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VARIABILITY OF SKIPJACK RESPONSE TO LIVE BAIT

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ABSTRACT

Observations made from commercial skipjack live-bait fishing boats, operating from Honolulu, revealed that catch rates for each school of skipjack had a general pattern: the rates rose to a peak and then declined with elapsed fishing time. In this paper, peak catch rate and duration of fishing after the peak were selected as measures of biting response and were compared with data on location, the weather, time of day, and stomach contents. With a fork length of 60 cm. as the dividing line between small and large skipjack, the peak catch rates for small fish were higher than those for large fish, but this was attributed to the greater ease of catching small fish. The peak catch rate of large skipjack increased with the distance from land. The postpeak duration of fishing for large skipjack was found to be negatively correlated with volume of stomach contents and relative time since the last major feeding. Large skipjack feeding on fast-swimming fish seemed to show a better response to chum (live bait) than did those feeding on slow-swimming fish. Weather conditions did not seem to affect the peak catch rate or the postpeak duration. The relation of biting response to time of day was not obvious.

VARIABILITY OF SKIPJACK RESPONSE TO LIVE BAIT

By Heeny S. H. Yuen, *Fishery Research Biologist*, BUREAU OF COMMERCIAL FISHERIES

Fishermen in the Hawaiian Islands chum live bait to attract skipjack (*Katsuwonus pelamis*) to the ship and to hold them there. The reaction of skipjack to chumming may vary from no response to feverish feeding activity which results in a sizable catch. In reporting the results of live-bait fishing aboard research ships of the Pacific Oceanic Fishery Investigations [1] in Hawaiian waters, Royce and Otsu (1955) stated that fish were caught from only 43 percent of the schools chummed. Time and bait expended on nonresponding schools represent a considerable economic loss to the fishermen, particularly because of the short supply of bait.

If the efficiency of the fisherman is to be improved, the factors which contribute to the variability of skipjack responses to chum should be ascertained. A prerequisite to this would be to measure the extent of variability of biting behavior. It is the intent of this study to measure and determine the reasons for the variability of skipjack response to chum.

Perhaps the measure of variability of response will have further application. For instance, it may be used to evaluate the success of new bait species and artificial baits, or to compare the response of skipjack in unexploited areas to that of present commercially successful areas.

Factors influencing the biting behavior of skipjack, as presented by past studies, may be classified as environmental, physiological, and psychological or perhaps psychophysiological. Among the environmental factors in the Japanese skipjack fishery, Imamura (1949) mentioned water clarity, current velocity, weather, abundance of natural food, and time of day. Transparency, chlorinity, and temperature of the water are advanced by Uda (1940b) as affecting skipjack catches, but probably as migrational rather than response determinants. Uda (1940a) and Suyehiro (1938) also mentioned time of day as a factor. The latter also noted the effect of seasons and the proximity of land on biting behavior.

The first physiological factor that comes to mind when considering biting response is the state of hunger. Both Uda (1933) and Suyehiro (1938) investigated its effect; the former in terms of fullness of the stomach and the latter in terms of time since last feeding. That the state of gonad development may also be a factor is indicated by Brock (1954) who reported a dearth of ripe individuals despite extensive sampling of the Hawaiian skipjack fishery.

The factor that was considered as a psychological or psychophysiological one was the possible preference of the skipjack for certain species of prey or perhaps for prey with certain types of behavior. This possibility was conjectured because of Suyehiro's (1938) statement that skipjack feeding on pelagic forms responded to chum better than those feeding on inshore forms. The effect of school size, if any, would also fall in this category.

The size of the skipjack and the fishing effort measured by the number of hooks fished were also considered as possible factors.

Since the data were collected by investigators who were permitted aboard commercial vessels with the provision that they would not interfere with the fishing operations, not all of the possible factors mentioned could be measured. Unfortunately, the data not collected fell in the environmental category.

Operations on a skipjack sampan are not geared to accommodate observers, but the following captains and crews went out of their way to make us comfortable and to help us collect our materials: Yoshiichi Teramae and crew of the M/V *Neptune*, Tsuruichi Sarae and crew of the M/V *Orion* (1956), Richard Kinney and crew of the M/V *Orion* (1957), Noboru Tsue and crew of the M/V *Buccaneer*, Tom Fukunaga and crew of the M/V *Angel*, and Kuniyoshi Asari and crew of the M/V *Marlin*.

NOTE.—Approved for publication September 26, 1958.

[1] Redesignated Bureau of Fisheries Biological Laboratory, Honolulu, effective January 1, 1959.

METHODS

COLLECTION OF DATA

Data were collected by observers who accompanied skipjack sampans throughout the 1956 and 1957 skipjack seasons, April through September, at about weekly intervals. Only the more successful and larger of the sampans were chosen because the probabilities of getting data would be enhanced and the larger deck permitted collection of materials with less interference to fishing operations.

A review of fishing operations described in greater detail by June (1951) follows: the boat leaves port early enough to be at a promising fishing area at daybreak. It is usually held on an arbitrary course while the scouts scan the ocean for birds that flock over fish schools. When a flock is sighted, the boat is steered to head it off. On reaching the head of the flock, the boat is slowed, water sprays are turned on, and chumming is started. The bait is dribbled out as evenly as possible until signs of surfacing fish are seen astern. When the fish begin to surface, the chummer intensifies the chumming until the fish are directly at the stern within reach of the hooks, at which time he reduces the rate of chumming to what he considers a minimum to keep the school at the boat. If the school moves away without responding, chumming is stopped and the boat accelerated to get into position for another attempt. As soon as the school has been successfully lured to the boat, the fishermen get into position at the stern and start fishing. The school is fished until the bait supply is exhausted or until the captain decides that the rate of catching is too slow to be worth while. The catch is stored as soon as fishing is stopped, and the boat then proceeds homeward or to look for more schools depending on the bait supply and hour of day.

The fishing of 92 skipjack schools was observed. Recording of data started with the sighting of a flock. The time of sighting was recorded to the nearest minute. During the approach a description of the weather was recorded. It included the height of the waves, an estimate of wind velocity and direction, the type of clouds and amount of sky covered, and light conditions. "Light" was described as bright sun, cloudy-bright, hazy, dull, and raining.

A running description of the activity of the flock was kept during the approach, and when the boat was close enough an estimate was made of the number in each flock and the species. The flocks were described as flying high, diving, scattering, regrouping, enlarging, etc. In the beginning, attempts were made to estimate the direction and velocity of the flocks but these were abandoned as being unreliable. As soon as contact with the school was made, its location was approximated.

The times of the following events were recorded to the nearest 5 seconds: (1) the beginning and end of each pass, (2) the first signs of fish surfacing in response to the chum, (3) the start of fishing, and (4) the landing of the first fish. During the few instances when the slowing of the boat and the start of chumming did not coincide, the latter was considered to be the start of the pass. The placement of hooks in the water signified the start of fishing.

As fish were caught, each was tallied on a counter. At the end of each minute (when the second hand pointed to 12) the reading was recorded with the time. If fishing did not start exactly on a minute, an error with a limit of plus or minus 30 seconds was introduced in the first minute. On earlier trips the catch was recorded at 2-minute intervals. Occasionally an individual fisherman left his post to change his fishing pole or to perform other duties such as helping the chummer, or to gaff fish. Each change in the number of men fishing and the time was noted, except when a man went to change his pole, a temporary absence.

