site; no distinct migration patterns were evident.

— 67 —

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— (68) —

FOOD HABITS OF STRIPED BASS, ROCCUS SAXATILIS, IN THE SACRAMENTO-SAN JOAQUIN DELTA

DONALD E. STEVENS

This paper describes the food habits of striped bass older than three months, in the Delta of the Sacramento and San Joaquin rivers. Most of the older descriptions (Smith, 1896; Scofield, 1910; Scofield and Coleman, 1910; Scofield and Bryant, 1926; Scofield, 1928, 1931; Shapovalov, 1936; Hatton, 1940; Johnson and Calhoun, 1952) of striped bass food habits in the Sacramento-San Joaquin estuary are merely qualitative or fragmentary. More recently, Heubach, Toth, and McCready (1963) examined a large number of stomachs of bass younger than 6 months from the Delta, but they examined few stomachs of older bass. Ganssle (1966) has described striped bass food habits in the estuary between the Delta and the lower end of San Pablo Bay, and Thomas (1967) has studied the diet of striped bass from the Sacramento and San Joaquin rivers above the Delta down to San Francisco Bay. To avoid duplication of my work, Thomas did not attempt Delta-wide coverage.

This paper is based on an analysis of stomach contents of 8,628 striped bass from eight types of Delta environments. The stomachs were collected from September 1963 through August 1964. The mysid shrimp, Neomysis awatschensis, and the amphipods, Corophium stimpsoni and Corophium spinicorne, were the most important foods of young bass. As bass grew their diet shifted to forage fishes, primarily small striped bass and the threadfin shad, Dorosoma petenense. The composition of the diet varied by season and area.

There is some evidence that N. awatschensis was a preferred food of young bass. Stomach contents differed for bass collected by different sampling gear. The amount of food in stomachs of year-old bass decreased significantly from the lower to the middle to the upper San Joaquin River. Differences in the length and coefficient of condition of bass from these same zones may be a direct result of the differences in food intake.

METHODS

Collecting methods are described by Turner (see p. 12). Stomachs were examined on the boat as the fish were removed from the nets. Most food organisms were counted and measured at this time. Only those food organisms that could not be identified on the boat were taken to the laboratory for analysis.

The data were analyzed by percent frequency of occurrence in the stomachs and percent of diet by volume. Volumes of the food organisms were not measured directly. For the most common foods, mean volumes were determined and they were multiplied by the number of organisms eaten [(Table 1)]. These means were determined from the volume of water displaced by a known number of each food organism freshly collected from the Delta. Volumes of foods eaten infrequently were visually estimated.

— 69 —

Variations in the digestion rates of food organisms were not compensated for in the analysis. In their study of young-of-the-year striped bass food habits, Heubach, *et al.* (1963) found under controlled conditions that Neomysis mercedis (now N. awatschensis) was recognizable 6 hours after ingestion whereas Corophium spinicorne could be identified after 8 hours. Large organisms, such as forage fishes, are probably recognizable longer after consumption than most small invertebrates, so the value of invertebrates as compared with forage fishes may be underestimated in the analysis by frequency of occurrence. This error was probably reduced in the volume analysis, since when making that analysis, each food item was considered to be at pre-ingestion size.

TABLE 1

Mean Volume Displacement (cc) of Food Organisms of Striped Bass

Food Organisms	
Invertebrates	
Cladocerans and Copepods	0.0005
Amphipods, *Corophium stimpsoni and Corophium spinicorne*	0.0034
Tendipedids	0.0030

Mysid Shrimp, *Neomysis awatschensis* (Length mm)	1–5	6–8	9–11	11–14	15–20
	0.0010	0.0028	0.0079	0.0152	0.0332

Fishes (Length cm)	2	3	4	5	6	7	8	9	10	11
Threadfin shad, *Dorosoma petenense*	—	0.25	0.8	1.5	2.8	4.4	7.2	10.5	14.0	19.0
American shad, *Alosa sapidissima*	—	0.25	0.5	1.1	2.4	3.6	5.1	7.3	9.9	13.7
Pond smelt, *Hypomesus transpacificus*	0.1	0.25	0.4	0.8	1.4	2.4	4.0	—	—	—
Striped bass, *Roccus saxatilis*	0.3	0.5	0.9	1.4	2.3	3.7	6.0	9.1	12.4	—

TABLE 1

Mean Volume Displacement (cc) of Food Organisms of Striped Bass

To be considered important, a food must be eaten by a significantly large proportion of the bass in significantly large amounts. No objective limits to what is and what is not "significantly large" were set, so my classification of a food as important is a matter of my own judgment after reviewing its frequency of occurrence in bass stomachs and the volume with which it was found.

In this paper, the diet of bass of different sizes during each season of the year is described first. Then local variations in diet that are essential to an understanding of the ecology of the Delta are described. After these seasonal and geographic differences in food habits are documented, this information is reviewed and conclusions are drawn about the individual important foods of striped bass. These sections are followed by sections on food selectivity, differences in stomach contents of bass caught by different sampling gear, and the growth of bass as related to their food intake.

GENERAL DELTA-WIDE FOOD HABITS

To obtain Delta-wide coverage of the food habits of each of four age-groups of bass, an attempt was made to examine 20 stomachs from bass of each age-group collected with each of three types of net at each

station each month. Most of the time, that many bass of each age-group were not caught with each type of net at each station, so the sample was somewhat smaller. Yet, the sample was still stratified, so to portray the diet with reasonable accuracy, the result from each stratum was weighted by the proportion of the total Delta bass population that it represented.

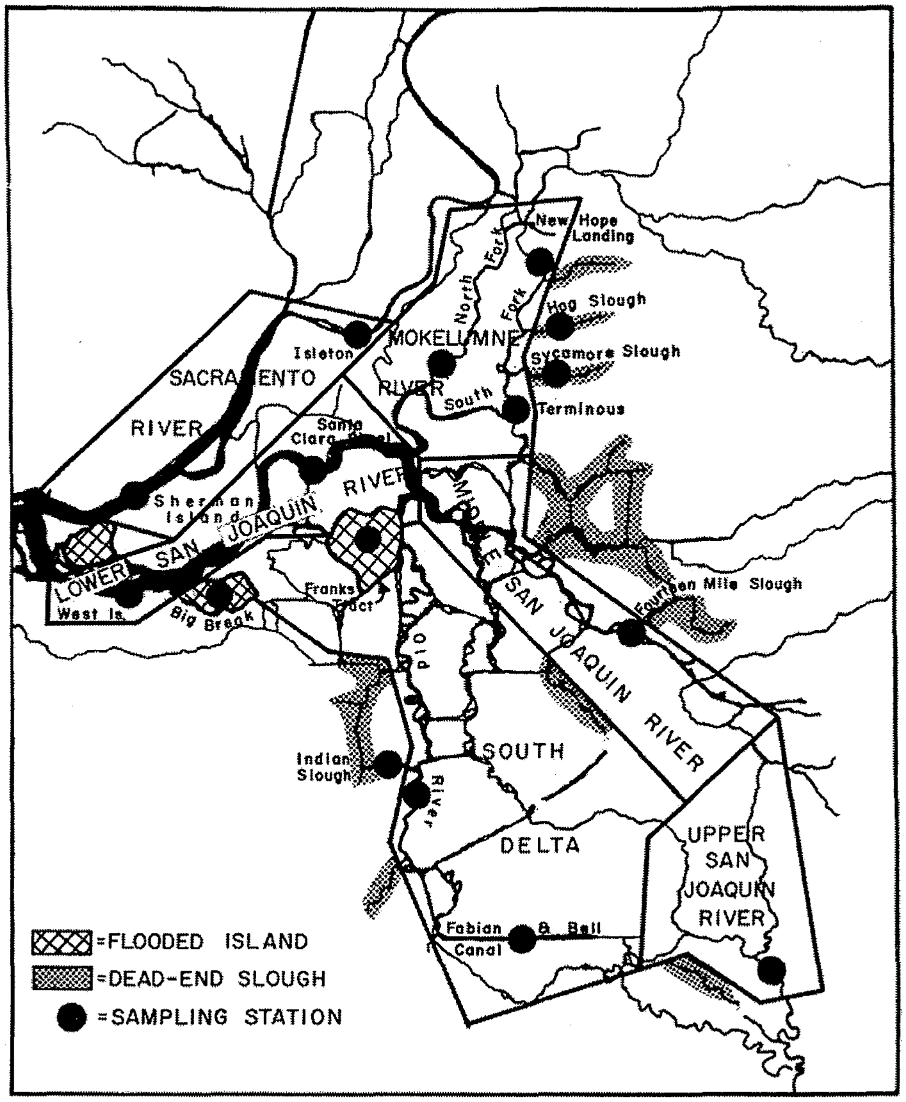

FIGURE 1. Location of sampling stations and areas of similar environments.

FIGURE 1. Location of sampling stations and areas of similar environments

Sasaki (see p. 50) has divided the Delta into eight environmental zones based on river systems and flow (Figure 1). From his catches of young bass and the area of each of these zones, he has estimated the percentage of the total population of young bass in the Delta in each zone during each season (see p. 54). He has done the same for juvenile

bass (see p. 65), and Radtke has done it for subadult and adult bass (see pp. 22 and 21). My analysis of the Delta-wide food habits of each age-group of striped bass is based on food habit data from each of these zones weighted by the percent of the total population found there.

The percentage of the population of bass in the Delta utilizing a food item was estimated by multiplying the percentage of the total Delta population of bass in each zone by the percent occurrence of the food item in the stomachs of bass in the appropriate zones and summing the products of these calculations.

