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ESTIMATES OF LARVAL TUNA ABUNDANCE IN THE CENTRAL PACIFIC

BY DONALD W. STRASBURG

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ABSTRACT

Certain aspects of larval tuna sampling were studied by an analysis of the catches of the 0, 0–60, 70–130, 140–200, and 0–200 meter plankton tows made on 15 cruises in Hawaii, the equatorial Pacific, and French Oceania. The use of paired nets showed that the catch of a single net could be duplicated, and that plankton nets were therefore reliable tools for sampling the abundance of tuna larvae.

Most larval tuna were captured between the surface and 60 meters, with 20–25 percent more between 70 and 130 m., and practically none between 140 and 200 m. Marked night-day differences in catch occurred at the surface but became less at greater depths. Most of these differences were attributable to vertical migration rather than net-dodging. The 0–200 m. tow, fishing through the entire depth range of larval tuna, was regarded as the best of the tows tested.

Larval skipjack and frigate mackerel were rarely captured during the day by the 0 and 0-60 m. tows, but this was not true for yellowfin. Both skipjack and yellowfin began to appear at the surface in the afternoon but disappeared at sunset, to reappear somewhat later. This disappearance from the surface was correlated with the rise of the deep scattering layer.

The dominant size group in the larval tuna catch measured from 4.0-4.9 mm. total length. Many larvae of 2.0–2.9 mm. total length were presumed to have escaped through the net meshes, while larvae longer than 5 mm. may have escaped by dodging.

No significant relations were found between the numbers of adult yellowfin and skipjack and their respective larvae.

ESTIMATES OF LARVAL TUNA ABUNDANCE IN THE CENTRAL PACIFIC

By Donald W. Strasburg, *Fishery Research Biologist*,
Bureau of Commercial Fisheries

For the past several years the Pacific Oceanic Fishery Investigations (POFI), of the U. S. Fish and Wildlife Service, has sampled adult tuna stocks as a means of evaluating the tuna resources of the central Pacific Ocean. Deep-swimming tunas, such as large yellowfin (*Neothunnus macropterus*), bigeye (*Parathunnus sibi*), and albacore (*Germo alalunga*), were taken by longlining, and surface dwelling tunas, such as skipjack (*Katsuwonus pelamis*), and small yellowfin and albacore, have been captured by live-bait fishing, gillnetting, and trolling. The catches obtained by these methods were used as indices of the availability, distribution, and abundance of the tuna, and the biological studies of adult fish contributed information on reproductive cycles, food habits, growth rates, and other phenomena.

For some of the above operations, good fishing localities could frequently be judged by the presence of sea birds, knowledge of the circulation features, water of a certain color or temperature, or other factors, but in the absence of such guides, fishing sites were more or less randomly selected. In areas where sea birds were scarce or absent, such as a large part of the open ocean, our knowledge of surface tuna abundance was scanty, thus raising the question of the reliability of the several guides. Another inadequacy of the sampling method was that running ripe fish were rarely caught, either because of their migration from the fishing grounds, cessation of feeding during spawning, or the breaking up of schools during the reproductive period. There was little precise information, therefore, on the time and place of spawning except for the general trends evident from gonadal studies.

It was believed that a study of the eggs, larvae, and juveniles of tuna would be of considerable aid in filling certain gaps in our knowledge. The occurrence of eggs and larvae, as collected in plankton tows, should indicate the recent or continuing presence of adult fish independently of external indicators, and should prescribe the time and place of spawning with accuracy, depending on current drift and ontogenetic age. With reliable estimates of abundance, it should be possible to determine the numerical relations between adult tuna, their eggs, and larvae.

Before these major problems could be studied effectively it was necessary to consider the sampling methods employed. Among other things, it was requisite to know the reliability of a plankton tow as a method of capturing tuna eggs and larvae, and also to standardize the time and depth of tow so that meaningful comparisons could be made between samples. Because of its occasionally profound effect on the catch, it was desirable to understand the rudiments of larval tuna behavior. A study of these problems resulted in the present report, but because tuna eggs are not presently identifiable, its scope is limited to larval and juvenile forms. I should like to express my gratitude to Walter Matsumoto for his help in identifying tuna larvae, and to other POFI staff members who aided in collecting and processing the samples and in reviewing the manuscript.

METHODS

Collecting

All larvae reported upon were collected by plankton tows made from the POFI vessels *Hugh M. Smith* and *Charles H. Gilbert*. Three cruises were limited to the Hawaiian area, and 12 took place in the equatorial Pacific with some emphasis on the waters of French Oceania. Matsumoto (1958) has already presented data for 8 of these 15 cruises (*Hugh M. Smith* cruises 5, 6, 7, 8, 11, 14, 15, and 18). The operational areas of the remaining 7 cruises are shown in figure 1, and appendix tables 5 through 11 summarize catch and effort for each station.

