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FOOD OF YOUNG-OF-THE-YEAR STRIPED BASS (*ROCCUS SAXATILIS*) IN THE SACRAMENTO-SAN JOAQUIN RIVER SYSTEM[1]

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INTRODUCTION

Young-of-the-year striped bass were studied to obtain a comprehensive knowledge of their year-round diet in the Sacramento-San Joaquin River system. This knowledge will help explain variations in migration, growth, and year-class strength, which will in turn aid in predicting the effects of future environmental changes on striped bass.

One such change will occur in the near future with the development of the California Water Plan. This plan will drastically alter water flow and salinity patterns in the Delta, thus changing the distribution and relative abundance of striped bass food organisms. Knowledge of the striped bass diet is necessary to insure adequate consideration for this species in the project design.

The movement of threadfin shad (*Dorosoma petenense*) into the Delta will bring about another change. These fish have dramatically altered other environments after becoming established (Kimsey *et al.*, 1957), and they have already started to migrate into the Delta from upstream reservoirs where they were introduced in 1959 and 1960 to provide more forage for warmwater game fish. Kimsey (1958) theorized that they might compete with small striped bass, stating, "Some competition for food would be certain to occur and there is a possibility that it would be severe. The overall effect on the striped bass population might be more serious than the more obvious predation problem."

Finally, this information may be useful in protecting the habitat from pollution by providing evidence of the value of many invertebrates which are usually first to feel its effects.

Previous striped bass food habit studies in California have identified the major food organisms consumed by adults (Smith, 1896; Scofield, 1910; Scofield and Bryant, 1926; Scofield, 1928, 1931; Shapovalov, 1936; Hatton, 1940; and Johnson and Calhoun, 1952). The only prior information concerning food habits of young-of-the-year bass is from three local studies (Scofield and Bryant, 1926; Shapovalov, 1936; and

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Hatton, 1940), which do not describe the general food habits of the population. The stomach contents of approximately 2,500 young-of-the-year striped bass collected between 1956 and 1961 were examined to fill this void. The data are summarized in this paper.

DESCRIPTION OF STUDY AREA

Striped bass inhabit approximately 1,000 miles of waterways in the Sacramento-San Joaquin River system, plus San Pablo and San Francisco bays, and the Pacific Ocean off the coast of Central California. Young-of-the-year bass are concentrated primarily in the Sacramento-San Joaquin Delta and San Pablo Bay (Figure 1). This area is bounded roughly by Sacramento on the north, Stockton to the east, Tracy to the south, and San Pablo Bay to the west.

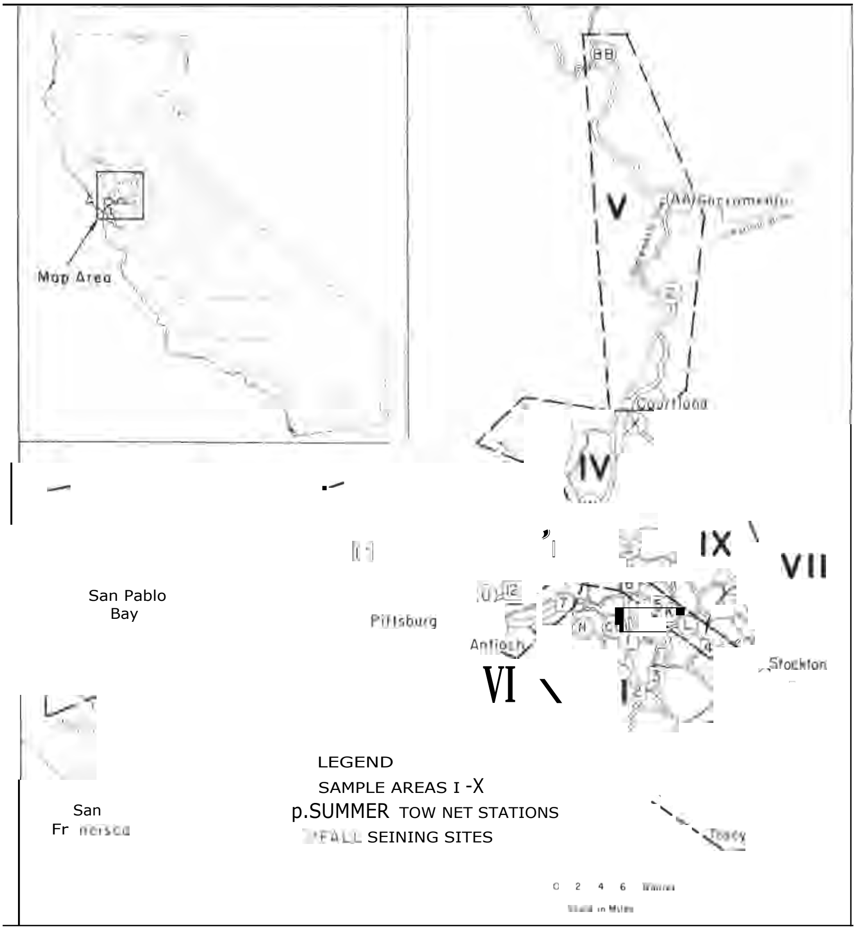

FIGURE 1. The lower Sacramento-San Joaquin River system showing areas with tow net and seining stations.

