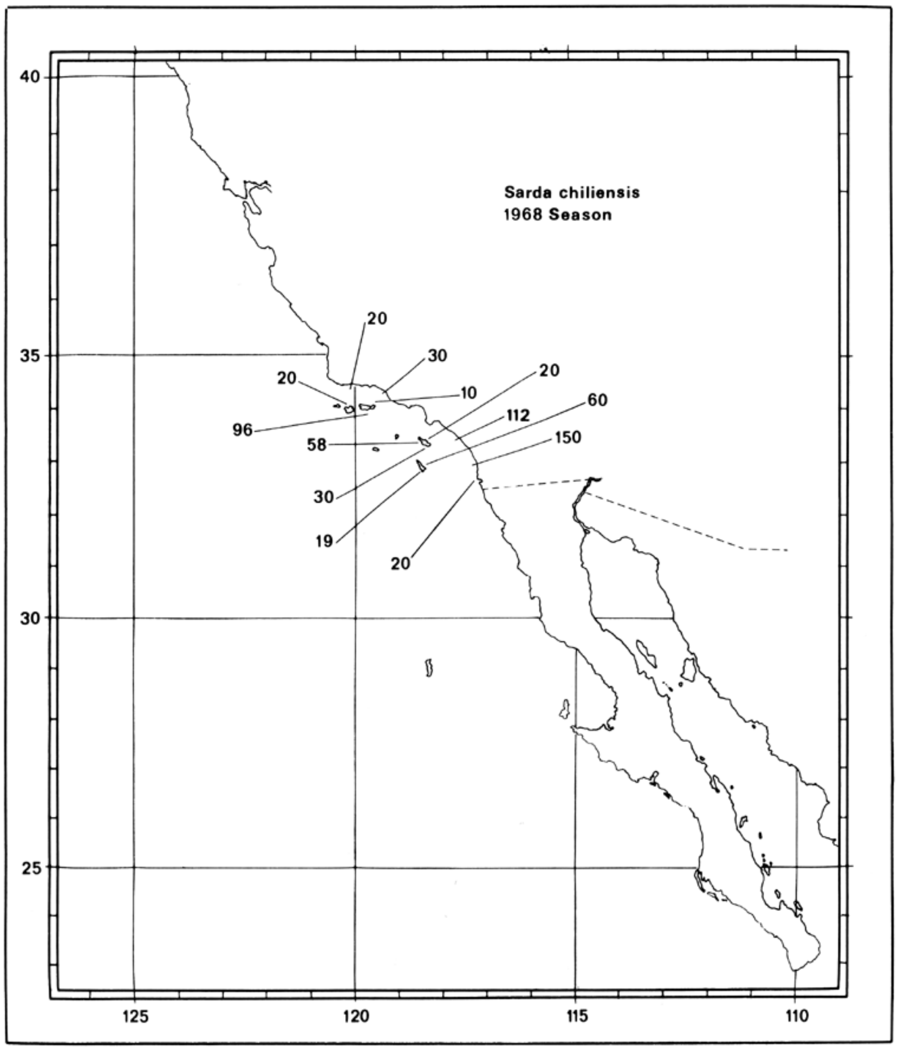

FIGURE 18. Number and location of Pacific bonito samples collected in 1968.

FIGURE 18. Number and location of Pacific bonito samples collected in 1968.

lat. 25°37'N, long. 113°23'W; 20 offshore from Abreojos Point, lat. 26°42'N, long. 113°34'W; and 10 offshore from Santo Domingo Point, lat. 26°19'N, long. 112°40'W (Figure 19) .

Bonito sampled ranged in size from 290 to 780 mm (fork length). These samples included age groups, I, II, III, and a few IV and V. The majority were age groups I and II (John J. Geibel, California Department of Fish and Game, personal communication).

4.2. RESULTS

4.2.1. Combined 1968 and 1969 Data

Only 54.8 percent (821) of the stomachs we collected and examined contained food. We grouped these food items into four categories: (A) northern anchovy, Engraulis mordax, (B) common squid, Loligo opalescens,

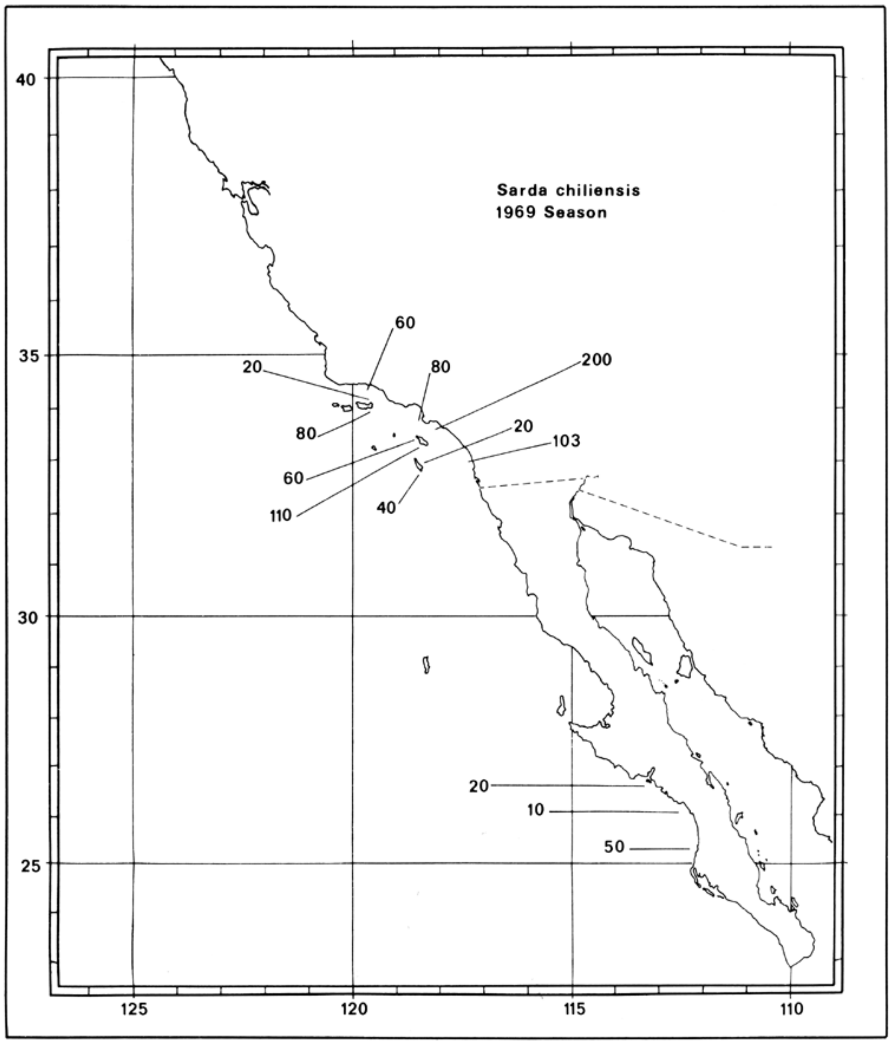

FIGURE 19. Number and location of Pacific bonito samples collected in 1969.

FIGURE 19. Number and location of Pacific bonito samples collected in 1969.

(C) fish other than E. mordax, and (D) unidentified. Only category (D) crosses phylogenetic lines.

Twelve fish species in nine families were the principal contributors to the bonito diet (Tables 16 and 17); they provided 91.1 percent by numbers; 81.8 percent in volume, and occurred in 86.4 percent of the stomachs containing food. Northern anchovy alone represented 75.5 percent numerically, 75.9 percent in volume, 56.3 percent in frequency of occurrence, and had an overall Index of Relative Importance of 8,524.

TABLE 16

Pacific Bonito Food Categories, 1968 and 1969

Category	Number	Percent number	Volume ml	Percent volume	Number of occurrences	Percent frequency of occurrence
A. *Engraulis mordax*	4,159	75.5	11,356.4	75.9	462	56.3
B. *Loligo opalescens*	448	8.1	2,690.7	18.0	207	25.1
C. Fish other than *E. mordax*	859	15.6	880.7	5.9	247	30.1
D. Unidentified	44	0.8	24.0	0.2	39	4.8
Total	5,510	100.0	14,951.8	100.0		
Fish only	5,018	91.1	12,237.1	81.8	709	86.4

TABLE 16

Pacific Bonito Food Categories, 1968 and 1969

Fish other than E. mordax (Category C) were 15.6 percent by numbers, 5.9 percent by volume, 30.1 percent frequency of occurrence, and had an Index of Relative Importance of 647. Ten identified species and one genus, Sebastes, were in this category in addition to the unidentified fishes. Collectively the ten identified species and one genus made up only 1.7 percent by numbers, 4.4 percent in volume and 7.6 percent frequency of occurrence. The remaining unidentified fishes contributed 13.9 percent by numbers, 1.5 percent by volume, and 22.5 percent frequency of occurrence. Pacific saury, Cololabis saira, jack mackerel, Trachurus symmetricus, Pacific hake, Merluccius productus, and rockfish, Sebastes spp., were the four identified items which occurred in both years. The seven other species occurred only in a single year.

Common squid contributed 8.1 percent by numbers, 18.0 percent by volume, occurred in 25.1 percent of the stomachs containing food, and had an Index of Relative Importance value of 655. Unidentifiable items (Category D) made negligible contributions to the bonito's diet with an index of relative importance of only 5 (Table 18 and Figure 20).

4.2.2. Data by Individual Year

Northern anchovy and fishes other than E. mordax (Categories A and C) were the principal bonito diet in both years studied, 1968 and 1969. In 1968, northern anchovies and fish other than E. mordax together represented 84.7 percent by numbers, 81.3 percent by volume, and 88.4 percent frequency of occurrence (Table 19). In 1969, all fish represented 93.7 percent by numbers, 82.1 percent by volume, and 84.7 percent frequency of occurrence (Table 20, and Figures 21 and 22).

Northern anchovy alone (Category A) contributed 40.0 percent by numbers in 1968, and 90.0 percent in 1969. Volume figures for northern

TABLE 17
Pacific Bonito Food, 1968 and 1969

Food items	Major category	Number	Percent number	Volume ml	Percent volume	Frequency of occurrence	Percent frequency of occurrence
Vertebrates							
Fishes							
Engraulidae							
Engraulis mordax	A	4,159	75.5	11,356.4	75.9	462	56.3
Scomberesocidae							
Cololabis saira		27	0.5	190.8	1.3	16	1.9
Gadidae							
Merluccius productus		24	0.4	6.8	<0.1	15	1.8
Carangidae							
Trachurus symmetricus		16	0.3	185.6	1.2	13	1.6
Sciaenidae							
Genyonemus lineatus		1	<0.1	38.0	0.3	1	0.1+
Seriphus politus	C	3	<0.1	1.3	<0.1	2	0.2+
Embiotocidae							
Brachyistius frenatus		1	<0.1	10.0	<0.1	1	0.1+
Cymatogaster aggregata		1	<0.1	14.0	0.1	1	0.1+
Zalembius rosaceus		1	<0.1	9.0	<0.1	1	0.1+
Scorpaenidae							
Sebastodes spp.		12	0.2	5.8	<0.1	5	0.6
Stromateidae							
Peprilus simillimus		7	0.1+	195.0	1.3	6	0.7
Bothidae							
Citharichthys sordidus		1	<0.1	0.6	<0.1	1	0.1+
Unidentified fishes		765	13.9	223.8	1.5	185	22.5
Subtotal C		859	15.6	880.7	5.9	247	30.1
Subtotal A & C (all fishes)		5,018	91.1	12,237.1	81.8	709	86.4
Invertebrates							
Cephalopods							
Loligo opalescens	B	448	8.1	2,690.7	18.0	207	25.1
Onychoteuthis boreali-japonicus		1	<0.1	3.7		1	0.1+
Unid. cephalopods		17	0.3+	9.9		16	2.0
Crustaceans	D				0.2		
Pleuroncodes planipes		4	<0.1	5.6		4	0.5
Crab megalops larvae		3	<0.1	0.1		1	0.1+
Unidentified animals		19	0.3+	4.7		17	2.0
Subtotal D		44	0.8	24.0	0.2	39	4.8
TOTALS		5,510	100.0	14,951.8	100.0	--	--

TABLE 17
Pacific Bonito Food, 1968 and 1969

TABLE 18

Summary of Pacific Bonito Food Items by Major Categories for 1968 and 1969

Year and Quarter	Major Category	Percent Number N	Percent Volume V	Percent Frequency Occurrence F	Index of relative importance (N + V) F
1968 First Quarter	A. *Engraulis mordax*	40.2	46.7	45.8	2,858
	B. *Loligo opalescens*	51.1	50.1	70.8	7,165
	C. Fish other than *E. mordax*	8.3	3.1	0.8	9
	D. Unidentified	0.4	0.1	0.4	1
Second Quarter	A. *Engraulis mordax*	60.5	84.2	59.5	8,610
	B. *Loligo opalescens*	18.6	13.0	18.9	597
	C. Fish other than *E. mordax*	16.3	2.0	37.8	692
	D. Unidentified	4.6	0.8	10.8	58
Third Quarter	A. *Engraulis mordax*	27.6	86.5	45.0	5,135
	B. *Loligo opalescens*	4.5	1.5	8.9	53
	C. Fish other than *E. mordax*	66.4	11.9	46.6	3,649
	D. Unidentified	1.5	0.1	6.7	11
Fourth Quarter	A. *Engraulis mordax*	77.3	85.6	62.4	10,165
	B. *Loligo opalescens*	9.5	6.4	18.8	299
	C. Fish other than *E. mordax*	11.7	8.0	24.7	487
	D. Unidentified	1.5	tr	3.9	6
Total 1968	A. *Engraulis mordax*	40.0	73.5	52.8	5,993
	B. *Loligo opalescens*	13.9	18.6	21.3	692
	C. Fish other than *E. mordax*	44.7	7.8	35.6	1,869
	D. Unidentified	1.4	0.1	5.6	8
1969 First Quarter	A. *Engraulis mordax*	75.3	83.2	56.5	7,825
	B. *Loligo opalescens*	14.4	19.7	41.3	1,408
	C. Fish other than *E. mordax*	9.9	17.0	39.1	1,052
	D. Unidentified	0.4	0.1	2.1	1
Second Quarter	A. *Engraulis mordax*	87.8	36.1	54.8	6,790
	B. *Loligo opalescens*	8.6	61.4	33.3	2,331
	C. Fish other than *E. mordax*	2.8	1.8	17.8	82
	D. Unidentified	0.8	0.7	5.0	8
Third Quarter	A. *Engraulis mordax*	95.2	96.0	70.8	13,537
	B. *Loligo opalescens*	1.5	2.4	13.8	54
	C. Fish other than *E. mordax*	3.0	1.5	31.2	140
	D. Unidentified	0.3	0.1	4.2	2
Total 1969	A. *Engraulis mordax*	90.0	77.4	58.9	9,860
	B. *Loligo opalescens*	5.8	17.7	28.2	663
	C. Fish other than *E. mordax*	3.7	4.7	25.8	217
	D. Unidentified	0.5	0.2	4.1	3
Combined 1968 and 1969	A. *Engraulis mordax*	75.5	75.9	56.3	8,524
	B. *Loligo opalescens*	8.1	18.0	25.1	655
	C. Fish other than *E. mordax*	15.6	5.9	30.1	647
	D. Unidentified	0.8	0.2	4.8	5

tr = Trace.

