Food Habits of Striped Bass, Roccus Saxatilis (Walbaum)
in the Sacramento-Rio Vista Area of the Sacramento River

By

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A.B. (University of California) 1961

THESIS

Submitted in partial satisfaction of the requirements for the degree of

MASTER OF ARTS

in

Zoology

in the

GRADUATE DIVISION

of the

UNIVERSITY OF CALIFORNIA

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INTRODUCTION

The purpose of this study was to determine the food habits of the striped bass, Roccus saxatilis (Walbaum) and the extent of predation by this species upon young king salmon, Oncorhynchus tshawytscha in the Sacramento River between Rio Vista and Sacramento. Previous studies in California of the food of striped bass have been concentrated in the area between Antioch in the lower Sacramento-San Joaquin Delta and San Francisco Bay.

The striped bass is an anadromous member of the family Serranidae and is an important game and food fish throughout it's range. Mature striped bass normally ascend the Sacramento and San Joaquin Rivers for spawning in the spring months, then descend to the bay and coastal ocean waters for the summer and fall months. Some bass, however, can usually be found in the river throughout the year. During the course of this study, bass ranging from 10 to 15 inches in size were found to be particularly abundant in the area from May through September.

The striped bass was native on the Atlantic Coast from the Gulf of St. Lawrence to northern Florida with centers of abundance including the Chesapeake and Delaware Bay regions, and the waters of New York and southern New England. Striped bass were introduced to California in 1879. The initial plant was transported from New Jersey waters and released in Carquinez Straits at Martinez. Three years later a second plant of 300 New Jersey fish was made in Suisun Bay near Army Point (Scofield and Bryant, 1926). The present Pacific Coast range of the striped bass lies between the Columbia River, Washington, and southern California. The main center of distribution in the west is San Francisco Bay and the Sacramento-San

Joaquin Delta. An abundant population also occurs in Coos Bay in Oregon.

ACKNOWLEDGMENTS

The author wishes to thank those persons who assisted in completion of the study.

Dr. Paul R. Needham gave continued encouragement and guidance throughout the course of the study and critically reviewed the manuscript. Drs. A. Starker Leopold and Robert L. Usinger critically reviewed the manuscript.

Messrs. John.P. O'Connell, Robin De Mandel, E. H. Krampert, Stephen B. Mathews, J. Rupsen, Harold Sassman, Alan Stevens, and Donald Thau aided in collection of the bass stomachs which were examined. The operators of Uncle Bobbie's Resort at Rio Vista, Courtland Dock at Courtland and Cliff's Place at Freeport kindly permitted the writer to collect stomachs from bass caught by their patrons.

Messrs. Eldon Hughes, Richard J. Hallock and George H. Warner provided California Department of Fish and Game records concerning abundance of fishes at Carquinez Straits, and releases of king salmon from Coleman and Nimbus Hatcheries. Mr. John Pelnar of the U.S. Fish and Wildlife Service also provided data concerning salmon releases from Coleman Hatchery. Mr. William Heubach of the California Department of Fish and Game suggested the use of Seaburg's stomach sampler and assisted in collection of bass.

Several fellow students provided assistance. Mr. John Shimizu identified the insects which were found in several stomachs and helped collect bass. Mr. John Hopkirk aided in identification of some of the partially digested fish. Mr. Robert Behnke also assisted in identification of fish and provided technical advice concerning the manuscript.

Mrs. Jeanette Yeazell, librarian at the University of California Medical Library in San Francisco, helped prepare the manuscript. Mrs. Dixie O'Connell kindly drew the map of the study area, and Mrs. Emily Reid assisted with the other drawings. Mrs. E. F. Stevens and Mrs. Karl Katlas typed the manuscript.

This study was supported by a scholarship granted for two years by the Tyee Club of San Francisco, and the author wishes to express his sincere gratitude for their generosity.

PREVIOUS STUDIES

Accounts of striped bass food habits on the Atlantic coast were published as early as 1871. In that year Verrill reported that the stomachs of several bass taken at Great Egg Harbor, New Jersey contained shrimp. Chesapeake Bay studies show that anchovies, Anchova mitchelli; menhaden, Brevoortia tyrannus; spot, Leiostomus xanthurus; and croaker, Micropogon undulatus, make up the greater portion of the diet of larger bass and that crustaceans, annelids, and insects are important items in the diet of smaller bass (Hildebrand and Schroeder, 1928; Truitt and Vladykov, 1937; Hollis, 1952).

Studies on juvenile bass in New York waters have been reported by Curran and Ries (1937) and Townes (1937). Freshwater shrimp, Gammarus fasciatus and chironomid larvae were the most important foods. Merriman (1937, 1941) examined 550 bass stomachs, mostly from Connecticut waters. His findings disclosed that shiners or silversides, Menidia menidia notata; menhaden; shrimp, Palaemonetes vulgaris; and mummichogs or killifish, Fundulus heteroclitis and F. majalis, are common food types. Merriman (1941) also reported on the analysis of stomachs of three juvenile bass ranging from 6.0 to 7.5 centimeters standard length taken in the Parker River, Massachusetts, and 30 juveniles and yearlings from the Delaware River, New Jersey. The Parker River bass all had been feeding on shrimp, Crago septemspinosus, but those from the Delaware River were large enough to have become more voracious in their feeding habits, as is evidenced by the fact that 19 of 30 stomachs contained the remains of fish while the others were empty.

In North Carolina, stomach contents of 101 striped bass from the Albemarle Sound region and Manteo included at least 11 species of fish and five species of crustaceans (Merriman 1941).

On the West Coast, the analysis of stomachs from 66 adult striped bass caught in the Umpqua River, Oregon identified the following foods: tomcod, surfsmelt, sea perch, jack smelt, flounders, squawfish, sculpins, pilchard, crabs and shrimp. Seaward migrant king salmon were present in the lower river at the time of this study, but it is claimed that they were overlooked in favor of more abundant species (Anonymous, 1946). Morgan and Gerlach (1950) reported on the examination of 1018 stomachs from the Coos Bay area, Oregon in 1948, 1949, and 1950. Fifty per cent of these were found to be empty. During most of the year, fish which occur in large schools were the predominent food items. Foods included viviparous perch, herring, anchovies, sand lances, surf smelt, sculpins, shrimp and crabs. During April, May, and June, trout and salmon fry and fingerlings formed almost seven per cent of the diet. Shapovalov (1936) reported on the examination of six bass taken in Coos Harbor which contained 10, 11, 14, 15, 20, and 22 trout and salmon fingerlings, respectively.

Concerning the diet of the striped bass in California, Smith (1896) concluded that the introduced carp was the principal food. He stated that at this time seven out of ten bass caught in the rivers or sold in the San Francisco markets contained carp. Shapovalov (1936), however, asserted that it is impossible to take Smith's statement literally in the light of more recent findings which indicate that carp are not a prominent item in the stomach contents of striped bass.

Although several specimens were found in stomachs of bass, carp were not an important food of striped bass in the present study. Carp were probably introduced to the Sacramento River sometime in the 1870's and may have been in the midst of a population explosion during the time of Smith's

report. According to Smith, in 1884 the carp supply was enormous, and the market price at that time was only 1½ cents per pound. It is probable that carp were formerly more important as a striped bass prey. Scofield and Coleman (1910) seem to support this idea when they state that the food of adult striped bass in the rivers is principally carp, hardheads, and splittails. Scofield and Coleman also reported that the examination of 50 stomachs of three inch bass captured in Napa Creek on September 10, 1908, showed marine worms to comprise 50 per cent of the diet, marine crustaceans 48 per cent, and small fish two per cent.

According to Scofield and Bryant (1926), Mr. W. P. West of Napa examined bass stomachs which contained crabs, minnows, clams, duck entrails, and sardines. After a random examination of stomachs over a period of three years, Scofield (1928a) stated that because of their continual presence in large numbers, small fish, shrimp, crabs, clams, periwinkles, sardines, anchovies, smelt, gobies, minnows, and herring form the main diet of the striped bass. Scofield (1928b) mentioned that a school of bass fed on the coelenterate Vellela at the mouth of the Salinas River. He also reported that bass eat their own young in great quantities.

Shapovalov (1936) examined 47 bass from Waddell Creek lagoon, Santa Cruz County, which were feeding on small crustaceans, Gammarus sp., Corophium sp., and Exosphaeroma sp.; sticklebacks, Gasterosteus aculeatus; gobies, Eucyclogobius newberryi; young silver salmon, Oncorhynchus kisutch; steelhead, Salmo gairdnerii; and sculpins, Cottus sp.. Shapovalov also examined 43 stomachs from bass taken in San Francisco Bay and the Delta Region. Twelve of these bass came from the Sacramento-Rio Vista sector of the Sacramento River. One taken at the American River mouth contained two sardine

heads. Contents of stomachs from two bass taken in the Brickyards area near Sacramento consisted of vertebrae of a three inch long fish, one herring head, and half of a herring body. Eight of the nine bass taken in the Rio Vista area contained no food, and the other contained half of a crab. Vertebrae of the unidentified fish and the half a crab were probably natural foods; the herring and sardine heads are obviously bait.

Hatton (1940) reported on the stomach analysis of 224 bass collected with a gill net at Pittsburg during March, April and May. Of this catch, 56.6 per cent contained no food. Fish or fish remains were present in 34.0 per cent, and 11.2 per cent contained crustaceans. He also recorded results of the examination of 76 stomachs from yearling bass captured at Martinez in September and November. Several species of crustaceans proved to be the most important item in the diet. Neomysis were the most common food in the stomachs of 58 yearling bass from the same area in February and March.

Johnson and Calhoun (1952) examined stomachs from a series of bass caught by anglers in waters from San Rafael to Martinez; during the summer period, shrimp, Crago sp. and anchovies, Engraulis mordax were the most important foods. Neomysis was the dominant organism in the winter sample. Bass in the winter sample were caught in the San Joaquin River between Antioch and Middle River.

Raney (1952) presents a detailed review of previous publications on striped bass food habits.