This entire area is estuarine in nature. Flow reversals, as a result of tidal action, occur regularly as far upstream as Courtland on the Sacramento River and Stockton on the San Joaquin River. On maximum ebb tides, water velocities approach 7.5 feet per second in Carquinez Strait (U.S. Dept. of Commerce). Above the confluence of the two rivers, water velocities reach a maximum of 3 to 4 feet per second. Water velocities in the Sacramento River channel are slightly greater than in the other more meandering waterways of the Delta. In recent years, the Sacramento River has supplied over 65 percent of the total flow to the Delta (California Department of Water Resources, 1959-1962a ; and unpublished data).

Water salinity ranges from nearly sea water in San Pablo Bay to fresh water in the middle and upper Delta. The maximum encroachment of 1,000 ppm of chlorides is usually a few miles above Anioch during the summer and fall, but winter and spring runoff forces this salinity line down to Suisun Bay (U.S. Department of the Interior, 1957-1962). Waters above the confluence of the two rivers are essentially fresh for most of the year.

While flowing through the rich agricultural central valley of California, both rivers become laden with nutrients and are quite turbid upon entering the Delta. Secchi disk measurements at bass collecting sites during the summer were consistently less than 1 foot. In San Pablo Bay, the turbidity is reduced by sea water dilution.

The physical environmental characteristics, briefly described here, influence the distribution and abundance of potential striped bass food organisms, and hence, affect striped bass food habits.

METHODS

Young-of-the-year striped bass were collected in conjunction with other field activities between 1956 and 1961. Most summer collections were made with a tow net in the course of spawning success surveys (Harold K. Chadwick, MS.). All of the fall and the few winter and spring collections were made by seining.

All fish were preserved in 10 percent formalin for stomach examination at a later date.

Fork lengths of bass were measured in tenths of inches and the fish were divided into three groups—bass smaller than 1 inch, which were collected primarily in June and the first few weeks in July ; bass 1 inch long or longer, which were taken in June, July and August ; and bass from 2 to over 4 inches long, which were taken in September, October, and November.

Approximately 10 fish were examined from each sample. The number examined depended on the number of fish collected and the uniformity of the stomach contents. Bass over 0.4 inches long were dissected and examined under a dissecting microscope. Smaller fish were pressed between a microscope slide and cover slip and examined under a compound microscope. Since these small fish were transparent, their food could be identified easily without dissection.

Only organisms found in the esophagus and stomach were recorded, although remains in the intestines were occasionally useful in identifying remains in the stomach. In stomachs containing many copepods, the total number was estimated by projecting counts of one-fourth or one-half of the contents. Comparison of these estimates with actual counts disclosed little error.

Stomach contents were summarized by frequency of occurrence (percentage of all stomachs containing food which contained a given food item) and the numerical method (the total number of a species divided by the total number of stomachs containing food). Volumetric or [illegible] measurements were not practical, since the stomachs contained such small amounts.

Plankton samples gathered throughout the study area served as a reference collection. The copepods, P[illegible] and

TABLE 1

Collecting Areas and Stations for Young-of-the-Year Striped Bass (1956-1961)

A[illegible] D[illegible]	Summer [illegible] (T[illegible]) S[illegible]	N[illegible]	F[illegible] (S[illegible]) S[illegible]	N[illegible]
I. S[illegible] P[illegible] B[illegible]				28
				16
II. S[illegible] R[illegible]	25	18	E	33
C[illegible] S[illegible]	17	56	F	30
P[illegible]	27	20		
M[illegible] S[illegible]	28	62		
	13	72		
	29	75		
	14	31		
	15	68		
	16	86		
III. S[illegible] R[illegible]	12	62	(1	24
P[illegible]	11	111	V	62
R[illegible] V[illegible]	10	68		
IV. S[illegible] R[illegible]			Y	41
R[illegible] V[illegible] C[illegible];			W	38
[illegible] S[illegible] S[illegible]			X	31
V. S[illegible] R[illegible]			Z	25
C[illegible]			AA	29
F[illegible] R[illegible]			BB	1
VI. S[illegible] J[illegible] R[illegible]	30	110	G	45
P[illegible]	7	[illegible]		
[illegible] M[illegible] R[illegible]	8	82		
VII. S[illegible] J[illegible] R[illegible]	6	86	K	30
[illegible] M[illegible] R[illegible]	5	78	L	31
S'3[illegible]	4	05	M	30
	33	5		
VIII. S[illegible]	1	120	H	24
S[illegible] J[illegible] R[illegible]	2	97	I	41
	3	66		
	31	33		
IX. M[illegible] R[illegible]			5	30
[illegible] S[illegible] J[illegible]			T	13
S[illegible]				
X. S[illegible] J[illegible] R[illegible]			N	27
M[illegible]; [illegible] S[illegible] S[illegible]			P	29

Acartia clausii, were identified as *Pseudodiaptomus* until late in the study. Therefore, they could not be separated in the summaries.