The possibilities for error, especially when the fish were landed rapidly, were ever present with the observer watching the time, tallying the number of fish caught, accounting for the movements of the fishermen, and recording. Another method which decreased the amount of work during the hectic time of fishing and thereby reduced the possibilities of error was later used. This included the use of a movie camera with a single-frame trigger and a marine clock with white numerals against a black background. These were mounted facing each other (fig. 1). The shutter was released as each fish was caught, resulting in an exact record of the time of capture. The number of frames used corresponded to the number of fish

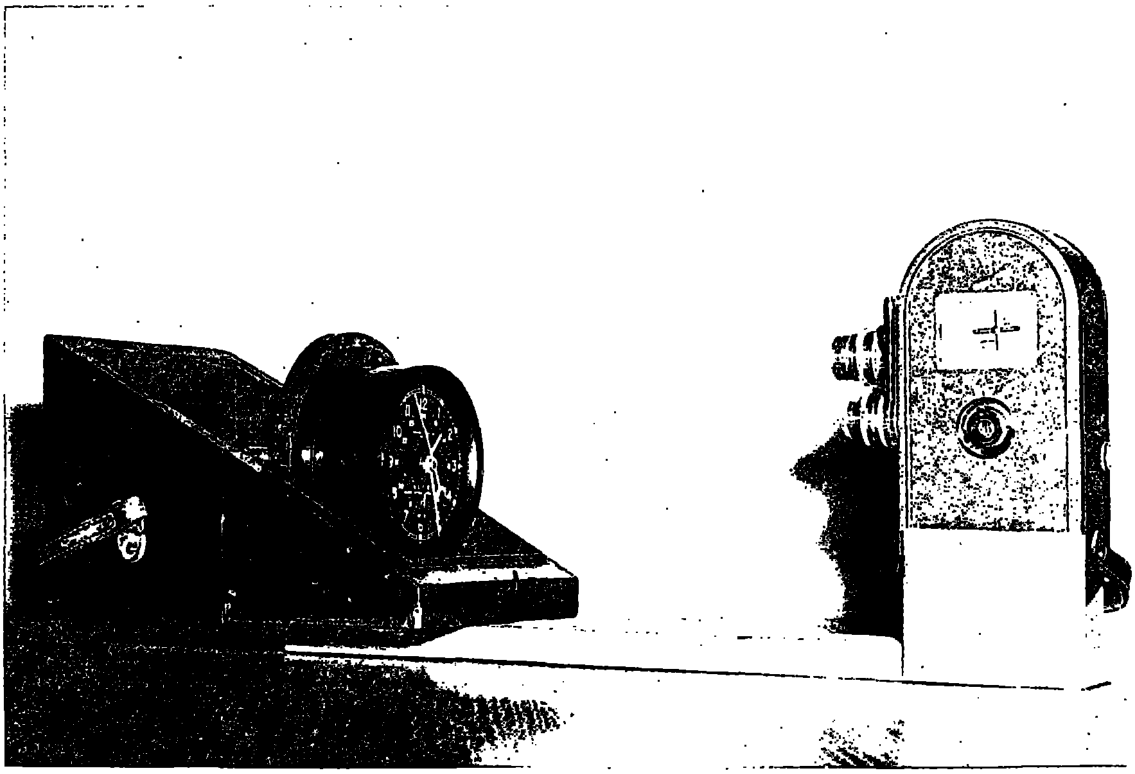

FIGURE 1.—Photograph of clock and camera setup.

caught. An additional hand on the clock was manipulated to point to the numeral corresponding to the number of men fishing at any time.

The precision of this system depended on the speed at which the single-frame trigger could be operated. The smallest possible interval of time between frames was 0.6 second. This means that when several fish were caught simultaneously, the record would indicate that they were caught 0.6 second apart.

At the cessation of fishing, the skipjack were randomly sampled. At first the sample size was 20, but this was later reduced to 10. The sample comprised the entire catch when the catch was less than the prescribed sample size.

The fork length of each fish in the sample was taken, then the stomach and a piece of the gonads were removed and placed in a muslin bag. The stomach was punctured while in the bag and the bag secured and placed in approximately 10-percent formalin. Five hundred and thirteen fish, representing 43 schools, were treated in this manner.

During the period between the 1956 and 1957 seasons, the personnel of the M/V *Buccaneer* collected 60 stomach samples from 6 schools. The data collected with the samples included: (1) the location of the school, (2) the time of fishing, (3) an estimate of the weight of the total catch from the school, (4) an estimate of the average weight of the fish, and (5) a statement of whether fish response was good, fair, or poor.

TREATMENT OF DATA

The rate at which the fish were caught, in terms of fish per hook-minute, was calculated for each minute of elapsed fishing time for the schools observed later in the study. For the schools observed earlier, the nature of the data did not permit the rates to be calculated for intervals of less than 2 minutes.

In the identification of the stomach contents the fish were placed in their families, mollusks in their suborders, and crustaceans in their orders. The individuals in each category were counted. The volume for each category was ascertained by water

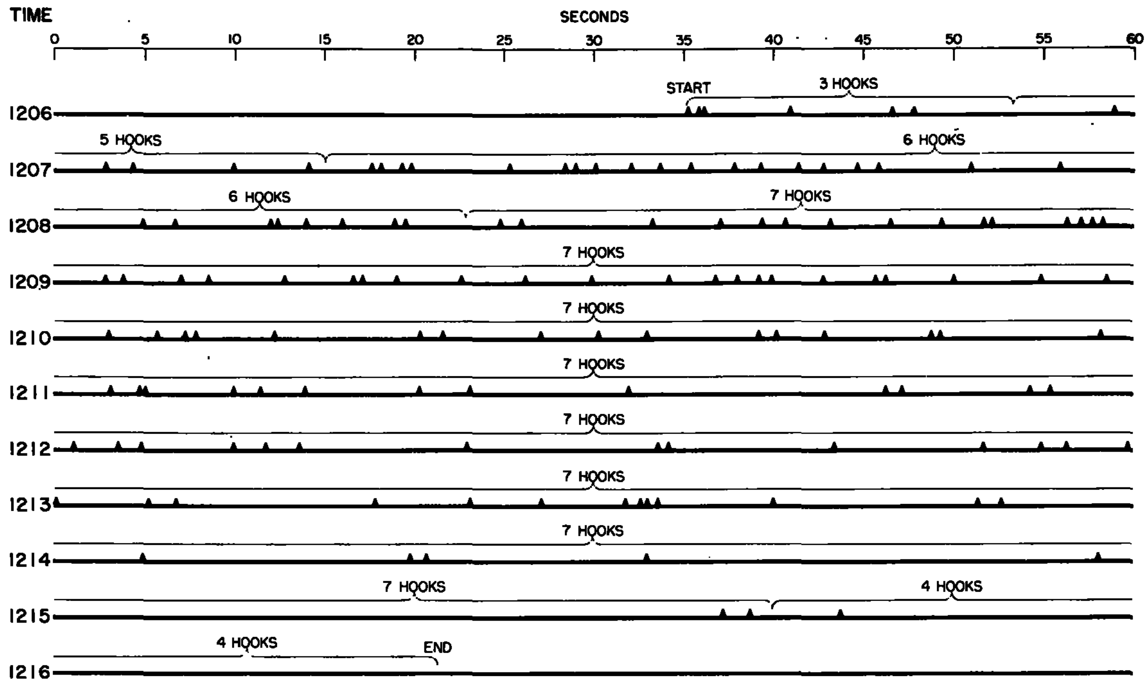

FIGURE 2.—Plot of the landing of individual skipjack, and time. Each mark represents one skipjack.

displacement to the nearest 0.1 ml. or with an error of about 1 percent depending on the volume. In addition, all fish were ranked by relative stage of digestion.

The fork lengths of the smallest and largest fish in each family from each sample of stomachs were measured. This disclosed the size range of each fish family consumed by an individual skipjack school. The lengths of the squid mantles were likewise measured. Linear measurements of other items were not attempted.

Digested remains were identified whenever possible as fish, mollusks, or crustacean. Otherwise they were classified as "gurry." Volumetric measurements were taken as described earlier.

The bait found in stomachs received the same treatment as other fish, but the results were discarded as unreliable because skipjack often regurgitate much of the bait as they are caught or soon after. At times food deeper in the stomach is also regurgitated but the amount seems negligible.