STUDY AREA

Stomach contents were analyzed from striped bass caught by the writer and companions in the following localities: Sacramento River near Freeport, confluence of Sutter Slough and Sacramento River, Sacramento River beneath the Paintersville Bridge near Courtland, upper confluence of Steamboat Slough and Sacramento River, Delta Cross Channel, and confluence of Three Mile Slough and Sacramento River. Bass stomachs were also obtained from anglers at fishing resorts in the general area of capture. Collections were made at resorts located near Freeport, Courtland, and Rio Vista.

The Sacramento River near Rio Vista averages one-half mile in width. Above Rio Vista the river narrows, averaging only 400 to 500 feet in width. Depths in the Rio Vista area range up to 34 feet. In the upper section of the study area depths range up to 52 feet. The depth at the Paintersville Bridge, where much of the work was done, is approximately 20 feet.

METHODS AND MATERIALS

Five hundred and ninety-eight stomachs were obtained from bass caught by the writer and companions with a gill net, with cut sardine bait, and with artificial lures. Seventy-two samples were gathered from anglers using sardine bait in the aforementioned locations. Stomach samples were collected in the months of May, June, July, August, September and November of 1962; and February, March and April of 1963. During the winter months it is difficult to obtain samples as few striped bass are caught in the study area during this period. Of all stomachs inspected, 63.3 per cent were without food. Bass were caught on sardine baits during all months. Artificial lures were used only during June, July and August. The gill net was used only in July.

Fork length of the fish was measured to the nearest 0.5 inch. Striped bass averaging 12 inches and ranging from 8 to 32.5 inches were personally captured during the period from May to September. Bass shorter than the 16 inch legal size limit could be taken under the regulations of the writer's scientific collecting permit; therefore these fish averaged smaller than those collected from anglers throughout the rest of the year. Angler caught fish were all necessarily greater than the 16 inch total length minimum size limit. This size corresponds with 15 inches fork length.

Because of the value of the striped bass as a game fish, it was undesirable to kill a large number of those personally captured, solely for the purpose of taking stomach samples. Instead, a method of sampling stomach contents similar to that described by Seaburg (1957) was used. This method consists of two copper tubes, one mounted on top of the other, inserted down

the esophagus of the fish. Water is flushed into the stomach through one tube and foods in the stomach are flushed out through the other. A one gallon garden spray, suggested by Mr. William Heubach of the California Department of Fish and Game, was used to pump water under pressure instead of the rubber bulb used by Seaburg. The stomach sampler proved to be quite efficient. In about 95 per cent of the bass, the entire content of the stomach was completely flushed. In about 5 per cent, unflushed food objects, too large to be excavated through the outlet tube were indicated by bits of debris in the flushing water. These percentages were determined by sacrificing and cutting open approximately one out of ten bass which appeared to be completely flushed, and all those bass which apparently still contained food.

The collected contents of stomachs were wrapped in cheese cloth, labeled, and preserved in a solution of ten per cent formalin. At the time of examination the numbers of each food type were determined by actual count, and the volume percentage of each item was determined by water displacement in a graduated cylinder. The identification of foods was made to the lowest taxonomic group possible. Total length of undigested organisms was measured in millimeters. Partially digested fish were cleared and stained, using the technique described by Clothier (1950). Identification of these cleared and stained fish was made by comparison of vertebrae and other skeletal characteristics with known specimens. Bait items, such as pieces of sardine, were not included in the analysis.

GENERAL CONSIDERATIONS WITH REGARD TO SEASONAL FOOD CONSUMPTION

The striped bass diet was found to vary according to time of year and locality sampled. A species of crayfish, Pacifastacus leniusculus, introduced from Oregon (Riegel, 1959) was found to be a food in all areas sampled upstream from Rio Vista. Crayfish were an important food during most months in which stomachs containing natural food were obtained. Often only parts such as chelipeds or walking legs were found in bass stomachs. In other instances merely gastroliths were present; these apparently remain long after the rest of the crayfish has been digested.

The freshwater smelt, Hypomesus olidus, was the most important food during March and April, and was also important during June and August. This species formed only 19.9 per cent of the total August diet but in the sample obtained at the Three Mile Slough Bridge it made up 64.9 per cent of the food. Freshwater smelt was the only item found in stomachs of bass caught at both the extreme upstream and downstream ends of the study area.

Young king salmon were the most important food during June, July and August. A unique, highly localized, situation exists at the Paintersville Bridge, where predation by bass on young salmon, freshwater smelt and possibly other species occurs on the river surface beneath the shadow of the bridge during these months. All ten other bridges crossing the Sacramento River and adjacent sloughs between Sacramento and Three Mile Slough were checked on several occasions during the same period that surface predation was taking place at the Paintersville Bridge. In no case was any surface activity observed, except at Three Mile Slough during late August when bass were observed feeding predominately on freshwater smelt. Salmon were also found in stomachs of bass caught at the confluence of Sutter Slough and the

Sacramento River, and in the Sacramento River near Freeport. All undigested salmonids found in stomachs during the summer months were king salmon; therefore those partially digested specimens determined by skeletal characteristics to be salmonids were included in the king salmon category. It is possible that some of these salmonids were actually steelhead or silver salmon.

Myscid shrimp, Neomysis mercedes, were the only food present in stomachs examined during February. This month was the only one in which myscid shrimp were in the diet. The locality factor is probably the reason for this phenomenon, rather than seasonal variation in feeding habits. The entire February sample which consisted of only 12 stomachs was collected in the Rio Vista area where few stomachs were gathered during other months. More myscid shrimp would probably have been found in the striped bass diet had a larger number of stomachs been obtained in this locality during the rest of the year. The absence of this organism in stomachs of bass taken upstream is probably indicative of a decrease in salinity of the water above Rio Vista.

Evidence of cannabalism was found during July and August when young of the year bass were common in the diet of larger stripers.

Other foods determined to be part of the bass diet were : carp, Cyprinus carpio; splittail, Pogonichthys macrolepidotus; tule perch, Hysterocarpus traskii; Pacific lamprey, Entosphenus tridentatus; shad, Alosa sapidissima; goldfish, Crassius auratus; amphipods, Corophium sp.; chironomids, fam. Tendipedidae; and one polychaete.

Insects of the families Aphidae, Cicadellidae, Staphylinadae, Agontidae, Baetidae, Syrphidae, and Coccinellidae were found in stomachs of bass taken during June and July. In all cases when insect families

other than Tendipedidae were present, partially digested salmon were also found in the same stomach. It is probable that these insects gained entry to the bass stomachs by way of the salmon. Examination of the stomachs from several undigested salmon established the fact that they were feeding on insects of some of these families. Rutter (1903) found many insects in the diet of young salmon migrating through the study area.

The absence of chironomids in stomachs of bass over 13 inches in length was the only indication of any selective feeding by bass of different sizes. This finding differs from that of Shapovalov (1936) in Waddell Creek lagoon where bass of a size larger than 40 centimeters fed mainly on salmon, trout, and sculpins while those bass between 20 and 40 centimeters fed almost entirely on small crustaceans, sticklebacks, and gobies.

FOOD CONSUMPTION BY MONTH AND AREA

May

Contents of 14 stomachs from striped bass taken May 15 at the Paintersville Bridge were examined. One contained a crayfish and the other 13 were either empty or contained sardine bait. The deficiency of natural foods at this time may indicate such items were not readily available to bass in the Paintersville area.

June

One hundred and ten of some 229 stomachs examined from striped bass caught during June contained no natural food. Seaward migrant king salmon were the dominant food item. Of the 119 stomachs containing food, 105 or 88.2 per cent contained a total of 207 salmon. The total length of these salmon ranged from 60 to 100 millimeters and up to nine individuals were found in one stomach. Salmon formed 86.5 per cent of the food volume for June.

A total of 24 freshwater smelt were found in 20 samples or 16.8 per cent of the stomachs containing food during this month. The size of the freshwater smelt ranged from 73 to 80 millimeters. This species formed 11.1 per cent of the June food consumption.

Parts of crayfish were found in eight stomachs or 6.7 per cent of those containing food. Crayfish formed only 2.3 per cent of the June diet.

Fish taken at the Paintersville Bridge

One hundred and ninety-seven stomachs or 86 per cent of the June sample were examined from bass caught at the Paintersville Bridge. One hundred and seven of these stomachs contained food other than bait. One hundred

and ninety-eight salmon were present in 97 stomachs or 90.7 per cent of those with food. They made up 82.4 per cent of the diet. All 24 of the freshwater smelt found in the June sample came from bass caught in this area. They were present in 18.7 per cent of the stomachs containing food and comprised 11.6 per cent of the diet. Crayfish parts were found in two stomachs and a polychaete was present in one stomach.

Fish taken at Confluence of Sutter Slough and Sacramento River

The contents of 13 stomachs from striped bass taken in this area were determined. The four containing food held a total of five salmon. No other food organisms were present.

Fish taken in Freeport area

Salmon were also a dominant food item in the seven stomachs containing food from a sample of 18 bass caught in the Freeport area. One salmon was found in each of four stomachs and they formed 48.6 per cent of the total food volume. Crayfish parts were found in five stomachs and amounted to 44.3 per cent of the food consumption. One carp formed 7.1 per cent of the striped bass diet in this area.

Fish taken at upper confluence of Steamboat Slough and Sacramento River

The one stomach examined from a bass caught in this area contained a crayfish.

July

Two hundred and fifty-eight stomachs were examined from bass captured during July. Eighty-seven or 33.7 per cent of these contained natural food items. As in the previous month 67 salmon present in 55 stomachs or 63.2 per cent of those containing food were the dominant item. These salmon ranged from 63 to 108 millimeters in length and formed 65.1 per cent

of the total diet. No more than four individuals were present in one stomach.

Due to the large size of one specimen (147 millimeters), young striped bass were the second most important food found in stomachs sampled during July. Thirteen individuals appeared in eight stomachs and comprised 16.3 per cent of the total volume.

Crayfish made up 13.3 per cent of the total food consumption. Crayfish were present in 11 stomachs or 12.6 per cent of those containing food.