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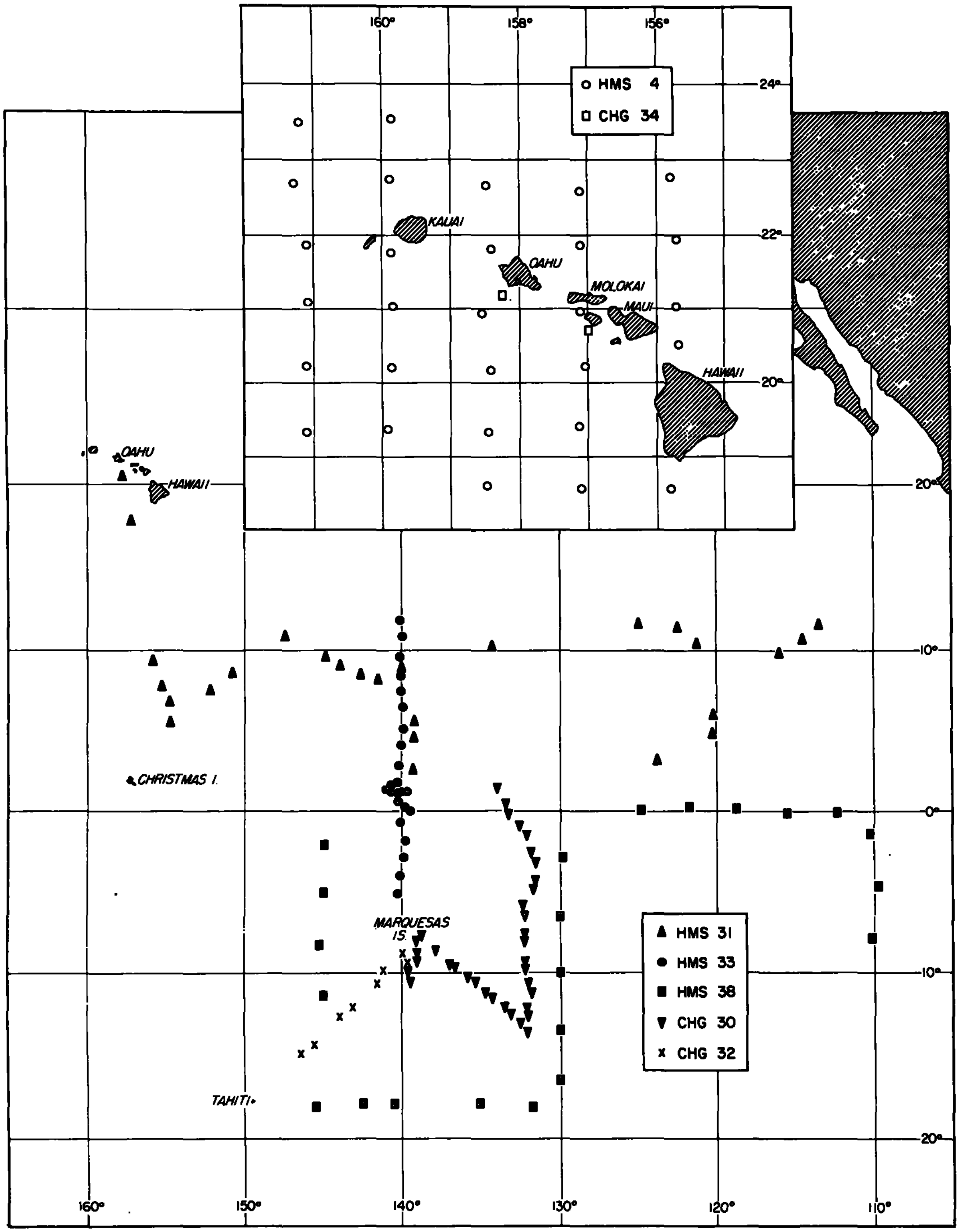

FIGURE 1.—Plankton stations sampled for larval tunas. HMS=*Hugh M. Smith*, CHG=*Charles H. Gilbert*.

All plankton nets employed were 1 meter diameter at the mouth and 5 meters in length. The nets were of two types, open and closing, the structural details of which are given by King and Demond (1953) and King and others (1957). On early cruises the nets were fabricated of Dufours bolting silk or silk grit gauze (30XXX body and 56XXX rear section), but these materials were later replaced by nylon (#656 Nitex body and #308 Nitex rear section); for all nets, mesh apertures were 0.66 mm. in width in the body and 0.31 mm. in the rear section and bag. The nets were equipped with flowmeters to measure the amount of water strained.