TABLE 2

Method of Estimating Percentage of Bass Population Utilizing a Food Organism

Environmental Zone	Percentage of Population		Percent Frequency of Occurrence of Food Item in Stomach		
Lower San Joaquin River	42.7	×	96.3	=	41.1
Middle San Joaquin River	3.0	×	50.0	=	1.5
Upper San Joaquin River	1.0	×	0.0	=	0.0
Sacramento River	31.8	×	88.2	=	28.0
Mokelumne River	0.5	×	8.3	=	0.0
South Delta	6.2	×	42.9	=	2.7
Flooded Islands	13.1	×	66.7	=	8.7
Dead-end Sloughs	1.7	×	75.0	=	1.2
	Percentage of Population Utilizing Food Item			=	83.2

TABLE 2

Method of Estimating Percentage of Bass Population Utilizing a Food Organism

The percentage of the total diet volume formed by a food item was estimated in a similar manner. First the percentage of the total Delta population of bass in each zone was multiplied by the mean volume of that food item in the stomachs of bass from the appropriate zone, and the products were summed to obtain a total weighted mean volume

TABLE 3

Method of Estimating the Total Weighted Mean Volume of a Food Item

Environmental Zone	Percentage of Population		Mean Volume (cc) of Food Item A in Stomachs		Weighted Mean Volumes of Food A
Lower San Joaquin River	42.7	×	0.0317	=	0.135
Middle San Joaquin River	3.0	×	0.0171	=	0.005
Upper San Joaquin River	1.0	×	0.0000	=	0.000
Sacramento River	31.8	×	0.0444	=	0.141
Mokelumne River	0.5	×	0.0042	=	0.000
South Delta	6.2	×	0.0067	=	0.004
Flooded Islands	13.1	×	0.0198	=	0.026
Dead-end Sloughs	1.7	×	0.0701	=	0.012
	Total of Weighted Mean Volumes of Food A			=	0.323

TABLE 3

Method of Estimating the Total Weighted Mean Volume of a Food Item

[Table 3]. Then, to obtain the percentage of total volume formed by that food item, the total weighted mean volume was divided by the sum of the total weighted mean volumes of all food items [Table 4].

The estimates resulting from these calculations are presented in Tables 5 through 8 for all food organisms.

TABLE 4

Method of Estimating the Percentage of Total Diet Volume Formed by a Food Item

Food Item	Total of Weighted Mean Volume of Food Items[1]				Percent of Total Volume
Food A	0.323	÷	.855	=	38
Food B	0.129				15
Food C	0.403				47
Sum	0.855				

[1] See Table 3 for method of estimating total of weighted mean volumes.

TABLE 4

Method of Estimating the Percentage of Total Diet Volume Formed by a Food Item

Diet of Young Bass

Young bass are defined by Sasaki (see p. 44) as the 1963 year-class. They were hatched about 3 months before this study started in the fall of 1963 and were a few months past 1-year old when the study terminated in the summer of 1964. During this period, they grew from a range of 5 to 12 cm in September 1963 to a range of 12 to 23 cm in August 1964.

N. awatschensis was their most important food [(Table 5)]. This mysid was the only organism consumed in quantity by a large percentage of the young bass during every season.

Significant amounts of the amphipods, C. stimpsoni and C. spinicorne, were eaten by about a third to a half of the young bass. I judge Corophium to be the second most important food of young bass.

A very few of the young bass ate small threadfin shad as early as the fall of 1963 when threadfins were abundant (see Turner p. 160), and the bass themselves were only a few months old. During the winter and spring, the bass were larger, but small fish were not abundant and were rarely eaten. In the summer, the bass were even larger, and they fed occasionally on the new crops of threadfin shad and small striped bass.

During the winter, a few young bass fed extensively on pieces of sardine and anchovy bait discarded by anglers or stolen from their hooks.

In the fall, cladocerans and copepods were eaten by less than one percent of the young bass. In contrast, Heubach, *et al.* (1963) found that these plankton were eaten quite frequently by young bass during this season. The difference in my results could be due to differences in food availability from one year to another, but I believe the difference really reflects differences in food selection by bass of different sizes. The bass collected by Heubach, *et al.*, were all shorter than 11 cm (2.0–4.5 in). Because stomachs of bass shorter than 11 cm are too small to handle expediently in the field, most of the bass in my samples were longer than that length.

TABLE 5

Stomach Contents of Young Striped Bass in the Delta [1]

Food Items	Fall		Winter		Spring		Summer		Average	
	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol
Annelids										
Polychaete (*Neanthes limnicola*)	--	--	--	--	--	--	Tr	Tr	Tr	Tr
Unidentified Annelid	--	--	--	--	Tr	Tr	--	--	Tr	Tr
Crustaceans										
Cladocerans and/or Copepods	Tr	Tr	3	Tr	2	Tr	1	Tr	2	Tr
Mysid shrimp (*Neomysis awatschensis*)	85	36	84	44	86	81	65	30	80	48
Isopod (*Exosphaeroma oregonensis*)	--	--	Tr	1	--	--	--	--	Tr	Tr
Unidentified Isopod	--	--	--	--	--	--	Tr	Tr	Tr	Tr
Amphipods (*Corophium*)	39	13	30	5	37	7	56	7	40	8
Crayfish (*Pacifastacus leniusculus*)	--	--	--	--	Tr	Tr	Tr	Tr	Tr	Tr
Unidentifiable shrimp	--	--	--	--	Tr	2	Tr	Tr	Tr	1
Insects										
Tendipedids	2	Tr	2	Tr	2	Tr	8	Tr	4	Tr
Other insects	--	--	Tr	Tr	--	--	--	--	Tr	Tr
Molluscs										
Asiatic clam (*Corbicula fluminea*)	Tr	1	Tr	1	--	--	Tr	Tr	Tr	Tr
Fishes										
Threadfin shad (*Dorosoma petenense*)	1	45	--	--	--	--	6	41	2	22
American shad (*Alosa sapidissima*)	--	--	--	--	1	2	Tr	2	Tr	1
Unidentifiable Clupeids	--	--	--	--	--	--	Tr	Tr	Tr	Tr
Pond smelt (*Hypomesus transpacificus*)	--	--	--	--	--	--	Tr	Tr	Tr	Tr
White catfish (*Ictalurus catus*)	--	--	--	--	--	--	Tr	Tr	Tr	Tr
Striped bass (*Roccus saxatilis*)	--	--	--	--	--	--	7	19	2	5
Starry flounder (*Platichthys stellatus*)	--	--	--	--	Tr	Tr	--	--	Tr	Tr
Unidentifiable fishes	--	--	--	--	Tr	3	Tr	1	Tr	1
Fish eggs	--	--	--	--	Tr	Tr	--	--	Tr	Tr
Sardine and anchovy bait	1	6	3	49	Tr	4	Tr	Tr	1	15
Stomachs examined	320		946		1,303		1,274			
Percent containing food	85		73		84		81			

[1] Stomach content data for young bass in each of the eight environmental zones in the Delta were weighted by the percent of the total Delta population of young bass found there and summed (see text, p. 71).

TABLE 5

Stomach Contents of Young Striped Bass in the Delta

Diet of Juvenile Bass

Juvenile bass are the 1962 year-class (see Sasaki, p. 59). They were slightly more than 1 year old at the start of the study and had passed the end of their second year at the end of the study. Their lengths varied from 13 to 25 cm in September 1963 to 24 to 35 cm in August 1964.

N. awatschensis was a very important food each season [Table 5]. It was especially important in the winter and spring.

Juvenile bass often fed on fishes. In the fall, the distribution of the juveniles was such that a large percentage were in areas where threadfin shad were abundant; as a result threadfins were eaten by about one quarter of the population and by volume made up most of the diet. In the winter and spring, small fishes were scarce in the Delta and only a few were eaten. Large numbers of small striped bass of the new year-class became available in the summer (see Sasaki, p. 47); they were preyed upon by about one-quarter of the juveniles.

About one-quarter to one-third of the juveniles fed on some Corophium each season, but they consumed relatively small quantities, so Corophium were not really too important.

In the winter and spring, about 10 percent of the juveniles ate portions of sardine and anchovies which had been used for bait by anglers.

TABLE 6

Stomach Contents of Juvenile Bass in the Delta [1]

Food Items	Fall		Winter		Spring		Summer		Average	
	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol
Annelids										
Polychaete (*Neanthes limnicola*)	Tr	Tr	--	--	--	--	--	--	Tr	Tr
Crustaceans										
Cladocerans and/or Copepods	--	--	Tr	Tr	Tr	Tr	--	--	Tr	Tr
Mysid shrimp (*Neomysis awatschensis*)	39	2	84	11	79	29	64	11	66	13
Isopod (*Exosphaeroma oregonensis*)	--	--	--	--	Tr	Tr	--	--	Tr	Tr
Amphipods (*Corophium*)	22	Tr	27	Tr	31	Tr	31	2	28	1
Crayfish (*Pacifastacus leniusculus*)	Tr	Tr	--	--	Tr	1	Tr	Tr	Tr	Tr
Crab (*Rhithropanopeus harrisii*)	1	1	--	--	--	--	--	--	Tr	Tr
Unidentifiable shrimp	--	--	1	Tr	--	--	1	1	Tr	Tr
Insects										
Tendipedids	9	Tr	--	--	1	Tr	3	Tr	3	Tr
Other insects	--	--	1	Tr	--	--	--	--	Tr	Tr
Molluscs										
Asiatic clam (*Corbicula fluminea*)	Tr	Tr	--	--	--	--	Tr	Tr	Tr	Tr
Fishes										
Unidentified Ammocoete	--	--	--	--	Tr	Tr	Tr	Tr	Tr	Tr
Threadfin shad (*Dorosoma petenense*)	27	72	3	38	1	11	2	4	8	31
American shad (*Alosa sapidissima*)	2	3	--	--	--	--	1	4	1	2
King salmon (*Oncorhynchus tshawytscha*)	--	--	--	--	1	1	1	3	Tr	1
Pond smelt (*Hypomesus transpacificus*)	--	--	--	--	1	3	2	8	1	3
White catfish (*Ictalurus catus*)	--	--	--	--	--	--	Tr	Tr	Tr	Tr
Striped bass (*Roccus saxatilis*)	4	7	1	8	Tr	1	26	55	8	18
Unidentifiable fishes	15	14	1	7	5	29	6	11	7	15
Sardine and anchovy bait	2	1	13	36	9	24	Tr	Tr	6	15
Stomachs examined	655		365		544		473			
Percent containing food	69		71		70		61			

[1] Stomach content data for juvenile bass in each of the eight environmental zones in the Delta were weighted by the percent of the total Delta population of juvenile bass found there and summed (see text, p. 71).

TABLE 6

Stomach Contents of Juvenile Bass in the Delta

Diet of Subadult Bass

Subadult bass are defined by Radtke (see p. 15) as the 1961 year-class. These bass were 2 years old several months before the start of the study; they were 3 years of age shortly before the study terminated. In September, subadults were 26 to 37 cm long; by August they were 36 to 47 cm long.