One freshwater smelt was found in each of three stomachs. This species comprised only 0.7 per cent of the total volume for July. Two splittail, a native cyprinid, occurred in one stomach and formed 0.9 per cent of the July diet. Two specimens of another native species, the tule perch, were present in the stomach samples. They made up 3.2 per cent of the total food. One American shad formed 0.4 per cent of the July food consumption and one carp comprised 0.2 per cent of the diet.

Chironomid adults, larvae, and pupae were present in 18.0 per cent of the stomachs containing food. In no case were chironomids present in a sufficient quantity to make a volume measurement. Although 36 individuals were found in one of the stomachs, usually less than five individuals were present. Due to the small size and numbers of these organisms they cannot be considered an important food of the bass population sampled.

An amphipod was present in each of three stomachs or 3.4 per cent of those containing food. As with the chironomids, they were insignificant as a diet item.

Fish taken at the Paintersville Bridge

Two hundred and eight stomachs, equal to 80.6 per cent of the

July sample, were sampled from bass caught at the Paintersville Bridge. Only 35.6 per cent or 74 stomachs contained food. Sixty-five salmon in fifty-three stomachs or 71.6 per cent of those containing food formed 72.0 per cent of the diet. Twelve of the 13 young striped bass came from the stomachs of bass collected in this area. They were found in seven stomachs or 9.5 per cent of those containing food, and made up 17.9 per cent of the food consumption. Crayfish were present in five stomachs and amounted to 4.1 per cent of the diet. The two tule perch comprised 3.6 per cent of the food. The combined volumes of two splittail, three freshwater smelt, one shad and one carp formed 2.4 per cent of the total for the Paintersville area. Chironomids were present in 10 stomachs or 13.5 per cent of those containing food, and amphipods were present in three stomachs.

Fish taken at confluence of Sutter Slough and Sacramento River

Nine of the 20 stomachs examined from this area contained no food. five others contained only chironomids. Crayfish present in three stomachs made up 60.9 per cent of the total volume. Two salmon and one striped bass comprised the rest of the diet.

Fish taken at the Delta Cross Channel

Particles from a crayfish exoskeleton found in one stomach were the only natural food present in this sample. The other 14 stomachs were either empty or contained sardine bait.

August

Fifty of the 72 stomachs examined from striped bass caught in August contained no natural food organisms. Thirteen freshwater smelt present in 9 stomachs or 40.9 per cent of those containing food were the most frequent item encountered, however they made up only 19.9 per cent of the

total volume. The reason for this low percentage is that they were rather small, averaging only 45 millimeters in total length. A total of five salmon up to 100 millimeters in length were found in five stomachs and comprised 61.2 per cent of the diet. Each of four stomachs contained one young striped bass. These bass formed 10.4 per cent of the food. Two stomachs contained crayfish parts for 2.0 per cent of the total diet and one Pacific lamprey ammocoete composed 5.9 per cent of the August food. Chironomids were present in two stomachs.

Fish taken at the Paintersville Bridge

Forty-two of the 52 stomachs examined from striped bass caught at the Paintersville Bridge held no natural food. One salmon was present in each of five stomachs or 50 per cent of those containing food. They amounted to 88.3 per cent of the total volume. The lamprey formed 8.5 per cent of the volume, and one striped bass and the crayfish parts made up the rest of the diet.

Fish taken at confluence of Three Mile Slough and Sacramento River

The contents of 20 stomachs from bass caught in this area were determined. Twelve or 60 per cent contained food. The 13 freshwater smelt were the dominant item, occurring in nine stomachs and making up 64.9 per cent of the diet. Striped bass were found in 3 stomachs and formed 33.0 per cent of the food. Unidentified, fish, vertebral fragments made up the remaining 2.1 per cent of the stomach contents.

September

Contents of 25 stomachs from striped bass taken September 8 at the Paintersville Bridge were determined. Sixteen of these were found to contain no natural food. Crayfish present in seven stomachs were the most

important item forming 97.5 per cent of the total volume. One carp, the only fish occurring in this series of stomachs, formed 2.6 per cent of the September diet. Chironomids occurred in two stomachs.

November

Nine stomachs from angler-caught bass ranging in size from 17 to 28 inches were obtained in the Courtland area. Natural foods were conspicuous by their absence. Six of the stomachs contained only sardine bait and the remaining three were without food.

February

A sample of 12 bass stomachs was obtained from anglers in the Rio Vista area on February 23 and 24. The fish ranged from 16 to 28 inches in fork length. A total of 23 myscid shrimp were found in three of the 12 stomachs. These organisms were the only food other than the sardines used for bait.

March

Thirty-three stomachs were examined from bass caught by anglers in March. Two stomachs were examined from fish caught in the Courtland area and two others were examined from fish taken near Rio Vista. All four of these were empty. The remainder of the March sample consisted of stomachs from bass caught in the Freeport area. These fish ranged from 15 to 37 inches in fork length.

A total of 39 freshwater smelt ranging in size from 72 to 84 millimeters formed 81.6 per cent of the March diet. This species was present in all 12 of the stomachs containing natural food items. Two partially digested salmonids, probably king salmon, in the 70 to 80 millimeter size range made up 8.2 per cent of the food consumption. The remainder of the

diet consisted of one crayfish and one goldfish.

April

Due to heavy unseasonal rainfall, the Sacramento River was high and muddy during this month; therefore few fish were caught by anglers in the study area. A sample of 18 stomachs was obtained from bass ranging from 15 to 29 inches in size. Four of these bass were caught in the Freeport area and the remainder were taken in the vicinity of Rio Vista.

Freshwater smelt were the only food found in the sample. Three members of this species were present in the stomach of one bass caught near Freeport, and one freshwater smelt was found in each of two stomachs from bass taken in the Rio Vista area.

COMPARISON OF METHODS OF CAPTURE

Two of the three means used to obtain striped bass for this study, artificial lures and the gill net, were successful only when bass were actively feeding on the surface. Bass could be taken effectively fishing on the bottom with sardine bait at times when they could not be obtained by either of the two other methods. There are two arguments against using artificial lures to capture bass for stomach analysis:

1--The lure looks like a small fish and as a result biases the sample toward those bass feeding on small fish.

2--The lure might bias the sample toward the bass which catch fleeing prey more often than those in a random sample of the population.

It might also be argued that a larger percentage of bass caught on sardine bait are slower and more sedentary in their feeding habits than those in a random sample of the population.

The gill net should be non-selective in these respects. Taking fish by this means proved to be difficult, however, because during the summer months when bass were feeding on the surface, they were usually able to avoid a drifting net. Owing to the volume of water flow and presence of snags, a net could not be set or drifted along the river bottom at any time during the year. Comparison of stomach contents from lure caught fish and gill net caught fish on the day in which an adequate gill net sample was obtained, shows no significant difference between the stomach contents of bass taken by the two methods (Table 4). There was also relatively little difference between the foods of bass caught on artificial lures and of those taken on sardine bait at the Paintersville Bridge during the month of June (Table 1).

During July, crayfish and young striped bass formed a larger portion of the diet of bass caught on sardine bait than of the diet of bass caught with a gill net and artificial lures. Salmon were a more prevalent food in the stomachs of bass taken by the latter two methods (Table 2). Because there was little difference in the stomach contents of bass caught by the different methods in June, it appears that the difference during July cannot be accounted for by the method of capture, but that it is due to depth of feeding and time of capture. The diet of bass caught with a gill net, and by artificial lures consisted mainly of salmon because these bass were caught only when actively feeding on salmon within a few feet of the surface. Correspondingly, a smaller portion of empty stomachs were found in bass caught on artificial lures than in bass caught on sardine bait during both June and July (Tables 1 and 2). Splash counts, average number of salmon found per examined stomach, and records of downstream migrant salmon (Calif. Dept. Fish and Game Mar. Res. Br., 1962a-1962i) indicate that young salmon are less abundant during July than during June. As a result, other food organisms now comparatively more abundant, formed a greater portion of the diet of those bass caught on sardine bait.

Because relatively little surface feeding occurred, no fish were caught on lures at the Paintersville Bridge during August. All bass sampled during this month were caught on sardine bait. Although a larger number of bass stomachs were examined for every salmon found (Table 5), salmon formed a greater part of the bass diet than in the previous month (Tables 2 and 3). Splash counts and California Dept. of Fish and Game data on downstream migrants show that salmon were less abundant during August than during July. These facts seem to indicate that other organisms present in the June and

July diet of the striped bass were also less available during August. A higher percentage of empty stomachs was also found in the August sardine-bait caught sample than in either the June or July sample taken by this method (Tables 1, 2, and 3).

SPLASH COUNTS

In the Paintersville area, splashes on the river surface made by schools estimated to be of three to more than 100 bass chasing salmon, freshwater smelt, and possible other species could be observed from the bridge or from an anchored boat. Counts were made of the groups of splashes occurring in the main channel between the center piers of the bridge, every other half hour for four consecutive hours or more, on 15 dates between June 13 and September 8. Hourly counts were obtained by interpolating between the half hours which were actually counted. These counts show the peak of feeding activity to be determined by current conditions and daylight.

On seven occasions the current cycle was determined for the period during which splash groups were counted. Figure 3 shows the peak of activity to occur after the period of minimum current and prior to the period of maximum current. Minimum activity generally coincided with minimum current. The average time taken by three successive 100 foot drifts of a floating cork was used to calculate current velocity. Measured velocities varied between 0.49 and 2.14 feet per second and were undoubtedly affected by tide, run-off from the watershed, and dam releases.

No splashes were observed or heard before sunrise or after sunset. Eighty per cent of the stomachs of bass caught on artificial lures in the first hour after sunrise contained no food, further indicating these fish were not feeding at night. The absence of night feeding probably reflects the inability of bass to see seaward migrant salmon passing through the semi-turbid water, rather than a lack of downstream migration during this period. Studies by French and Wahle (1959) and Meehan and Siniff (1962)

have shown that young king salmon tend to move at night, rather than during daylight hours. These studies were of fish in clear water habitats, and Meehan and Siniff are of the opinion that the tendency may decrease as turbidity increases; however there is no reason to believe this behavior should be reversed in more turbid waters.