TABLE 18

Summary of Pacific Bonito Food Items by Major Categories for 1968 and 1969

anchovy were similar in both years; 73.5 percent in 1968, and 77.4 percent in 1969. Frequency of occurrence values also were close; 52.8 percent in 1968, and 58.9 percent in 1969. The Index of Relative Importance in 1968 for northern anchovy was 5,993, and in 1969 it was 9,860.

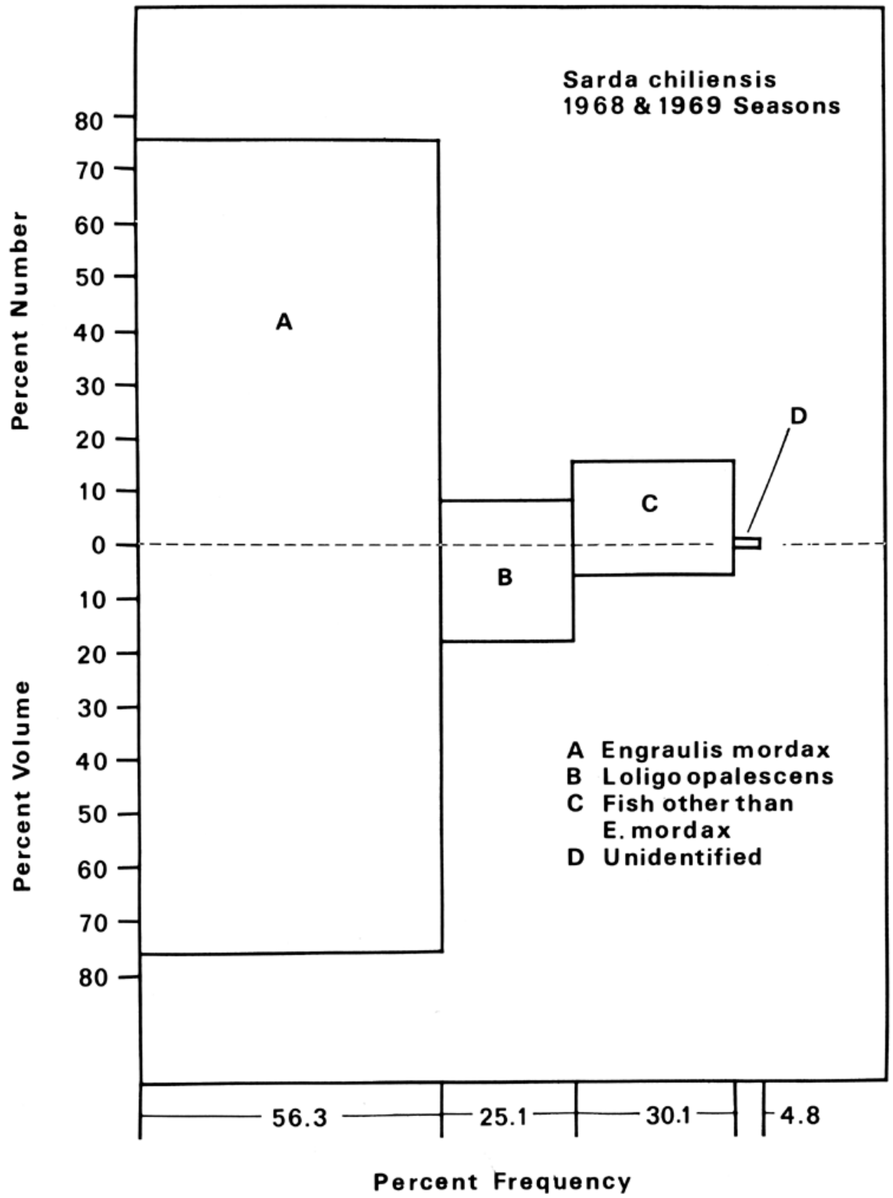

FIGURE 20. Percent composition by major food categories in number, volume, and frequency of occurrence; Pacific bonito 1968 and 1969.

FIGURE 20. Percent composition by major food categories in number, volume, and frequency of occurrence; Pacific bonito 1968 and 1969.

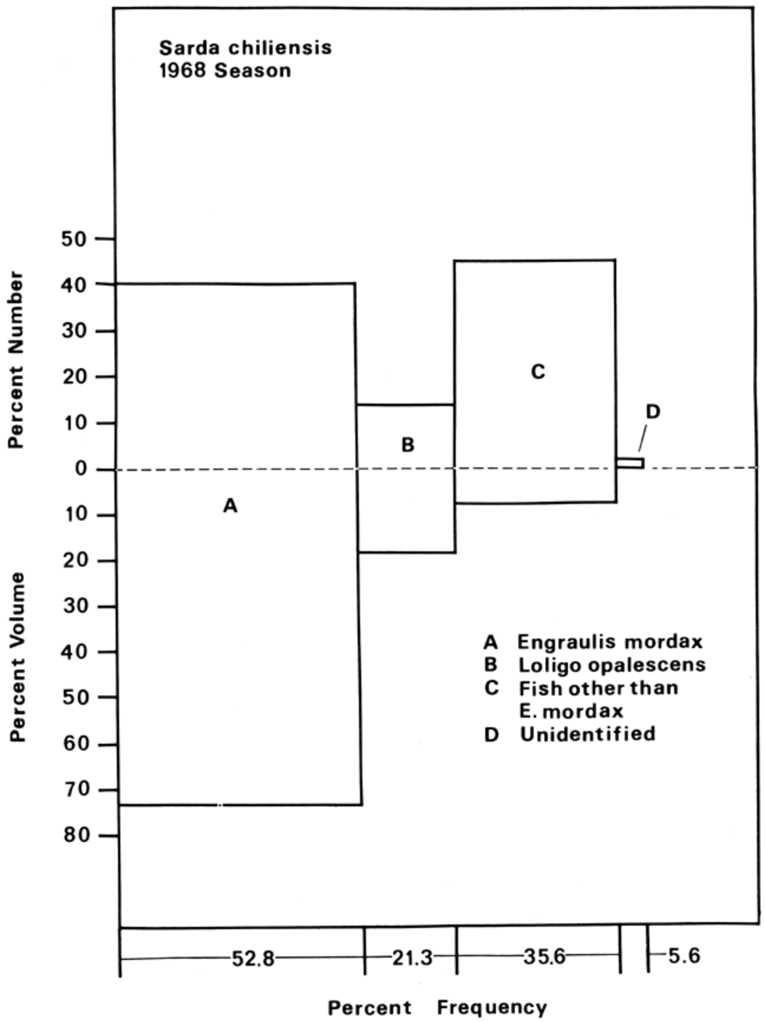

FIGURE 21. Percent composition by major food categories in number, volume, and frequency of occurrence; Pacific bonito 1968.

FIGURE 21. Percent composition by major food categories in number, volume, and frequency of occurrence; Pacific bonito 1968.

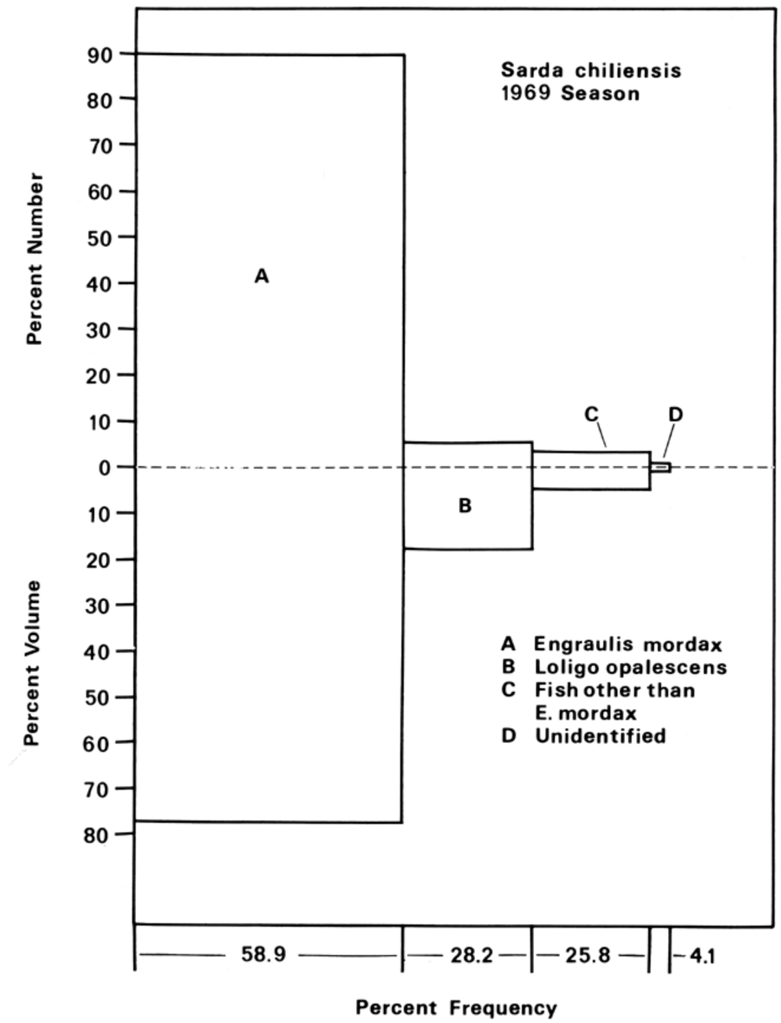

FIGURE 22. Percent composition by major food categories in number, volume, and frequency of occurrence; Pacific bonito 1969.

FIGURE 22. Percent composition by major food categories in number, volume, and frequency of occurrence; Pacific bonito 1969.

TABLE 19

Pacific Bonito Food, 1968

Food items	Major category	Number	Percent number	Volume ml	Percent volume	Frequency of occurrence	Percent frequency of occurrence
Vertebrates							
Fishes							
Engraulidae							
Engraulis mordax	A	636	40.0	4,025.3	73.5	188	52.8
Scomberesocidae							
Cololabis saira		19		178.3	3.3	8	2.2
Gadidae							
Merluccius productus		7		1.3	<0.1	4	1.1
Carangidae							
Trachurus symmetricus		6		106.1	1.9	4	1.1
Sciaenidae							
Seriphus politus	C	1	2.5	1.2	<0.1	1	0.3
Embiotocidae							
Brachyistius frenatus		1		10.0	0.2	1	0.3
Zalembius rosaceus		1		9.0	0.1	1	0.3
Scorpaenidae							
Sebastes spp.		4		1.5	<0.1	2	0.5
Bothidae							
Citharichthys sordidus		1		0.6	<0.1	1	0.3
Unidentified fishes		672	42.2	124.7	2.3	105	29.5
Subtotal C		712	44.7	432.7	7.8	127	35.6
Subtotal A & C (all fishes)		1,348	84.7	4,458.0	81.3	315	88.4
Invertebrates							
Cephalopods							
Loligo opalescens	B	221	13.9	1,018.3	18.6	76	21.3
Unidentified cephalopods		5	0.3	0.3	<0.1	5	1.4
Crustaceans							
Crab megalops larvae	D	3	0.2	0.1	<0.1	1	0.3
Unidentified animals		15	0.9	3.4	<0.1	14	3.9
Subtotal D		23	1.4	3.8	0.1	20	5.6
TOTALS		1,592	100.0	5,480.1	100.0	--	--

TABLE 19
Pacific Bonito Food, 1968

TABLE 20

Pacific Bonito Food, 1969

Food items	Major category	Number	Percent number	Volume ml	Percent volume	Frequency of occurrence	Percent frequency of occurrence
Vertebrates							
Fishes							
Engraulidae							
Engraulis mordax	A	3,523	90.0	7,331.1	77.4	274	58.9
Scomberesocidae							
Cololabis saira	C	8	1.3	12.5	0.1	8	1.7
Gadidae							
Merluccius productus		17		5.5	<0.1	11	2.4
Carangidae							
Trachurus symmetricus		10		79.5	0.8	9	1.9
Sciaenidae							
Genyonemus lineatus		1		38.0	0.4	1	0.2
Seriphus politus		2		0.1	<0.1	1	0.2
Embiotocidae							
Cymatogaster aggregata		1		14.0	0.1+	1	0.2
Scorpaenidae							
Sebastes spp.		8		4.3	<0.1	3	0.7
Stromateidae							
Peprilus simillimus		7		195.0	2.1	6	1.3
Unidentified fishes		93	2.4	99.1	1.1	80	17.2
Subtotal C		147	3.7	448.0	4.7	120	25.8
Subtotal A & C (all fishes)		3,670	93.7	7,779.1	82.1	394	84.7
Invertebrates							
Cephalopods							
Loligo opalescens	B	227	5.8	1,672.4	17.7	131	28.2
Onychoteuthis boreali-japonicus	D	1	<0.1	3.7	0.2	1	0.2
Unidentified cephalopods		12	0.3	9.6		11	2.3
Crustaceans							
Pleuroncodes planipes		4	0.1	5.6		4	0.9
Unidentified animals		4	0.1	1.3		3	0.7
Subtotal D		21	0.5	20.2	0.2	19	4.1
TOTALS		3,918	100.0	9,471.7	100.0	--	--

TABLE 20
Pacific Bonito Food, 1969

Fish other than E. mordax (Category C) constituted 44.7 percent by numbers, 7.8 percent by volume, and 35.6 percent frequency of occurrence in 1968 and had an Index of Relative Importance of 1,869. In 1969 fish other than E. mordax comprised 3.7 percent by numbers, 4.7 percent by volume, and 25.9 percent frequency of occurrence with an Index of Relative Importance of 216. In 1968, unidentified fish alone were 42.2 percent by numbers. In 1969, unidentified fish were only 2.4 percent by numbers in Category C. Improved efficiency in otolith recovery and increased sophistication in otolith identification for 1969 samples account for this diversity. A large percentage of the unidentified fish recorded in 1968 was probably northern anchovies.