Subadults fed primarily on fishes [Table 7]. In the fall, threadfin shad and small striped bass were abundant in the Delta and both were consumed by more than one-third of the subadult bass. In the winter, even though numbers of threadfin shad and small striped bass in the Delta decreased, they still made up most of the diet. The percentage of the subadults that ate small bass did decrease somewhat; however, the percentage of the subadults that fed on threadfins increased slightly. By spring, there were few threadfin shad and striped bass of a size suitable for food in the Delta. Correspondingly, the occurrence of these fishes in stomachs of subadults decreased appreciably. In the summer, when the new year-classes of striped bass and threadfin shad became available, they were preyed upon more frequently. Small bass were especially prevalent in the summer diet of the subadults.

A significant percentage of the subadults fed on N. awatschensis in the winter, spring, and summer, and on Corphium in the spring; but

— 75 —

because the amounts that were consumed were relatively small, I consider these crustaceans to be of minor importance.

TABLE 7

Stomach Contents of Sub-Adult Bass in the Delta [1]

Food Items	Fall		Winter		Spring		Summer		Average	
	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol
Crustaceans										
Mysid shrimp (*Neomysis awatschensis*)	6	Tr	22	Tr	37	2	34	2	25	1
Amphipods (*Corophium*)	2	Tr	5	Tr	21	Tr	13	Tr	10	Tr
Crayfish (*Pacifastacus leniusculus*)	1	Tr	Tr	Tr	2	6	Tr	Tr	1	2
Unidentifiable shrimp	Tr	Tr	2	Tr	--	--	--	--	1	Tr
Insects										
Other insects	--	--	--	--	--	--	1	--	Tr	Tr
Fishes										
Unidentified Ammocoete	--	--	--	--	Tr	Tr	--	--	Tr	Tr
Threadfin shad (*Dorosoma petenense*)	36	67	39	68	5	13	12	25	23	43
American shad (*Alosa sapidissima*)	3	2	1	1	--	--	--	--	1	1
Pacific herring (*Clupea pallasi*)	--	--	--	--	1	Tr	--	--	Tr	Tr
Unidentifiable Clupeids	Tr	Tr	6	2	--	--	3	4	2	2
King salmon (*Oncorhynchus tshawytscha*)	Tr	1	--	--	4	10	--	--	1	3
Pond smelt (*Hypomesus transpacificus*)	1	Tr	1	1	2	4	--	--	1	1
Carp (*Cyprinus carpio*)	Tr	Tr	--	--	--	--	--	--	Tr	Tr
White catfish (*Ictalurus catus*)	Tr	Tr	--	--	--	--	--	--	Tr	Tr
Striped bass (*Roccus saxatilis*)	39	23	20	22	14	41	42	54	29	35
Unidentifiable Centrarchids	--	--	--	--	--	--	Tr	Tr	Tr	Tr
Unidentifiable fishes	21	4	6	3	15	20	12	15	14	10
Sardine and anchovy bait	4	1	9	3	7	5	--	--	5	2
Stomachs examined	455		234		312		241			
Percent containing food	47		58		29		36			

[1] Stomach content data for sub-adult bass in each of the eight environmental zones in the Delta were weighted by the percent of the total Delta population of sub-adult bass found there and summed (see text, p. 71).

TABLE 7

Stomach Contents of Sub-Adult Bass in the Delta

Diet of Adult Bass

All bass older than 3 years in the fall of 1963 were classified as adult bass (see Radtke, p. 15). In the summer of 1964, at the end of the study, they were all older than 4 years. In September 1963, these bass were 38 cm or longer; in August 1964 they were 48 cm or longer.

The diet of adults was almost entirely fishes, especially small bass and threadfin shad [Table 8]. In the fall, small bass were eaten by almost one-half of the adults and threadfin shad were eaten by about one-quarter of the adults. In the winter, the percentage of the adults that fed on small bass decreased somewhat, but the percentage of adults that preyed upon threadfin shad increased; so both of these fishes were eaten by about one-third of the adults.

In the spring, when few threadfin shad and small bass were in the Delta, they were each eaten by about one-quarter of the adult bass. The occurrence of threadfin shad in the stomachs of adults decreased to 6 percent and that of small bass increased to 50 percent in the summer; however, only 21 stomachs with food were examined so these percentages may not be very meaningful.

Sardine and anchovy bait occurred in about one-sixth of the stomachs during the fall, winter, and summer. Bait did not occur in any stomachs in the spring sample.

TABLE 8

Stomach Contents of Adult Bass in the Delta [1]

Food Items	Fall		Winter		Spring		Summer		Average	
	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol
Crustaceans										
Mysid shrimp (*Neomysis awatschensis*)	--	--	--	--	16	Tr	--	--	4	Tr
Amphipods (*Corophium*)	--	--	--	--	7	Tr	--	--	2	Tr
Crayfish (*Pacifastacus leniusculus*)	Tr	Tr	--	--	Tr	Tr	--	--	Tr	Tr
Crab (*Rhithropanopeus harrisii*)	--	--	1	Tr	--	--	--	--	Tr	Tr
Unidentifiable shrimp	--	--	1	Tr	--	--	10	1	3	Tr
Fishes										
Unidentified Ammocoete	--	--	Tr	Tr	1	Tr	--	--	Tr	Tr
Threadfin shad (*Dorosoma petenense*)	24	15	34	56	24	27	6	4	22	26
American shad (*Alosa sapidissima*)	8	12	4	6	--	--	--	--	3	4
Unidentifiable Clupeids	--	--	14	2	--	--	--	--	4	Tr
King salmon (*Oncorhynchus tshawytscha*)	--	--	--	--	6	3	5	1	3	1
Pond smelt (*Hypomesus transpacificus*)	--	--	Tr	Tr	2	Tr	--	--	1	Tr
Carp (*Cyprinus carpio*)	--	--	Tr	1	--	--	--	--	Tr	Tr
Goldfish (*Carassius auratus*)	--	--	Tr	Tr	--	--	--	--	Tr	Tr
Sacramento blackfish (*Orthodon microlepidotus*)	--	--	--	--	Tr	Tr	--	--	Tr	Tr
Sacramento hitch (*Lavinia exilicauda*)	--	--	--	--	Tr	Tr	--	--	Tr	Tr
Striped bass (*Roccus saxatilis*)	44	56	32	26	25	56	50	43	38	45
Bluegill (*Lepomis macrochirus*)	Tr	1	--	--	1	5	--	--	Tr	2
Black crappie (*Pomoxis nigromaculatus*)	--	--	Tr	Tr	Tr	Tr	--	--	Tr	Tr
Three-spined stickleback (*Gasterosteus aculeatus*)	--	--	Tr	Tr	--	--	--	--	Tr	Tr
Unidentifiable fishes	30	9	8	4	18	9	12	3	17	6
Sardine and anchovy bait	18	7	17	5	--	--	16	49	13	15
Stomachs examined	223		574		531		174			
Percent containing food	41		37		12		12			

[1] Stomach content data for adult bass in each of the eight environmental zones in the Delta were weighted by the percent of the total Delta population of adult bass found there and summed (see text, p. 71).

TABLE 8

Stomach Contents of Adult Bass in the Delta

In both the spring and early summer, only a very small percentage of the stomachs contained food. Although few small fishes were available at this time, I do not believe that the scarcity of food in the stomachs was a result of poor forage conditions. If it was merely a lack of suitable forage that caused the reduced food intake, angler catches should be rather large in the Delta in the spring since adult bass are so abundant in the Delta during that season (see Radtke, p. 17; Calhoun, 1952). However, catches by anglers are actually quite small. The mean catch of bass on sport-fishing party boats in the Delta was not above 0.14 per angler hour during any spring between 1961 and 1964, and a creel census conducted by the California Department of Fish and Game, indicated that the catch on many days was as low as 0.05 bass per angler hour (Thomas Doyle, pers. commun.). A suggestion (Hollis, 1952) that striped bass do not feed heavily when they near spawning is relevant. Bass spawn in the Delta during April, May, and June (see Farley, p. 30), and most of the stomachs examined during the spring and summer were collected during these months.

GEOGRAPHICAL VARIATIONS IN DIET

In this section, the diet and abundance of bass and the abundance of their food organisms in each environmental zone of the Delta are reviewed.

Lower San Joaquin River [(Table 9)]

This zone was one of the most important nursery areas in the Delta for young bass (see Sasaki, p. 57); it was also a very important nursery for juvenile bass (see Sasaki, p. 64). The large quantities of N. awatschensis that were consumed by these bass reflected the large concentrations of N. awatschensis that were present (Turner and Heubach, 1966). Stomachs of the young bass contained as many as 100 or 150 individual N. awatschensis. Stomachs of the juvenile bass often held 200 to 300 N. awatschensis. Corophium were of some importance to young bass in the fall, but only small amounts were consumed by young bass during the rest of the year. The abundant young bass provided most of the forage for large bass.

Middle San Joaquin River [(Table 10)]

During the fall, winter, and spring, N. awatschensis was the most important invertebrate eaten by bass in this zone; however, only a small percentage of the young bass in the Delta were here until the summer (see Sasaki, p. 52) when concentrations of N. awatschensis in the environment (Turner and Heubach, 1966) had decreased from the relatively high winter and spring levels, and Corophium had become a more important food.

The large numbers of threadfin shad which were eaten here in the fall and winter reflected the extreme concentrations of this species in the environment (see Turner, p. 161). Stomachs of adult bass contained as many as 24 threadfins averaging 10 cm *FL*. In the fall, the threadfin shad was the most important food of juvenile bass, and in that season about one-half of the juveniles in the Delta were in this zone (Sasaki, p. 63). The bass in this area also ate a few of their own young.

Upper San Joaquin River [(Table 11)]

The upper San Joaquin River was not an important zone for bass of any age-group. Each season only a very small percentage of the bass in the Delta were here (see Sasaki, pp. 54 and 65; Radtke, pp. 21 and 22). The few young bass inhabiting this area fed primarily on Corophium. A significant percentage of these bass also fed on the tendipedid larvae and pupae which were fairly abundant in the bottom sediments (Hazel and Kelley, 1966). N. awatschensis was scarce (Turner and Heubach, 1966), and was consumed in quantity only by juvenile bass in the fall. Much of the diet of juveniles was formed by Corophium and sardine and anchovy bait. The threadfin shad was the most common forage fish in stomachs of large bass. It was consumed most frequently in the winter and spring.