Trematodes, nematodes, and Acanthocephala were found in the stomachs in small quantities. These were assumed to be parasites and were not considered.

RESULTS

GENERAL INFORMATION ON FISHING

No fish were caught from 52 percent of the schools chummed.

The rate at which the skipjack took the hooks varied. More often than not the fish seemed to bite in short flurries (fig. 2). This may be due to the distributional makeup of skipjack schools. In the few times when the fish could be clearly seen in the water, the schools seemed to be aggregates of many small groups of about 10 fish each.

When the catch rates are plotted against elapsed fishing time at 1- or 2-minute intervals (fig. 3), they present an assortment of shapes. In general there is a rise to a peak with a subsequent decline. Figure 3, *A* shows a relatively early peak, with irregular rise and decline and is typical of most of the plots. Occasionally there are variations as seen in figure 3: *B* illustrates a later peak; *C* has a sharper decline; and *D*, the major peak, is not particularly dominant. *E* is an example of a school that responded poorly. An average of 32.7 percent of the total catch was made during the prepeak period.

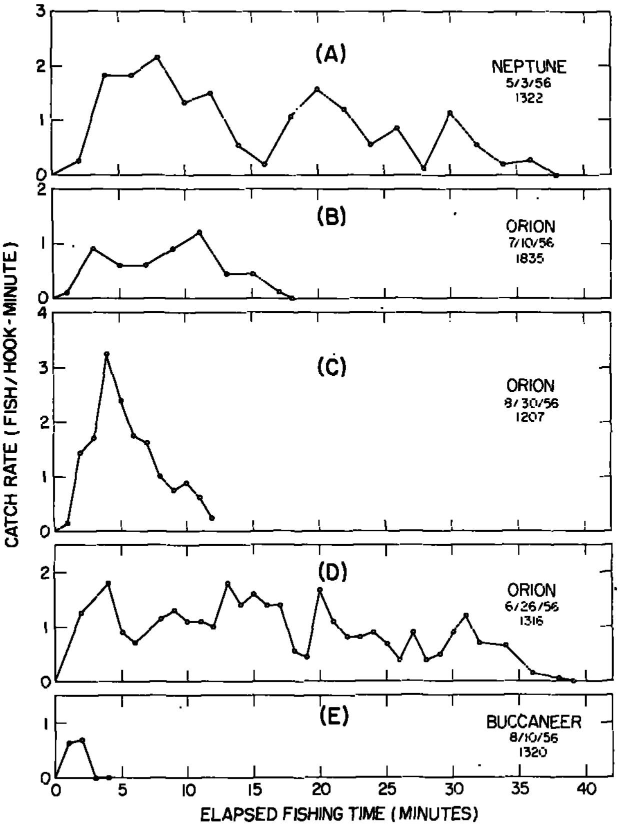

Figure 3.—Plots of catch rates against elapsed fishing time. *A*, typical. *B*, late peak. *C*, sharp decline. *D*, no dominant peak. *E*, poor response.

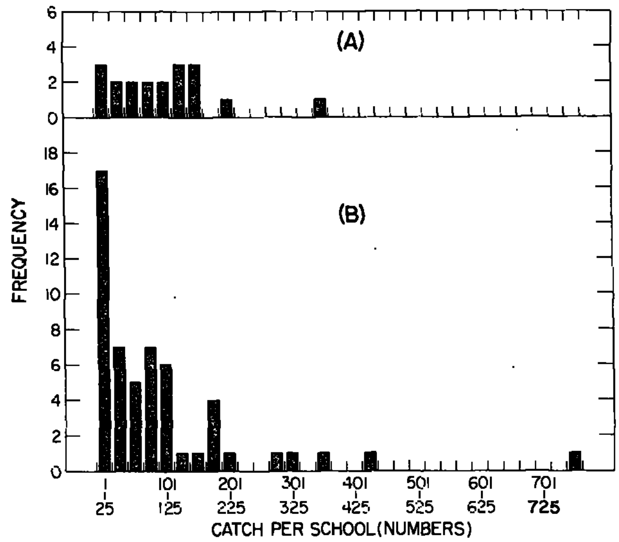

Figure 4.—Frequency distributions of catch per school. *A*, represents skipjack smaller than 60 cm. fork length. *B*, represents skipjack greater than 60 cm. fork length.

MEASURES OF BITING RESPONSE

Total catch per school is probably the most convenient measure of a school's response to chum. This would be the measure of most interest if it were to be applied toward estimating the fishing potential of a new area. Of the schools observed, the catch per school ranged from 1 to 773. The frequency distributions of catch per school (fig. 4) were not normal. Since the lengths of the fish fell into two distinct groups (fig. 5), the distributions were plotted separately.[2]

However convenient a measure the total catch may be, it is difficult to translate into terms of fish behavior because it is a reflection of a sum of behavioral and non-behavioral factors. We sought a measure of biting response that would be indicative of both behavior and yield. Correlation procedures as described by Snedecor (1946) were applied to the data to determine which of the measures of the fishing operation were associated with total catch. Since most of the frequency distributions of the various measures were skewed and sometimes truncated, Spearman's method of rank correlation was used. Computing a series of correlation coefficients is not condoned because the probability of encountering a significant correlation due to chance is increased. In this and a later section, however, such computations were included in preliminary surveys to gain information on which to base hypotheses and were not used as grounds for acceptance or rejection.

Fishing duration, which is defined as the time from the introduction of hooks into the water to their final withdrawal, was found to be highly correlated with total catch.[3] The rank correlation coefficient ($r_s=0.710^{**}$) with 84 degrees of freedom is well beyond the 1-percent level of significance. (In accordance with common practice, 2 asterisks (**) will be used to mark values beyond the 1-percent level of significance and one asterisk (*) to mark values beyond the 5-percent level.) Fishing duration ranged from 1 to 82 minutes. The frequency distributions of fishing

[2] *Hereafter the fish will be designated as large or small depending on whether the sample means of fork lengths were more or less than 60 cm., respectively.*

[3] Data for this and other procedures are tabulated in the appendix, table 5.

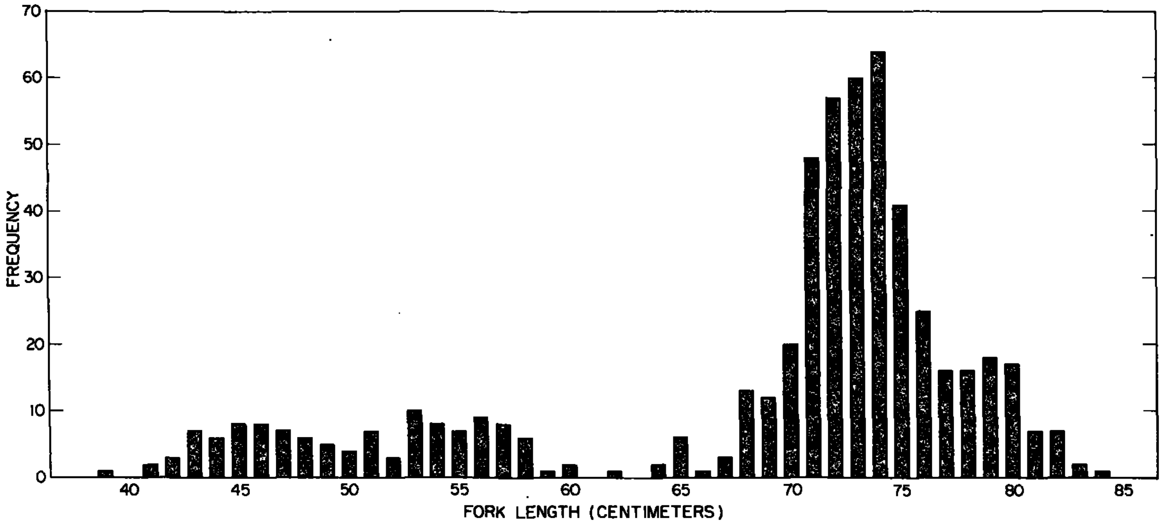

FIGURE 5.—Frequency distribution of fork lengths of skipjack sampled.

duration of small and large fish (fig. 6) does not depict any obvious difference between the two.