Splash counts revealed the shadow of the bridge to be a definite factor in determining the area in which surface predation took place. On June 13, an overcast day, the bass were observed chasing their prey as far as 100 yards upstream from the bridge. On this date, two-thirds of the splashes were observed in an area where, on clear days, less than one-tenth of the splashes occur. Most activity usually occurred within the confines of the bridge shadow and not further than 50 feet upstream from it.

According to counts, the greatest predation took place on June 25 when 461 groups of splashes were observed during one half hour period (Table 6). A total of 60 salmon and one freshwater smelt were found in 25 striped bass stomachs collected on this date.

A peak hour of predator activity was determined for each day of observation. This hour was given a rank of 100 per cent. The observed number of splashes during each hour period before and after the peak hour period were rated in terms of per cent of the peak period.

Figure 4 is a composite of the relationships between the number of splashes occurring during the hour periods before and after the peak hour period, and the number of splashes occurring during the peak hour period. From Figure 4, it may be determined that on the average day, 19.8 per cent of the total daily activity occurs during the peak hour period; therefore

the approximate number of splashes occurring during a day was obtained by multiplying the number of splashes counted during the peak hour period of that day by a factor of 5.05. The constant 5.05 was used because 5.05 x 19.8 per cent $\cong$ 100 per cent.

To estimate the daily amount of predation on salmon based on splash observations, the ratio of salmon to other fishes in the stomach contents of the bass was calculated. The estimated total splashes occurring during a day was then reduced by this ratio. For example: if 1000 splashes were estimated to occur, and 8 of 10 fishes found in bass stomachs were determined to be salmon, 80 per cent or 800 of the splashes were attributed to predation on salmon. On any given day the percent of salmon in the bass diet was based on the examination of a minimum of 10 bass stomachs. If less than 10 stomachs were examined, then the average ratio of salmon to other fishes in the diet of the bass during that calendar week was applied. In 457 striped bass stomachs examined from June 9 to August 14 at the Paintersville Bridge, 268 salmon comprised 85.1 per cent of the total fishes consumed.

When daily total splashes attributed to predation on salmon in the main channel were plotted against the time between June 3 and September 8, and a curve drawn, the area of the curve was found to equal 39,000 salmon (Figure 5). June 3 was picked for the starting point of the curve because it was on this date that Mr. Harold Sassman (personal communication), a bridge tender, first observed the occurrence of surface activity. The writer had his first opportunity to observe such activity on June 9.

The total beneath the curve is probably an underestimate of the number of salmon actually preyed upon during this period. It does not

take into consideration the salmon which fall prey to bass beneath the surface or those on the surface under the bridge between the main channel and both shores. Splashes occurred but were not counted in the latter area which is comparable in size to that of the main channel underneath the bridge. While a certain percentage of salmon included in the splash counts certainly escape, this number is undoubtedly exceeded by those preyed upon but not counted. If the estimate is doubled to include those splashes not counted, a figure of 78,000 salmon is obtained.

Occurrence of surface predation at the Paintersville Bridge appears to be related to releases of king salmon fingerlings from Nimbus Hatchery into the American River. Nimbus Hatchery is located approximately 40 miles upstream from the Paintersville Bridge. Salmon of the size range being preyed upon, were released on May 28 and 31; and June 1, 4, 7, 20, 21, 25, 26, 27, and 28. Fish in these releases ranged from 15 to 8 per ounce. The last release prior to May 28 was on May 11 when the salmon averaged 48 per ounce; salmon of this size are much smaller than those found in bass stomachs from June 9 to August 14.

The first date that surface predation was noticed was June 3, six days after the first of the above series of releases. Predation may have actually taken place, unnoticed, for a day or two prior to June 3. As splash groups were not counted until June 13, no index of predation intensity prior to this date was obtained. One June 25, the peak date of observed predation, striped bass accounted for approximately 3,875 salmon. This date was four and five days after the releases of June 21 and 20. Theoretically splash counts five days after the releases of June 25 to 28 should have indicated heavy predation during the period from June 30 to July 3 or 4. Estimated

splash numbers on June 30 were the second highest totaled but were less than half those counted on June 25 (Figure 7). Unfortunately splash groups were not tallied again until July 7 when approximately 675 splashes occurred. The lack of counts from some of the above mentioned dates may have had the effect of significantly reducing the estimate of the number of salmon preyed upon.

The last releases of fingerling king salmon from Coleman Hatchery into Battle Creek were made on May 9. Dralle (1962) indicates salmon released from Coleman Hatchery require two weeks to reach Rio Vista, a distance of approximately 200 miles. Therefore the bulk of these fingerlings should have passed through the Paintersville area several weeks prior to the first occurrence of surface predation.

Although the total number of salmon migrating down the Sacramento River is not known, the quantity preyed upon at the Paintersville Bridge is undoubtedly an insignificant portion of the total seaward migrants. According to California Department of Fish and Game records, hatchery releases alone totaled more than 36,000,000 salmon.

On March 21 and March 28, fingerling salmon were released at Rio Vista (Dralle, 1962). The earliest date on which the California Department of Fish and Game captured one of these marked fingerlings with a mid-water trawl at Carquinez Straits was April 5. (California Dept. Fish and Game, Mar. Res. Br., 1962 c; 1962 d). These figures seem to indicate that salmon require a time period of not less than 15 days to travel from Rio Vista to Carquinez Straits. In order to construct a working approximation, the writer arbitrarily added five days to the 15 day period as a means of estimating the travel time from the Paintersville Bridge to Carquinez Straits.

The average number of seaward migrant salmon captured per trawl at Carquinez Straits could then be used to indicate intensity of the downstream migration through the Paintersville area. These averages were calculated from data presented in California Department of Fish and Game Marine Resources Branch Cruise Reports (Calif. Dept. Fish and Game Mar. Res. Br., 1962a-1962i) and indicate that the main portion of the seaward migrant salmon have passed through the study area prior to the first occurrence of surface predation by striped bass at the Paintersville Bridge (Figure 6).

DISCUSSION

The most important finding of this study is that young king salmon are a major food item in the diet of striped bass in the study area during June, July and August. Although predation by striped bass on young salmon had been suspected for years (Scofield, 1928a; Scofield 1931; Sumner and Smith 1940), there are no previous records of bass predation on salmonids occurring in the Sacramento-San Joaquin River system.

On the basis of the examination of a gill net collection of 224 adult bass taken between March 13 and May 4, 1939 at Pittsburg and bass caught by anglers from the Yuba River near Marysville, and Potato Slough in the San Joaquin delta, Hatton (1940) concluded salmonids form no important part of the food of the striped bass in the Sacramento River system.

It is the opinion of this writer that Hatton and other previous workers were looking for bass predation on salmonids in the wrong area. Fry (1962) looks upon the Sacramento River system as a giant inverted funnel. Using the same analogy it may be seen that earlier California studies of striped bass food habits were centered in the wide end of the funnel. The specimens examined in the present study were obtained in the narrow section of the funnel. In the wide end of the funnel seaward migrant salmon may be distributed over an area several miles in width, rather than concentrated where the river is only several hundred feet wide.

Studies on the Eel River indicate young king salmon to be schooled in upper tidewater but scattered at the mouth of the river (Murphy and Shapovalov, 1951). The Sacramento River differs from the Eel River in that it does not empty directly into the ocean; instead it is characterized by an extensive delta and bay system. If the behavior of young salmon is

similar in both the Sacramento and Eel Rivers, schools of salmon migrating down the Sacramento River would probably disperse in the lower Delta where they are no longer confined by relatively close river banks. If this hypothesis is true, fingerling salmon would be less vulnerable to predation in the lower Delta Region, Suisun, San Pablo and San Francisco Bays than when schooled in the upper river.

It is generally agreed that predatory fish usually feed upon whatever prey is most available. Monthly totals of fishes captured with a midwater trawl in Carquinez Straits by the California Department of Fish and Game, show other possible prey fishes to be from 54 to 7215 times as abundant as salmonids (Calif. Dept. Fish and Game Mar. Res. Br., 1962a-1962i). Shrimp and other bottom dwelling organisms known to form part of the striped bass diet and these fishes, particularly the vulnerable schooling species such as anchovies, Engraulis mordax; herring, Clupea pallasi; and Sacramento smelt, Spirinchus thaleichthys, undoubtedly act as effective buffers against predation upon salmonids. This buffer effect is probably another reason why previous workers have not found salmonids in the diet of the striped bass from the Sacramento River system. Although some salmonids must certainly be preyed upon, they would form an extremely small portion of the striped bass food in the waters where other species are so much more abundant.

Similarly, in the spring months when the seaward migration of fingerling salmon should be relatively heavy through the study area, analysis of striped bass stomach contents shows freshwater smelt to be the dominant food. Members of this species, apparently spawning in the area, are probably present in such numbers that they are more readily obtained than

young salmon. Freshwater smelt might also be most abundant at the lower depths where striped bass are usually found, whereas downstream migrant salmon are known to be most abundant near the surface. One hundred and fifty-eight young salmon were caught with a fyke net fished at the surface of the Sacramento River near Hood, while in the same period, a similar net fished at the bottom caught only eight salmon (Hatton, 1940).

Evidently freshwater smelt leave the Courtland-Freeport area soon after their spawning period. Most specimens present in stomachs of bass caught in this area had ripe ovaries or testes and only three were found after June 25.

One can only hypothesize why predation on seaward migrant salmon occurs on the river surface only at the Paintersville Bridge and then only after the bulk of the downstream migration has already passed through this area. Bass of the size range responsible for most of the predation were captured in the area on May 15, but none had been feeding on salmon. It is possible that a certain minimum number of bass must be present before competition and crowding forces some individuals or schools to increase their foraging activity on the surface where they find the young salmon. The minimum density necessary for salmon predation may not be present at the bridge until June, due to insufficient immigration from other areas prior to this time. If adequate density is present prior to the period of predation, perhaps the first surface activity could be triggered by a sudden influx of large, relatively concentrated groups of fingerling salmon. Such an influx probably occurs because of the previously mentioned releases from Nimbus Hatchery. If fingerling salmon were held at Nimbus Hatchery during the period from mid-May to late June, then released, it would be

interesting to see if surface predation on salmon by striped bass would still occur at the Paintersville Bridge in early June or if the first occurrence of such activity would not appear until after the late June hatchery releases. The necessary minimum density of bass may never be reached at the other bridges in the study area, or if this density is reached it is possible other unknown factors prevent occurrence of this unique feeding activity.