Three identified species, Pacific saury, jack mackerel, and Pacific hake, and the genus Sebastes were the only four food items worthy of mention in 1968. Four other identified species contributed only one fish each.

In 1969 the same four main food items occurred in the fish other than E. mordax category: Pacific saury, jack mackerel, Pacific hake, and Sebastes spp.; in addition Pacific pompano, Peprilus simillimus, occurred in a very few stomachs. Only three other identified species occurred in 1969 and were represented by only one or two fish out of a total of 3,670 fish.

The common squid made similar contributions to the bonito's diet in both 1968 (IRI 692) and 1969 (IRI 663). In 1968 common squid made up 13.9 percent by numbers, 18.6 percent by volume, and 21.3 percent frequency of occurrence. In 1969 common squid comprised 5.8 percent by number, 17.7 percent by volume, and 28.2 percent frequency of occurrence. Volume, frequency of occurrence, and index of relative importance values were especially close.

4.2.3. Seasonal Variations in Diet

Data examined on a calendar quarter basis revealed some seasonal variations in bonito diet. Common squid contributed most to the bonito's diet in the first and second quarters of both years (Figures [23] [24] [25] [26] [27] [28] [29]). Common squid had an Index of Relative Importance of 7,615 in the first quarter of 1968, dropping to 597 in the second quarter, and 53 in the third quarter. In the fourth quarter of 1968, the Index of Relative Importance for common squid rose to 299.

In the first quarter of 1969, common squid's Index of Relative Importance rose to 1,408, further to 2,331 in the second quarter, and again fell to 54 in the third quarter of 1969 (Table 18).

The pattern of small contributions to bonito's diet by common squid in the third quarter of both years and relatively substantial contributions in the first half of the year is in part a manifestation of the common squid's concentrating behavior associated with its reproductive cycle (Fields, 1965).

Northern anchovies maintained relatively high index of relative importance values throughout the year. The lowest value was in the first quarter of 1968 (IRI 2,858), when common squid had its highest value of any quarter in the period of study (IRI 7,165). In the second quarter of 1968, northern anchovies had an index of relative importance of 8,610, in the third quarter 5,135, and in the fourth quarter 10,165.

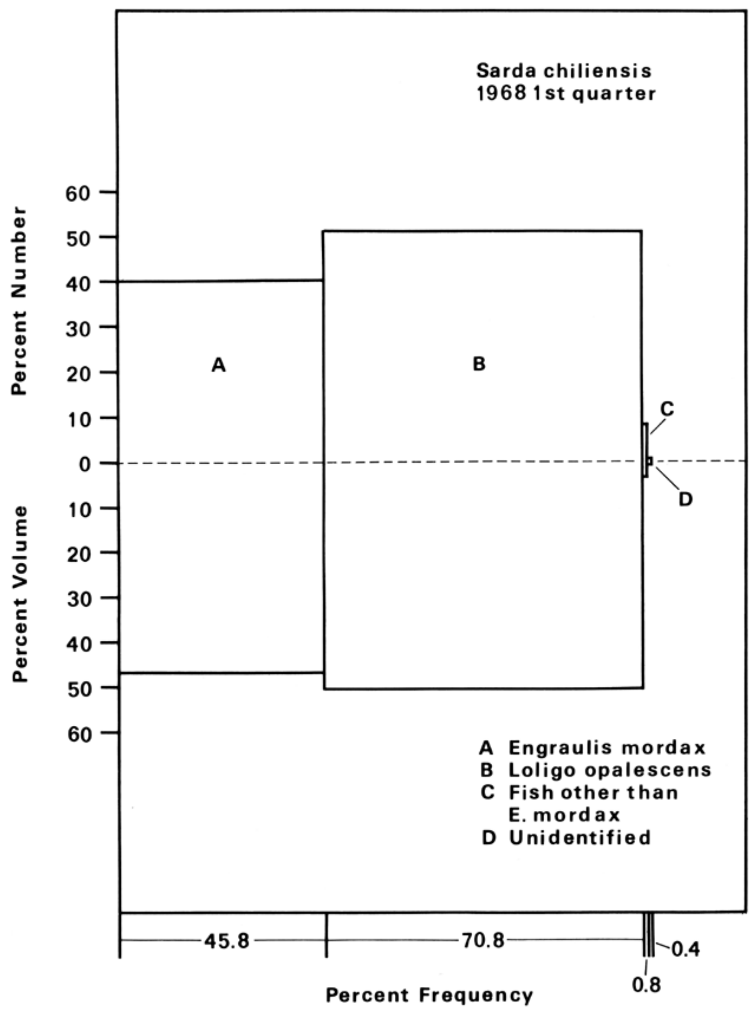

FIGURE 23. Percent composition by major food categories in number, volume, and frequency of occurrence; Pacific bonito, first quarter 1968.

FIGURE 23. Percent composition by major food categories in number, volume, and frequency of occurrence; Pacific bonito, first quarter 1968.

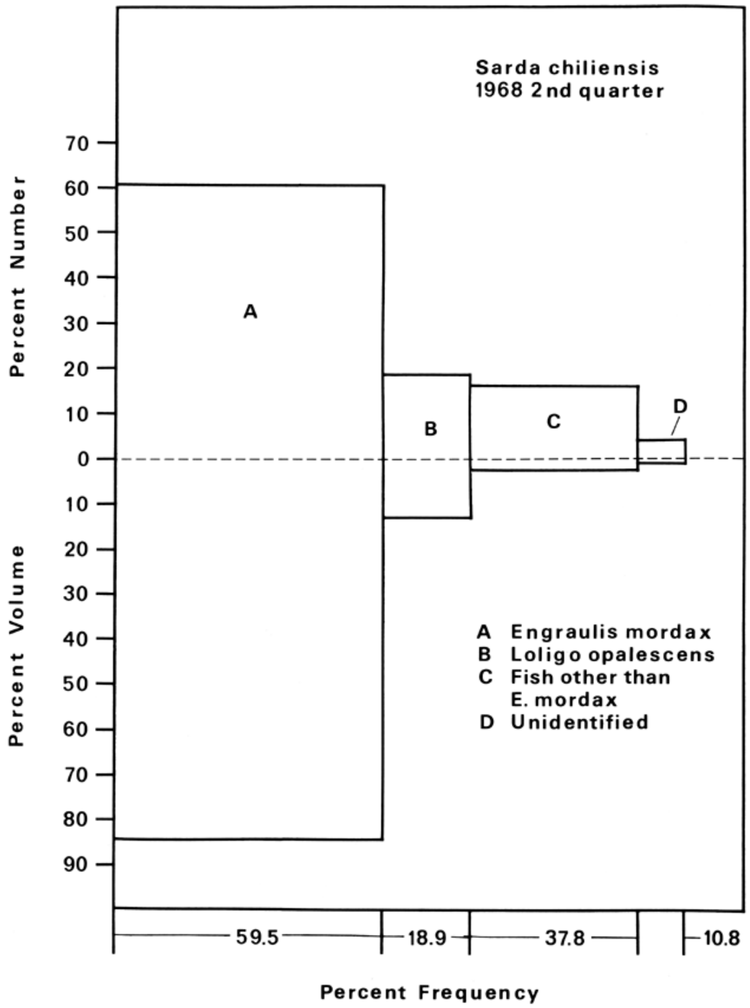

FIGURE 24. Percent composition by major food categories in number, volume, and frequency of occurrence; Pacific bonito, second quarter 1968.

FIGURE 24. Percent composition by major food categories in number, volume, and frequency of occurrence; Pacific bonito, second quarter 1968.

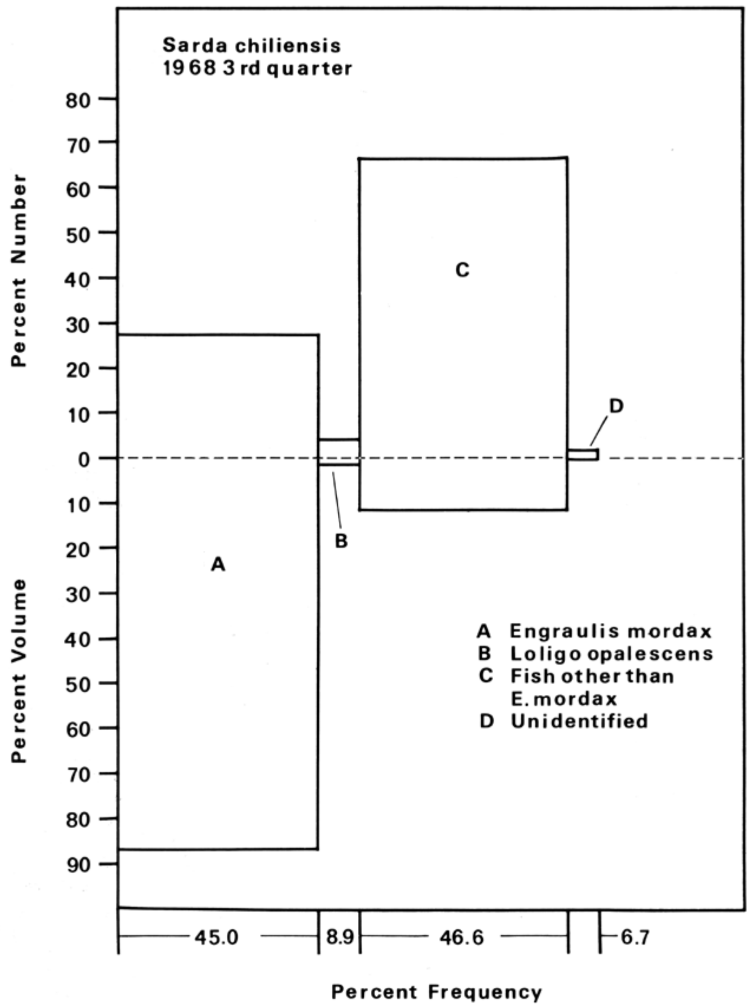

FIGURE 25. Percent composition by major food categories in number, volume, and frequency of occurrence; Pacific bonito, third quarter 1968.

FIGURE 25. Percent composition by major food categories in number, volume, and frequency of occurrence; Pacific bonito, third quarter 1968.

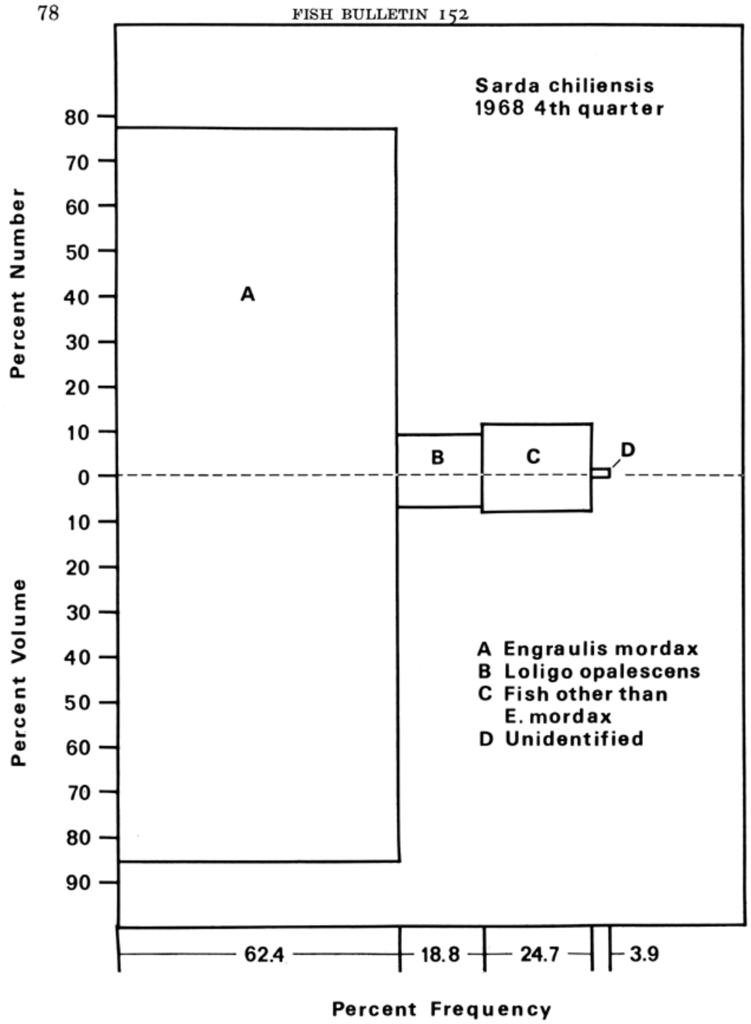

FIGURE 26. Percent composition by major food categories in number, volume, and frequency of occurrence; Pacific bonito, fourth quarter 1968.

FIGURE 26. Percent composition by major food categories in number, volume, and frequency of occurrence; Pacific bonito, fourth quarter 1968.