Three types of plankton tows were made: horizontal open net tows, oblique open net tows, and oblique closing net tows. For this study only those horizontal open net tows which fished at the surface were considered, and these can be termed simply surface or 0-meter tows. They fished just deeply enough so that the nets did not break the surface. Oblique open net tows were made from the surface to about 60 m. and from the surface to about 200 m.; for brevity these are designated as 0–60 m. and 0–200 m. tows. The oblique closing net tows involved a string of three nets, the upper one being an open net fishing from the surface to approximately 60 m., the middle a closing net fishing from about 70 to 130 m., and the lower a closing net fishing from about 140 to 200 m. These are designated as 0–60 m., 70–130 m., and 140–200 m. tows, with the first being indistinguishable from the 0–60 m. oblique open net tow. Ordinarily, tows were ½-hour in duration, but some were as short as 15 minutes or as long as 1 hour, at towing speeds of 2.5 to 3.5 knots.

Processing

At the completion of each tow the nets were hauled aboard, hosed down to remove plankton residues, and the samples transferred to glass fruit jars and preserved in 10-percent borax-neutralized formalin. As soon as possible after returning to the laboratory all fish and fish eggs were removed, and, from these, all young tuna were sorted and transferred to clean formalin for storage.

Identification

Larval tuna were identified principally with reference to Matsumoto's two recent papers (Matsumoto 1958 and 1959). POFI's extensive collections provided comparative material, and in some cases Matsumoto examined the specimens. The vast majority of specimens were referable to skipjack (*Katsuwonus pelamis*), yellowfin (*Neothunnus macropterus*), frigate mackerel (*Auxis thazard* and *Auxis* sp.), and little tunny (*Euthynnus yaito*); these are designated by their common names throughout the balance of this report. Of the unidentified material, a few specimens belonged to species for which the larvae are undetermined, and the remainder were severely mutilated.

Terminology

Larva denotes a specimen lacking the full complement of vertical fin spines and rays. This term includes most individuals below about 11 mm. in total length.

Length is total length, measured from the tip of the snout to the end of the longest caudal ray; where the caudal is forked, length is fork length.

Abundance is expressed as the number of larvae per thousand cubic meters of water strained, and also as the number of larvae beneath 10 square meters of sea surface.

Time is expressed in terms of the 24-hour clock, with zone time being used in each case.

Invertebrate plankton volume is the displacement volume measured subsequent to the removal of all fish, fish eggs, and organisms larger than 5 cm. longest dimension.

RELIABILITY OF A SINGLE SAMPLE

It was reasoned that if the catch made by one plankton net could be duplicated by another fishing at the same time and place, then plankton nets are reliable tools for sampling larval tuna within certain limitations of the sampling method. Reliability was first tested on *Charles H. Gilbert* cruise 30 to the Marquesas Islands. Two surface nets were launched simultaneously at 2000 hours each night; they fished about 20 feet apart for one-half hour after which they were retrieved, rinsed, the cod-ends replaced, and the procedure repeated for a second half-hour. Fourteen stations, each including a 4-haul series, were occupied, but the sampling was apparently done in the off-season (Aug.–Sept.) with respect to Marquesan tuna spawning, and few larvae were collected. A second test was made during January-March on *Hugh M. Smith* cruise 38 to French Oceania. Here, two half-hour tows were taken each night, one immediately following the other, so that members of a pair of samples differed slightly in time and space. The data obtained from these tests are listed in detail in the appendix and in summary form in table 1. With respect to the latter, it should be noted that all species of tuna larvae were combined and that only those stations were considered where larvae were taken by one or more nets.

TABLE 1.—*Numbers of larval tuna captured by paired night surface tows, with analyses of variance based on transformed data*

$$\left[x' = \log\left(\frac{x+1}{10{,}000\text{m}^3}\right)\right]$$

Charles H. Gilbert cruise 30

Station No.	Position	Time: First ½ hr.	Time: Second ½ hr.
3	Port	3	1
	Starboard	1	2
7	Port	1	0
	Starboard	1	2
9	Port	1	0
	Starboard	0	0
13	Port	2	1
	Starboard	1	2
15	Port	0	0
	Starboard	1	0
17	Port	0	0
	Starboard	0	1
21	Port	14	13
	Starboard	17	26
23	Port	4	1
	Starboard	2	1
25	Port	0	0
	Starboard	2	0
32	Port	5	2
	Starboard	1	4

Analysis of variance

Source	Degrees of freedom	Sum of squares	Mean square
Time (T)	1	0.0185	0.0185
Stations (S)	9	4.5071	**0.5008
Positions (P)	1	0.0168	0.0168
T×S	9	0.1549	0.0172
T×P	1	0.1102	0.1102
S×P	9	0.2258	0.0251
T×S×P	9	0.2540	0.0282
Total	39	5.2873	

Hugh M. Smith cruise 38

Station No.	Time: First ½ hr.	Time: Second ½ hr.
23	9	18
45	2	0
47	11	4
49	0	2
54	4	1
57	7	47
59	13	21
64	2	1
66	3	1
75	2	2
79	16	4
82	56	61
85	10	13

Analysis of variance

Source	Degrees of freedom	Sum of squares	Mean square
Time	1	0.0023	0.0023
Stations	12	5.6160	0.4680
T×S	12	0.9542	0.0795
Total	25	6.5725	

**Indicates a significant F value ($p<0.01$).

A preliminary examination of the data indicated that they were skewed, and this was verified by plotting station variances against station means for the *Charles H. Gilbert* samples (fig. 2). A logarithmic transformation was accordingly performed, using the expression $x' = \log\left(\frac{x+1}{V}\right)$, where V is the volume of water strained in ten-thousand cubic meters. The use of the quantity $(x+1)$ eliminated all zero terms. An analysis of variance was made on the transformed data (table 1). Interaction terms were assumed to be negligible, and were used to test significance.