SUMMARY

1. Six hundred and seventy stomachs of striped bass, Roccus saxatilis, taken in the Sacramento River between Rio Vista and Sacramento were examined. Of these stomachs, 36.7 per cent contained natural food items.

2. The diet was found to vary according to time of year and locality sampled.

3. Crayfish, Pacifastacus leniusculus; freshwater smelt, Hypomesus olidus; and king salmon, Oncorhynchus tshawytscha were the most important food items. Young striped bass; carp, Cyprinus carpio; splittail, Pogonichthys macrolepidotus; tule perch, Hysterocarpus traskii; Pacific lamprey, Entosphenus tridentatus; shad, Alosa sapidissima; goldfish, Crassius auratus; myscid shrimp, Neomysis mercedes; amphipods, Corophium sp.; and chironomids, fam. Tendipedidae formed the remainder of the diet.

4. The absence of chironomids in stomachs of bass over 13 inches in length was the only indication of selective feeding by bass of different sizes.

5. Salmon formed a greater portion of the diet of bass caught with a gill net and by artificial lures than of those taken on sardine bait during the month of July. This difference may be accounted for by depth of feeding and time of capture.

6. The daily peak of surface feeding upon seaward migrant salmon at the Paintersville Bridge during the summer months was found to occur after the period of minimum current and prior to the period of maximum current.

7. Counts of splashes made by schools of bass chasing young

salmon revealed the bridge shadow to be a definite factor in determining the area of surface predation.

8. The number of salmon preyed upon by striped bass at the Paintersville Bridge during June, July and August was determined to be between 39,000 and 78,000.

9. Surface feeding upon fingerling salmon at the Paintersville Bridge does not occur until after the main portion of the seaward migrants have already passed through this area.

10. Occurrence of surface predation upon young salmon by striped bass at the Paintersville Bridge seems to be related to releases of salmon fingerlings from Nimbus Hatchery into the American River.

11. Salmon have not previously been found in the striped bass diet in the Sacramento-San Joaquin River system because food studies have been centered in areas where salmon are probably dispersed and less abundant than other prey.

TABLE 1

Comparison of stomach contents of striped bass caught on artificial lures and sardine bait during June 1962 at the Paintersville Bridge

Method of capture	sardine bait	artificial lures	total
Number stomachs examined	27	170	197
Number empty stomachs	17	82	99
Percent empty stomachs	63.0	48.2	50.3
Percent stomachs with food containing salmon	90.0	90.7	90.7
Percent total diet--salmon	94.7	87.5	88.0
Percent stomachs with food containing crayfish	-	2.1	1.9
Percent total diet--crayfish	-	0.5	0.5
Percent stomachs with food containing freshwater smelt	20.0	18.6	18.7
Percent total diet--freshwater smelt	5.3	12.0	11.6
Percent stomachs with food containing polychaetes	10.0	-	0.9

TABLE 2

Comparison of stomach contents of striped bass taken by three methods during July 1962 at the Paintersville Bridge

Method of capture	sardine bait	artificial lures	gill net	total
Number stomachs examined	105	90	13	208
Number empty stomachs	80	51	3	134
Percent empty stomachs	76.2	56.7	23.1	64.4
Percent stomachs with food containing salmon	40.0	87.2	90.0	71.6
Percent total diet--salmon	25.5	88.8	100.0	72.0
Percent stomachs with food containing crayfish	16.0	2.6	-	6.8
Percent total diet--crayfish	12.1	1.0	-	4.1
Percent stomachs with food containing freshwater smelt	4.0	5.1	-	4.1
Percent total diet--freshwater smelt	2.2	0.3	-	0.8
Percent stomachs with food containing striped bass	20.0	5.1	-	9.5
Percent total diet--striped bass	60.2	0.5	-	17.9
Percent stomachs with food containing carp	-	2.6	-	1.4
Percent total diet--carp	-	0.4	-	0.2
Percent stomachs with food containing splittail	-	2.6	-	1.4
Percent total diet--splittail	-	1.8	-	1.0
Percent stomachs with food containing tule perch	-	5.1	-	2.7
Percent total diet--tule perch	-	6.5	-	3.6
Percent stomachs with food containing shad	-	2.6	-	1.4
Percent total diet--shad	-	0.8	-	0.4
Percent stomachs with food containing chironomids	20.0	10.3	10.0	13.5
Percent stomachs with food containing Corophium	12.0	-	-	4.1

TABLE 3

Stomach contents of striped bass caught on sardine bait during August 1962 at the Paintersville Bridge

Method of capture	sardine bait
Number stomachs examined	52
Number empty stomachs	42
Percent empty stomachs	80.8
Percent stomachs with food containing salmon	50.0
Percent total diet--salmon	88.3
Percent stomachs with food containing crayfish	20.0
Percent total diet--crayfish	2.8
Percent stomachs with food containing striped bass	10.1
Percent total diet--striped bass	0.5
Percent stomachs with food containing lamprey	10.0
Percent total diet--lamprey	8.5
Percent stomachs with food containing chironomids	10.0

TABLE 4

Comparison of stomach contents of striped bass caught by gill net and artificial lures on July 2, 1962 at the Paintersville Bridge

Method of capture	artificial lures	gill net
Number stomachs examined	13	9
Number empty stomachs	5	0
Percent empty stomachs	38.5	0.0
Number stomachs containing salmon	8	9
Number of salmon	12	12
Number stomachs containing striped bass	1	0
Number of striped bass	1	0

TABLE 5

Trend in numbers of salmon preyed upon at the Paintersville Bridge from June 1962 to August 1962 as indicated by striped bass stomach analysis

Month	Method of capture	sardine bait	gill net	artificial lures	total
June	Number stomachs examined	27	-	170	197
	Number salmon found	16	-	182	198
	Average number salmon per stomach	.0593	-	1.071	1.005
July	Number stomachs examined	105	13	90	208
	Number salmon found	12	12	41	65
	Average number salmon per stomach	0.114	0.923	0.456	0.312
August	Number stomachs examined	52	-	-	52
	Number salmon found	5	-	-	5
	Average number salmon per stomach	0.096	-	-	0.096

TABLE 6

Counts of groups of splashes made by striped bass preying upon seaward migrant king salmon and other species in the main channel beneath the Paintersville Bridge from June 1962 to September 1962

Time	Date															
	June								July				Aug.			Sept.
	13	18	20	22	23	25	28	30	7	13	24	31	7	22		8
a.m.																
5:30-6:00			22													
6:00-6:30			8	2			1									
7:00-7:30			9	2			10									
8:00-8:30			28	4			75									
9:00-9:30			110	20			68		5			3				0
10:00-10:30			90	110	39	40	75	46	37	44		17	5			0
11:00-11:30			78	116	65	30	28	154	87	15	3	15	15	5		0
p.m.																
12:00-12:30	61		59	98	88	46		129	34	8	20	4	4	12		0
1:00-1:30	70		52	98	128			104	10	4	11	1	7	10		
2:00-2:30	35			53	59	338	28	80	2		29		1	3		
3:00-3:30	57	79		48	62	461	34			3	35					
4:00-4:30	39	50		52		181	4			10	17					
5:00-5:30		135		43		234				8	7					
6:00-6:30		106		42		182				1						
7:00-7:30		83	16			72										
8:00-8:30		20	0			16										
8:30-9:00		1														