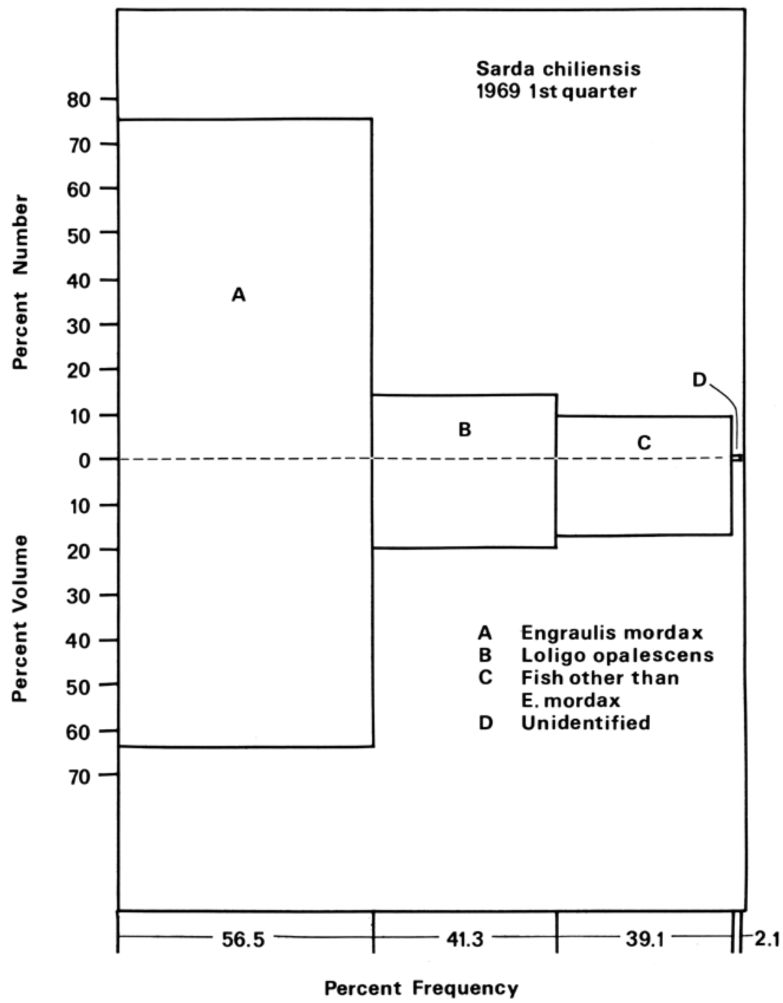

FIGURE 27. Percent composition by major food categories in number, volume, and frequency of occurrence; Pacific bonito, first quarter 1969.

FIGURE 27. Percent composition by major food categories in number, volume, and frequency of occurrence; Pacific bonito, first quarter 1969.

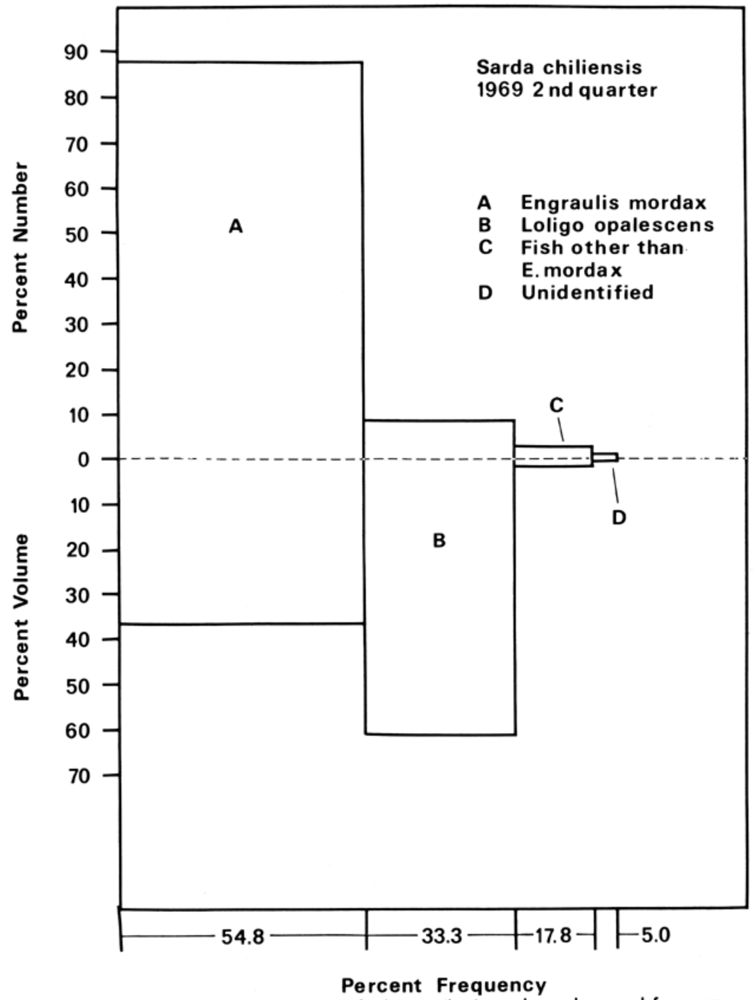

FIGURE 28. Percent composition by major food categories in number, volume, and frequency of occurrence; Pacific bonito, second quarter 1969.

FIGURE 28. Percent composition by major food categories in number, volume, and frequency of occurrence; Pacific bonito, second quarter 1969.

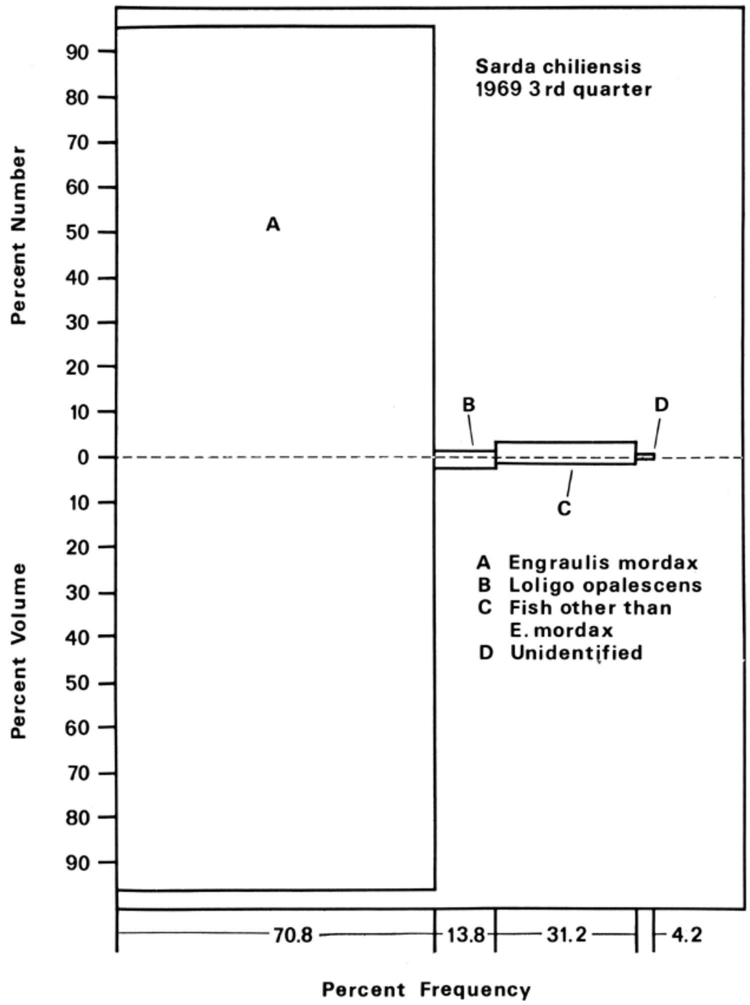

FIGURE 29. Percent composition by major food categories in number, volume, and frequency of occurrence; Pacific bonito, third quarter 1969.

FIGURE 29. Percent composition by major food categories in number, volume, and frequency of occurrence; Pacific bonito, third quarter 1969.

In 1969, northern anchovies had an Index of Relative Importance value of 7,825 in the first quarter, 6,790 in the second quarter, and 13,537 in the third quarter.

Fish other than E. mordax showed a high Index of Relative Importance in the third quarter of 1968 (3,649) and an Index of Relative Importance for the third quarter of 1969 of only 140. We attribute this disparity to our increased proficiency in otolith recovery and identification for the 1969 samples. In the 1968 samples, we consider a large part of the unidentified fish in the fish other than E. mordax category to have been anchovies. For all other quarters studied, the fish other than E. mordax category Index of Relative Importance ranged from 9 in the first quarter of 1968 to 1,052 in the first quarter of 1969. The low value of IRI 9 in the first quarter of 1968 is associated with the extremely high value of 7,165 for common squid in this quarter.

Excluding the 1968 first and third quarters and the 1969 first quarter, Index of Relative Importance values for fish other than E. mordax range between a low of 82 in the second quarter of 1969 to a second quarter of 1968 value of 692.

4.3. DISCUSSION

Our investigation clearly revealed northern anchovy was the major food item in the diet of Pacific bonito. Common squid ranks as the species next in importance as bonito food, mainly from January through June. Common squid's main occurrence in bonito food in the first half of the year corresponds with their known shoaling behavior during spawning (Fields, 1965). Miscellaneous fish and a few crustaceans make up the small remainder of bonito's diet.

We know of no other studies of Pacific bonito's feeding habits in California or in Baja California, Mexico, waters. We located one earlier reference to bonito's food (Bell, 1960) which states, "The preferred food of bonito appears to be small fishes, such as anchovies and sardines. Occasionally, they rely heavily upon squid." However, no study was indicated. Our examination of 1,498 stomachs concurs with Bell's a priori statement.

4.4. REFERENCES

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Fields, William Gordon. 1965. The structure, development, food relations, reproduction and life history of the squid, Loligo opalescens Berry. Calif. Dept. Fish and Game, Fish Bull., (131) :1–108.

5. A PICTORIAL GUIDE TO BEAKS OF CERTAIN EASTERN PACIFIC CEPHALOPODS

INGRID L. K. IVERSON and LEO PINKAS
Marine Resources Region
California Department of Fish and Game

5.1. CEPHALOPOD IDENTIFICATION

Identification of cephalopods in the stomachs of marine predators (fish, whales, porpoise, seals, birds, squid, and others) by external morphology almost is impossible because rapid digestion obliterates key characteristics. Internal structures available for possible identification include the pen, radula, and paired mandibles or beaks. Experience indicates that pens do not occur in all species, and are frequently broken; radula are small, fragment easily, and are difficult to find; while the horny beaks are common to all cephalopods, can be seen with the unaided eye, resist digestion, and are frequently the sole item in an otherwise empty stomach.

Occurrence and possible use of beaks for identifying cephalopods in the stomach contents of marine predators have been observed, described, developed, and utilized by other investigators (Malcolm R. Clarke, 1962). Clarke, utilizing over 500 cephalopods from a wide geographical range, focused his studies at the familial level with particular emphasis on the relationship of beak size to total length and weight. He constructed keys to aid in identifying a beak, upper or lower, to the familial level.

It was our desire, for the current food habit study, to identify stomach contents to the lowest possible taxa. Crustaceans and vertebrates presented less of a problem than cephalopods because their hard parts resisted digestion. John E. Fitch (1964, 1967, and personal communication), Fitch and Brownell (1968), Eziuzo (1963), and others have developed the identification of fish via otoliths to a fine degree.

Their success prompted us to explore the relationships between cephalopodian external morphology and beak form and structure at the specific level.

We collected a series of beaks from positively identified cephalopods captured in the eastern North Pacific Ocean. Study material came from various collections including the Allan Hancock Foundation, Scripps Institution of Oceanography, University of California at Santa Barbara, and the California Department of Fish and Game.

The following series of drawings, by Iverson, is a result of our studies. Almost without exception each set of beaks differs in some degree or feature from all others. These drawings, plus our reference collection, as well as other references were invaluable in identifying the octopus and squid encountered in the various stomachs.

A cephalopod beak consists of separate upper and lower parts; these are capable of grasping or biting, in a way somewhat analogous to jaws of higher animals. The descriptive terms of the beak are: rostrum (cutting edge), jaw angle, hood, crest, wing, and lateral wall (Clarke, 1962). The rostrum of the lower beak extends beyond that of the upper. Diagnostic characters distinguishing beaks of different species are: size, color, length and curvature of rostrum, markings at the angle where the rostrum meets the wing, length of wing and the presence or absence of a ridge or fold in the lateral wall. The lower beak is the most useful in species identification.

Octopus beaks are easily distinguished from squid beaks. The rostra of both upper and lower octopus beaks are short; the upper rostrum of a squid beak is long, curved and pointed. The lateral walls of an octopus beak are relatively smaller than those of a squid beak; the color is usually darker and extends over the entire octopus beak.

Juveniles and adults of the same species differ only in size and coloration. Pigmentation increases with size and age; thus the sparse color of the juvenile beak becomes more intense and spreads in varying stages and degrees to the tip of the wing and across the lateral wall in the adult.

The construction of an artificial key to identify beaks was considered and rejected as premature. Cephalopod taxonomy is unstable and incomplete; for example, several specimens could be identified only to the familial or generic level and a number of undescribed species are currently under investigation (S. Stillman Berry, personal communication).

It is our hope, that in the interim between Berry's (1912) comprehensive review of eastern North Pacific cephalopods and some future compilation that the following drawings will be of value.

5.2. REFERENCES

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Fitch, John E., and Robert L. Brownell Jr. 1968. Fish otoliths in cetacean stomachs and their importance in interpreting feeding habits. J. Fish. Res. Bd. Canada, 25 (12) : 2561–2574.