The peak catch rate expressed in terms of fish per hook-minute was also found to be significantly correlated with total catch (r_s=0.796**). The range of this variate for both large and small fish is about the same. The frequency distributions of peak catch rates of large and small fish (fig. 7), however, show quite divergent modes. A dominant mode for the large fish lies somewhere between 0.40 and 1.00 fish per hook-minute, while for the small fish the mode seems to be between 3.20 and 3.40 fish per hook-minute. This difference in peak catch rates cannot be attributed entirely to behavioral differences of the two sizes. An undetermined part of the difference is due to the greater ease with which the fishermen land the smaller fish.

The elapsed time from the start of fishing to the peak catch rate (hereafter called prepeak duration) and the time interval from the peak catch rate to the end of fishing or postpeak duration, were also compared with total catch. Postpeak duration and total catch were found to be highly correlated (r_s=0.750**), while the prepeak duration and total catch were not (r_s=0.204). Prepeak duration ranged from 0.5 to 42.5 min-

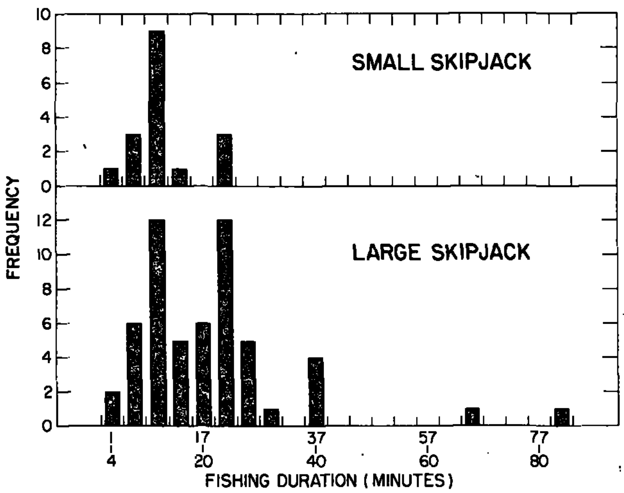

FIGURE 6.—Frequency distributions of fishing duration of large and small skipjack.

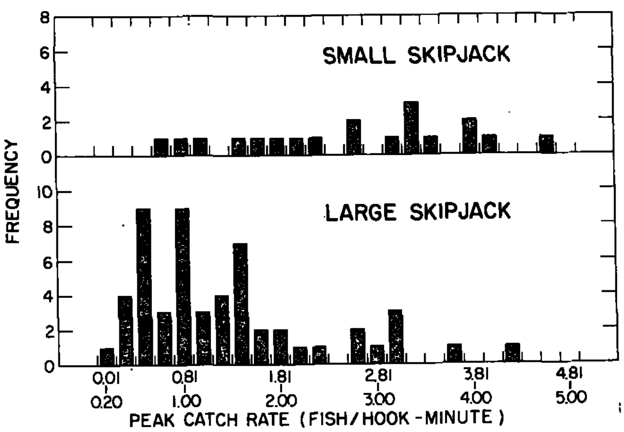

FIGURE 7.—Frequency distributions of peak catch rates for large and small skipjack.

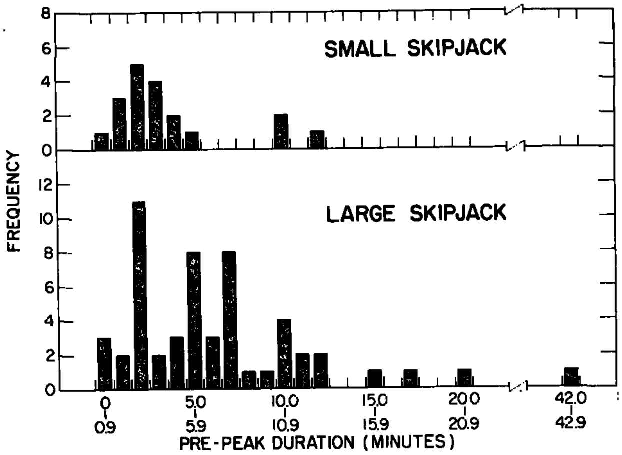

Figure 8.—Frequency distributions of prepeak duration for large and small skipjack.

utes (fig. 8) and postpeak duration ranged from 0 to 77 minutes (fig. 9).

The average increase per minute of the prepeak catch rates and the average decrease per minute of the postpeak catch rates for each school were computed by using regression methods with the assumption that the rates of increase and decrease were linear. The frequency distributions of these rates, placed into categories of large and small fish (fig. 10), show greater skewness in the distributions for the large fish. Total catch was found to be significantly correlated with the rate of prepeak increase (r_s=0.395**) but not with the rate of postpeak decline (r_s=−0.009).

Another factor that affected the total catch was the mean number of hooks fished per minute. The rank correlation coefficient was 0.259*. The grand mean number of hooks fished was 7.38±1.42.

Total catch did not seem to be influenced by the number of passes needed to stop a school (range 1 to 12 passes) nor the time interval from the start of the successful pass to the start of fishing (range of 0 to 31 minutes). The r_s values were −0.043 and 0.111, respectively.

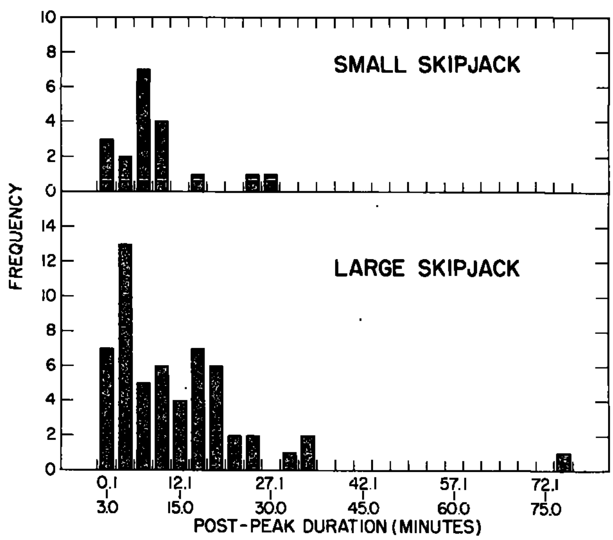

Figure 9.—Frequency distributions of postpeak duration for large and small skipjack.

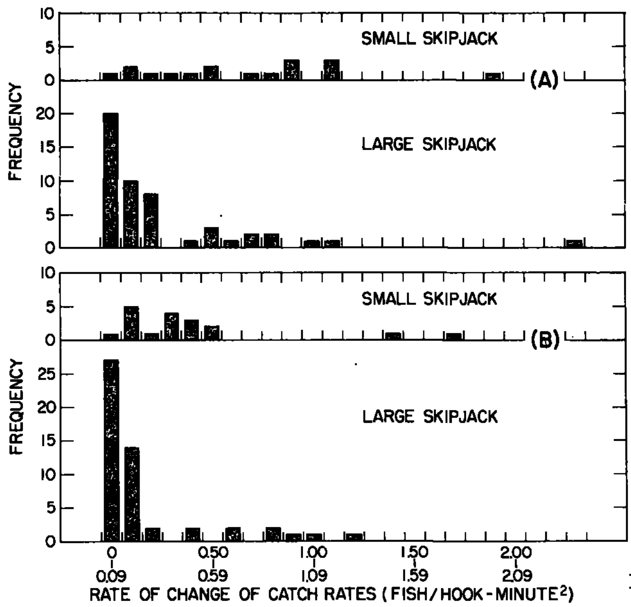

Figure 10.—*A*, Frequency distributions of rate of increase of peak catch rates. *B*, Frequency distributions of rate of decrease of postpeak catch rates.