The relative rates of digestion of the principal food organisms (copepods, *Neomysis mercedis*, and *Corophium spinicorne*) were also determined. This information was needed to evaluate any bias arising from differences in digestion rates.

For these experiments, bass 2.5 to 4.5 inches long were collected by seining and held in an outdoor tank. They were transferred, 15 at a time, to a 20-gallon aquarium and held without food for one week. The organism to be tested was introduced into this tank, and the bass were allowed to feed for 20 minutes, except when all organisms were consumed in a shorter time. The bass were then placed in a clean tank and one was killed every half hour and its stomach contents examined. Organisms in the stomach were compared with preserved specimens to aid in denoting changes. The water temperature was 61° F throughout the experiments.

RESULTS

To simplify our data presentation, and to show variation in the food habits of young-of-the-year bass, collecting sites were grouped into 10 major ecological areas, based upon differences in bass food habits, and differences in the physical characteristics of the environment (Figure 1, Table 1). Areas I, IV, V, IX and X are believed to be of minor importance to young-of-the-year bass during the summer, and no bass were collected there. Fall collections were obtained from all 10 areas.

SUMMER DIET

During the summer, bass food habits varied by area and by size of fish.

In the Sacramento River below Pittsburg, *Neomysis* was the most important food of all size groups (Table 2). Copepods were second, with

TABLE 2

Stomach Contents of Young-of-the-Year Striped Bass in the Sacramento River between Carquinez Strait and Pittsburg (Area II), 1956–1961

Food item	Summer (June-August)				Fall (September-November)	
	0.1- 1.0 inch bass (108 bass containing food)		1.1 - 3.0 inch bass (297 bass containing food)		2.0- 4.5 inch bass (58 bass containing food)	
	Percentage frequency of occurrence	Number per stomach	Percentage frequency of occurrence	Number per stomach	Percentage frequency of occurrence	Number per stomach
Neomysis	55	1.6	85	5.8	77	13
Corophium	1	trace	18	0.6	14	0.4
C[illegible]	2	trace	4	0.3	0	0
Copepods	41	0.8	19	6.4	45	31
Pseudodiaptomus and/or *Acartia*	4	0.1	3	0.9	26	14
Eurytemora	29	0.6	15	1.7	41	17
Cyclops	0	0	3	0.6	0	0
Diaptomus	0	0	6	2.8	0	0

Eurytemora and *Pseudodiaptomus* or *Acartia* the most common genera. *Corophium* was eaten frequently by bass over 1 inch long.

From Pittsburg to Rio Vista on the Sacramento River and to the mouth of the Mokelumne River on the San Joaquin River, copepods and *Ncomysis* ranked first and second in frequency of occurrence in bass 1 inch long or shorter, while the order was reversed in bass over 1 inch long (Tables 3 and 4). *Eurytemora*, *Diaptomus*, and *Cyclops* were the most common copepod genera. The frequency of occurrence of cladocera and *Corophium* was higher in these areas than in downstream areas.

On the San Joaquin River from the mouth of the Mokelumne River to Stockton and in the sloughs south of the San Joaquin River, the importance of *Neomysis* declined markedly, while copepods and cladocerans became more important in the bass' diet (Tables 5 and 6). *Diaptomus* and *Cyclops* were the most common copepods.

Other organisms were of minor importance in the bass' diet. *Crago* and crab zoea were found in bass collected in Montezuma Slough and Suisun Bay. Tendipedid larvae and pupae were eaten by bass in the fresh water of the Sacramento and San Joaquin rivers. Fish remains were found in two bass. A bass 1.6 inches long, collected at Station 5 in June 1961, contained what was probably a bass 0.2 inches long. Another bass, 2.1 inches long, caught at Station 10 in August 1961, contained an unidentified fish vertebra. Tule fragments *(Scirpus)* and other plant debris were in a number of bass stomachs.

In general, the percentage frequency of copepod occurrence was greater in small bass than large ones, while the frequency of occurrence of larger plankton, *Neomysis* and *Corophium,* was greater in larger bass. The occurrence of cladocera did not appear to be related to fish size. Larger bass generally had more organisms in their stomachs.

The influence of salinity on the relative abundance of copepod genera in the diet of bass was readily recognizable. At stations with a high mean salinity, *Eurytemora* was the dominant genus (Figure 2). As the salinity decreased upstream, the observed percentages of fresh-water genera, *Diaptomus* and *Cyclops*, increased.