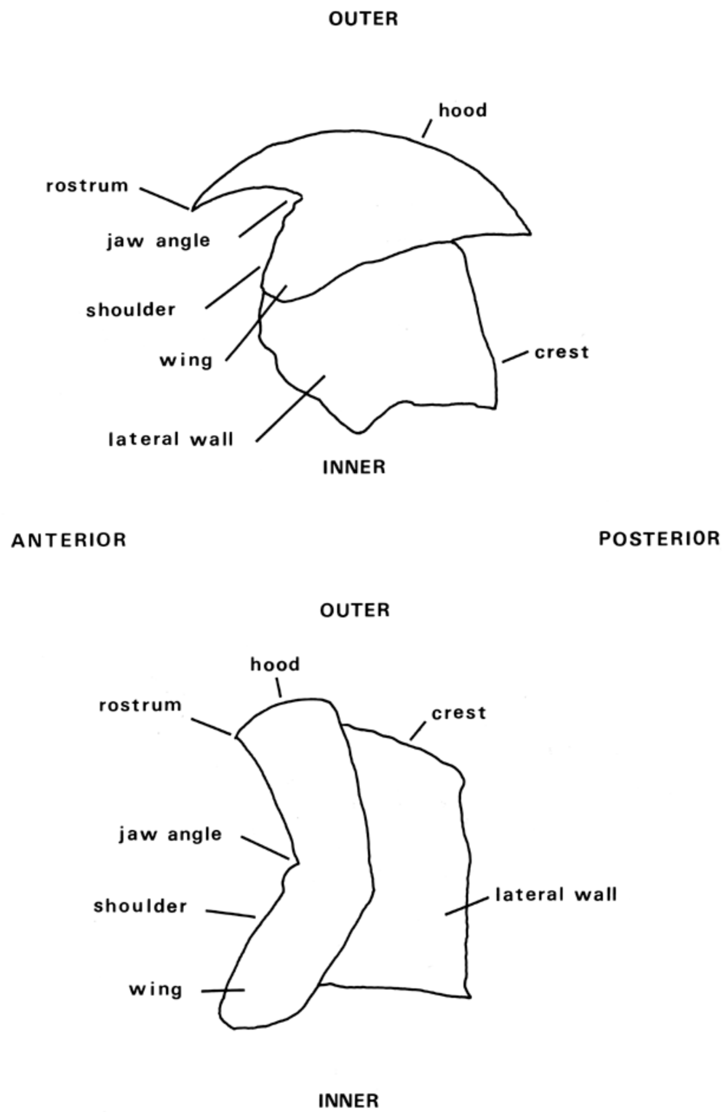

FIGURE 30. Generalized diagram of a pair of cephalopod beaks, lateral view, depicting the various parts and descriptive terms, after Clarke (1962). U = upper beak; L = lower beak; O = outer view; J = juvenile.

FIGURE 30. Generalized diagram of a pair of cephalopod beaks, lateral view, depicting the various parts and descriptive terms, after Clarke (1962). U = upper beak; L = lower beak; O = outer view; J = juvenile.

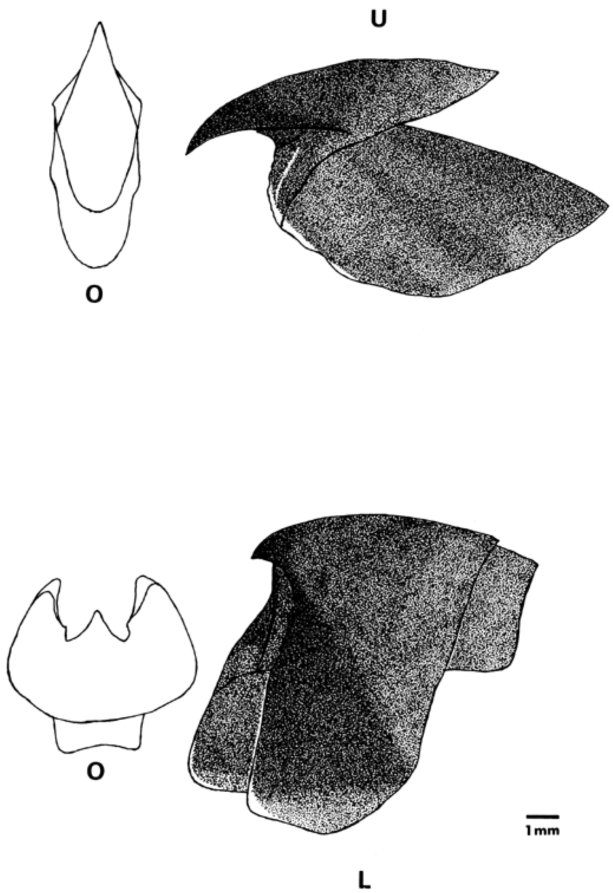

FIGURE 31. *Vampyroteuthis infernalis;* total length of specimen 271.0 mm. Beaks very dark, colored entirely. Upper beak: jaw angle rounded; lateral walls relatively long and shallow with a slight fold. Lower beak: wings broad; hood and wings covering lateral walls almost entirely.

FIGURE 31. Vampyroteuthis infernalis; total length of specimen 271.0 mm. Beaks very dark, colored entirely. Upper beak: jaw angle rounded; lateral walls relatively long and shallow with a slight fold. Lower beak: wings broad; hood and wings covering lateral walls almost entirely.

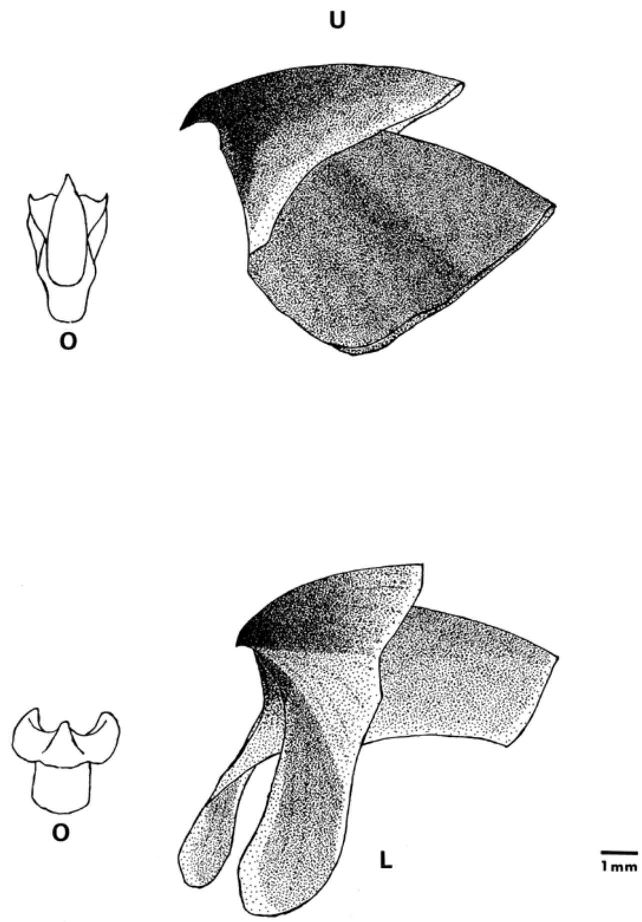

FIGURE 32. *Opisthoteuthis californiana*; total width across specimen 295.0 mm. Upper beak: jaw angle approximately 90 degrees, but rounded at apex; rostrum short, hooked; lateral walls deep with slight fold. Lower beak: jaw angle indistinct; wings narrow, long; rostrum short.

FIGURE 32. Opisthoteuthis californiana; total width across specimen 295.0 mm. Upper beak: jaw angle approximately 90 degrees, but rounded at apex; rostrum short, hooked; lateral walls deep with slight fold. Lower beak: jaw angle indistinct; wings narrow, long; rostrum short.

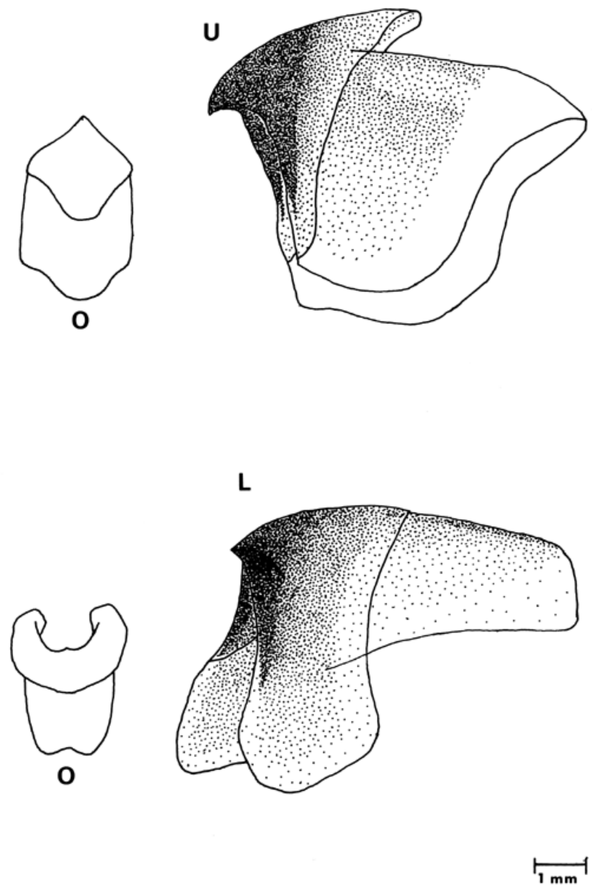

FIGURE 33. *Argonauta* sp. *(nouryi?)*; total length of specimen 162.0 mm. Color concentrated on rostra of beaks. Upper beak; jaw angle semi-circular; rostrum short, hooked; lateral walls deep with slight fold. Lower beak: jaw angle obtuse; rostrum short; wings broad; hood about half as long as crest; lateral walls taper posteriorly.

FIGURE 33. Argonauta sp. (nouryi?); total length of specimen 162.0 mm. Color concentrated on rostra of beaks. Upper beak; jaw angle semi-circular; rostrum short, hooked; lateral walls deep with slight fold. Lower beak: jaw angle obtuse; rostrum short; wings broad; hood about half as long as crest; lateral walls taper posteriorly.

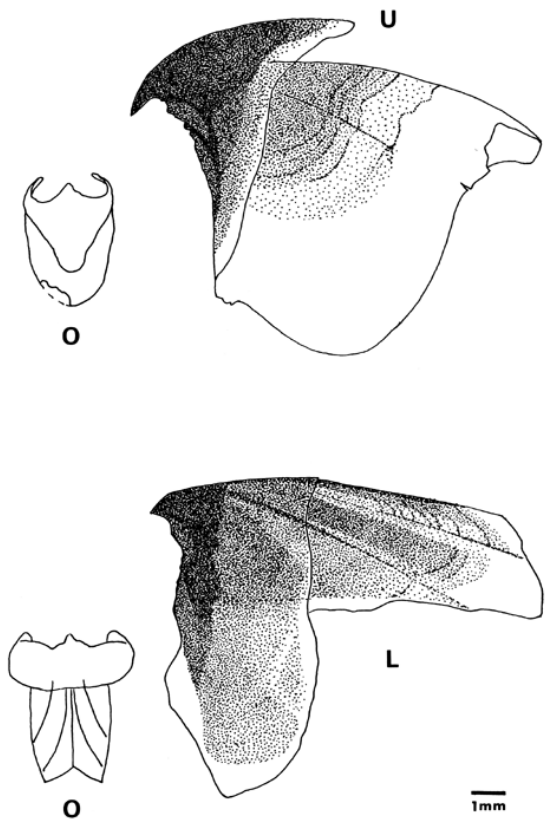

FIGURE 34. *Ocythoe tuberculata*; total length of adult specimen 135.0 mm. Upper beak: jaw angle indistinct; rostrum short and curved; lateral walls broad and deep. Lower beak: jaw angle indistinct; rostrum short and pointed; wings broad; lateral walls shallow. Entire juvenile beaks were not found; however, appear to be similar to the adult.

FIGURE 34. Ocythoe tuberculata; total length of adult specimen 135.0 mm. Upper beak: jaw angle indistinct; rostrum short and curved; lateral walls broad and deep. Lower beak: jaw angle indistinct; rostrum short and pointed; wings broad; lateral walls shallow. Entire juvenile beaks were not found; however, appear to be similar to the adult.

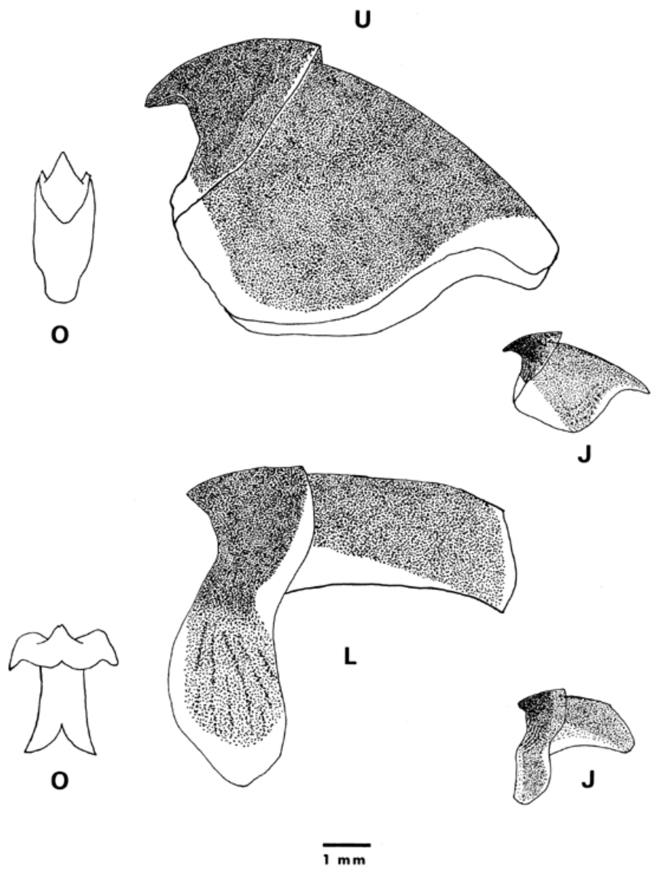

FIGURE 35. *Octopus bimaculatus*; total length of specimens: adult 420.0 mm, juvenile 49.0 mm. Both adult and juvenile beaks almost entirely colored, adult beaks are darker. Upper beak: jaw angle indistinct, variable; rostral tip worn broad and usually blunt; hood short. Lower beak: jaw angle indistinct; rostrum short, often worn flat in adults with an indentation in the midline; lateral walls shallow.