South Delta [(Table 12)]

Relatively few bass of any size inhabited the south Delta (see Sasaki, pp. 54 and 55; Radtke, pp. 21 and 22). The young bass in this area usually fed on Corophium, although in the winter N. awatschensis was a more important food. N. awatschensis was never particularly abundant in the environment (Turner and Heubach, 1966), but it was still the most important food of juvenile bass.

TABLE 9

Stomach Contents of Striped Bass in the Lower San Joaquin River

Food Items	Young Bass								Juvenile Bass								Sub-Adult Bass								
	Fall		Winter		Spring		Summer		Fall		Winter		Spring		Summer		Fall		Winter		Spring		Summer		F
	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ
Crustaceans																									
Cladocerans and Copepods	--	--	--	--	1	Tr	--	--	--	--	--	--	1	Tr	--	--	--	--	--	--	--	--	--	--	--
Mysid shrimp (*Neomysis awatschensis*)	96	82	89	94	95	89	98	80	95	34	82	12	93	58	83	16	30	2	35	Tr	46	4	50	5	--
Unidentified Isopod	--	--	--	--	--	--	1	Tr	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Amphipods (*Corophium*)	30	18	28	6	29	4	32	2	21	3	24	Tr	34	Tr	23	Tr	6	Tr	6	Tr	11	Tr	5	Tr	--
Unidentifiable shrimp	--	--	--	--	Tr	2	--	--	--	--	1	Tr	--	--	--	--	2	Tr	6	Tr	--	--	--	--	--
Insects																									
Tendipedids	--	--	--	--	--	--	1	Tr	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Molluscs																									
Asiatic clam (*Corbicula fluminea*)	--	--	--	--	--	--	--	--	1	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Fishes																									
Unidentified Ammocoete	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	1	--	--	--	--	--	--	--	--	--
Threadfin shad (*Dorosoma petenense*)	--	--	--	--	--	--	--	--	1	8	1	35	--	--	--	--	--	--	12	9	4	9	5	11	--
American shad (*Alosa sapidissima*)	--	--	--	--	1	2	--	--	--	--	--	--	--	--	--	--	11	12	--	--	--	--	--	--	14
Pacific herring (*Clupea pallasi*)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	4	Tr	--	--	--
King salmon (*Oncorhynchus tshawytscha*)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2	10	--	--	11	25	--	--	--
Carp (*Cyprinus carpio*)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2	1	--	--	--	--	--	--	--
Striped bass (*Roccus saxatilis*)	--	--	--	--	--	--	7	18	1	24	1	16	--	--	21	68	53	70	41	85	18	46	40	60	68
Unidentifiable fishes	--	--	--	--	Tr	1	Tr	1	2	22	--	--	4	32	8	14	6	5	--	--	7	7	10	24	36
Sardine and anchovy bait	--	--	--	--	Tr	2	--	--	2	11	12	38	4	9	--	--	2	1	12	5	14	8	--	--	4
Stomachs examined	105		292		279		211		174		132		164		185		82		35		59		52		[illegible]
Percent containing food	75		63		78		85		87		70		79		66		57		49		48		38		[illegible]

TABLE 9

Stomach Contents of Striped Bass in the Lower San Joaquin River

TABLE 10

Stomach Contents of Striped Bass in the Middle San Joaquin River

Food Items	Young Bass								Juvenile Bass								Sub-Adult Bass								F
	Fall		Winter		Spring		Summer		Fall		Winter		Spring		Summer		Fall		Winter		Spring		Summer		
	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ
Crustaceans																									
Cladocerans and Copepods	--	--	--	--	5	Tr	2	Tr	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Mysid shrimp (*Neomysis awatschensis*)	50	1	94	14	81	69	40	5	14	Tr	82	12	56	3	21	2	--	--	20	Tr	40	Tr	--	--	--
Isopod (*Exosphaeroma oregonensis*)	--	--	--	--	--	--	--	--	--	--	--	--	5	2	--	--	--	--	--	--	--	--	--	--	--
Amphipods (*Corophium*)	50	1	33	1	53	19	68	9	17	Tr	37	Tr	46	1	29	3	--	--	8	Tr	40	Tr	14	Tr	--
Crayfish (*Pacifastacus leniusculus*)	--	--	--	--	--	--	--	--	--	--	--	--	2	8	--	--	--	--	--	--	--	--	--	--	--
Crab (*Rhithropanopeus harrisii*)	--	--	--	--	--	--	--	--	2	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Insects																									
Tendipedids	--	--	--	--	1	Tr	14	Tr	12	Tr	--	--	--	--	12	Tr	5	Tr	--	--	--	--	--	--	--
Fishes																									
Threadfin shad (*Dorosoma petenense*)	25	98	--	--	--	--	14	75	43	76	4	30	5	22	21	30	84	95	69	93	--	--	21	42	61
American shad (*Alosa sapidissima*)	--	--	--	--	--	--	--	--	2	3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1[illegible]
Unidentifiable Clupeids	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	21	19	--
Pond smelt (*Hypomesus transpacificus*)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	4	2	--	--	--	--	--
White catfish (*Ictalurus catus*)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	4	3	--	--	--	--	--	--	--	--	--
Striped bass (*Roccus saxatilis*)	--	--	--	--	--	--	5	11	5	5	--	--	2	4	4	42	6	1	3	2	--	--	21	19	1[illegible]
Unidentifiable fishes	--	--	--	--	--	--	--	--	24	14	2	14	7	33	12	21	26	3	9	3	60	100	21	20	--
Sardine and anchovy bait	--	--	27	85	1	12	--	--	--	--	12	37	26	30	--	--	--	--	3	Tr	--	--	--	--	--
Stomachs examined	14		37		92		143		98		64		61		84		90		68		32		59		
Percent containing food	57		89		86		78		43		77		70		38		54		52		16		24		

TABLE 10

Stomach Contents of Striped Bass in the Middle San Joaquin River

TABLE 11

Stomach Contents of Striped Bass in the Upper San Joaquin River

Food Items	Young Bass								Juvenile Bass								Sub-Adult Bass								
	Fall		Winter		Spring		Summer		Fall		Winter		Spring		Summer		Fall		Winter		Spring		Summer		
	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ
Annelids																									
Unidentified Annelid	--	--	--	--	1	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Crustaceans																									
Cladocerans and Copepods	--	--	20	2	2	Tr	--	--	--	--	20	Tr	5	Tr	--	--	--	--	--	--	--	--	--	--	--
Mysid shrimp (*Neomysis awatschensis*)	--	--	8	1	36	10	5	Tr	35	49	40	2	16	4	12	Tr	--	--	--	--	--	--	--	--	--
Amphipods (*Corophium*)	86	3	92	43	89	38	87	9	8	Tr	20	Tr	84	5	88	4	33	Tr	--	--	--	--	--	--	--
Insects																									
Tendipedids	14	Tr	23	2	39	8	52	1	54	5	10	Tr	10	Tr	25	Tr	--	--	--	--	--	--	--	--	--
Molluscs																									
Asiatic clam (*Corbicula fluminea*)	--	--	--	--	--	--	--	--	8	Tr	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Fishes																									
Threadfin shad (*Dorosoma petenense*)	--	--	--	--	--	--	7	42	--	--	10	20	5	34	12	62	--	--	100	100	100	100	--	--	--
Carp (*Cyprinus carpio*)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Striped bass (*Roccus saxatilis*)	--	--	--	--	--	--	7	42	--	--	--	--	--	--	--	--	67	100	--	--	--	--	--	--	100
Unidentifiable fishes	--	--	--	--	1	39	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Fish eggs	--	--	--	--	1	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Sardine and anchovy bait	29	97	3	52	--	--	1	6	8	46	60	77	16	57	12	33	--	--	--	--	--	--	--	--	--
Stomachs examined	7		63		113		105		13		17		38		11		9		9		15		2		
Percent containing food	100		97		94		72		100		59		50		73		33		89		27		0		

TABLE 11

Stomach Contents of Striped Bass in the Upper San Joaquin River

TABLE 12

Stomach Contents of Striped Bass in the South Delta

Food Items	Young Bass								Juvenile Bass								Sub-Adult Bass								F
	Fall		Winter		Spring		Summer		Fall		Winter		Spring		Summer		Fall		Winter		Spring		Summer		
	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ
Annelids																									
Polychaete (*Neanthes limnicola*)	--	--	--	--	--	--	1	Tr	2	Tr	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Crustaceans																									
Cladocerans and Copepods	--	--	10	2	Tr	Tr	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Mysid shrimp (*Neomysis awatschensis*)	43	6	75	31	58	20	58	12	39	6	83	40	59	24	80	62	--	--	33	8	100	100	--	--	--
Isopod (*Exosphaeroma oregonensis*)	--	--	1	4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Amphipods (*Corophium*)	99	26	51	17	78	23	81	18	46	1	44	3	59	2	80	9	--	--	33	Tr	--	--	33	Tr	--
Crayfish (*Pacifastacus leniusculus*)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	33	65	--	--	--	--	--
Insecta																									
Tendipedids	14	1	3	Tr	14	1	18	1	32	2	--	--	19	Tr	--	--	--	--	--	--	--	--	--	--	--
Molluscs																									
Asiatic clam (*Corbicula fluminea*)	--	--	1	23	--	--	2	1	2	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Fishes																									
Unidentified Ammocoete	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Threadfin shad (*Dorosoma petenense*)	--	--	--	--	--	--	1	1	--	--	--	--	--	--	--	--	17	57	33	26	--	--	--	--	--
Unidentifiable Clupeids	--	--	--	--	--	--	1	6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Pond smelt (*Hypomesus transpacificus*)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Striped bass (*Roccus saxatilis*)	--	--	--	--	--	--	6	37	2	40	--	--	--	--	20	29	50	27	--	--	--	--	67	100	100
Bluegill (*Lepomis macrochirus*)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Unidentifiable fishes	--	--	--	--	1	28	3	22	2	16	--	--	3	9	--	--	33	16	--	--	--	--	--	--	--
Sardine and anchovy bait	7	66	1	23	Tr	28	1	4	11	33	6	48	12	64	--	--	--	--	--	--	--	--	--	--	--
Stomachs examined	17		128		210		157		59		23		50		8		10		4		31		7		
Percent containing food	82		88		87		74		75		78		64		62		60		75		3		43		

TABLE 12

Stomach Contents of Striped Bass in the South Delta

Few stomachs of the older bass had food. Threadfin shad were the most important forage fish. They were present in 11 of the 22 stomachs of adult bass, and 2 of the 13 stomachs of subadult bass that contained food. All except one were eaten during the winter. In the fall, winter, and summer, a few of the stomachs contained small bass.