The percentage of the total bass population utilizing each food organism was estimated by multiplying the percentage of the bass population in each area by the average percentage occurrence of the food item in all bass and totaling the percentages. These percentages of frequency of occurrence were: *Neomysis,* 59 percent ; copepods, 50 percent ; cladocerans, 23 percent ; and *Corophium,* 12 percent. Since these estimates are based on tow net surveys which sampled only the major areas inhabited by young-of-the-year bass, the true picture would be slightly different.

FALL DIET

Bass food habits changed little in the fall in Areas II and III (Tables 2 and 3). The greatest changes were a marked increase in copepod consumption and decline of *Neomysis* in the San Joaquin River (Tables 4 and 5).

[3] During the summers of 1959-1961, the estimated fractions of the young bass population occurring in various areas were: Area II, 34 percent ; Area III, 30 percent ; Area VI, 18 percent ; Area VII, 8 percent ; and Area VIII, 10 percent (Harold K. Chadwick, MS.).

TABLE 3

Stomach Contents of Young-of-the-Year Striped Bass in the Sacramento River between Pittsburg and Rio Vista (Area III), 1956-1961

Food item	Summer (June-August)				Fall (September-November)	
	0.1-1.0 inch bass (93 bass containing food)		1.1-3.0 inch bass (108 bass containing food)		2.0-4.5 inch bass (75 bass containing food)	
	Percentage frequency of occurrence	Number per stomach	Percentage frequency of occurrence	Number per stomach	Percentage frequency of [illegible]	Number per stomach
Neomysis	49	1.0	80	6.3	83	7.1
Corophium	4	0.1	10	0.2	16	0.6
C[illegible]	34	1.6	41	5.6	0	0
Copepods	61	3.2	52	75	20	37
Pseudodiaptomus and/or Acartia	0	0	0	0	1	0.3
Eurytemora	26	0.7	17	4.0	19	27
Cyclops	12	0.2	22	6.5	8	0.6
Diaptomus	2	trace	33	64	19	8.2
T[illegible] larvae	0	0	1	trace	1.4	trace
T[illegible] pupae	0	0	0	0	1.4	trace

TABLE 4

Stomach Contents of Young-of-the-Year Striped Bass in the San Joaquin River between Pittsburg and the Mouth of the Mokelumne River (Area VI), 1956-1961

Food item	Summer (June-August)				Fall (September-November)	
	0.1-1.0 inch bass (71 bass containing food)		1.1-3.0 inch bass (183 bass containing food)		2.0-4.5 inch bass (44 bass containing food)	
	Percentage frequency of occurrence	Number per stomach	Percentage frequency of occurrence	Number per stomach	Percentage frequency of occurrence	Number per stomach
Neomysis	48	1.1	86	6.1	34	1.5
Corophium	11	0.1	37	0.7	11	0.2
C[illegible]	18	0.3	12	0.9	50	8.5
Copepods	56	1.6	34	23	84	299
Pseudodiaptomus and/or *Acartia*	0	0	3	0.5	0	0
Eurytemora	17	0.3	15	4.3	73	49
Cyclops	3	trace	4	12	64	215
Diaptomus	21	1.0	21	6.1	32	35
T[illegible] larvae	0	0	1	trace	2	0.1
T[illegible] pupae	0	0	0	0	2	0.1

TABLE 5

Stomach Contents of Young-of-the-Year Striped Bass in the San Joaquin River between the Mouth of the Mokelumne River and Stockton (Area VII), 1956-1961

Food item	Summer (June-August)				Fall (September-November)	
	0.1-1.0 inch bass (89 bass containing food)		1.1-3.0 inch bass (124 bass containing food)		2.0-4.5 inch bass (91 bass containing food)	
	Percentage frequency of occurrence	Number per stomach	Percentage frequency of occurrence	Number per stomach	Percentage frequency of occurrence	Number per stomach
Neomysis	16	0.4	32	2.3	0	0
Corophium	2	trace	16	0.4	27	0.8
Cladocera	39	1.4	48	11	30	11
Copepods	84	6.9	71	61	100	593
Eurytemora	10	0.2	12	0.4	15	2
Cyclops	44	1.8	20	17	100	239
Diaptomus	71	4.9	67	34	100	352
Tendipedid larvae	0	0	1	trace	1	trace
Tendipedid pupae	0	0	1	trace	0	0

TABLE 6

Stomach Contents of Young-of-the-Year Striped Bass in the Sloughs South of the San Joaquin River (Area VIII), 1956-1961