The analysis of variance produced no significant F-values except for the "stations" category. Because the station interval varied from 90 to 200 miles, significant differences are not surprising, particularly in view of the extended geographical coverage of the two cruises (fig. 1). However, between-station differences are of less interest than are those types of variability leading to errors in estimating spatial and temporal abundance.

It is difficult to conceive of a biological situation leading to statistically different port and starboard catches, for any such differences would

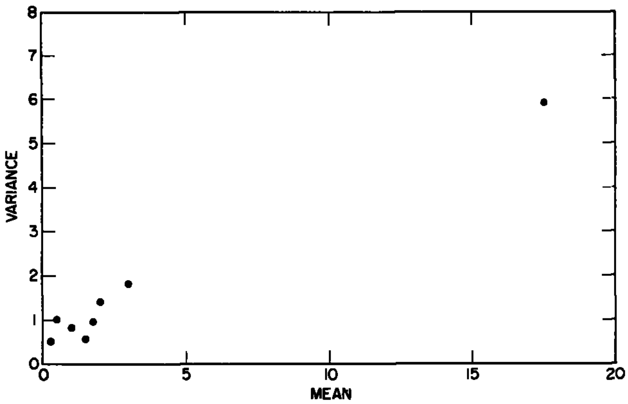

FIGURE 2.—Unadjusted larval tuna catches showing relation between means and variances. Data from surface tows taken on *Charles H. Gilbert* cruise 30 (table 1), stratified by station.

tend to be canceled in random sampling. On an a priori basis one could almost say that the statistical test was unwarranted, but before concluding that the catches of the two nets were duplicates it is well to consider additional information available from table 1. The fact that a logarithmic transformation was necessary implies contagion, or in other words, tuna larvae are not randomly distributed in the ocean. They apparently occur in patches, perhaps resulting from spotty spawning, early attempts to school or form feeding aggregations, or other factors. Under these circumstances a single measurement is not too reliable an estimate of larval abundance. It is possible to set fiducial limits to the catch listed in table 1 by use of the error terms' mean squares, these being estimates of the population parameter, σ^2. Ninety-five percent (2σ) confidence limits were selected, and these were converted to ratios by use of their antilogs. For the *Charles H. Gilbert* data, the 95-percent limits were 46 percent ($100 \times 1/2.17$) and 217 percent (100×2.17), while for the *Hugh M. Smith* samples the limits were 27 and 366 percent. For one tow to differ significantly from another, its catch would have to be either less than about ½ (¼), or greater than 2 (3) times the catch of the second tow.

No statistical differences were found between samples taken a half-hour apart at night; the subject of a change in catch with the advance of night is discussed later in this report.

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VARIATIONS IN THE DISTRIBUTION OF LARVAL TUNA

General Vertical Distribution

Wade (1951) and, more recently, Matsumoto (1958) have demonstrated marked differences in larval tuna abundance between day and night surface catches. Matsumoto suggested that these differences were caused by a vertical diurnal migration of tuna larvae, with the fish rising to the surface at night and descending to depths probably not greater than 50 meters during the day. In addition to vertical migration, this diurnal variation in the catch could also be produced by the larvae dodging the net. Larvae should be able to see an approaching plankton net more clearly during the day than at night.

In order to compare the relative importance of migration and dodging in larval tuna sampling, a study was made of the night and day catches of nets fishing at several depths. The data for all species of tuna larvae were pooled, and an average catch was calculated from all available samples (*Hugh M. Smith* cruises 4, 5, 6, 7, 8, 11, 14, 15, 18, 31, 33, and 38; *Charles H. Gilbert* cruises 30, 32, and 34). The data were derived principally from samples containing at least one tuna larva, as it was reasoned that the inclusion of zero catches would introduce another variable, namely the complete absence of larvae, as opposed to merely not catching them. Where more than one net was used at a station, all samples, including zero catches, were considered when any net caught a tuna larva. Histograms showing the average catch per thousand cubic meters of water strained are presented in figure 3.