FIGURE 35. Octopus bimaculatus; total length of specimens: adult 420.0 mm, juvenile 49.0 mm. Both adult and juvenile beaks almost entirely colored, adult beaks are darker. Upper beak: jaw angle indistinct, variable; rostral tip worn broad and usually blunt; hood short. Lower beak: jaw angle indistinct; rostrum short, often worn flat in adults with an indentation in the midline; lateral walls shallow.

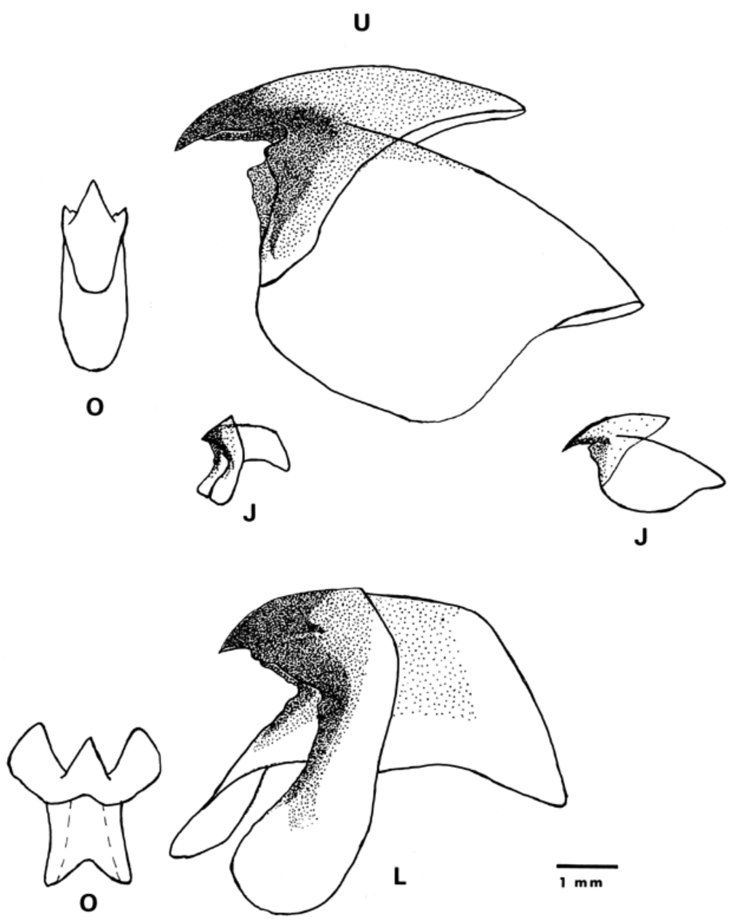

FIGURE 36. *Loligo opalescens;* mantle length of specimens: adult 108.0 mm, juvenile 37.5 mm. Color concentrated on rostra of upper and lower beaks. Upper beak: jaw angle recessed; rostrum short in comparison to hood length. Lower beak: jaw angle obtuse; no ridge on lateral walls; dark area extends along the rostrum and shoulder without any discontinuity near jaw angle.

FIGURE 36. Loligo opalescens; mantle length of specimens: adult 108.0 mm, juvenile 37.5 mm. Color concentrated on rostra of upper and lower beaks. Upper beak: jaw angle recessed; rostrum short in comparison to hood length. Lower beak: jaw angle obtuse; no ridge on lateral walls; dark area extends along the rostrum and shoulder without any discontinuity near jaw angle.

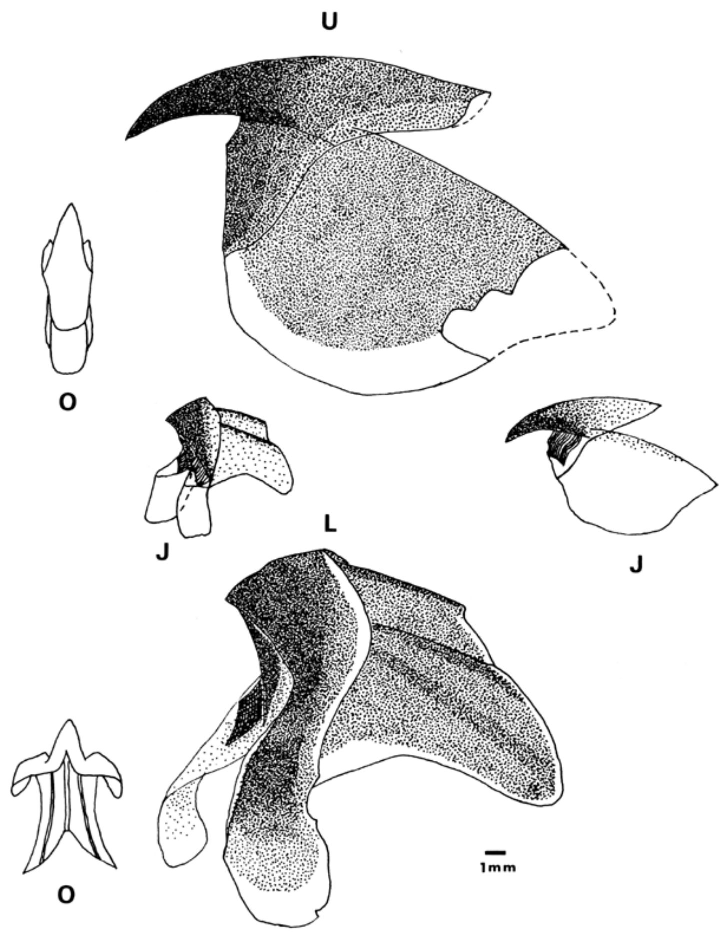

FIGURE 37. *Onychoteuthis boreali-japonicus;* total length of specimens: adult 515.0 mm, juvenile 80.0 mm. Adult beaks colored entirely except for margin of lateral walls; juvenile colored less, more transparent. Upper beak: jaw angle acute with slight false angle in larger specimens; prominent striated dark segment on wing at jaw angle of juvenile. Lower beak: jaw angle obtuse; narrow ridge on lateral wall becoming broader posteriorly; hood short.

FIGURE 37. Onychoteuthis boreali-japonicus; total length of specimens: adult 515.0 mm, juvenile 80.0 mm. Adult beaks colored entirely except for margin of lateral walls; juvenile colored less, more transparent. Upper beak: jaw angle acute with slight false angle in larger specimens; prominent striated dark segment on wing at jaw angle of juvenile. Lower beak: jaw angle obtuse; narrow ridge on lateral wall becoming broader posteriorly; hood short.

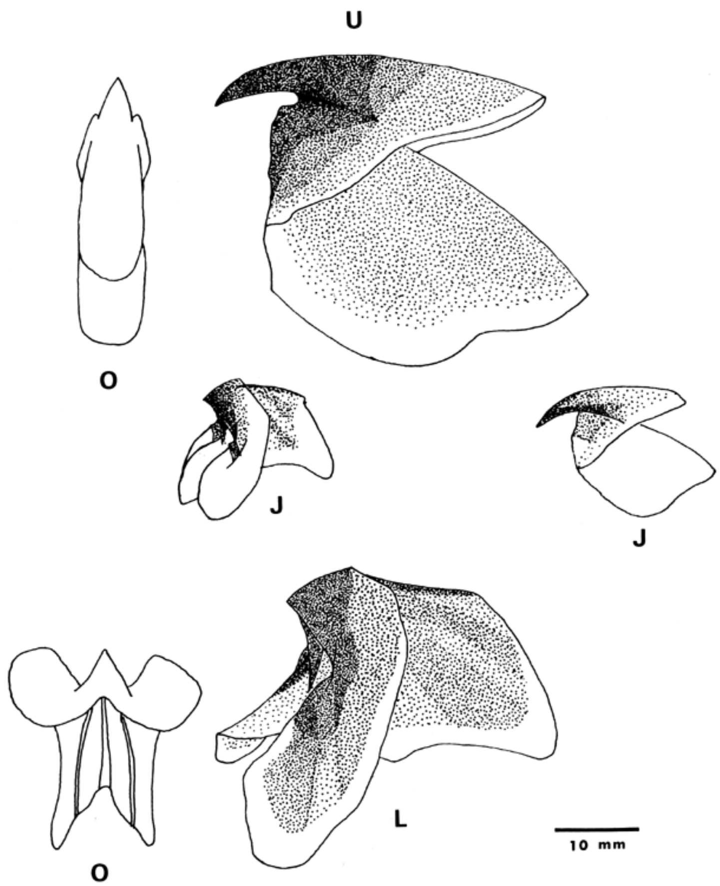

FIGURE 38. *Moroteuthis robusta;* mantle length of specimens: adult 895.0 mm, juvenile 48.0 mm. Upper beak: similar to *Onychoteuthis boreali-japonicus;* striation less distinct; color less black. Lower beak: similar to *O. boreali-japonicus;* a fold on lateral wall rather than a ridge; color less black.

FIGURE 38. Moroteuthis robusta; mantle length of specimens: adult 895.0 mm, juvenile 48.0 mm. Upper beak: similar to Onychoteuthis boreali-japonicus; striation less distinct; color less black. Lower beak: similar to O. boreali-japonicus; a fold on lateral wall rather than a ridge; color less black.

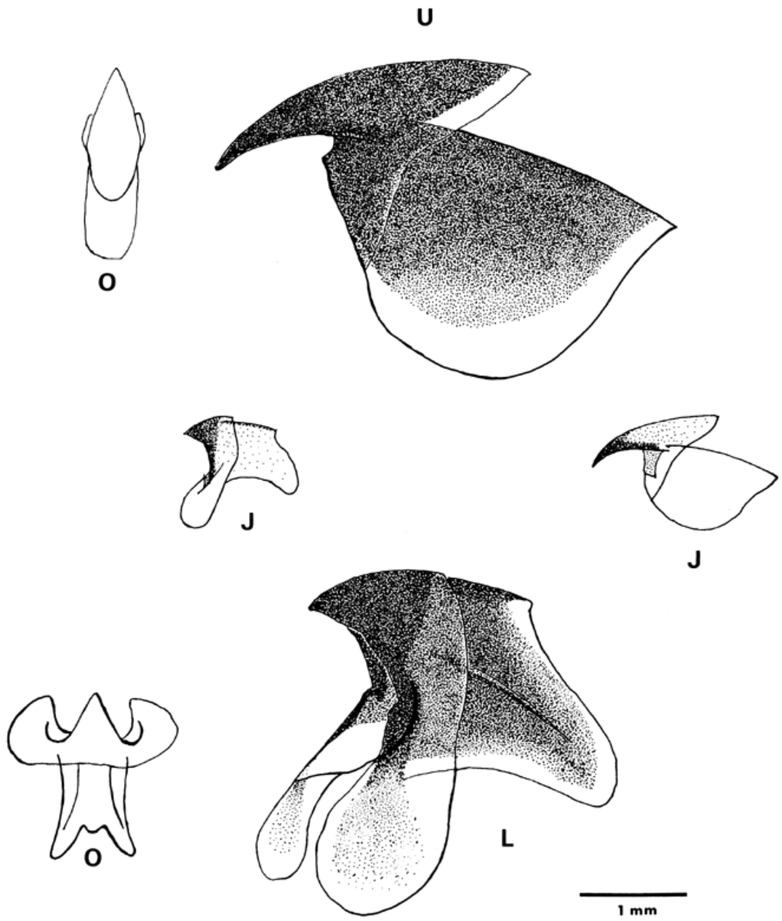

FIGURE 39. *Abraliopsis felis;* total length of specimens: adult 70.0 mm, juvenile 40.0 mm. Adult beaks small, nearly entirely colored; lateral walls of juvenile beak transparent. Upper beak: jaw angle acute and recessed; rostrum long, sharply pointed; crest and hood diverge at about 30 degree angle. Lower beak: jaw angle obtuse; distinct narrow ridge on lateral wall.

FIGURE 39. Abraliopsis felis; total length of specimens: adult 70.0 mm, juvenile 40.0 mm. Adult beaks small, nearly entirely colored; lateral walls of juvenile beak transparent. Upper beak: jaw angle acute and recessed; rostrum long, sharply pointed; crest and hood diverge at about 30 degree angle. Lower beak: jaw angle obtuse; distinct narrow ridge on lateral wall.

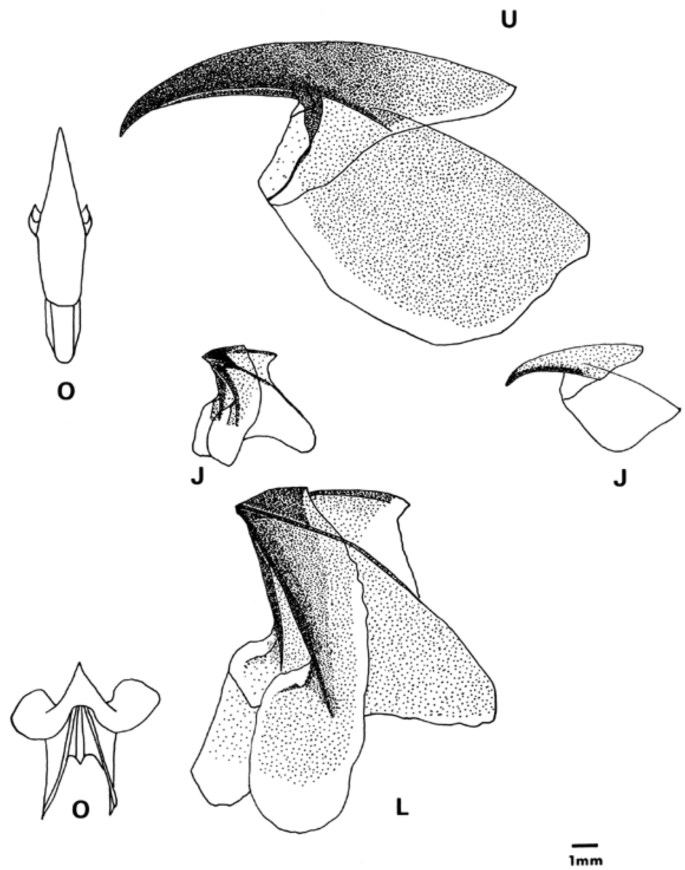

FIGURE 40. *Octopodoteuthis sicula;* mantle length of specimens: adult 130.0 mm, juvenile (arms damaged) 45.0 mm. Lateral walls of adult beak darkened while those of juvenile are transparent. Upper beak: hood and rostrum long, narrow, and distinctly curved as in a scythe. Lower beak: jaw angle about 90 degrees; distinct ridge extends to posterior edge of lateral wall; rostrum is relatively long; wings are broad.