STUDY AREA

FIGURE 1

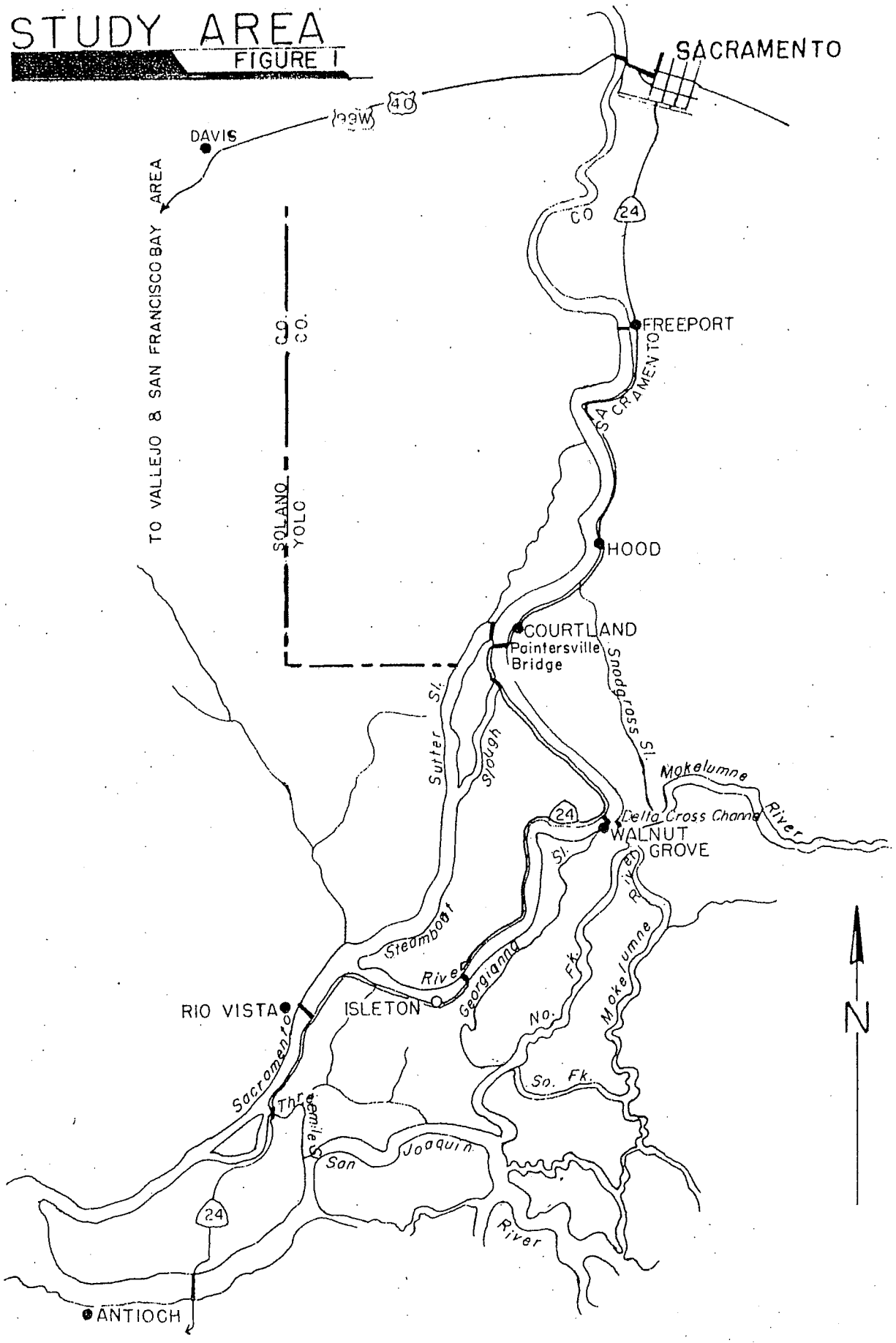


FIGURE 2 Percent Composition by Volume of Food found in Striped Bass Stomachs:

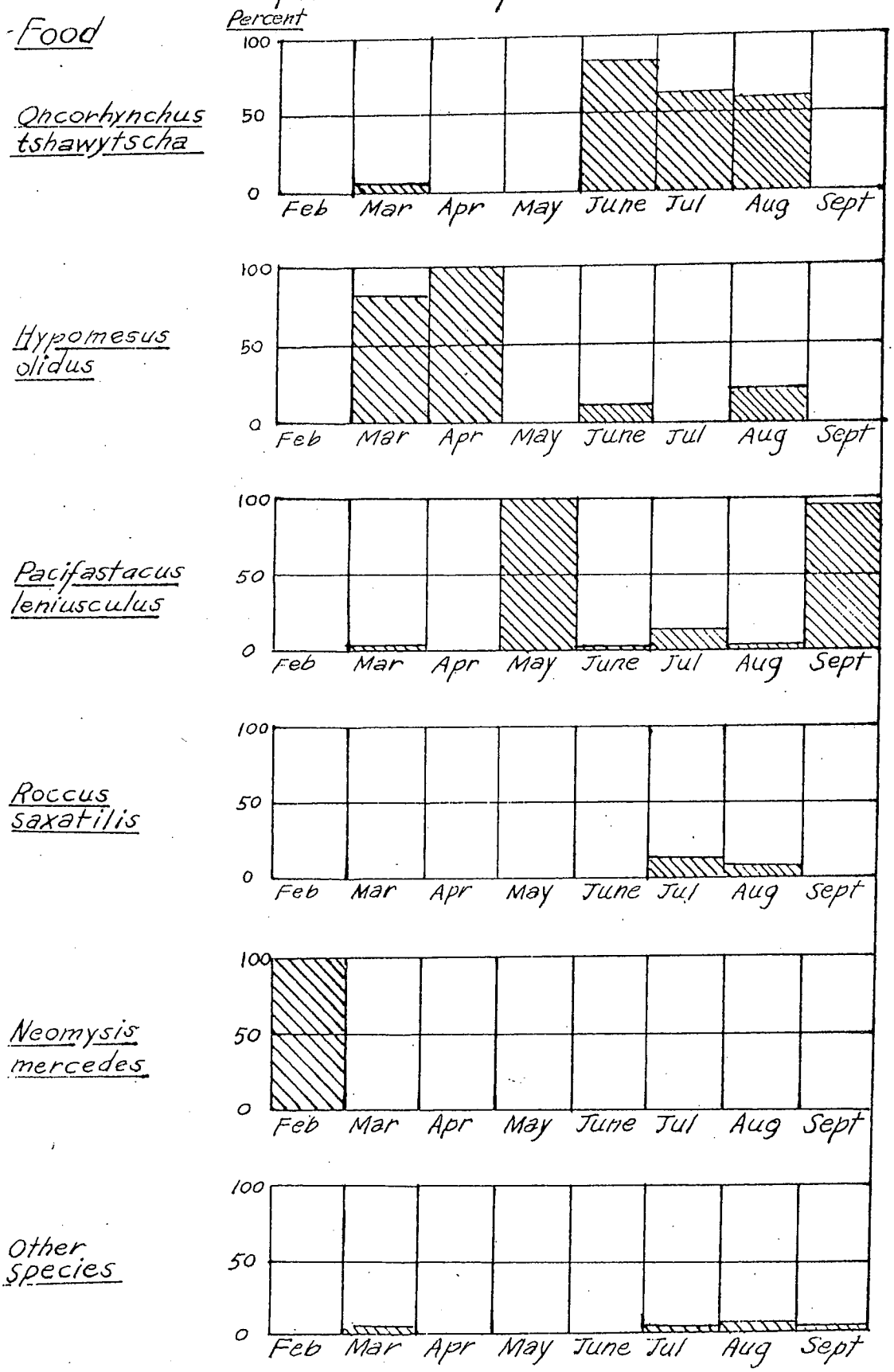
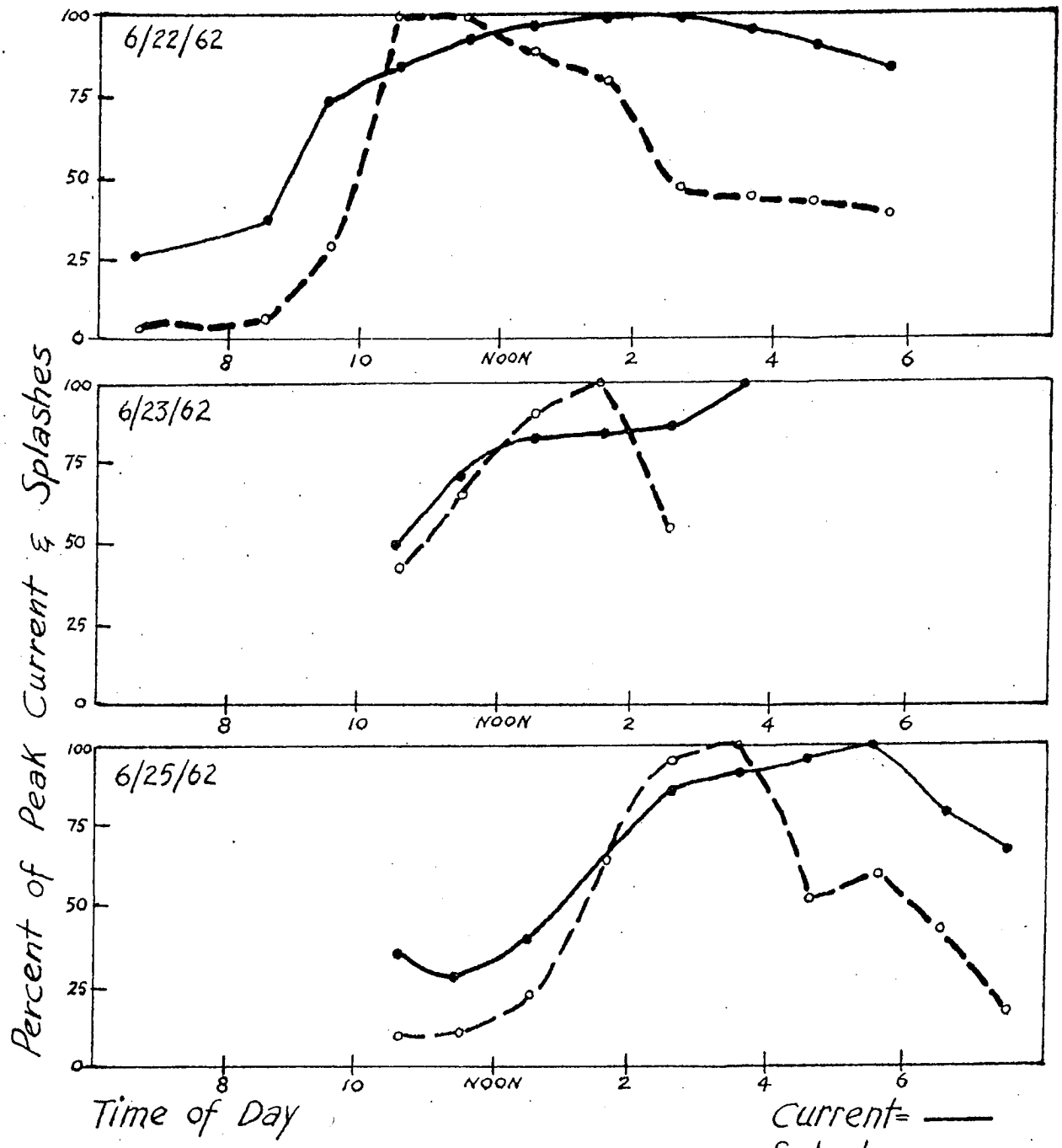


FIGURE 3
Relationship between Surface Predation by Striped Bass on Seaward Migrant King Salmon & other Species & coinciding Current Velocity.