Sacramento River [(Table 13)]

In the fall, about one-third of the young bass in the Delta were in the Sacramento River, but during the rest of the year this proportion was much smaller (See Sasaki, p. 54). The proportion of the juvenile bass in this area was quite small in the fall, but it increased each season until the summer when it peaked at about one-quarter of the population in the Delta (see Sasaki, p. 65). N. awatschensis was quite abundant in the environment (Turner and Heubach, 1966) and was the most important food of these age-groups. These bass also consumed a fair number of Corophium. Young striped bass were the predominant forage fish.

Mokelumne River [(Table 14)]

The Mokelumne River was of small importance as a nursery area for young and juvenile bass (see Sasaki, pp. 58 and 66). Turner and Heubach (1966) found that N. awatschensis was scarce here in all seasons, but this mysid was the most important food of the juveniles from this area and of those young bass here in the winter and spring. In the fall and summer, young bass fed more often on Corophium.

Only a few stomachs from the older bass contained food. The threadfin shad was the most common of the forage fishes in them.

Flooded Islands [(Table 15)]

The proportion of the Delta population of young and juvenile bass in flooded islands varied seasonally from 5 to 18 percent. These bass fed largely on N. awatschensis in the winter and spring. In the fall and summer, Corophium were a more important food source. In contrast, Turner and Heubach (1966) did not collect any N. awatschensis in these areas during the winter, but they did collect a few in the other seasons.

Depending on season, from 20 to 52 percent of the subadult and adult bass in the Delta inhabited the flooded islands (see Radtke, pp. 21 and 22). These bass preyed primarily on small striped bass and threadfin shad.

Dead-end Sloughs [Table 16]

Few bass of any size populated the dead-end sloughs (see Sasaki, pp. 54 and 65; Radtke, pp. 21 and 22). N. awatschensis was the most important invertebrate utilized as food, although it was never abundant in the environment (Turner and Heubach, 1966). Corophium were only of small importance as a food. The threadfin shad, which was so abundant in these sloughs (see Turner, p. 161) was, by far, the most important forage fish. Stomachs of adult and subadult bass often contained more than 10 threadfins. Juvenile bass in these sloughs also consumed a substantial number of threadfins. A few individuals of many other species of fishes were also eaten by the larger bass.

TABLE 13

Stomach Contents of Striped Bass in the Sacramento River

Food Items	Young Bass								Juvenile Bass								Sub-Adult Bass								
	Fall		Winter		Spring		Summer		Fall		Winter		Spring		Summer		Fall		Winter		Spring		Summer		Fa
	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ
Annelids																									
Unidentified Annelid	--	--	--	--	1	6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Crustaceans																									
Cladocerans and Copepods	--	--	--	--	18	Tr	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Mysid shrimp (*Neomysis awatschensis*)	88	79	51	54	75	70	86	55	53	13	36	7	53	4	57	10	--	--	10	Tr	30	1	27	1	14
Isopod (*Exosphaeroma oregonensis*)	--	--	3	6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Amphipods (*Corophium*)	31	21	38	6	30	10	33	2	38	5	27	Tr	18	Tr	17	Tr	--	--	--	--	30	Tr	--	--	--
Crayfish (*Pacifastacus leniusculus*)	--	--	--	--	1	7	--	--	--	--	--	--	--	--	--	--	5	5	--	--	10	20	--	--	14
Unidentifiable shrimp	--	--	--	--	--	--	1	Tr	--	--	--	--	--	--	2	2	--	--	10	3	--	--	--	--	--
Insects																									
Tendipedids	3	Tr	14	2	4	Tr	--	--	9	Tr	--	--	--	--	5	Tr	--	--	--	--	--	--	--	--	--
Other Insects	--	--	1	2	--	--	1	Tr	--	--	9	2	--	--	--	--	--	--	--	--	--	--	--	--	--
Fishes																									
Threadfin shad (*Dorosoma petenense*)	--	--	--	--	--	--	--	--	2	31	--	--	3	25	--	--	--	--	--	--	--	--	20	14	--
American shad (*Alosa sapidissima*)	--	--	--	--	1	7	4	10	--	--	--	--	--	--	2	7	5	6	20	28	--	--	--	--	--
King salmon (*Oncorhynchus tshawytscha*)	--	--	--	--	--	--	--	--	--	--	--	--	3	3	2	10	--	--	--	--	--	--	--	--	--
Pond smelt (*Hypomesus transpacificus*)	--	--	--	--	--	--	1	2	--	--	--	--	3	11	7	23	5	1	--	--	10	21	--	--	--
Striped bass (*Roccus saxatilis*)	--	--	--	--	--	--	12	30	6	30	--	--	--	--	38	42	65	75	20	25	20	43	67	78	43
Unidentifiable fishes	--	--	--	--	--	--	1	1	2	5	9	30	9	24	5	7	20	4	--	--	--	--	7	7	--
Sardine and anchovy bait	--	--	1	31	--	--	--	--	6	16	27	60	18	34	--	--	10	9	40	44	10	6	--	--	29
Stomachs examined	75		129		145		140		64		27		60		62		52		18		39		27		[illegible]
Percent containing food	91		57		77		89		83		41		57		68		38		56		20		56		[illegible]

TABLE 13

Stomach Contents of Striped Bass in the Sacramento River

TABLE 14

Stomach Contents of Striped Bass in the Mokelumne River

Food Items	Young Bass								Juvenile Bass								Sub-Adult Bass								
	Fall		Winter		Spring		Summer		Fall		Winter		Spring		Summer		Fall		Winter		Spring		Summer		Fa
	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ
Crustaceans																									
Cladocerans and Copepods	--	--	--	--	--	--	5	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Mysid shrimp (*Neomysis awatschensis*)	8	2	98	55	74	43	47	13	78	46	88	41	71	5	41	3	--	--	--	--	--	--	--	--	--
Isopod (*Exosphaeroma oregonensis*)	--	--	--	--	--	--	1	Tr	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Amphipods (*Corophium*)	92	18	12	1	54	19	70	11	24	3	4	Tr	32	Tr	35	1	17	Tr	--	--	--	--	--	--	--
Crayfish (*Pacifastacus leniusculus*)	--	--	--	--	--	--	2	8	--	--	--	--	3	Tr	6	9	--	--	--	--	12	30	50	10	--
Insects																									
Tendipedids	4	Tr	--	--	3	Tr	17	Tr	--	--	--	--	--	--	12	Tr	--	--	--	--	--	--	--	--	--
Molluscs																									
Asiatic clam (*Corbicula fluminea*)	8	80	--	--	--	--	--	--	--	--	--	--	--	--	6	6	--	--	--	--	--	--	--	--	--
Fishes																									
Unidentified Ammocoete	--	--	--	--	--	--	--	--	--	--	--	--	3	3	--	--	--	--	--	--	38	9	--	--	--
Threadfin shad (*Dorosoma petenense*)	--	--	--	--	--	--	1	7	--	--	--	--	3	25	--	--	17	14	--	--	12	18	50	30	--
American shad (*Alosa sapidissima*)	--	--	--	--	--	--	6	40	--	--	--	--	--	--	6	3	--	--	--	--	--	--	--	--	--
King salmon (*Oncorhynchus tshawytscha*)	--	--	--	--	--	--	--	--	--	--	--	--	3	24	--	--	--	--	--	--	--	--	--	--	--
White catfish (*Ictalurus catus*)	--	--	--	--	--	--	2	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Striped bass (*Roccus saxatilis*)	--	--	--	--	--	--	2	18	--	--	--	--	--	--	24	49	17	18	--	--	--	--	--	--	--
Black crappie (*Pomoxis nigromaculatus*)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Starry flounder (*Platichthys stellatus*)	--	--	--	--	1	6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Unidentifiable fishes	--	--	--	--	--	--	--	--	--	--	--	--	--	--	12	30	50	68	--	--	25	20	100	60	100 1
Sardine and anchovy bait	--	--	2	44	1	31	--	--	6	51	12	59	21	42	--	--	--	--	--	--	25	24	--	--	--
Stomachs examined	28		70		120		153		35		34		47		19		16		0		22		10		11
Percent containing food	86		83		80		80		49		74		70		90		38		--		38		20		1

TABLE 14

Stomach Contents of Striped Bass in the Mokelumne River

TABLE 15

Stomach Contents of Striped Bass in Flooded Islands

Food Items	Young Bass								Juvenile Bass								Sub-Adult Bass								
	Fall		Winter		Spring		Summer		Fall		Winter		Spring		Summer		Fall		Winter		Spring		Summer		Fa
	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ
Crustaceans																									
Cladocerans and Copepods	5	Tr	--	--	6	4	--	--	--	--	--	--	2	Tr	--	--	--	--	--	--	--	--	--	--	--
Mysid shrimp (*Neomysis awatschensis*)	67	40	99	58	96	83	71	17	29	1	69	11	89	35	47	6	2	Tr	18	Tr	31	Tr	31	Tr	--
Amphipods (*Corophium*)	87	59	8	2	23	3	76	11	61	5	8	Tr	24	2	70	16	2	Tr	4	Tr	40	Tr	54	Tr	--
Crab (*Rhithropanopeus harrisii*)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Unidentifiable shrimp	--	--	--	--	--	--	--	--	--	--	4	3	--	--	--	--	--	--	--	--	--	--	--	--	--
Insects																									
Tendipedids	--	--	1	Tr	--	--	3	Tr	--	--	--	--	--	--	6	Tr	--	--	--	--	--	--	8	Tr	--
Fishes																									
Threadfin shad (*Dorosoma petenense*)	--	--	--	--	--	--	--	--	10	36	--	--	--	--	--	--	33	51	22	24	10	10	15	32	12
American shad (*Alosa sapidissima*)	--	--	--	--	--	--	Tr	8	3	11	--	--	--	--	2	11	--	--	--	--	--	--	--	--	6
Unidentifiable Clupeids	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	18	12	--	--	--	--	--
Striped bass (*Roccus saxatilis*)	--	--	--	--	--	--	11	64	3	14	4	25	--	--	32	66	44	41	30	50	20	74	38	55	59
Unidentifiable fishes	--	--	--	--	1	10	Tr	Tr	5	20	--	--	4	54	2	Tr	24	6	7	8	10	15	15	13	35
Sardine and anchovy bait	--	--	2	40	--	--	--	--	10	13	23	61	2	9	--	--	5	2	11	6	--	--	--	--	59
Stomachs examined	63		148		188		200		124		33		63		87		128		57		64		45		4[illegible]
Percent containing food	100		78		94		92		75		79		86		61		43		47		16		29		3[illegible]