Summarizing (table 1), the measured factors which seemed to influence the catch were (1) postpeak duration, (2) fishing duration, (3) peak catch rate, (4) mean number of hooks per minute, and (5) rate of increase of prepeak catch rates. Of these the peak catch rate and the postpeak duration were chosen as measures of skipjack response for use in later analyses. These, we thought, would be measures of two different aspects of response to chum. The peak catch rate would measure the degree of interest or intensity of the skipjack in feeding, and the postpeak duration would measure the duration of interest.

This by no means implies that these aspects are separate entities. In fact, the rank correlation coefficient between the two is 0.382** which may be interpreted to mean that factors common to both exist, or that one is influenced by the other.

Another consideration is that these measures may also be associated with school size. It is conceivable that a larger school would result in a longer postpeak duration. Perhaps the fish in a larger school would be more densely distributed which would result in a higher peak catch purely on a mechanical basis. It is also possible that behavior is influenced by school size. Unfortunately these possibilities must remain as conjectures for the present as no means for measuring the school size was available.

TABLE 1.—*Correlation coefficients of total catch with various measures of fishing*

Measure	Degrees of freedom	r
Fishing duration	84	0.772**
Peak catch rate	84	.614**
Prepeak duration	84	.201
Postpeak duration	84	.868**
Rate of prepeak increase	71	.274*
Rate of postpeak decrease	73	−.120
Mean number of hooks	84	.289**
Number of passes	81	−.06
Time from start of pass to start of fishing	79	.01

DESCRIPTION OF STOMACH CONTENTS

For descriptive purposes, the group designated as small fish was further divided into two groups with 50 cm. as the separating point. The volume of the stomach contents varied markedly with fish size. The mean volume for large fish was 35.6 ml./fish. The school means ranged from 2.4 to 154.1 ml./fish. Skipjack 50 to 60 cm. in fork length showed a mean volume of 20.4 ml./fish with school means ranging from 1.5 to 55.6 ml./fish, while skipjack shorter than 50 cm. had a mean volume of 9.1 ml./fish with school means ranging from 1.3 to 15.2 ml./fish.

The food of the skipjack of the different size groups was alike and consisted of fish, mollusks, and crustaceans, but in different proportions. During the fishing season, fish accounted for 91 percent by volume of the large skipjack's diet but contributed less to the food of the smaller skipjack (fig. 11). The percentage compositions of fish in the stomachs of skipjack of 50 to 60 cm. long and skipjack less than 50 cm. long were 70 percent and 40 percent, respectively. On the other hand, mollusks and crustaceans were of relatively increasing importance with a decrease in size.

The six schools sampled during the off season, October 1956 through March 1957, produced somewhat different percentage compositions (fig. 12). Three of the schools were composed of skipjack estimated at 12 to 13 pounds and the other three consisted of skipjack estimated at 22 pounds. All of these fish would be classified as large. The percentage of fish in the stomachs was 59 percent as compared to 91 percent found during the season.

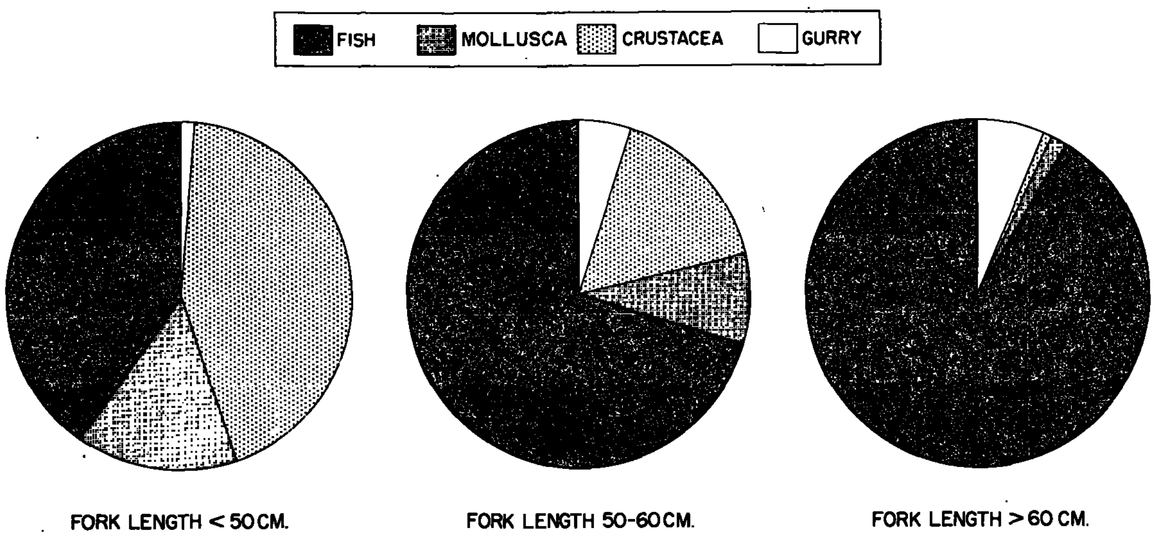

FIGURE 11.—Diagrams illustrating the composition by volume of the stomach contents of three sizes of skipjack caught during the fishing season.

Another difference between the diets of season and nonseason skipjack was the percentage of crustaceans. The figures are 36 percent for nonseason skipjack and less than 1 percent for season skipjack.

Representatives of 30 fish families and a few unidentified fish were found in the stomach contents. The families are listed in table 2 in order of percentage of total mean volume. The percentages listed are for fishes of the season and were calculated in the following manner to compensate

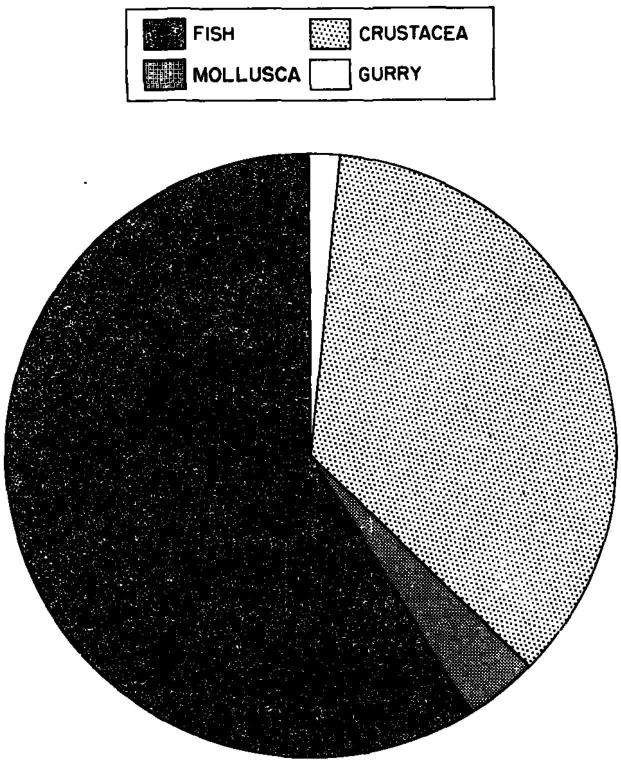

Figure 12.—Diagram illustrating the composition by volume of stomach contents of large skipjack caught during the off season.

for the difference in sample sizes. First, the mean volume of each category in units of ml./stomach was taken for each school. Then the total mean volume of each category was divided by the grand total mean volume and converted to percentages. In this way the contents from each school were given equal weight regardless of sample size. Carangids (genus *Decapterus*) were by far the most important item in terms of both volume and occurrence. The genus *Cubiceps* of the family Nomeidae also contributed considerably to the volumes. Gurry, a small piece of wood, and a cigarette butt were classed under miscellaneous.

FACTORS INFLUENCING BITING RESPONSE

As selected in a previous section, peak catch rate and postpeak duration were used as measures of biting response. These were compared with a number of possible factors by correlation procedures or by plotting.