Of the several tendencies apparent in figure 3 perhaps the most noteworthy is the over-all decline in catch with depth. About 75–80 percent of the larvae occurred between the surface and 60 m., about 20–25 percent between 70 and 130 m., and practically none below this depth (closing nets operating from 332–127 m., and from 812–355 m. failed to capture tuna larvae on *Hugh M. Smith* cruise 33). In the night hauls a marked decrease was evident between the surface, 0–60, 70–130, and 140–200 m. captures, with the catches of the 0–200 m. tows being midway in number between those from the surface and 140–200 m. In the day hauls, on the other hand, there was a slight increase in catch with depth between the

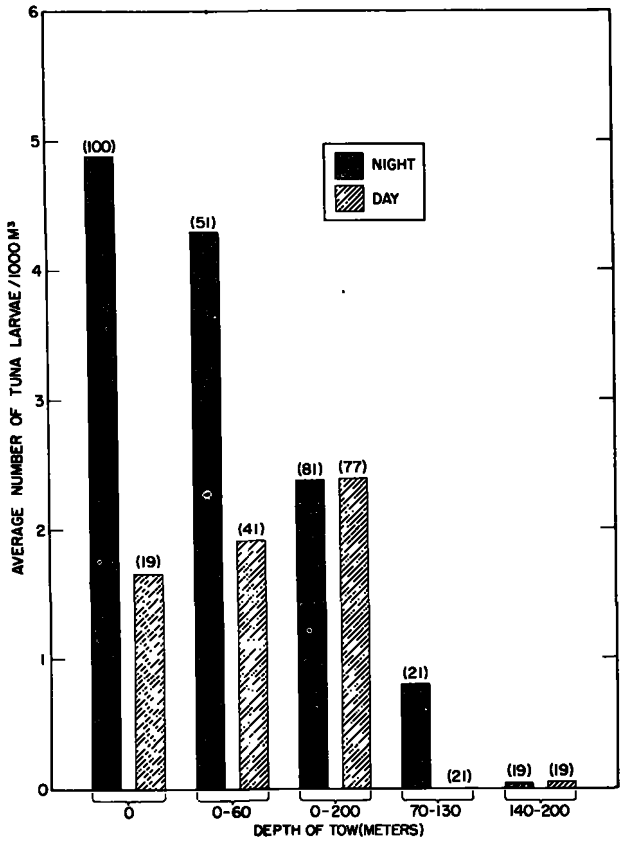

Figure 3.—Night and day variation in larval tuna catch with depth. Number of tows is shown in parentheses. The number of larvae obtained at each depth were as follows: 0 m.–927; 0–60 m.–432; 0–200 m.–592; 70–130 m.–20; and 140–200 m., 2.

surface, 0–60, and 0–200 m. tows. This illustrates an additional point as follows: the increase with depth may indicate a reduction in the amount of dodging with a decrease in illumination, or it may represent a downward migration during the daylight hours. This contrasts with the situation found for night catches where the density of larvae was much greater toward the surface. Such a change in abundance obviously signifies vertical migration, and, although dodging is a factor, we believe that migration is of greater importance in determining the number of larvae captured at a given depth and time.

Another tendency shown in figure 3 is the night-day difference in catch at various depths. This difference is most marked in the surface tows, less between 0 and 60 m., of dubious status at 70–130 m. because of the small numbers involved, and apparently lacking at 140–200 m. The average catch of the 0–200 m. tows (which encompassed this entire range) showed no night-day difference. The fact that the night-day ratio decreased with depth cannot be used to evaluate the separate effects of vertical migration and net-dodging, and it is of interest here chiefly because of its bearing on sampling vagaries. Shallow tows (0 or 0–60 m.) caught about half as many tuna larvae during the day as at night, whereas 0–200 m. tows caught the same number during each period. Deep closing-net tows (70–130 and 140–200 m.) showed little or no night-day differences, but their catches were too small for good comparisons.

In comparing the catches made at different towing depths the question arises as to whether larval tuna are at times restricted to the upper layers by temperature. Some evidence that they are restricted in this manner is given in figure 4, where the temperatures at various depths are plotted against closing net catches from these depths (sampling was completely stratified in time and space). Here the larvae can be seen to abound in the warm surface layers, and all captures at 70–130 m. were made where the water was 60°F. or warmer. One of the two larvae taken at 140–200 m. was captured at a station where a tongue of 60°F. water projected well down into this depth range, but no explanation

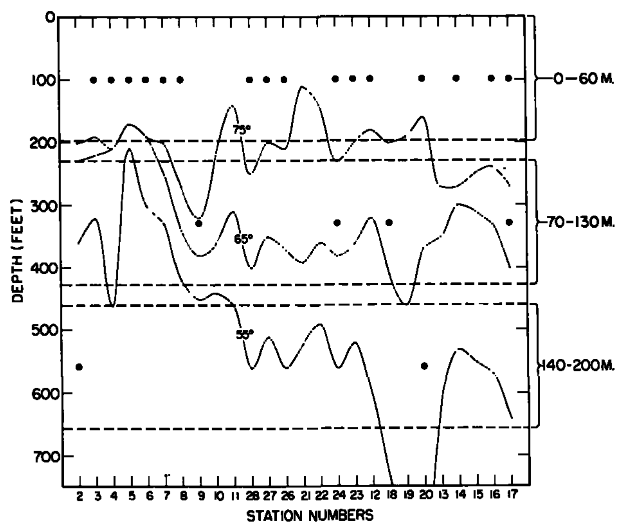

Figure 4.—Isotherm depths at plankton stations, *Hugh M. Smith* cruise 33. Stations are ranked from north to south; temperature and depth measurements derived from bathythermograph traces. Dots represent closing net tows yielding tuna larvae.

is offered for the larva taken in 52–55°F. water between 140 and 200 m. Aside from this one instance, it appears that 60°F. is the minimum temperature at which tuna larvae occur.