TABLE 15

Stomach Contents of Striped Bass in Flooded Islands

TABLE 16

Stomach Contents of Striped Bass in Dead-End Sloughs

Food Items	Young Bass								Juvenile Bass								Sub-Adult Bass								
	Fall		Winter		Spring		Summer		Fall		Winter		Spring		Summer		Fall		Winter		Spring		Summer		Fa
	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ
Crustaceans																									
Cladocerans and Copepods	--	--	--	--	2	Tr	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Mysid shrimp (*Neomysis awatschensis*)	75	39	93	95	88	97	82	8	16	Tr	68	2	54	7	38	2	4	Tr	20	Tr	13	Tr	5	Tr	--
Amphipods (*Corophium*)	12	6	26	5	24	3	19	Tr	13	Tr	4	Tr	20	Tr	6	Tr	4	Tr	--	--	13	Tr	10	1	6
Crayfish (*Pacifastacus leniusculus*)	--	--	--	--	--	--	--	--	3	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Insects																									
Tendipedids	--	--	--	--	2	Tr	6	Tr	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Molluscs																									
Asiatic clam (*Corbicula fluminea*)	--	--	--	--	--	--	--	--	3	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Fishes																									
Unidentified Ammocoete	--	--	--	--	--	--	--	--	--	--	--	--	5	8	--	--	--	--	--	--	--	--	--	--	--
Threadfin shad (*Dorosoma petenense*)	12	55	--	--	--	--	13	78	50	70	36	98	3	21	44	57	71	83	77	97	70	91	60	81	36
American shad (*Alosa sapidissima*)	--	--	--	--	--	--	3	3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Unidentifiable Clupeids	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	7	2	--	--	--	--	5	4	--
Pond smelt (*Hypomesus transpacificus*)	--	--	--	--	--	--	1	2	--	--	--	--	--	--	6	25	--	--	--	--	--	--	--	--	--
Carp (*Cyprinus carpio*)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Goldfish (*Carassius auratus*)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Hitch (*Lavinia exilicauda*)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Sacramento blackfish (*Orthodon microlepidotus*)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
White catfish (*Ictalurus catus*)	--	--	--	--	--	--	1	1	--	--	--	--	--	--	--	--	4	1	--	--	--	--	--	--	--
Striped bass (*Roccus saxatilis*)	--	--	--	--	--	--	7	6	5	9	--	--	3	10	--	--	7	7	3	1	--	--	10	7	21
Bluegill (*Lepomis macrochirus*)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	6
Black crappie (*Pomoxis nigromaculatus*)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Unidentifiable Centrarchids	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	10	5	--
Three-spined stickleback (*Gasterosteus aculeatus*)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Unidentifiable fishes	--	--	--	--	--	--	2	2	18	17	--	--	13	40	19	13	18	8	6	2	13	8	10	3	29
Sardine and anchovy bait	--	--	--	--	--	--	--	--	3	1	--	--	8	14	6	3	--	--	--	--	4	1	--	--	--
Stomachs examined	11		79		156		109		88		35		61		37		68		43		50		39		54
Percent containing food	73		87		78		62		43		80		62		43		41		81		46		51		2[illegible]

TABLE 16

Stomach Contents of Striped Bass in Dead-End Sloughs

— 87 —

IMPORTANCE OF INDIVIDUAL FOODS

In any season, only five items ever occurred in more than 10 percent of the stomachs of bass of any age. These items were N. awatschensis, Corophium, small striped bass, threadfin shad, and discarded or stolen sardine and anchovy bait. In this section their importance to each of the four age groups of bass is reviewed.

Neomysis awatschensis

N. awatschensis was by far the most important food of young bass. During the fall, winter and spring, it was consumed by more than 84 percent of the young bass. In the summer, even though concentrations of N. awatschensis peaked in the environment (Turner and Heubach, 1966), its occurrence in the stomachs of young bass decreased to 65 percent. This decrease reflected a change in the relative abundance and distribution of the young bass. In the fall, winter and spring, a large percentage of the young bass in the Delta inhabited the lower San Joaquin River where concentrations of N. awatschensis were high. In the summer, the percentage of the bass in this area decreased considerably and the percentage increased in the middle San Joaquin River (see Sasaki, p. 54) where N. awatschensis was not as available.

N. awatschensis was also a very important food of juvenile bass. In the winter and spring, more than 79 percent of the juveniles consumed N. awatschensis. During the fall and summer, when forage fishes were readily available, fewer juveniles fed on N. awatschensis.

N. awatschensis was eaten by a few subadult and adult bass, but it was not an important part of their diet.

Corophium

Corophium were eaten by large numbers of young and juvenile bass, especially by young bass in those areas of the Delta where N. awatschensis was scarce. They were consumed by a few subadult and adult bass also. These amphipods are too small to be a very important food of any but the young bass.

Small Striped Bass

Young striped bass were one of the important foods of adult and subadult bass. In the fall, they were eaten by about two-fifths of the subadults and adults. In the winter and spring, as the young bass became less abundant and larger (see Sasaki, p. 49), they were eaten less frequently. In the summer, when the new year-class of young bass became available, there was a sharp increase in the percentage of the subadults and adults that had eaten small bass. These new young-of-the-year bass were also of importance as a food of juvenile bass.

Threadfin Shad

Threadfin shad were also a very important food source for subadult and adult bass. They were especially important in the fall when they were extremely abundant in the middle San Joaquin River and the dead-end sloughs, and in the winter when their numbers were decreasing (see Turner, p. 164). In the winter, numbers of small bass also decreased (see Sasaki, p. 49), so the threadfins were still one of the more available forage species. In the fall, the threadfins were also

quite prominent in the diet of juvenile bass. They were eaten by only a very few young bass.

Sardine and Anchovy Bait

A surprisingly large percentage of the adult bass had eaten quantities of sardine and anchovy bait which had either been discarded by anglers or stolen from their hooks. In the winter and spring, bait was also consumed by a small but significant percentage of the juvenile bass. It was eaten by relatively few young or subadult bass.

FOOD SELECTIVITY

Some organisms in the Delta that were of a size suitable for food were seldom eaten. For example, small American shad were very abundant during the summer and fall (see Stevens, p. 101), but few were consumed by bass. Similarly, Hazel and Kelley (1966) collected zoobenthos from the Delta belonging to 35 taxa; they found that the two species of Corophium, tendipedids, Corbicula fluminea, and oligochaetes were abundant; however, bass stomachs contained benthic organisms belonging to only 8 taxa and Corophium were the only benthos utilized in appreciable quantity.

Young bass seem to prefer N. awatschensis over Corophium [Table 17]. Indices of concentrations of N. awatschensis and Corophium in the environment when compared with the frequency of occurrence of these organisms in the stomachs of young bass, show that young bass fed primarily on Corophium only if Corophium were abundant and N. awatschensis was scarce. If N. awatschensis and Corophium were abundant, if N. awatschensis was abundant and Corophium were not, and if N. awatschensis and Corophium were scarce, young bass fed primarily on N. awatschensis.

TABLE 17

Occurrence of *Neomysis awatschensis* and *Corophium* in Stomachs of Young Striped Bass Compared with the Abundance of *N. awatschensis* [1] and *Corophium* [2] in the Environment

Area	Mean Seasonal Percent Frequency of Occurrence of N. *awatschensis* in Stomachs of Young Bass	Mean Seasonal Percent Frequency of Occurrence of *Corophium* in Stomachs of Young Bass	Abundance of N. *awatschensis* in Environment	Abundance of *Corophium* in Environment
Lower San Joaquin River	94.8	29.5	A	A
Dead-End Sloughs	84.3	20.4	S	S
Sacramento River	75.2	32.8	A	A
Franks Tract	73.3	55.5	S	S
Middle San Joaquin River	66.1	51.3	A	S
North Fork of Mokelumne River and South Fork of Mokelumne River at New Hope Landing	59.7	45.1	S	S
Old River-Fabian and Bell Canal	58.4	72.0	S	A
Mokelumne River at Terminous	52.3	65.2	S	A
Upper San Joaquin River	12.3	88.2	S	A

[1] Based on mean season catch of N. *awatschensis* with a Clarke-Bumpus plankton net (Turner and Heubach, 1966).
A = abundant (28–75 N. *awatschensis* per cubic meter of water).
S = scarce (0– 6 N. *awatschensis* per cubic meter of water).
[2] Based on mean numbers of *Corophium* caught with a Peterson dredge by Hazel and Kelley (1966).
A = abundant (30–57 *Corophium* per square foot).
S = scarce (6–20 *Corophium* per square foot).

TABLE 17

Occurrence of Neomysis awatschensis and Corophium in Stomachs of Young Striped Bass Compared with the Abundance of N. awatschensis and Corophium in the Environment

Small bass and threadfin shad were eaten at a rate more directly related to their density in the environment. Turner (see p. 161) indicates that threadfin were most concentrated in the middle San Joaquin River and dead-end sloughs, and in these areas large bass preyed on them heaviest. Sasaki (see p. 49) has shown that the greatest concentrations of small bass occurred in the lower San Joaquin River, Sacramento River, and flooded islands, and they were utilized by large bass more frequently in these areas than in the rest of the Delta.

EFFECT OF SAMPLING GEAR ON RESULTS

It has been shown in this paper that bass stomach contents differed in the various environmental zones of the Delta. These differences are probably an effect of differences in the availability of foods in the different zones, and food preferences.

There were also differences in the availability of different kinds of food organisms within each zone, particularly at different depths of the channels. N. awatschensis (Turner and Heubach, 1966) and Corophium are generally most abundant near the bottom of the channels, the vertical distribution of small striped bass is quite variable (Chadwick, 1964; see Sasaki, p. 46), and threadfin shad are most abundant at the surface (see Turner, p. 160). Because the otter trawl collected bass from near the bottom of the channels and the midwater trawl collected bass from near the surface, it was possible to compare the stomach contents of bass collected at different depths, and consequently determine if the results of this study might have been influenced by the proportion of the sample collected by each type of trawl. Chi square, two-way classification tests were used to determine if in the summer of 1964 the proportion of young bass utilizing each of the important food organisms was significantly different from each type of trawl.