Table 2.—*Stomach contents of skipjack from 34 schools*

Contents		Percentage of total mean volume	Occurrence (number of schools)
Fish	Carangidae	45.01	27
	Nomeidae	20.25	10
	Molidae	6.45	6
	Thunnidae	3.14	13
	Gempylidae	2.27	19
	Sudidae	1.53	1
	Holocentridae	1.04	11
	Chaetodontidae	.92	21
	Bramidae	.59	10
	Scorpaenidae	.28	15
	Mullidae	.13	4
	Acanthuridae	.11	9
	Balistidae	.11	7
	Sphyraenidae	.10	1
	Exocoetidae	.07	2
	Serranidae	.06	1
	Diodontidae	.05	1
	Synodontidae	.04	4
	Priacanthidae	.03	2
	Blenniidae	.02	3
	Ammodytidae	.02	3
	Fistularidae	.01	2
	Antigonidae	.01	1
	Cirrhitidae	.01	2
	Dactylopteridae	.01	2
	Ostraciidae	.01	4
	Syngnathidae	Trace	1
	Pomacentridae	Trace	1
	Tetrodontidae	Trace	1
	Pegasidae	Trace	1
	Unidentified fish	.42	20
Mollusks	Decapoda	2.28	24
	Octopoda	.02	1
Crustacea	Stomatopoda	2.51	24
	Decapoda	.94	23
	Amphipoda	.08	7
	Isopoda	Trace	5
	Euphausiacea	Trace	1
Miscellaneous		11.49	34

SKIPJACK SIZE

The mean length of the skipjack for each school was found to be significantly correlated with peak catch rate ($r_s = -0.475$**). As mentioned earlier, this is at least in part attributed to the greater facility with which the small fish were landed. Correlation between mean length and postpeak duration ($r_s = -0.058$) was not significant.

HUNGER AND TIME SINCE LAST MAJOR FEEDING

The mean volume of the stomach contents (ml./stomach) for each school was used as a measure of the state of hunger. The time since the last major feeding was expressed by the lowest stage of digestion found in the dominant fish family or families in the stomach contents of a school, using the following criteria:

Stage 1. Fish intact.
Stage 2. Skin or head missing.
Stage 3. Part of flesh missing
Stage 4. Skeletal remains.

Since the rate of digestion is not known, this measure is a relative one. Only the large skipjack caught during the season provided sufficient data for this study.

Since the stage of digestion was found to be highly correlated with the mean volume ($r_s = -0.607^{**}$), partial correlation procedures (Snedecor 1946) were used to assess the relations of these variates to biting response. Although the variates did not meet the assumption of normality, we found no other satisfactory technique and thought that these relations should be investigated.

The peak catch rate was not significantly correlated with either variate. This is in contrast to the findings of Uda (1933) and Suyehiro (1938). The former stated that skipjack with stomachs between the extremes of fullness and emptiness tended to respond more poorly to fishing when their stomachs were emptier. The latter observed that skipjack which had fed recently did not bite so well as those that were hungry. His measure of the recentness of feeding was the depth of the rugae; i.e., a smooth stomach lining indicated recent feeding. We suspect, however, that the depth of the rugae is directly related to the state of distention of the stomach, which depends upon the amount of food in it.

Multiple correlation computations of postpeak duration with stage of digestion and mean volume resulted in $R = -0.565^{*}$. In further computations, the partial correlation coefficient between postpeak duration and stage of digestion, independent of mean volume, was found to be -0.535^{*} and that between postpeak duration and mean volume, independent of stage of digestion, was found to be -0.506^{*}. That is to say, the postpeak duration was longer when the major items in the stomachs were in the earlier stages of digestion and the stomachs were emptier.

From this we hypothesize that live-bait fishing techniques employed in Hawaii generally do not create a state of feeding excitement in the skipjack, but exploit an already existing one which apparently is caused by the presence of natural food. The fact that less than one-half of the schools respond to chum supports the hypothesis. Furthermore, the correlations infer that the state of excitement diminishes with feeding or with time if the skipjack were not satiated when the natural food became unavailable.

PREY BEHAVIOR

In order to determine whether any association existed between prey behavior and biting behavior of skipjack, schools were grouped according to families of fish in their stomachs. Only first and second stages of digestion were considered, and, if a school of fish had representatives of several families, the school was tabulated in each family classification. The mean peak catch rate and mean postpeak duration for each group represented by four or more schools were computed. As an example, the mean peak catch rate and the mean postpeak duration were calculated for all schools with the family Carangidae in the first and second stages of digestion.

The families are listed in tables 3 and 4 in descending order of their means. If the families were classified by their swimming abilities, the

TABLE 3.—*List of fish families and peak catch rate means*

Family	Mean peak catch rate (fish/hook-minute)
Nomeidae	1.92
Thunnidae	1.55
Carangidae	1.51
Gempylidae	1.47
Chaetodontidae	1.43
Scorpaenidae	1.31
Molidae	1.30
Acanthuridae	1.17

TABLE 4.—*List of fish families and postpeak duration means*

Family	Postpeak duration (minutes)
Nomeidae	17.7
Thunnidae	17.5
Gempylidae	17.4
Scorpaenidae	16.4
Acanthuridae	15.8
Carangidae	15.3
Molidae	14.1
Chaetodontidae	12.8

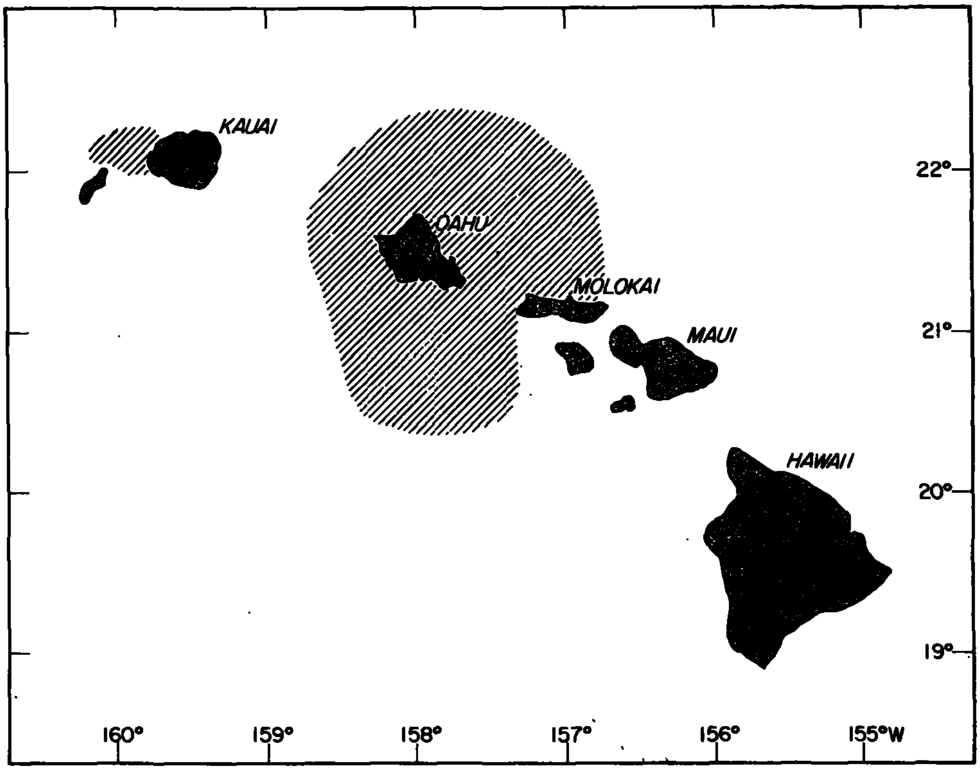

FIGURE 13.—Chart showing the areas of fishing where observations were made.

fast swimmers would include the families Thunnidae, Carangidae, Gempylidae, and Nomeidae, while the remainder would be considered slow swimmers. The fast swimmers are in the top four positions of table 3 and in the top three positions of table 4. It therefore appears that skipjack feeding on fast-swimming fish exhibit a more favorable biting behavior than skipjack feeding on slow-swimming fish.