Food item	Summoner (June-August)				Fall (September-November)	
	0.1-1.0 inch bass (158 bass containing food)		1.1-3.0 inch bass (145 bass containing food)		2.0-4.5 inch bass (61 bass containing food)	
	Percentage frequency of occurrence	Number per stomach	Percentage frequency of occurrence	Number per stomach	Percentage frequency of occurrence	Number per stomach
Neomysis	17	0.3	21	0.7	11	0.2
Corophium	10	0.1	32	0.7	95	7.8
Cladocera	39	0.9	56	11	7	0.2
Copepods	84	8.5	80	87	36	3.2
Pseudodiaptomus and/or Acartia	0	0	1	trace	0	0
Eurytemora	13	0.4	13	0.4	13	1.0
Cyclops	27	0.9	57	16	23	1.6
Diaptomus	62	6.9	74	70	21	0.6
Tendipedid larvae	0	0	0	0	3	trace

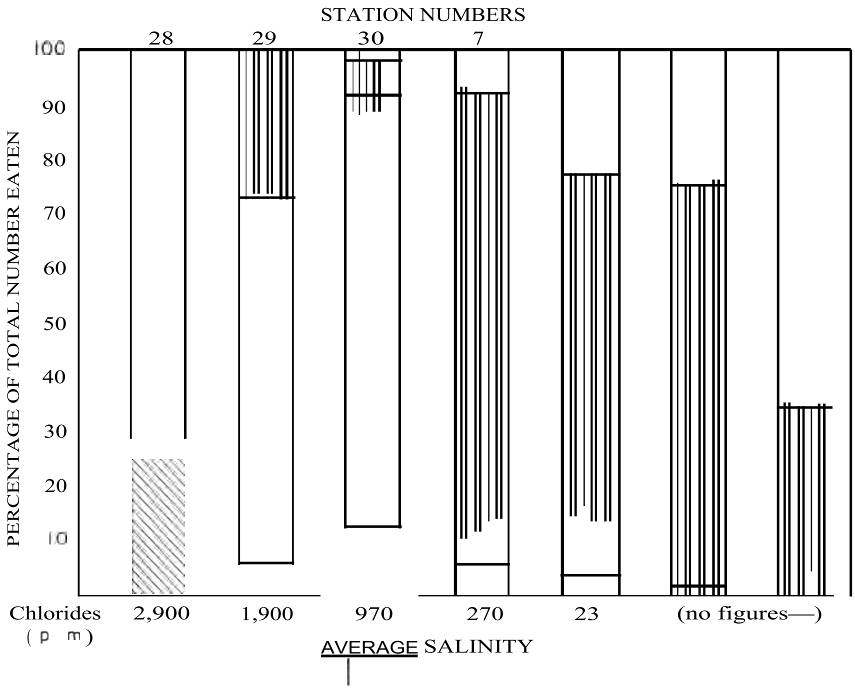

FIGURE 2. Relative importance of the copepods, *Pseudodiaptomus* and/ or Acartia (P), *Eurytemora* (E), *Diaptomus* (D), and Cyclops (C), in the diets of young-of-the-year bass from stations of various salinities in the Sacramento San Joaquin Delta, 1959-1961.

In the sloughs south of the San Joaquin River, almost every bass contained *Corophium*, a considerable increase from the summer months (Table 6). The frequency of occurrence of all other organisms was less.

San Pablo Bay and the upper Sacramento and San Joaquin rivers were sampled only in the fall. In San Pablo Bay, amphipods (*Corophium* sp., *Anisogammarus*, and unidentified genera), *Nereis*, and *Neomysis* were the principal food organisms (Table 7). Over one-third of the bass contained clam sphons. Although these could not be identified, they were probably from *Macoma*, since these are the only clams there with long separate siphons. Copepods and isopods were also eaten by bass in this area.

TABLE 7

Stomach Contents of 42 Young-of-the-Year Striped Bass in San Pablo Bay (Area I), September-November, 1956-1960

Food item	*Percentage frequency of occurrence*	*Number per stomach*
Neomysis	31	0.6
Amphipods	45	2
Copepods	12	7.1
Pseudodiaptomus and/or *Acartia*	10	4.2
Unidentified Copepods	2	2.9
Isopods	10	0.2
Nereis		0.8

In upriver areas tendipedid larvae and pupae become increasingly important. In the Sacramento River above Freeport and in the San Joaquin River above Mossdale these dipterans were by far the most important food organisms (Table 8). They were also in a number of bass collected in the Mokelumne River and adjoining sloughs, but *Corophium* was the principal food item.