The tests indicated three major differences in stomach contents [Table 18]. The proportion of the stomachs that contained threadfin shad was significantly larger in the sample from the midwater trawl than in the sample from the otter trawl, and the proportions of the stomachs that contained N. awatschensis and Corophium were significantly larger in the sample from the otter trawl than in the sample from the midwater trawl.

TABLE 18

Frequency of Important Foods Compared for Stomachs of Young Striped Bass Collected in the Midwater and Otter Trawls in Summer, 1964 in All Environmental Zones

Food Item	Midwater Trawl		Otter Trawl		X^2	Percentile (1 d.f.)
	Obs. Freq.	Exp. Freq.	Obs. Freq.	Exp. Freq.		
N. awatschensis	213	236	433	410	10.13	0.995
Corophium	183	211	393	365	13.38	0.995
Threadfin Shad	31	13	5	22	37.32	0.995
Striped Bass	25	27	48	46	0.09	—
Stomachs Containing Food	360		624			

TABLE 18

Frequency of Important Foods Compared for Stomachs of Young Striped Bass Collected in the Midwater and Otter Trawls in Summer, 1964 in All Environmental Zones

These differences in stomach contents could have resulted directly (i) from bass caught at different depths having fed on different organisms or (ii) from bass caught in the midwater trawl having formed a larger than normal proportion of the sample from zones where threadfin shad were most available and/or from bass caught in the otter trawl having formed a larger than normal proportion of the sample from zones where N. awatschensis and Corophium were most available.

Further inspection of the data revealed that in the two zones, (middle San Joaquin River and dead-end sloughs) where threadfin shad were most densely distributed, the proportion of the sample formed by bass caught in the midwater trawl was, in fact, large. Bass caught in the midwater trawl formed 47 percent of the trawl-caught sample in these two zones; whereas they made up only 37 percent of the trawlcaught sample for all zones combined. Therefore, the proportion of bass utilizing each food organism was also compared for the midwater and otter trawl samples from the middle San Joaquin River and dead-end sloughs only. Chi square tests indicated that the same three differences in stomach contents were significant [Table 19].

TABLE 19

Frequency of Important Foods Compared for Stomachs of Young Striped Bass Collected in the Midwater and Otter Trawls in Summer, 1964 in Middle San Joaquin River and Dead-end Sloughs

Food Item	Midwater Trawl		Otter Trawl		X^2	Percentile (1 d.f.)
	Obs. Freq.	Exp. Freq.	Obs. Freq.	Exp. Freq.		
N. awatschensis	50	60	80	70	6.42	0.975
Corophium	22	44	74	52	34.91	0.995
Threadfin Shad	26	13	3	16	23.91	0.995
Striped Bass	8	6	5	7	0.78	—
Stomachs Containing Food	99		117			

TABLE 19

Frequency of Important Foods Compared for Stomachs of Young Striped Bass Collected in the Midwater and Otter Trawls in Summer, 1964 in Middle San Joaquin River and Dead-end Sloughs

On the basis of the chi square tests, I have concluded that the results of this food habits study were influenced by the proportion of the sample collected with each type of trawl. The validity of the results of this study might have been increased if it were possible to weight accurately the sample from each trawl according to the proportion of the population in the strata of water that it represented. However, the catch data indicate that the vertical distribution of young bass varied considerably over time and between sampling stations (see Sasaki, Table 2, p. 47), and only fragmentary data were available on the vertical distribution of other age groups; therefore, it was not possible to estimate meaningful weight factors.

The proportion of the stomachs that contained food also varied with the sampling gear (Figure 2). To demonstrate this point it was necessary to compare proportions representing each gear for only one age-group of bass because the proportion of the stomachs containing food varied with the age of the bass (Tables 5–8) and each gear caught a different proportion of the total sample of each age-group. Large numbers of individuals from only the juvenile age-group were caught by all three types of gear so this group was selected.

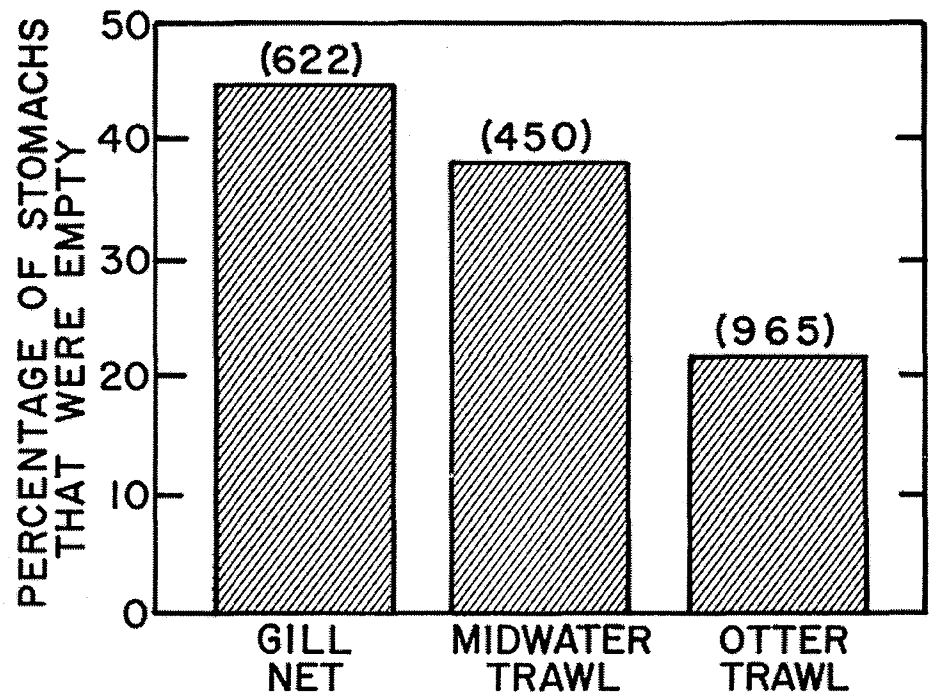

FIGURE 2. Percentage of juvenile bass stomachs that were empty compared to method by which the bass were collected. Numbers of stomachs examined are in parentheses.

FIGURE 2. *Percentage of juvenile bass stomachs that were empty compared to method by which the bass were collected. Numbers of stomachs examined are in parentheses.*

Two-way classification chi square tests indicated that the proportion of bass stomachs that contained food for each type of gear was significantly different from the proportion for each of the other two types of gear [Table 20]. The proportion of the bass with empty stomachs that were caught in the midwater trawl was larger than the proportion of the bass with empty stomachs from the otter trawl, and the proportion of bass with empty stomachs that were caught in the gill net was larger than that proportion for both the otter trawl and midwater trawl samples. The former difference probably reflected a greater abundance of food near the bottom, and the latter difference probably resulted from some of the stomachs' content being digested while the bass were in the net and unable to feed.

TABLE 20

Frequency of Empty Stomachs Compared for Juvenile Bass Collected by Three Types of Sampling Gear

Comparison	Midwater Trawl		Otter Trawl		Gill Net		X^2	Percentile (1 d.f.)
	Tot. Stomachs = 450		Tot. Stomachs = 965		Tot. Stomachs = 622			
	Obs. No. Empty Stomachs	Exp. No. Empty Stomachs	Obs. No. Empty Stomachs	Exp. No. Empty Stomachs	Obs. No. Empty Stomachs	Exp. No. Empty Stomachs		
Midwater Trawl vs. Otter Trawl	173	120	204	257	—	—	46.14	0.995
Midwater Trawl vs. Gill Net	173	189	—	—	278	261	3.93	0.950
Otter Trawl vs. Gill Net	—	—	204	293	278	189	98.12	0.995

TABLE 20

Frequency of Empty Stomachs Compared for Juvenile Bass Collected by Three Types of Sampling Gear

FOOD INTAKE AND BASS GROWTH

In the summer of 1964 there was a progressive change in the composition of the stomach contents of year-old bass from the lower to the middle to the upper San Joaquin River. In the lower river (Table 9), N. awatschensis occurred in almost all stomachs, Corophium were in about one-third of the stomachs, and tendipedids occurred in almost no stomachs. In the middle river (Table 10), only two-fifths of the stomachs contained N. awatschensis, Corophium occurred in more than two-thirds of the stomachs and were the most common food item, and tendipedids were in 14 percent of the stomachs. In the upper river (Table 11), N. awatschensis was in almost no stomachs, but seven-eights of the stomachs contained Corophium, and more than one-half contained tendipedids. These changes in diet almost certainly reflected a change in the kinds of food available (see p. 88).

There was not only the progressive change in diet composition, but there was also a corresponding progressive change in the intensity of food consumption. The amount of food in bass stomachs decreased significantly from the lower to the middle to the upper river [Table 21]. This decrease suggests that the total food availability decreased from the lowermost to the uppermost zone. In regard to this hypothesis, Ellis and Gowing (1957) found that the amount of food in stomachs of brown trout, Salmo trutta, was directly related to the amount of food in the section of the stream from which the trout were collected; and in a series of experiments, Ivlev (1961, pp. 19–40) found that the amount of food consumed by fishes depended on the mean concentration and degree of aggregation of food in the environment.

TABLE 21

Comparison of Mean Volumes of Food in Stomachs of Striped Bass from Three Environmental Zones of the San Joaquin River [1]

Environmental Zones and Mean Volumes of Food (cc)	t Value	Degrees of Freedom	Percentile
Lower River 0.1875 vs. Upper River 0.0172	3.61	82	0.99
Lower River 0.1875 vs. Middle River 0.0845	2.47	98	0.98
Middle River 0.0845 vs. Upper River 0.0172	3.28	80	0.99

[1] Bass were 14.5 to 16.5 cm FL and were collected during August 1964. Bass were selected from this size range to minimize variations in stomach capacities and to maximize the sample size without using effort additional to the regular sampling program.