STATE OF OVARY DEVELOPMENT

The ovaries collected from the large skipjack were all maturing. A few of the eggs were teased from the group of largest eggs in each ovary, and the diameters of five were measured. The greatest diameter found in each school was used as a rough measure of maturity. The correlations of egg diameters with peak catch rate (r_s=0.086) and postpeak duration (r_s=0.258) were not significant. The absence of ripe skipjack in the catch may be due to the reluctance of such skipjack to feed, but the stages of egg maturation other than ripeness do not appear to affect biting response.

LOCATION

All observations were made in the regions represented by the shaded areas in figure 13. The shaded area at the west end of the island of Kauai represents only one trip. The rest of the trips were within the shaded area around the island of Oahu.

The peak catch rate for large fish showed a positive significant correlation with distance from land (r_s=0.308*). For small fish, the correlation was not significant (r_s=0.057). No significant correlation was found between postpeak duration and distance from land for either large or small fish (r_s values of −0.040 and −0.224, respectively).

TIME OF DAY

Examination of peak catch rate, postpeak duration, and the percentage of schools successfully fished relative to time of day indicated no relation. Data on the Japanese skipjack fishery (Uda 1940a) show that catches were highest between 6 a.m. and 8 a.m., but the peak was not reflected in the catch rates. Suyehiro (1938) stated that fishing was best during early morning but provided no data.

WEATHER CONDITIONS

The weather conditions were predominantly uniform and biting behavior did not change on the unusual days. The height of the sea ranged from 1 to 10 feet, with 2 to 5 feet being the usual condition. Estimations of wind velocity ranged from 0 to 30 knots, but most of the estimates were between 10 and 20 knots. Most of the days were bright and sunny. The few darker days affected fishing only in decreasing the chances of sighting schools.

SUMMARY AND CONCLUSIONS

Commercial fishing of 92 skipjack schools was observed and resulted in the following information:

1. Fifty-two percent of the schools chummed yielded no fish.
2. The number of fish caught per school varied from 1 to 773.
3. Total fishing time per school varied from 1 to 82 minutes.
4. The number of passes required to stop a school varied from 1 to 12.
5. The mean number of hooks fished per school was 7.38 ± 1.42.
6. Although the catch rate varied during fishing operations, the general tendency was to rise to a peak and then decline with elapsed fishing time.
7. The peak catch rate ranged from 0.12 to 4.29 fish per hook-minute for large skipjack (fork length greater than 60 cm.) with a mode of 0.40 to 1.00 fish per hook-minute, while small skipjack (fork length less than 60 cm.) had a range of 0.75 to 4.62 fish per hook-minute with a mode of 3.20 to 3.40 fish per hook-minute.
8. The prepeak duration ranged from 0.5 to 42.5 minutes with a mode of 2 to 3 minutes.
9. The postpeak duration ranged from 0 to 77 minutes with a mode of 3 to 6 minutes.
10. The catch per school was affected by fishing duration, postpeak duration (which is part of fishing duration), peak catch rate, number of hooks fishing, and the rate of increase of prepeak catches.

Examination of the contents of 573 stomachs representing 49 schools revealed the following:

1. The mean volumes of stomach contents for skipjack of fork length greater than 60 cm., 50 to 60 cm., and less than 50 cm. were 35.6 ml., 20.4 ml., and 9.1 ml., respectively.
2. The percentage of fish in the stomachs collected during the fishing season decreased with a decrease in skipjack size while the percentages of mollusks and crustaceans increased.
3. The percentage of fish in the stomachs of large skipjack caught during the off season was less than that of those caught during the season. The reverse was true of the percentage of crustaceans.
4. The fish contributing most to the diet of skipjack were the genus *Decapterus*, of the family Carangidae, and the genus *Cubiceps*, of the family Nomeidae.
5. Representatives of more than 30 families of fish were found in the stomachs.

A study of the causal factors of the variation in biting response showed that—

1. Large skipjack tended to take the hooks faster the farther away they were from land.
2. The duration of response to chum was negatively correlated with mean stomach volumes and the stage of digestion of the dominant component of the stomach contents.
3. Skipjack feeding on fast-swimming fish were caught at a faster rate and fished for a longer period than those feeding on slow-swimming fish.
4. The relation between the state of ovary development and biting response is not clear, but only skipjack in the maturing stage were caught. In the maturing stage there was no correlation between biting response and a slight gradient in egg development.
5. Biting response was not affected by the time of day or weather conditions.

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APPENDIX

Data from schools fished during skipjack season

[Data from 6 schools fished in competition with other boats are not listed]

Date	Starting time	Total catch	Number of passes needed to stop school	Prepeak duration (minutes)	Postpeak duration (minutes)	Fishing duration (minutes)	Mean number of hooks fished (hooks/minute)	Peak catch rate (fish/hook-minute)	Rate of increase of pre-peak catch rates (fish/hook-minute)	Rate of decrease of post-peak catch rates (fish/hook-minute)	Distance from land (miles) [1]	Fish size [2]	Mean volume of stomach contents (ml./stomach)	Lowest stage of digestion of major components
1956														
May 3	1036	5	2	10.5	0.5	11	6.5	0.50	0.02	----------	----------	B	----------	----------
3	1322	280	1	7.0	31.0	38	7.9	2.17	.28	0.045	----------	B	----------	----------
8	1453	49	1	7.0	7.0	14	7.7	.88	.10	.125	30 W	B	----------	----------
8	1614	11	1	5.0	4.0	9	7.3	.42	.27	.124	----------	B	----------	----------
8	1630	47	1	15.0	6.0	21	6.9	.75	.03	.104	----------	B	----------	----------
8	1805	81	7	3.0	4.0	7	8.3	2.25	.62	.689	----------	B	----------	----------
15	0815	87	1	5.0	12.0	17	8.8	1.15	.18	.061	20 L	B	----------	----------
15	0900	66	3	5.0	16.0	21	8.1	1.06	.21	.068	20 L	B	----------	----------
16	1538	15	1	7.0	17.0	24	7.6	.29	.02	.014	18 L	B	----------	----------
June 21	0845	197	1	0.5	20.5	21	9.7	3.62	----------	.094	10 W	B	----------	----------
21	1203	47	1	1.0	13.0	14	9.1	0.75	----------	.065	15 W	----------	----------	----------
21	1412	773	1	5.0	77.0	82	9.7	3.18	.78	.031	20 W	B	18.6	1
26	1242	118	1	7.0	17.0	24	10.0	1.45	.16	.050	30 W	B	32.5	2
26	1316	355	1	3.0	36.0	39	9.9	1.80	.28	.032	30 W	B	14.1	3
26	1459	44	1	4.5	5.5	10	9.4	.89	.16	.114	30 W	B	----------	----------
26	1522	245	1	3.5	23.5	27	9.0	1.89	.50	.038	30 W	----------	----------	----------
26	1629	140	1	6.0	15.0	21	6.0	2.50	.42	.139	25 W	----------	----------	----------
29	1112	4	2	5.0	4.0	9	7.3	.12	.03	.034	----------	B	154.1	1
29	1142	104	1	9.0	13.0	22	9.0	1.20	.14	.084	----------	B	----------	----------
29	1613	110	1	7.0	18.0	25	7.8	1.50	.27	.052	----------	B	54.3	2
July 3	0910	79	2	12.0	12.0	24	7.5	1.00	.03	.041	10 W	B	41.6	2
4	1002	58	1	2.0	21.0	23	6.8	.69	.28	.019	10 W	B	41.6	1
4	1204	66	4	10.0	11.0	21	7.7	1.92	.14	.148	6 W	B	101.8	1
10	0907	54	2	2.0	16.0	18	9.0	1.22	.56	.044	15 W	B	22.6	2
10	0950	79	1	2.0	10.0	12	9.2	1.28	.59	.111	15 W	B	----------	----------
10	1002	32	1	2.0	10.0	12	8.2	.50	.18	.070	15 W	B	----------	----------
10	1116	106	3	7.0	16.0	23	8.9	1.50	.11	.089	6 W	B	9.1	2
10	1835	90	5	10.0	8.0	18	8.7	1.21	.08	.153	5 W	B	----------	----------
17	0824	4	3	6.0	.0	6	10.3	.22	.04	----------	10 W	B	----------	----------
17	1146	244	2	12.0	27.0	39	8.4	1.56	.09	.040	12 W	B	74.0	2
19	0811	39	1	8.0	5.0	13	6.2	.92	.08	.200	18 L	B	2.4	3
19	1245	140	12	7.0	14.0	21	6.7	1.83	.02	.121	50 L	B	5.7	3
19	1352	94	1	2.0	18.0	20	6.0	1.56	.71	.064	60 L	----------	----------	----------
24	1130	8	1	5.0	4.0	9	7.0	.21	.03	.065	10 L	B	37.3	2
24	1721	120	7	7.0	20.0	27	6.7	1.50	.20	.040	5 L	B	30.0	1
25	0916	6	4	5.0	2.0	7	6.0	.42	.14	.420	20 L	B	----------	----------
25	1602	12	5	5.0	5.0	10	6.0	.50	.09	.125	15 L	B	----------	----------
26	0734	23	1	11.5	5.5	17	7.8	.38	.01	.063	15 L	B	----------	----------
26	0918	43	1	17.5	12.5	30	7.4	.83	.01	.038	10 L	B	----------	----------
26	1248	51	1	20.5	5.5	26	7.0	.60	.01	.153	8 L	B	----------	----------
27	1003	165	1	42.5	22.5	65	6.0	1.40	.00	.041	10 L	B	----------	----------