TABLE 8

Stomach Contents of Young-of-the-Year Striped Bass in the Upper Sacramento-San Joaquin Delta, September-November, 1956-1960

Food item	Sacramento River from Rio Vista to Courtland; and Steamboat Slough (Area IV) (108 bass containing food)		Sacramento River from Courtland to the Feather River (Area V) (46 bass containing food)		Mokelumne River and sloughs between the San Joaquin and Sacramento rivers (Area IX) (42 bass containing food)		San Joaquin River above Mossdale; and Salmon Slough (Area X) (56 bass containing food)	
	Percentage frequency of occurrence	Number per stomach	Percentage frequency of occurrence	Number per stomach	Percentage frequency of occurrence	Number per stomach	Percentage frequency of occurrence	Number per stomach
Neomysis	15	1.3	2	trace	5	0.1	11	0.3
Corophium	77	7.2	2	trace	93	6.9	23	1.1
Cladocera	8	0.7	5	0.1	2	0.4	4	0.1
Copepods	6	0.6	5	0.1	5	0.2	7	13
Cyclops	4	0.1	2	trace	5	0.1	7	8.1
Diaptomus	5	0.5	2	trace	2	trace	7	1.6
Tendepidid larvae	39	1.1	87	0.9	24	0.4	93	7.0
Tendepidid pupae	16	0.2	65	2.8	14	0.4	64	2.9

One 3-inch bass collected at Freeport contained a 1-inch American shad (*Alosa sapidissima*). A 2-inch bass collected at Mossdale contained a small crayfish.

The food habits of young-of-the-year bass during the fall could not be related to their distribution, since it has not been studied in detail.

WINTER AND SPRING DIET

Bass were collected at only three stations during the winter. Four bass collected in Steamboat Slough (Station W) on February 8, 1961, contained *Neomysis*, and one had a smelt, *Hypomesus*. Of 15 bass taken in February and March, 1961, in the Sacramento River (Station V), 14 contained *Neomysis*. One also contained *Corophium*, one had three tendipedid larvae, and one had fish remains. Seventy bass collected in the San Joaquin River (Station G) between December 1956 and April 1957 contained by frequency of occurrence : *Neomysis*, 73 percent ; copepods, 58 percent ; and *Corophium*, 23 percent.

During April 1957, bass were collected from five stations. Ten bass from Sacramento Point (Station U), and seven collected near Rio Vista (Station V) on the Sacramento River contained *Neomysis*. One bass from Sacramento Point contained a *Corophium*. Of four bass collected near Ryde (Station Y), three contained plant debris, one contained two tendipedid larvae and three *Neomysis*, and one contained insect remains. Eleven bass from the San Joaquin River below Stockton (Station M) contained by frequency of occurrence : copepods, 91 percent ; cladocerans, 45 percent ; *Corophium,* 36 percent ; and *Neomysis,* 27 percent. Three bass from Salmon Slough (Station N) all contained *Neomysis,* and one had three *Corophium.*

No major change is evident in the winter and spring diets of young bass ; however, the limited number of collections inhibits making positive generalizations.

Short-term Variations

A year-round collection of bass from the San Joaquin River at Antioch presented an opportunity to determine short-term variations in stomach contents at a given station. Bass were collected frequently from September 1956 to April 1957, and in July and October 1957. The mean length of fish examined in July 1957, was 2.5 inches and the mean lengths of other samples ranged from 3.4 to 4.1 inches.

The bass fed on *Neomysis,* copepods, and *Corophium.* The percentage frequency of occurrence of these organisms varied widely from one sample to the next and seasonal changes were not evident (Figure 3).

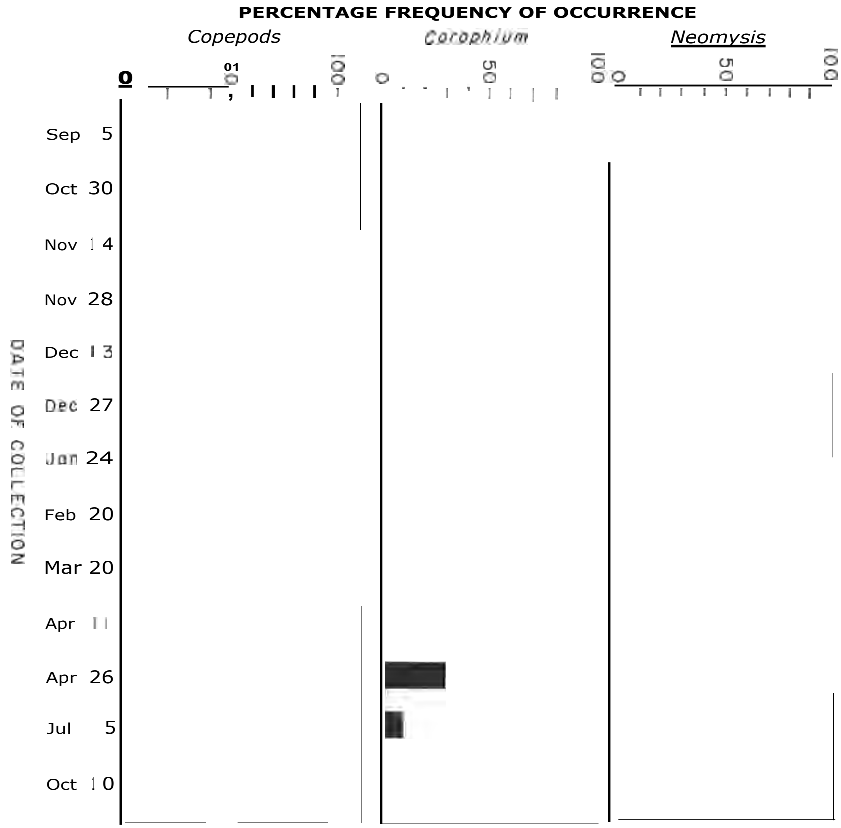

FIGURE 3. Percentage frequency of occurrence of three food organisms in the diets of young-of-the-year bass from the San Joaquin River at Antioch, 1956-57.