FIGURE 40. Octopodoteuthis sicula; mantle length of specimens: adult 130.0 mm, juvenile (arms damaged) 45.0 mm. Lateral walls of adult beak darkened while those of juvenile are transparent. Upper beak: hood and rostrum long, narrow, and distinctly curved as in a scythe. Lower beak: jaw angle about 90 degrees; distinct ridge extends to posterior edge of lateral wall; rostrum is relatively long; wings are broad.

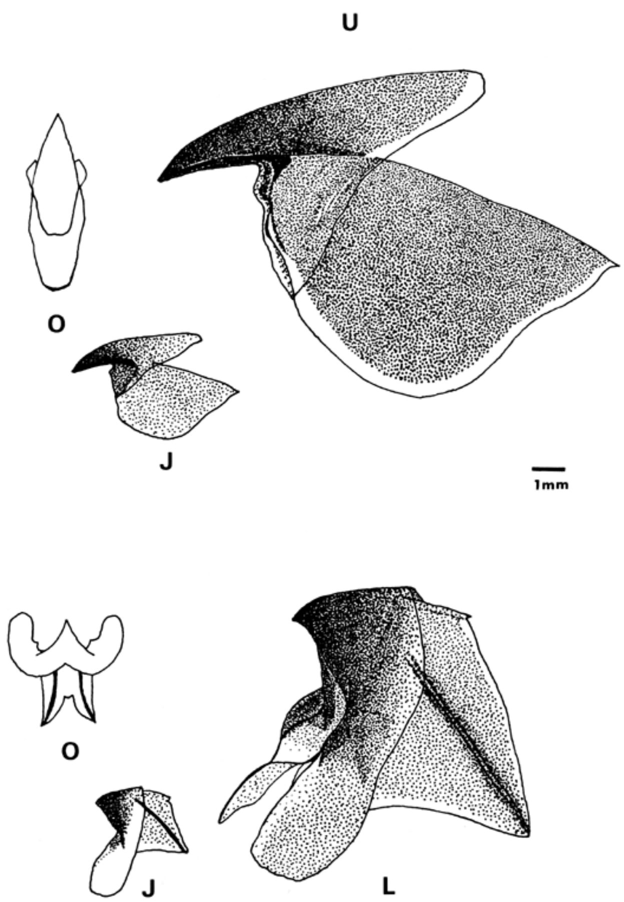

FIGURE 41. *Histioteuthis heteropsis;* mantle length of specimens: adult 82.0 mm, juvenile 21.0 mm. Adult beaks colored entirely. Upper beak: jaw angle approximately 90 degrees; distinct false angle present; shoulder irregular; crest and hood diverge at 30 degree angle. Lower beak: jaw angle obtuse; distinct narrow ridge on lateral wall extending to posterior corner; crest length shorter than hood length.

FIGURE 41. Histioteuthis heteropsis; mantle length of specimens: adult 82.0 mm, juvenile 21.0 mm. Adult beaks colored entirely. Upper beak: jaw angle approximately 90 degrees; distinct false angle present; shoulder irregular; crest and hood diverge at 30 degree angle. Lower beak: jaw angle obtuse; distinct narrow ridge on lateral wall extending to posterior corner; crest length shorter than hood length.

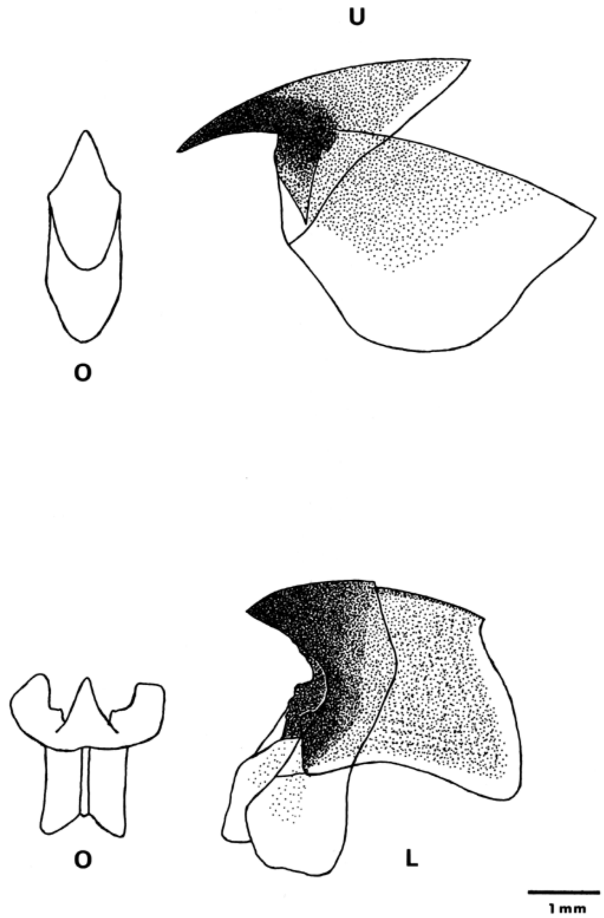

FIGURE 42. *Gonatus anonychus;* total length of specimen 137.0 mm. Rostrum and hood colored, lateral wall and wing partially pigmented. Upper beak: jaw angle acute; angle formed by posterior edge of hood and crest approximates 30 degrees; dark color concentrated on rostrum and about angle. Lower beak: jaw angle obtuse; broadly U shaped; dark color prominent at jaw angle.

FIGURE 42. Gonatus anonychus; total length of specimen 137.0 mm. Rostrum and hood colored, lateral wall and wing partially pigmented. Upper beak: jaw angle acute; angle formed by posterior edge of hood and crest approximates 30 degrees; dark color concentrated on rostrum and about angle. Lower beak: jaw angle obtuse; broadly U shaped; dark color prominent at jaw angle.

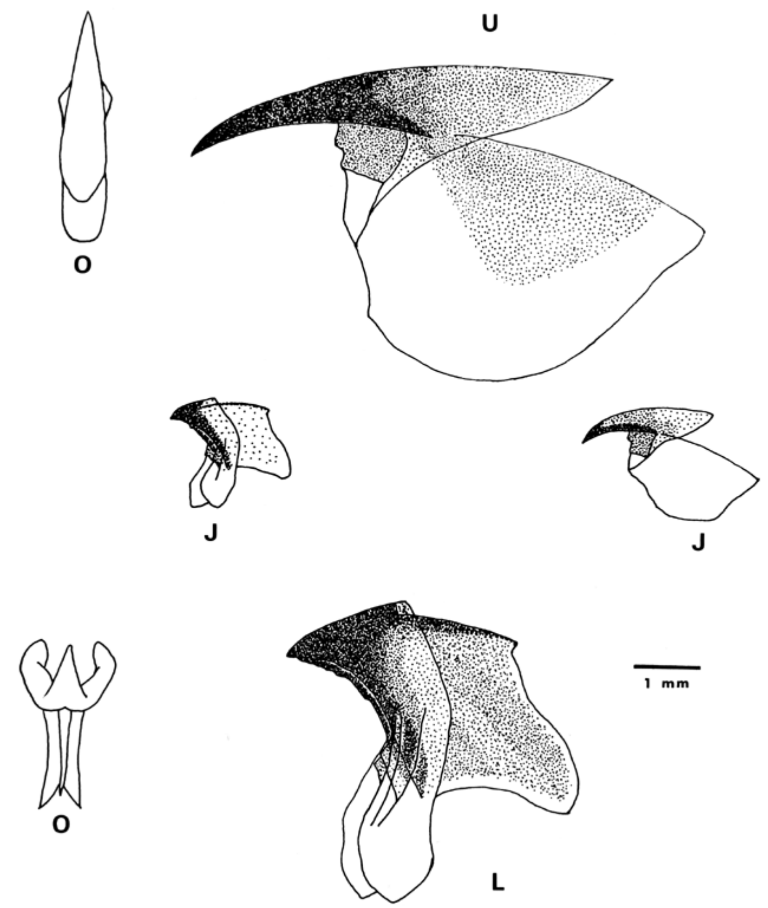

FIGURE 43. *Gonatus* sp.; total length of specimen: adult 112.0 mm, juvenile unknown. Upper beak: colored patch on lateral wall has the appearance of an isosceles triangle; rostrum long, slender, pointed. Lower beak: jaw angle clearly obtuse; rostrum and wing nearly equal in length; wings narrow; slight fold in lateral wall.

FIGURE 43. Gonatus sp.; total length of specimen: adult 112.0 mm, juvenile unknown. Upper beak: colored patch on lateral wall has the appearance of an isosceles triangle; rostrum long, slender, pointed. Lower beak: jaw angle clearly obtuse; rostrum and wing nearly equal in length; wings narrow; slight fold in lateral wall.

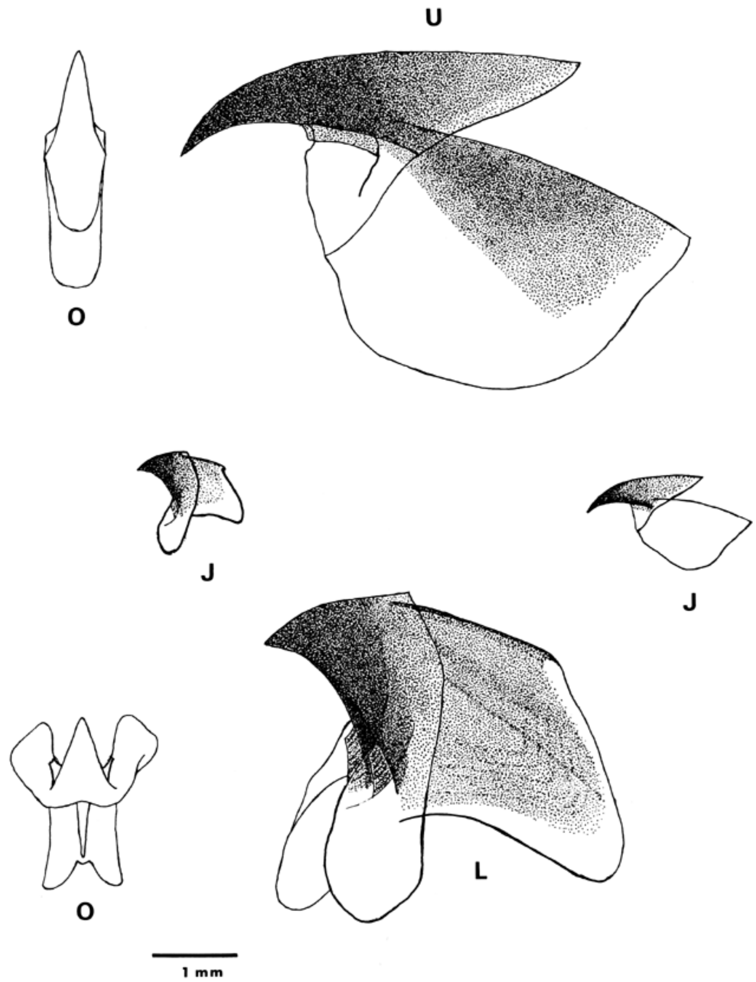

FIGURE 44. *Gonatus* sp. *(fabricii?)*; total length of specimens: adult unknown, juvenile unknown. Upper beak: colored patch on lateral wall has the appearance of a right 60-30 triangle; rostrum moderately long, curved, pointed. Lower beak: jaw angle obtuse; rostrum smooth, curved; rostrum and wing nearly equal in length; slight fold in lateral wall.

FIGURE 44. Gonatus sp. (fabricii?); total length of specimens: adult unknown, juvenile unknown. Upper beak: colored patch on lateral wall has the appearance of a right 60-30 triangle; rostrum moderately long, curved, pointed. Lower beak: jaw angle obtuse; rostrum smooth, curved; rostrum and wing nearly equal in length; slight fold in lateral wall.

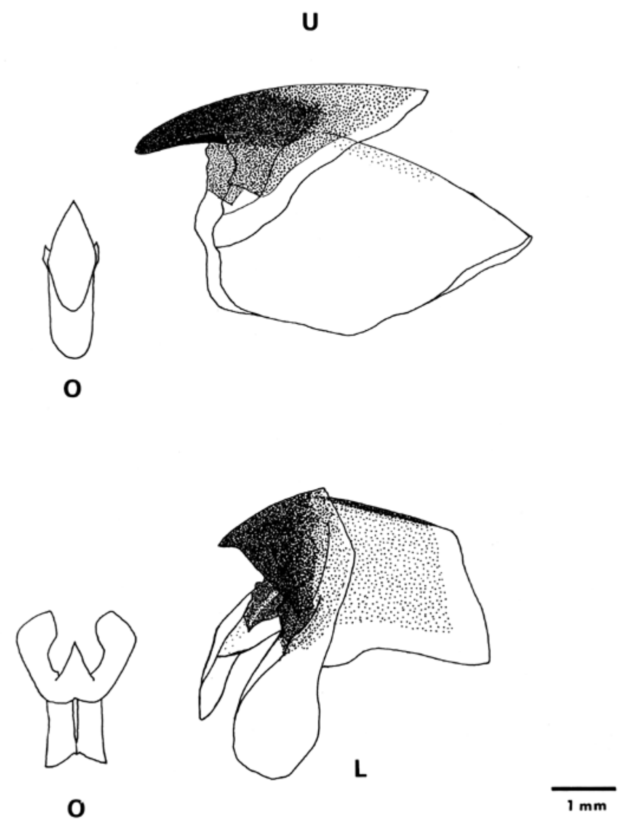

FIGURE 45. *Gonatopsis* sp.; mantle length of specimen 45.0 mm. Dark color concentrated on rostra of beaks. Upper beak: jaw angle obtuse; relatively short rostrum. Lower beak: large dark patch where lateral wall meets wing; no fold or ridge on lateral wall.