See footnotes at end of table.

Data from schools fished during skipjack season—Continued

Date	Starting time	Total catch	Number of passes needed to stop school	Prepeak duration (minutes)	Postpeak duration (minutes)	Fishing duration (minutes)	Mean number of hooks fished (hooks/minute)	Peak catch rate (fish/hook-minute)	Rate of increase of prepeak catch rates (fish/hook-minute)	Rate of decrease of postpeak catch rates (fish/hook-minute)	Distance from land (miles) [1]	Fish size [2]	Mean volume of stomach contents (ml./stomach)	Lowest stage of digestion of major components
1956														
Aug. 8	1221	30	4	2.5	9.5	12	5.6	1.67	1.17	0.171	30 L	B	18.6	3
9	0942	10	2	6.5	1.5	8	7.0	0.86	.09	.860	20 L	B	106.2	2
10	0810	35	3	2.5	4.5	7	6.9	1.83	1.16	.466	2 W	S	4.7	--------
10	1134	21	4	1.5	5.5	7	6.4	.92	--------	.103	¾ W	S	1.3	--------
10	1320	12	1	1.5	1.5	3	8.7	.70	--------	--------	50 L	B	--------	--------
22	1025	3	3	.5	1.5	2	7.0	.50	--------	--------	40 L	B	11.0	3
30	1207	123	9	3.5	8.5	12	7.8	3.25	.96	.332	30 L	S	15.1	--------
30	1331	171	3	3.5	8.5	12	7.5	4.00	.99	.294	30 L	S	22.6	--------
30	1407	19	1	2.5	2.5	5	7.2	1.14	.50	.570	30 L	S	20.7	--------
30	1440	139	1	11.5	18.5	30	7.2	1.75	.05	.071	25 L	--------	--------	--------
Sept. 12	0930	113	3	2.0	4.0	6	8.8	3.06	1.03	.630	30 L	B	9.2	3
12	0956	82	2	11.5	8.5	20	6.8	1.57	.03	.115	30 L	B	--------	--------
1957														
May 23	0750	52	2	2.5	.5	3	6.7	3.12	--------	--------	10 W	--------	--------	--------
23	0832	2	1	.5	.5	1	5.0	.40	--------	--------	20 W	--------	--------	--------
23	0846	13	1	1.5	.5	2	5.0	2.20	--------	--------	20 W	--------	--------	--------
23	0912	17	1	1.5	.5	2	6.0	2.14	--------	--------	20 W	--------	--------	--------
23	1301	22	3	2.5	5.5	8	6.9	1.00	.50	.123	20 W	B	4.5	3
23	1612	189	11	1.5	21.5	23	6.9	2.80	2.30	.109	25 W	B	--------	--------
June 13	1207	128	1	2.5	7.0	10	6.4	3.29	.58	.382	20 W	S	15.2	--------
19	1007	19	4	.5	8.5	9	8.6	.88	--------	.041	10 W	B	--------	--------
19	1023	19	1	4.5	8.5	13	7.5	.44	.09	.038	15 W	B	33.7	2
19	1222	23	3	10.5	2.5	13	7.4	1.00	.02	1.000	--------	B	--------	--------
19	1343	94	4	6.5	18.5	25	7.7	1.50	.18	.050	20 W	B	9.4	2
July 3	0950	111	5	10.5	10.5	21	5.6	4.62	.30	.189	3 W	S	3.3	--------
3	1040	358	--------	2.5	25.5	28	7.2	4.00	1.12	.156	20 L	S	11.0	--------
3	1207	142	--------	2.5	9.5	12	7.2	3.50	.95	.445	20 L	S	--------	--------
3	1228	67	1	3.5	6.5	10	6.9	2.71	.81	.385	25 L	S	--------	--------
3	1317	71	1	3.5	9.5	13	7.2	1.57	.15	.113	30 L	S	--------	--------
3	1353	207	1	12.5	8.5	21	7.3	3.38	.02	.405	30 L	S	--------	--------
3	1430	83	1	4.5	6.5	11	7.7	1.62	.25	.296	30 L	S	--------	--------
3	1510	95	1	10.5	1.5	12	6.8	2.71	.11	1.700	30 L	S	--------	--------
3	1528	6	1	.5	1.5	2	5.0	.75	--------	--------	30 L	S	--------	--------
3	1552	41	--------	1.5	10.5	12	6.6	2.12	1.12	.140	30 L	S	--------	--------
Aug. 1	1543	188	1	2.5	16.5	19	6.9	3.00	.72	.196	40 W	B	7.3	--------
1	1610	431	1	2.5	35.5	38	6.7	4.29	.86	.090	40 W	B	--------	--------
1	1747	2	2	.5	1.5	2	7.0	.29	--------	--------	40 W	--------	--------	--------
1	1753	337	1	10.5	14.5	25	6.9	3.57	.21	.233	40 W	--------	--------	--------
6	0626	157	1	4.5	27.5	32	7.9	2.33	.47	.031	1½ L	S	31.8	--------
14	0941	84	1	2.5	16.5	19	5.8	3.00	1.50	.103	30 L	--------	--------	--------
14	1007	15	2	2.5	12.5	15	6.5	.43	.22	.004	20 L	B	23.5	2
14	1806	158	1	5.5	15.5	21	6.9	3.14	.71	.172	10 L	S	55.6	--------
21	1353	133	2	1.5	7.5	9	7.6	4.14	1.94	.579	55 L	S	1.5	--------
21	1603	178	1	4.5	5.5	10	7.5	3.12	.44	.403	40 L	B	214.1	1
21	1706	13	4	2.5	0.5	3	5.0	1.40	--------	--------	40 L	--------	--------	--------
21	1734	315	1	2.5	25.5	28	7.7	2.71	.86	.069	40 L	B	--------	--------

[1] W=Windward. L=Leeward.
[2] B=mean length> 60 cm. S=mean length <60 cm.