TABLE 2.—*Correlation between larval tuna catches made by 0 meter, 0–60 m., and 0–200 m. tows on* Hugh M. Smith *cruise 38*

[Analyses performed on data transformed by $x' = \log\left(\frac{x+1}{10{,}000 \text{ m}^3 \text{ of water strained}}\right)$]

Comparison between—	Number of stations considered	Calculated r-value
First 0 m. and 0–200 meters	12	−0.03
Second 0 m. and 0–200 meters	13	0.10
First 0 m. and 0–60 meters	14	**0.67
Second 0 m. and 0–60 meters	14	*0.60
0–60 meters and 0–200 meters	14	0.22

*Indicates a significant r-value ($p<0.05$).
**Indicates a highly significant r-value ($p<0.01$).

The above data on vertical distribution and night-day variations are of aid in selecting sampling times and depths, but the basic reason for sampling larval tuna is to obtain estimates of their abundance. In order for these estimates to be meaningful it is requisite that they reflect the presence of all tuna larvae, or, in other words, one should be able to say that there are x larvae beneath y areal units of sea surface. If a plankton tow samples all of the larvae beneath a given surface area then its catch provides an estimate of absolute abundance. If the tow captures a fixed percentage of the larvae, then an abundance estimate can be made providing a conversion factor is available. Obviously a tow which catches no set portion of the larvae is useless in furnishing a reliable abundance estimate. With these points in mind it is well to consider the utility of the information afforded by the various plankton tows discussed above.

It has already been shown that larval tuna occur from the surface to depths of 140 to 200 m. Of the several tows considered, the 0–200 m. is the only one sampling this entire distribution, so that its catch is the best reference for comparative purposes. On cruise 38 of the *Hugh M. Smith*, 0–60 and 0–200 m. tows were taken simultaneously (from the same towing cable) each night, and these were followed by two successive one-half hour surface tows. Although these tows differed slightly from each other with respect to time and space they are the best available for the comparison, and correlation methods were used to determine the proportionality of their catches. The correlation analyses are summarized in table 2, where all species of tuna larvae were pooled and stations were disregarded if neither net captured a larval tuna. As in the analysis of reliability, the data were heteroscedastic, and a transformation in the form $x' = \log\left(\frac{x+1}{10{,}000 \text{ m}^3 \text{ water strained}}\right)$ was necessary.

The data in table 2 show that neither the surface nor the 0–60 m. tow captured a fixed fraction of the 0–200 m. catch. There were significant correlations between the surface and 0–60 m. captures, but these are of little importance because neither net sampled the entire vertical distribution of the fish. In the 0–60 m. and 0–200 m. tows, at least, the deep net sampled depths fished more extensively by the shallower net, and one would accordingly expect a "part-whole" correlation between their catches.

Figure 5 shows the tracks and catches of 0–60 and 0–200 m. tows at two stations where these nets were used simultaneously; at one station the catches were equal, at the other they differed considerably. Fishing depths were calculated from observed wire-angles, and thermocline depths from bathythermograph records. The dashed intercept lines of figure 5 delimit the time intervals in which the 0–200 m. tow fished in the

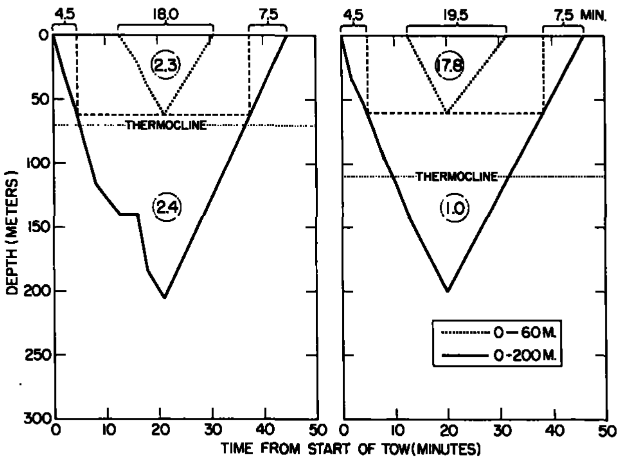

FIGURE 5.—Catch-depth-time relations for two stations where 0–60 m. and 0–200 m. tows were operated simultaneously at night (*Hugh M. Smith* cruise 38, stations 45 and 82). Left figure shows situation where catches were the same, right figure shows situation where catches were considerably different. Circled values represent catch (total tuna larvae per 1,000 cubic meters strained).