TABLE 21

Comparison of Mean Volumes of Food in Stomachs of Striped Bass from Three Environmental Zones of the San Joaquin River

Sasaki (see p. 55) describes differences in the mean length and mean coefficient of condition of year-old bass from the same three environmental zones. It seems reasonable to expect that these differences were related to the food intake. In support of this theory the mean length and mean coefficient of condition of the bass from the lower river was greater than that of the bass from the middle and upper river (Figure 3). However, the trends in food intake, fork length, and coefficient of condition of bass from the middle to the upper river do not agree. The mean fork length of bass from the middle river was the same as that of bass from the upper river, and the mean coefficient

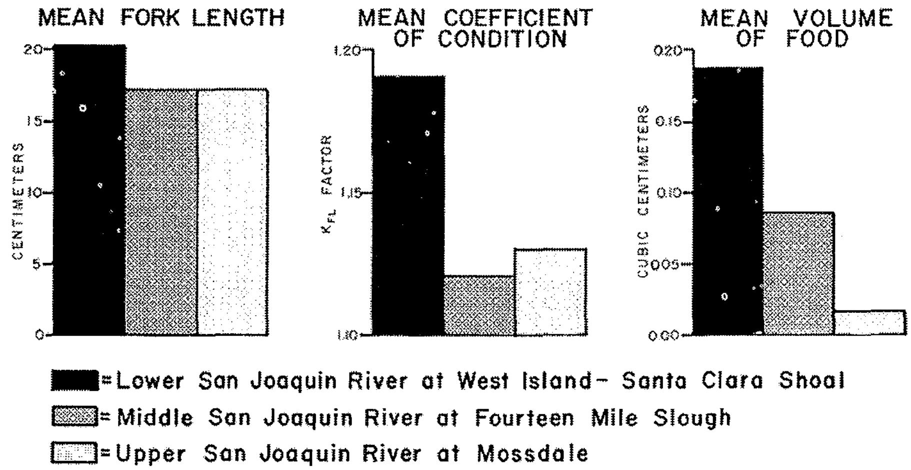

FIGURE 3. Mean volume of food per stomach, mean length, and mean coefficient of condition of year-old bass from the three environmental zones of the San Joaquin River during the summer of 1964.

FIGURE 3. *Mean volume of food per stomach, mean length, and mean coefficient of condition of year-old bass from the three environmental zones of the San Joaquin River during the summer of 1964.*

of condition of bass from the middle river was smaller, although not significantly smaller, than bass from the upper river; whereas the food intake was higher in the middle river than in the upper river. However, it should be noted here that there was a large increase in Sasaki's catches of year-old bass in the middle river from spring to summer (see p. 52); therefore, bass must have migrated there from another area. They may have come from upstream too recently to have put on growth consistent with their increased food intake. It is relevant that in the study by Ellis and Gowing (1957) the coefficient of condition of brown trout was highest in the section of the stream in which the food supply and food intake was highest.

DISCUSSION AND SUMMARY

The bass stomachs contained more than 30 different foods, but only 5 of these foods, N. awatschensis, Corophium, small striped bass, threadfin shad, and bait, were eaten by an appreciable percentage of bass during any season.

Young bass entered their first fall, feeding almost entirely on invertebrates (Figure 4). They continued to do so through the winter and spring. In their second summer of life, they began feeding on small fish, primarily new young-of-the-year striped bass and threadfin shad.

In the second fall of their life, the bass, now juveniles, fed nearly half on fish and half on invertebrates. During this period, threadfin shad and small striped bass were abundant and at the proper size. In the winter and spring when many of the small bass had moved

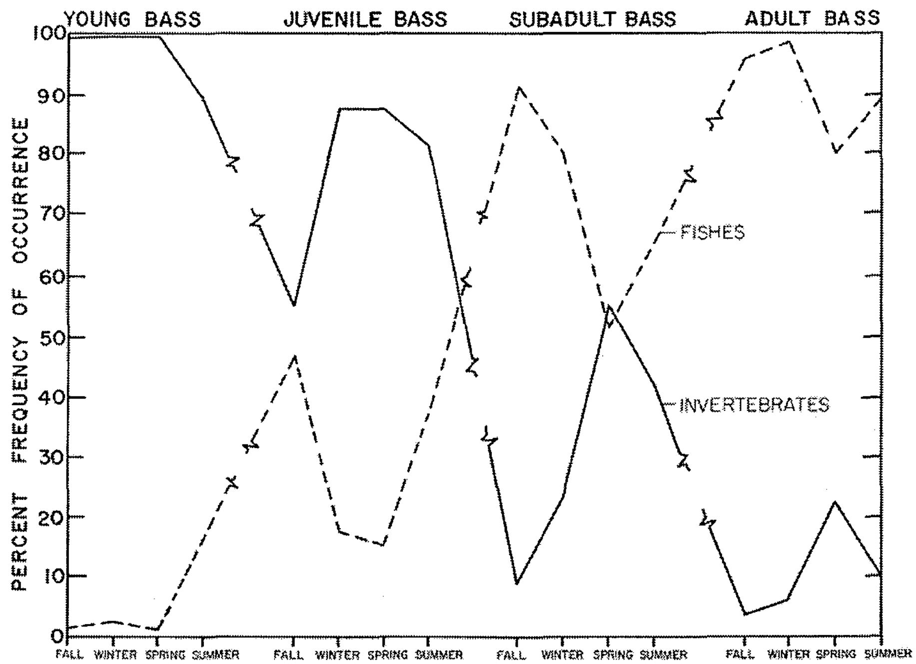

FIGURE 4. Percent frequency of occurrence of fishes and invertebrates in stomachs of striped bass of different ages from fall 1963 through summer 1964.

FIGURE 4. *Percent frequency of occurrence of fishes and invertebrates in stomachs of striped bass of different ages from fall 1963 through summer 1964.*

down into the bays below the Delta (see Sasaki, p. 49; and Ganssle, 1966), and the threadfin shad had died out (see Turner, p. 164), the juvenile bass returned to a diet formed largely by invertebrates. When the new crop of young-of-the-year bass and threadfin shad became available in the summer, the juveniles turned again toward a diet of small fish.

In the fall, the abundant small striped bass and threadfin shad comprised nearly the entire diet of the subadult bass. Like the juveniles, the subadults consumed less fish and more invertebrates in the winter and spring when small fishes were less numerous. The subadults returned to an almost exclusive fish diet when the new crops of small bass and threadfin shad arrived in the summer.

Adult bass fed primarily on small bass and threadfin shad. In the spring and early summer the adults reduced their food intake. This reduction was probably related to their spawning activities.

The shift from the diet of young bass which consisted primarily of invertebrates to the diet of the adult bass which was formed predominately by fishes was obviously a result of selective feeding by bass of different sizes. This shift in diet was not unexpected in view of findings of many other studies and conforms with the results of Ivlev's (1961, pp. 82–91) experiments showing that predators prefer to devour victims of the largest possible size.

Corophium were the only zoobenthos that bass utilized in significant amounts. These amphipods were the most abundant of the macro-organisms collected from the bottom of the Delta channels by Hazel and Kelley (1966). Corophium also are often found on the substrate

rather than in it, so are probably more available than those less abundant benthic animals which live in the substrate.

Few bass stomachs contained small king salmon. Oncorhynchus tshawytscha. Several biologists (Scofield, 1931; Shapovalov, 1936; Hatton, 1940) have speculated on how much striped bass prey upon seaward migrating salmon. Hatton (1940) analyzed stomach contents of 224 adult bass from the Delta during the salmon migration primarily to determine the extent of this predation. He found no salmon in the stomachs and concluded that they were not an important food source. Adult bass are spawning during the salmon migration; therefore, they would not be serious predators because they do not feed heavily then.

Recently, Thomas (1966) reported that juvenile bass consumed quantities of small salmon in the spring and summer in the Sacramento River above the Delta. This suggests that salmon are more available there than in the Delta. This availability may be a direct result of the greater clarity and/or small width of the river. The small salmon are necessarily more concentrated when in the relatively narrow river than when in the broad and diverging channels of the Delta. The availability of small salmon to striped bass in the Delta during the summer might also be low because other forage fishes, particularly young-of-the-year striped bass, act as a buffer against predation on the salmon.

Relatively few small American shad were eaten by striped bass, even during the summer when small shad were quite abundant. Thomas (1966) did not find many American shad in the stomachs of striped bass either. Why more bass did not prey upon this species is unknown.

Sardine and anchovy bait were consumed with surprising frequency by juvenile and adult bass. These baits may have either been discarded by anglers or stolen from their hooks.

Young bass grew best in the lower San Joaquin River where the mysid, N. awatschensis, was extremely abundant. A decrease in the concentration of N. awatschensis here would almost certainly reduce the rate of growth and perhaps the survival of these bass. Since this zone is the most important nursery area in the Delta for young bass (see Sasaki, p. 44), such a reduction would probably seriously affect the structure of the entire bass population.

Suitable forage fishes for striped bass were scarce in the Delta during the winter and spring. Both juvenile and subadult bass fed on invertebrates during this period. The rate of growth and survival of these bass might be improved if small forage fishes were more available at this time.

Because the availability of food organisms varied with depth, bass stomach contents varied with the depth at which the bass were collected. Different sampling gear was used to collect bass at different depths; therefore, the results of this study were influenced to some extent by the proportion of the sample collected by each type of gear.

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— 96 —

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— (97) —

DISTRIBUTION AND FOOD HABITS OF THE AMERICAN SHAD, ALOSA SAPIDISSIMA, IN THE SACRAMENTOSAN JOAQUIN DELTA

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This paper describes the distribution, migrations and food habits of the American shad in the Sacramento-San Joaquin Delta. The description is based on catches of shad in gill nets and trawls, on the estimation of gonad maturation in adult shad, and on the examination of contents of 269 stomachs of adult shad.

Adult shad were abundant in the Delta only during their spawning migration. The Sacramento and Mokelumne River systems supported larger runs than the San Joaquin River. There is evidence that while most shad spawned far upstream, some spawned in several areas in the Delta itself. The catch and gonad maturation data suggest that a large percentage of the adults die shortly after spawning, although there is also evidence that some spent shad do migrate seaward. Adult shad fed primarily on a mysid, Neomysis awatschensis, and copepods and cladocerans. Percentages of stomachs containing food were directly related to concentrations of food organisms in the environment.

Young shad were abundant in the Delta from July through November. Greatest concentrations occurred in the Sacramento River, Mokelumne River, dead-ends sloughs tributary to the Mokelumne River, and the San Joaquin River below the mouth of the Mokelumne River. Most of the young shad in the latter area probably originated in the Sacramento and Mokelumne rivers.

Some migrations of young shad within the Delta appeared to be related to the food supply.

METHODS

The trawling and gill netting procedures, locations of the sampling stations, and the method of estimating gonad maturation are described by Turner (see p. 12). Procedures used in the food habits analysis are the same as those described for striped bass by Stevens (see p. 68).

ADULT SHAD