continued

FIGURE 3

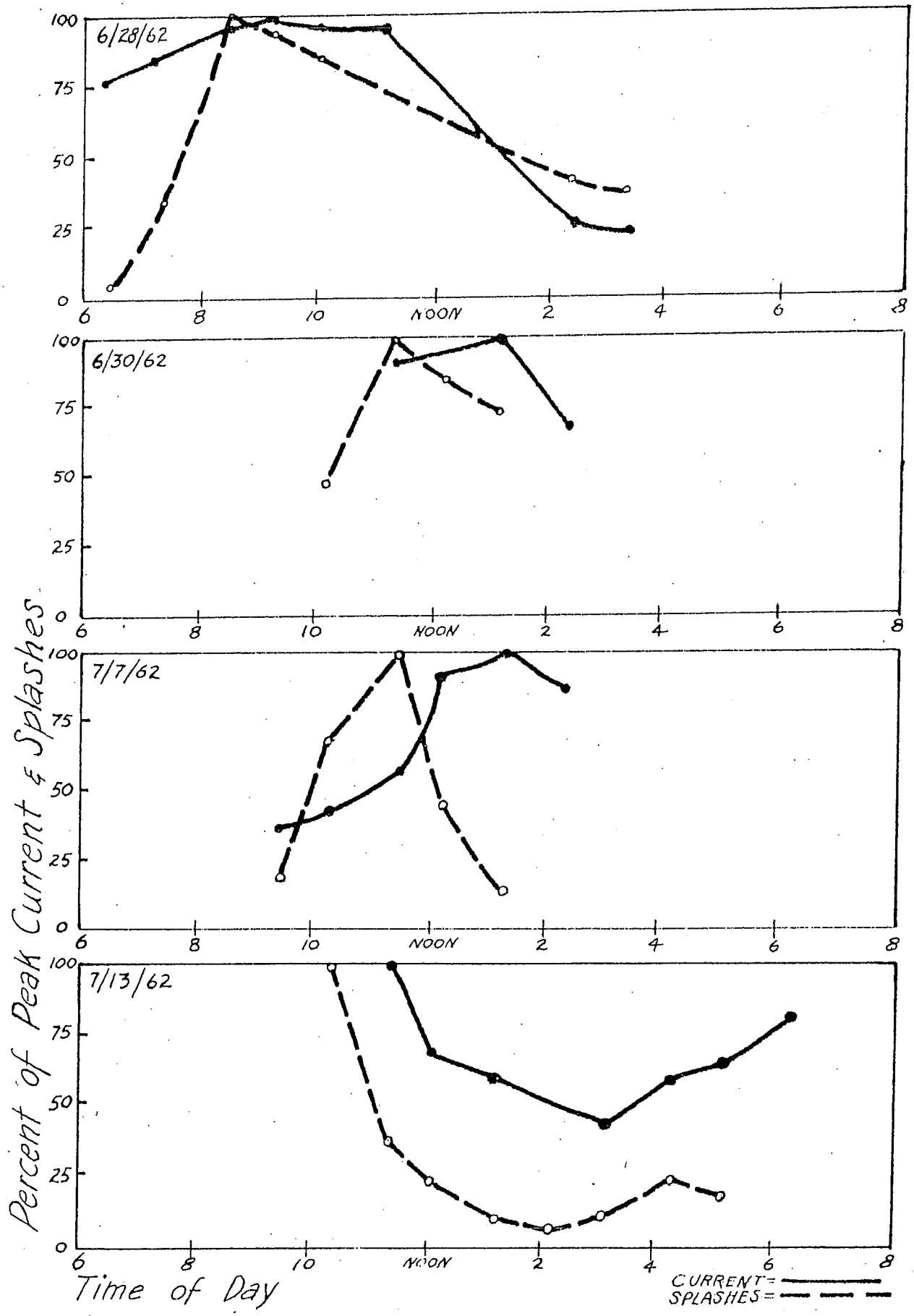

6/28/62
6/30/62
7/7/62
7/13/62
100
75
50
25
0
6
8
10
NOON
2
4
6
8
Percent of Peak Current & Splashes
Time of Day
CURRENT =
SPLASHES =

FIGURE 4 Relationship of Daily Predatory Activity by Striped Bass as based on Splash Observations at the Paintersville Bridge:

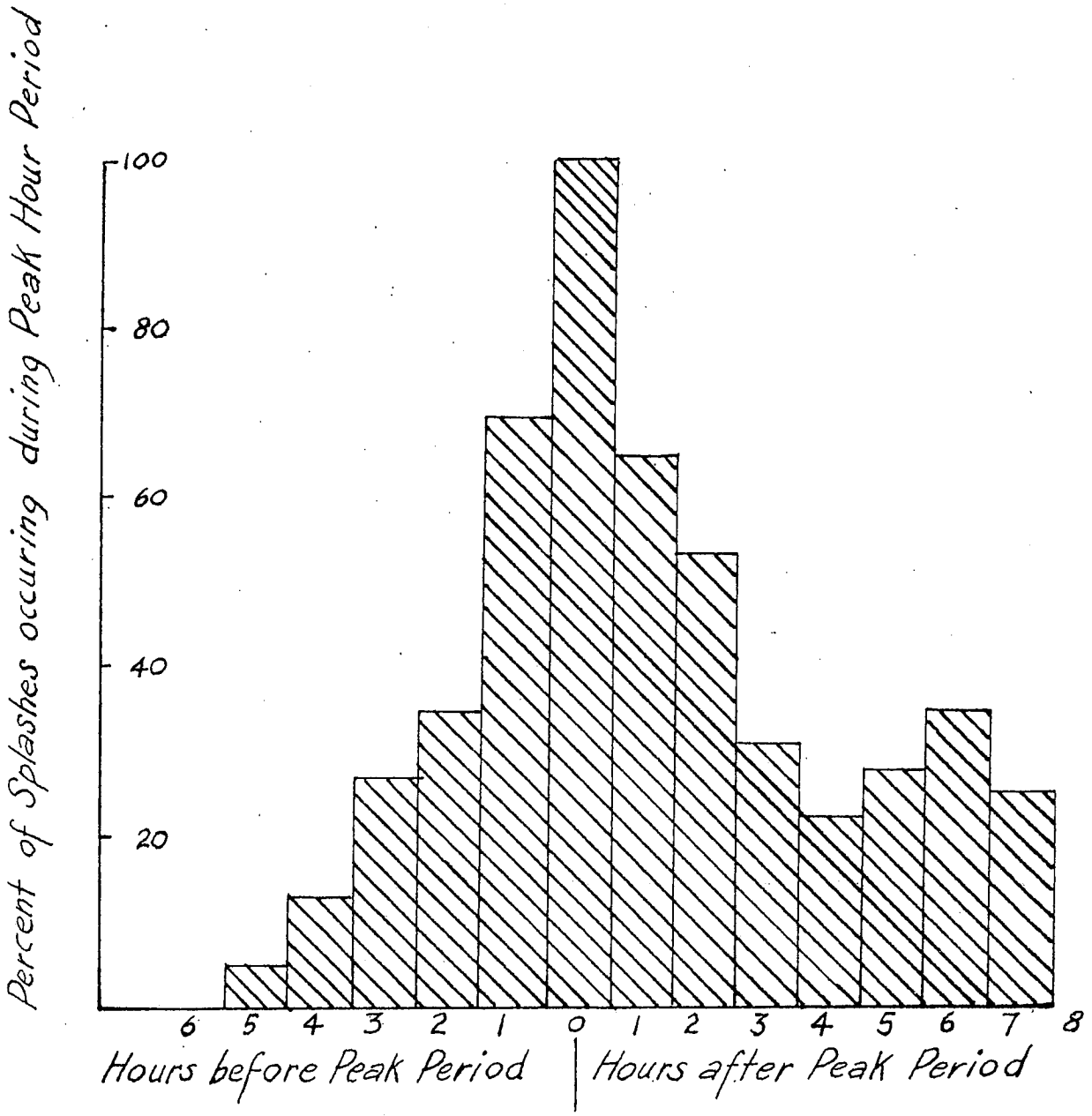


FIGURE 5 Total Splashes Attributed to Striped Bass Predation on Seaward Migrant King Salmon at the Paintersville Bridge during June, July & August.