depth range of the 0–60 m. tow, these amounting to 12 minutes for each station. For the left panel of figure 5, the total 0–200 m. catch should be twelve-eighteenths of the 0–60 m. catch plus an additional catch, C_1, taken at depths greater than those fished by the 0–60 m. net. For the right panel, the comparable expression would be 12/19.5 X (0–60 m. catch) + C_2. Substituting the 0–60 m. catch values, these expressions reduce to 1.5 + C_1 and 11.0 + C_2 larvae/1000 cubic meters. The former is a reasonable approximation of the actual 0–200 m. catch of 2.4 larvae/1000 cubic meters, whereas the latter differs decidedly from the actual catch of 1.0 larvae. The majority of 12 other stations similarly analyzed also showed marked differences, suggesting that the disproportionality between the 0–60 m. and 0–200 m. catches may be caused by a spotty distribution of tuna larvae. Thermocline depth did not appear to be related to the catch, although there were indications of a catch decline when the 0–200 m. net fished deeper than the 60° isotherm.

In the preceding discussion the abundance of larval tuna was expressed in terms of the volume of water strained. The conversion of this measure to one based on areal units of sea surface was accomplished with the aid of the following conventions. It seemed obvious that only those tows fishing throughout the vertical range of tuna larvae could furnish accurate information on the number of larvae beneath a given surface area. Of the various tows studied, the 0–200 m. was the only one meeting this depth requirement, with a special situation existing for 3-level closing nets. Transformation of the 0–200 m. data involved multiplying the number of larvae per cubic meter strained by 200 (the depth of tow in meters) to give the number beneath 1 square meter of surface, and then multiplying this value by 10 to give the number beneath 10 square meters. (This area of sea surface was selected as a standard since it gave abundance estimates of about the same magnitude as the number of larvae captured per tow.) Multiplication by depth presupposed that sampling was equally intense at all depths, an assumption borne out by the relatively smooth tracks of the 0–200 m. nets shown in figure 5.

POFI's 3-level closing nets fished at depths of approximately 0–60, 70–130, and 140–200 m., so that essentially the entire 0–200 m. depth range was sampled. The cumulative areal abundance estimate furnished by these 3 nets should nearly equal that of a 0–200 m. net if a similar conversion were made. In this case, however, the depth multiplier for each net was 60 (meters), and the "surface" occurred at 0, 70, and 140 m., respectively.

Figure 6 depicts the 0–60, 70–130, 140–200, and 0–200 m. data of figure 3 expressed as the number of larvae beneath 10 square meters of sea surface. It is apparent from figure 6 that the sum of the catches of the triple-net tows was less than the 0–200 m. catch, particularly during the day. Because of the two 10 m. gaps in the triple nets' depth range one might expect about a 10-percent differential (20/200) between the two catches. Because the inequality was 36 percent for the night hauls and 76 percent for the day hauls a

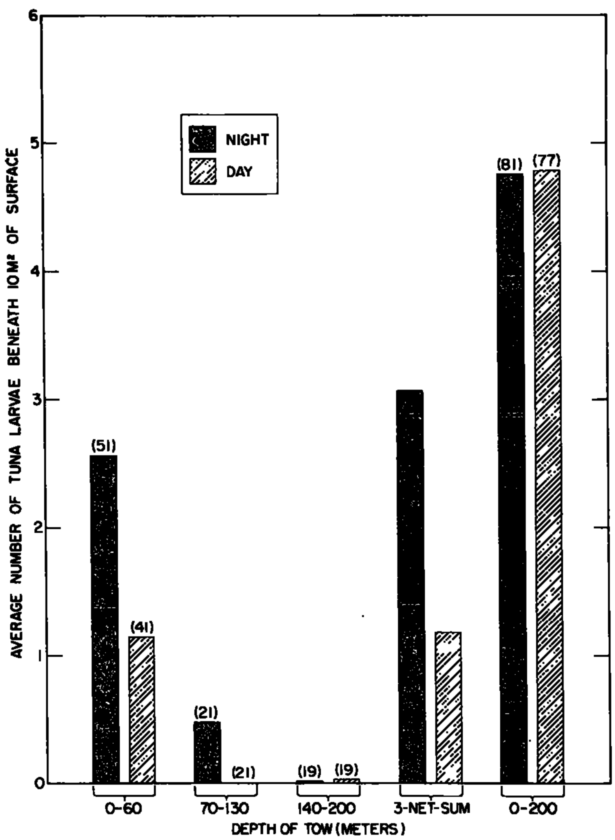

FIGURE 6.—Night-day variation in larval tuna catch with depth, expressed in terms of areal catch. Number of tows is shown in parentheses. The number of larvae obtained at each depth was as follows: 0–60 m.–432; 70–130 m.–20; 140–200 m.–2; and 0–200 m.–592.

poor sampling stratification is suggested. The same calculations made for the stations where 0–200 m. and triple-net tows were made together (*Hugh M. Smith* cruise 33, stations 18, 20, 26, and 28) produced a similar disparity (1.78 larvae/10m^2 for night 0–200 m. tows, and 0.91 larvae/10m^2 for night triple-net tows). How much of this is sampling artifact and how much is real can only be determined with more data.