There was no decrease in the percentage of bass containing food nor in the volume of ingested food in the cooler months.

Rate of Digestion

Most copepods were still identifiable to genus after 1 hour. In 1½ hours, only two of the six eaten could be identified to genus, using a compound microscope. After 5 hours the general form of copepods could be recognized, but none could be identified. Only detritus remained after 6 hours.

Although the bodies of *Neomysis* broke down as rapidly as copepods, the characteristic compound eyes and eye stalks remained intact and were identifiable after 6 hours.

Corophium was quite resistant to digestive juices and could be identified for up to 8 hours. After this time all remains had passed into the large intestine, where digestion proceeds very rapidly. Surprisingly, three of seven *Corophium* were still moving after ½ hour in a bass's stomach. All three were moving their pleopods and one individual was moving its pereiopods and antennae and reacted to the touch of a probe. After 1½ hours, one individual was still moving its pleopods.

Although the results might be modified if the bass had not been starved before the experiment, they indicate there are important differences in the rates of digestion of the three primary food organisms. These differences resulted in overestimating the relative importance of *Corophium*, and to a lesser extent *Neomysis*, in the diet.

Distribution of Plankton Organisms

Only limited work on the distribution and habitat of invertebrates in the Sacramento and San Joaquin rivers has been done.

Corophium has generally been classified as a brackish-water organism (Light, 1954). Felice (1958) collected it from Antioch to San Pablo Bay over a salinity range of 0.4 to 19 parts per thousand. However, it has recently been abundant in the fresh waters of the Sacramento River up to Ryde and less common up to Wilkins Slough below Colusa (California Department of Water Resources, 1962b). We collected *Corophium* in fresh water in the San Joaquin River and adjoining sloughs as far upstream as Stockton.

Neomysis mercedis, a mysid shrimp, occurs in brackish-water bays, estuaries, and in fresh water (Light, 1954). In 1914, Tattersal (1932) collected *Neomysis* throughout the San Francisco Bay area but found it most abundant above San Pablo Bay, where the salinity was low. He stated that salinity was the most important factor limiting its distribution in that area. During the present study, *Neomysis* was collected in plankton samples from Suisun Bay to Rio Vista in the Sacramento River and at Station 5 in the San Joaquin River, and it was found in bass collected during April in Salmon Slough near Tracy.

The copepods *Diaptomus* sp. and *Cyclops* sp. are freshwater forms and *Eurytemora affinis* and *Pseudodiaptomus euryhalinus* are brackish-water forms (Light, 1954). In the summer we collected copepods at every tow-net station, but they were more abundant in the rivers above Pittsburg. *Pseudodiaptomus euryhalinus* was found in the Sacramento River below Pittsburg. *Eurytemora affinis* was collected from Station 26 to Station 11 on the Sacramento River and Station 8 on the San

Joaquin River. *Cyclops vernalis* and *Diaptomus novamexicanus* were found primarily above Pittsburg in both rivers. *Acartia clausii* was taken in a sample from Suisun Bay but was not identified in any bass stomachs. *Atthyella* and *Eucyclops agilis* were collected occasionally in plankton samples but were seldom found in bass stomachs.

Although we did not take tendipedid larvae in dredge or plankton samples, the California Department of Water Resources (1962b) found them commonly above Rio Vista in the Sacramento River. In a bass taken at Freeport there were *Tendipes, Cryptochironomus,* and *Limnochironomus.* These organisms were eaten by bass in areas where the water was essentially fresh.

The cladocerans, *Bosmina, Daphnia,* and *Diaphanosoma,* were identified in plankton samples taken primarily above Pittsburg in the Sacramento and San Joaquin rivers. The first two are classified as freshwater forms (Light, 1954).

DISCUSSION

In this study, several major groups comprising over 20 species of small animals were eaten by young-of-the-year striped bass. Many of these organisms were also reported in previous food habits studies. Similar organisms (freshwater shrimp, tendipedid larvae, *Mysis,* annelids, *Crago, Latona, Cyclops, Eurytemora,* and fish) have been found in small bass on the Atlantic Coast (Pearson, 1938; Merriman, 1941).

Tule fragments and other plant debris were found in bass stomachs and they have also been reported by other California investigators. It is not known whether bass eat them deliberately or accidentally.