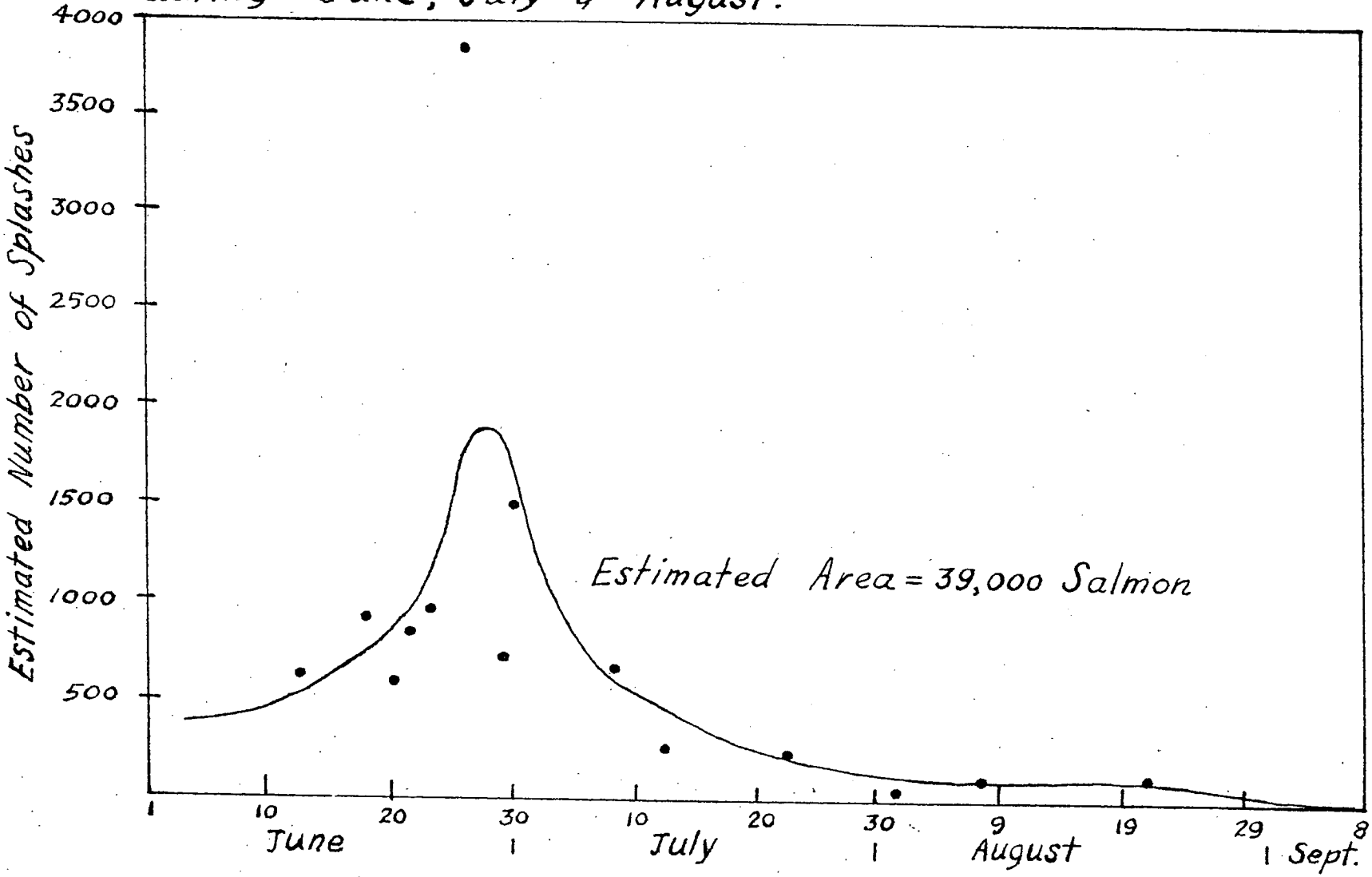


FIGURE 6 Comparison of Intensity of Downstream Run of Fingerling Salmon & Time of Predation on this Species by Striped Bass at the Paintersville Bridge.

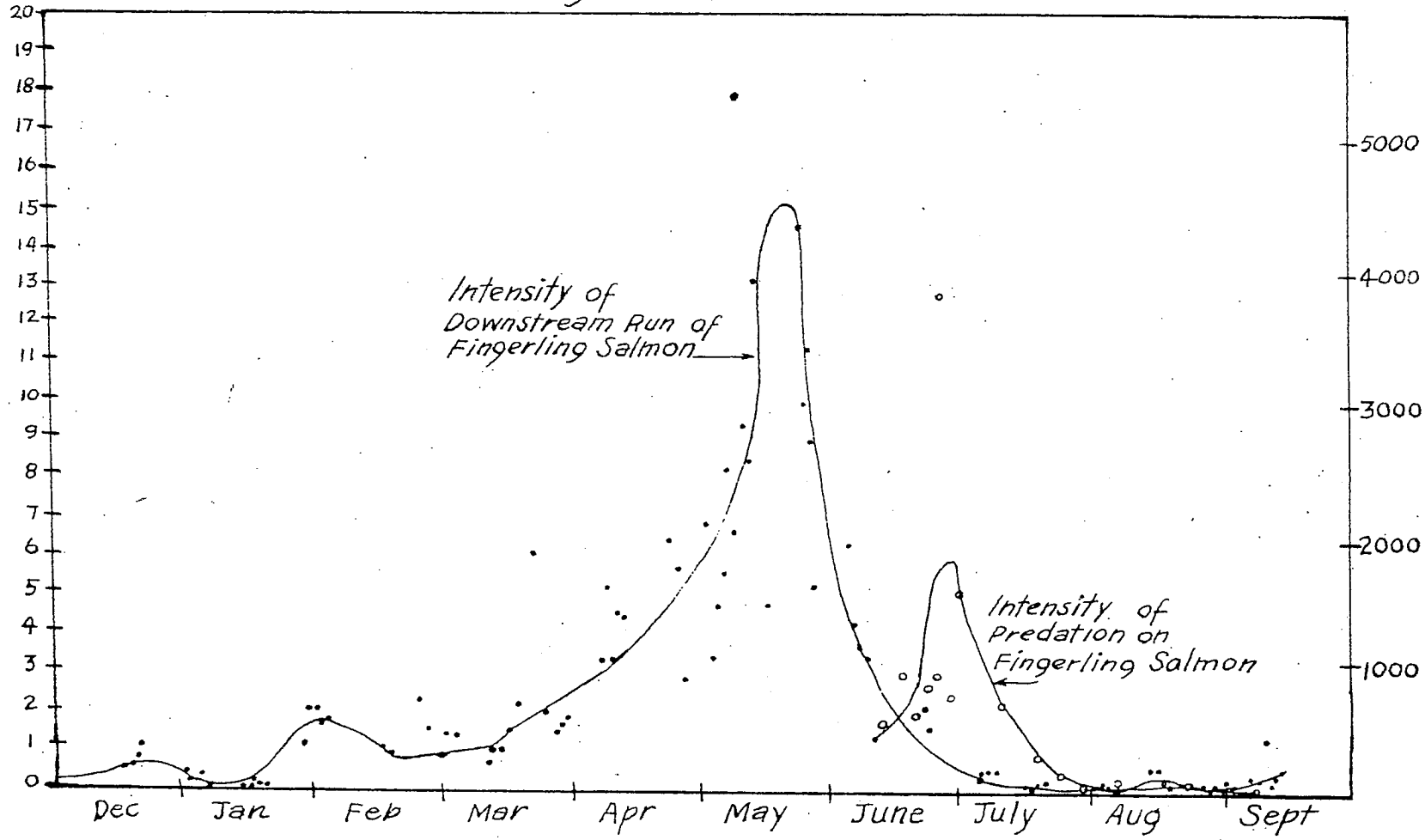
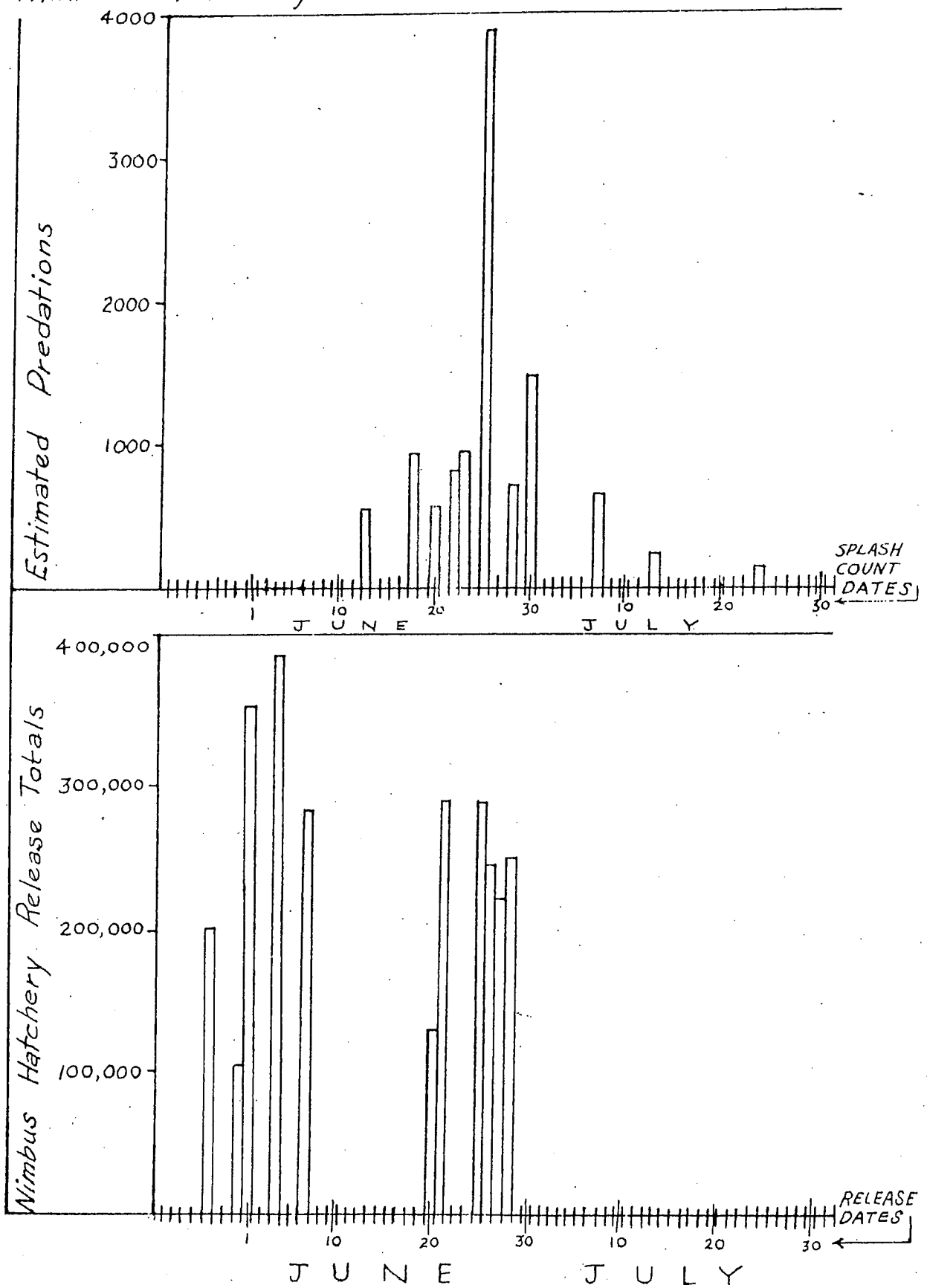


FIGURE 7 Comparison of Intensity of Predation on Fingerling King Salmon by Striped Bass & Release Dates of King Salmon Fingerlings from Nimbus Hatchery.



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1962 d Cruise Reports 62-N-1g and 62-N-1h Salmon.

1962 e Cruise Reports 62-N-1i, 5b, 5c, and 62-C-5d Salmon

1962 f Cruise Reports 62-N-6b and 6c Salmon.

1962 g Cruise Reports 62-N-7a and 7b Salmon.

1962 h Cruise Reports 62-N-8a and 8b Salmon.

1962 i Cruise Reports 62-N-9a, 9b, and 10a Salmon.

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