FIGURE 45. Gonatopsis sp.; mantle length of specimen 45.0 mm. Dark color concentrated on rostra of beaks. Upper beak: jaw angle obtuse; relatively short rostrum. Lower beak: large dark patch where lateral wall meets wing; no fold or ridge on lateral wall.

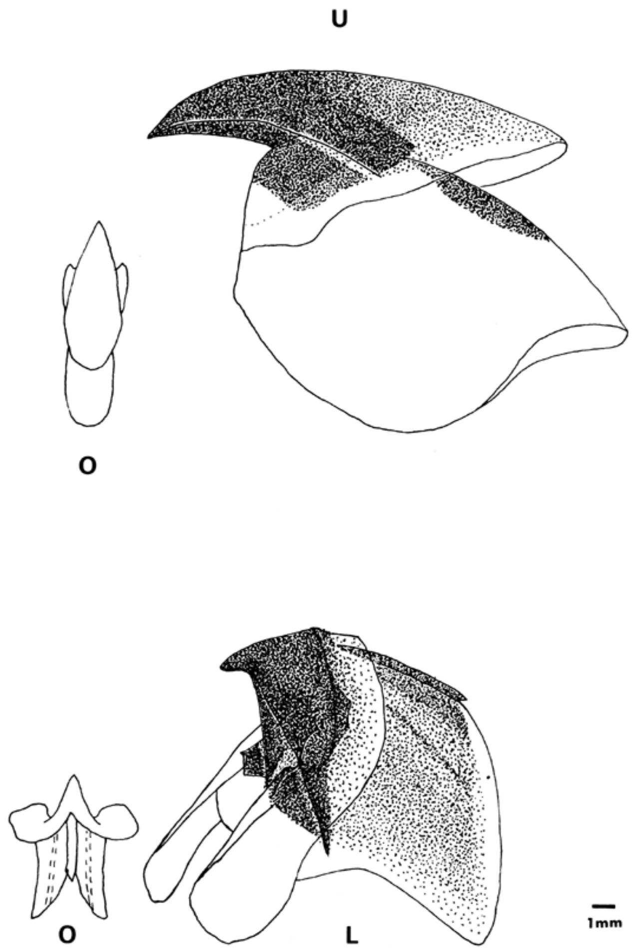

FIGURE 46. *Dosidicus gigas;* total length of specimens: adult 502.0 mm, juvenile 139.5 mm. Upper beak: jaw angle acute and recessed; darkening on crest of juvenile; isolated patch appears on each lateral wall in later stage. Lower beak: jaw angle acute and recessed; slight fold evident in lateral wall of larger specimens; dark patch appears on each wing of larger specimens.

FIGURE 46. Dosidicus gigas; total length of specimens: adult 502.0 mm, juvenile 139.5 mm. Upper beak: jaw angle acute and recessed; darkening on crest of juvenile; isolated patch appears on each lateral wall in later stage. Lower beak: jaw angle acute and recessed; slight fold evident in lateral wall of larger specimens; dark patch appears on each wing of larger specimens.

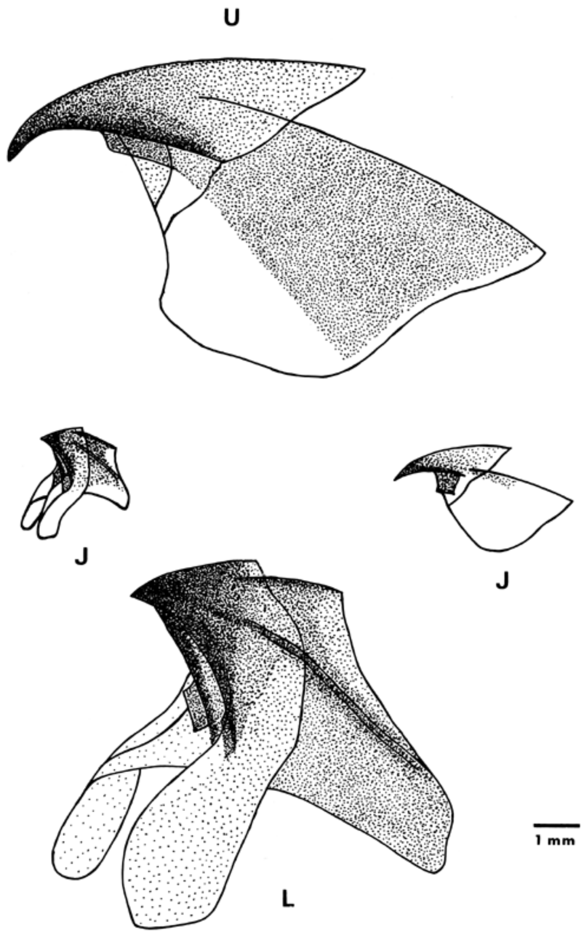

FIGURE 47. *Mastigoteuthis dentata;* total length of specimens: adult 205.0 mm, juvenile unknown. Upper beak: jaw angle curved, obtuse; rostrum hooked slightly; straight, well-defined line borders coloration on lateral wall. Lower beak: rostrum relatively long in proportion to hood; distinct narrow ridge on lateral wall, has appearance of being long in relation to width.

FIGURE 47. Mastigoteuthis dentata; total length of specimens: adult 205.0 mm, juvenile unknown. Upper beak: jaw angle curved, obtuse; rostrum hooked slightly; straight, well-defined line borders coloration on lateral wall. Lower beak: rostrum relatively long in proportion to hood; distinct narrow ridge on lateral wall, has appearance of being long in relation to width.

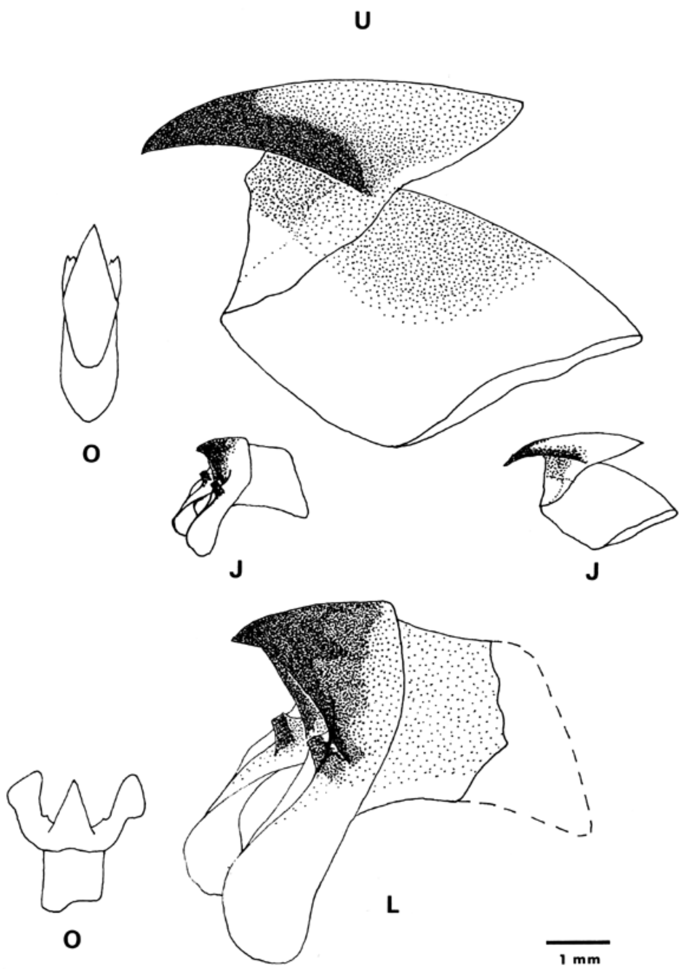

FIGURE 48. *Cranchia scabra;* mantle length of specimens: adult 95.0 mm, juvenile 65.5 mm. Upper beak: jaw angle acute and recessed; rostrum relatively short compared to hood. Lower beak: wing appears long compared to rostrum; prominent dark patch appears where lateral wall meets wing and rostrum; separated by clear strip from rostrum; no ridge or fold on lateral wall.

FIGURE 48. Cranchia scabra; mantle length of specimens: adult 95.0 mm, juvenile 65.5 mm. Upper beak: jaw angle acute and recessed; rostrum relatively short compared to hood. Lower beak: wing appears long compared to rostrum; prominent dark patch appears where lateral wall meets wing and rostrum; separated by clear strip from rostrum; no ridge or fold on lateral wall.

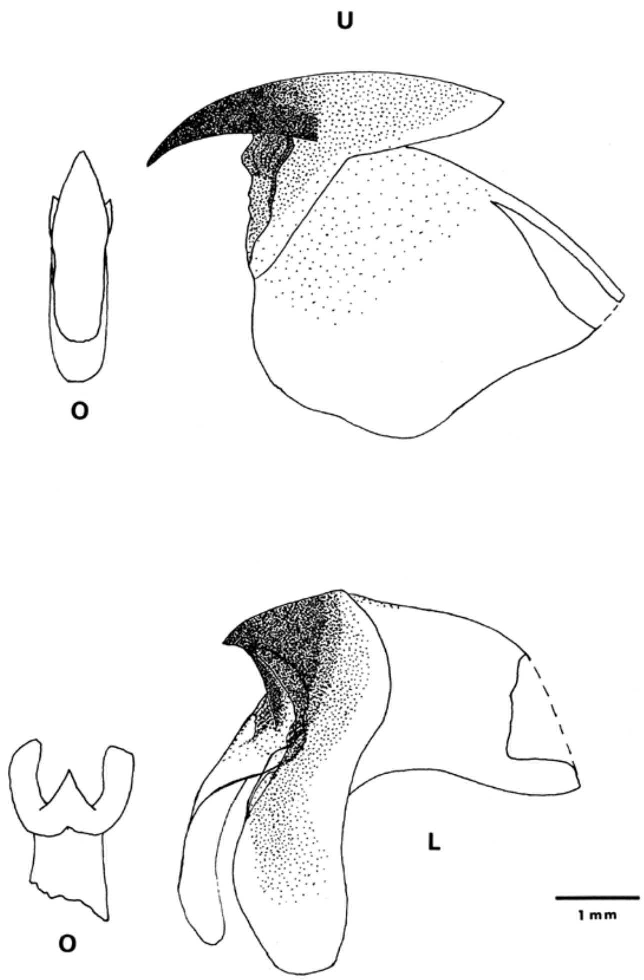

FIGURE 49. *Leachia* sp.; total length of specimens: adult 183.0 mm, juvenile 135.0 mm. Color concentrated on rostra of beaks. Upper beak: jaw angle acute and recessed; rostrum moderately long, curved, pointed. Lower beak: jaw angle is obtuse; rostrum slightly hooked; no fold or ridge in lateral wall.

FIGURE 49. Leachia sp.; total length of specimens: adult 183.0 mm, juvenile 135.0 mm. Color concentrated on rostra of beaks. Upper beak: jaw angle acute and recessed; rostrum moderately long, curved, pointed. Lower beak: jaw angle is obtuse; rostrum slightly hooked; no fold or ridge in lateral wall.

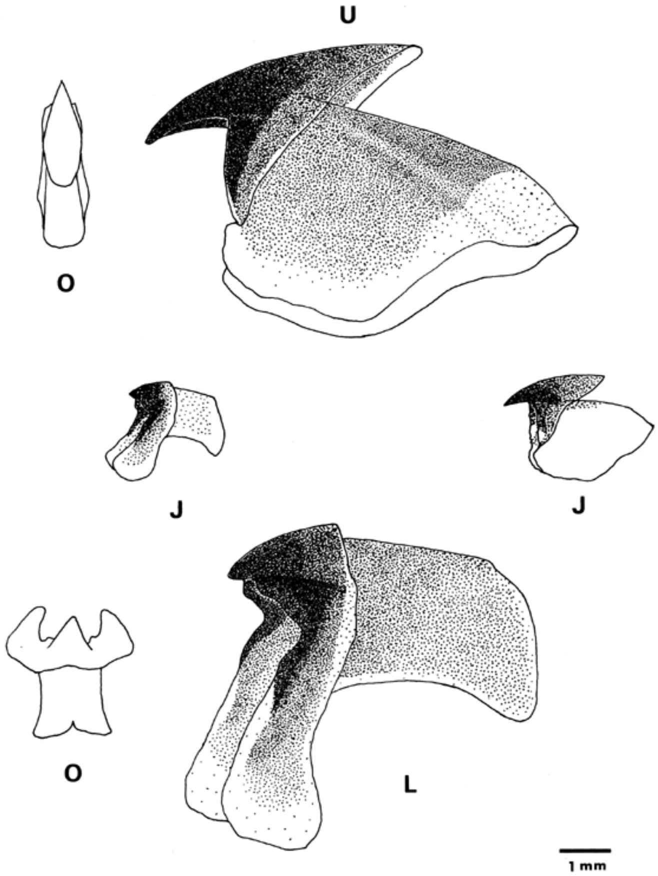

FIGURE 50. *Rossia pacifica;* total length of specimens: adult 127.0 mm, juvenile 80.0 mm. Adult beaks colored entirely except for lateral wall margin of upper beak. Lateral wall of juvenile upper beak transparent. Upper beak: jaw angle acute, well defined; rostrum moderately long; slight fold on lateral wall near crest; color concentrated on rostrum and around angle. Lower beak: jaw angle well defined, approximately 90 degrees; wing long, broadening at the inner end; rostrum short, blunt; color concentrated on rostrum and about the angle.

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FIGURE 50. Rossia pacifica; total length of specimens: adult 127.0 mm, juvenile 80.0 mm. Adult beaks colored entirely except for lateral wall margin of upper beak. Lateral wall of juvenile upper beak transparent. Upper beak: jaw angle acute, well defined; rostrum moderately long; slight fold on lateral wall near crest; color concentrated on rostrum and around angle. Lower beak: jaw angle well defined, approximately 90 degrees; wing long, broadening at the inner end; rostrum short, blunt; color concentrated on rostrum and about the angle.