This study's results were somewhat biased by the methods of analyzing the stomach contents. Frequency of occurrence is a better method than the numerical count for judging a food item 's value, since it is a measure of general utilization by the population. However, neither of these methods takes the size of the food organism or its rate of digestion into consideration. Due to differences in organism size, the results underestimate the importance of *Neomysis* and *Corophium.* On the other hand, differences in digestion rates result in underestimating the importance of copepods, and to a lesser extent *Neomysis,* in relation to *Corophium.*

Also, stomach contents sometimes varied greatly between successive samplings at a single station (Figure 3). As a result, the exact importance of any one food organism is difficult to determine.

Evaluation of any bias resulting from the two methods of collecting, tow netting and seining, was impossible since they were employed in different seasons.

Although sampling problems made the development of forage ratios impractical, the occurrence of plankton species in the stomach generally agreed with the distribution of plankton in the environment. But, with the exception of *Corophium, Nereis,* and tendipedids, bass did not feed on available benthic fauna in most areas. The annelids, *Nereis succinea, N. lighti, Capitella capitella,* and *Polydora uncata,* reported by Felice (1958) as occurring in brackish or freshwater areas, are examples.

Since the distribution of estuarine organisms is generally controlled by salinity (Gunter, 1961), salinity largely determines bass diet in most areas. This was exemplified by the relative importance of various copepod genera at stations of various salinities (Figure 2).

Water flow is also an important controlling factor and temperature, bottom type, and other ecological factors undoubtedly play significant roles. Differences in food eaten in Areas VIII and X in the fall resulted primarily from differences in water flow. Both areas are essentially fresh, but water movement in Area VIII was primarily tidal, while Area X was a lotic environment. In Area VIII, plankton (copecods and cladocerans) was the primary food, while in Area X plankton was presumably scarce, due to the one-way water flow, and bottom organisms (tendipedids) made up most of the diet.

Plankton blooms could account for the increase in copepod consumption in Areas VI and VII in the fall. Allen (1920) found copepods most abundant in the Stockton area in August and September, when the water was warm and stagnant.

Seasonal variations in the importance of *Corophium,* such as those in Areas VIII and IX, may have been related to its life cycle, of which little is known. This tube-dwelling organism is sometimes planktonic, since we have caught it in surface plankton samples. Some other amphipods are planktonic during their breeding season, so this might be the factor controlling *Corophium's* availability.

There were differences in stomach contents among different sizes of bass. Generally, as indicated by the summer food habits, larger bass fed on larger organisms. However, in the fall, bass fed less on *Neomysis* in all but Area III, while the frequency of occurrence of copepods was higher in Areas II, VI, and VII. Here again, seasonal variations in relative abundance and availability of a food organism could have caused this difference in bass food habits.

By comparing the distribution of young-of-the-year bass, as indicated by the spawning success surveys, and the food habits of these fish during the summer, the importance of *Neomysis* is clearly shown. Since *Neomysis* are considerably larger than copepods, their importance would be even greater on a weight basis. However, the importance of copepods and cladocerans to bass less than 1 inch long must not be overlooked. The availability of these organisms to newly-hatched bass may be a major factor affecting striped bass survival and abundance.

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Robert J. Toth planned the study. All three authors participated in the collection and analysis of stomachs. Final analysis and writing were done by William Heubach.

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Thomas E. Bowman, Smithsonian Institution, Washington, D.C., verified identification of the copepods and cladocerans. Milton Miller, University of California, Davis, examined the amphipods and isopods. Thomas Doyle, California Department of Fish and Game, identified the tendipedid larvae.

SUMMARY

Young-of-the-year striped bass inhabiting the Sacramento-San Joaquin Delta region fed primarily on *Neomysis,* copepods, cladocerans, *Corophium,* and tendipedid larvae.

In the summer, *Neomysis* was the most important food item of bass from Carquinez Strait to Rio Vista on the Sacramento River and Medford Island on the San Joaquin River, which is the general area inhabited by most of the young bass population. Above the mouth of the Mokelumne River, and in sloughs south of the San Joaquin River, copepods were the dominant food organism. *Neomysis* and *Corophiuni* were more important to bass over 1 inch long than to those under 1 inch, while copepods were less important to the larger fish. The consumption of cladocera was not related to size.

In the fall, copepods were more important, and *Neomysis* less important in the diet of bass from the San Joaquin River. Bass collected off the main channel of the San Joaquin and Sacramento rivers fed primarily on *Corophium.* Seasonal variations in abundance, or availability, of food organisms could account for these diet changes.

Tendipedid larvae and pupae were the principal food of bass collected in the rivers above the Delta, where there is less tidal movement and the water is fresh.

Fish were unimportant in the diet of young-of-the-year striped bass.

The occurrence of organisms in the stomachs generally agreed with the distribution of plankton organisms in the environment. Thus, food habits in any area were largely controlled by the factors controlling plankton distribution. Salinity and water flow were the most important of these factors.

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