It would appear that, of the various hauls employed, the 0–200 m. tow, by sampling the complete vertical range of larval tuna, produced the most useful information on their abundance. In addition, night-day catch variations were suppressed in this tow, although this might not be true in regions where a limiting isotherm, such as 60°, lies deeper than 200 m. Disadvantages of the 0–200 m. tow are that it may fish too deeply and its catch consists of relatively small numbers of tuna larvae (large numbers are frequently needed for statistical or other reasons). In an attempt to obtain a more representative sample of larval tuna POFI is presently testing a 0–140 m. oblique open-net tow. It is believed that the 0–140 m. sampling range covers the vertical distribution of tuna larvae, that day-night variations in catch will be small or absent, and that the number of captures can be increased by taking two half-hour samples per station. Where the major sampling goal is the capture of large numbers of larvae, then shallow tows at night are a better choice. In table 3, which shows the frequency of occurrence of catches of different magnitude by the several types of tow, it is apparent that our largest catches were obtained at night in surface or 0–60 m. tows. The noticeable species differences in day-night catch are discussed in the following section.

TABLE 3.—*Frequency of occurrence of catches of different magnitude in various types of tows*

Species and where caught	When caught	Number of larvae/1000m^3 strained: 0.1 to 3.9	4.0 to 7.9	8.0 to 11.9	12.0 to 15.9	16.0 to 19.9	20.0 to 29.9	30.0 to 39.9	40 to 59	60 to 99	100 to 199	500 to 1,000
SKIPJACK												
Surface	Day	2	1									
	Night	40	9	6	3		1	2				
0–60 m.	Day	15	1									
	Night	22	7	2					1			
0–200 m.	Day	44	4			1						
	Night	45	6	1	1							
70–130 m.	Day											
	Night	5										
140–200 m.	Day											
	Night	1										
YELLOWFIN												
Surface	Day	5	1									
	Night	48	8	3	2		1	1				
0–60 m.	Day	19										
	Night	22	7	1	1		1					
0–200 m.	Day	34	2									
	Night	44	1									
70–130 m.	Day											
	Night	3										
140–200 m.	Day											
	Night											
FRIGATE MACKEREL												
Surface	Day											
	Night	17		1			1	1	2	2	3	1
0–60 m.	Day	8										
	Night	6	3	1			2	2		1	1	
0–200 m.	Day	2										
	Night	4										
70–130 m.	Day											
	Night											
140–200 m.	Day	1										
	Night											

Diurnal Variation in Shallow-Tow Catches

Considering diurnal fluctuations in abundance, Wade (1951) found skipjack in 17 percent of his night surface samples but in only 3.6 percent of his day surface samples. He found a similar situation for what he termed *Euthynnus yaito* (little tunny), which was in reality frigate mackerel (Matsumoto, personal communication), but not for yellowfin. For the latter species, day and night tows were equally successful in capturing larvae, and high catches occurred randomly throughout a 24-hour period. Matsumoto (1958) noted a striking day and night disparity in the catch of "tuna larvae" (three species plus an unidentified category, combined) taken by surface tow, but any differences between skipjack and frigate mackerel, on the one hand, and yellowfin, on the other, were masked by his pooling of species. Actually his data (see below) included nearly 50 percent more skipjack and frigate mackerel, combined, than yellowfin.

The catch of tuna larvae at various times of day and at two sampling depths is shown in figure 7. Included are Matsumoto's data from *Hugh M. Smith* cruise 6, excluding his unidentified category, It is obvious that skipjack and frigate mackerel were infrequently captured at the surface during the day but were often taken there in numbers at night. Yellowfin were irregularly distributed throughout a 24-hour period, with low surface catches occurring chiefly at mid-morning. Skipjack showed about the same diurnal distribution in the 0–60 m. catches as in the surface captures, whereas the 0–60 m. frigate mackerel captures were much greater than at the surface. The 0–60 m. yellowfin catch was irregularly distributed and showed no clear relation to the surface catch. This pattern of an increase in catch at night could be caused by either vertical migration or less successful dodging as discussed previously. If dodging only were involved one would expect the catch to be essentially constant during the hours of darkness. In the case of skipjack this is manifestly not so, for the catch increased markedly between 1800–2000 and 0200–0400 hours, during which time illumination remained the same. Vertical migration therefore appears to be the major factor causing the increase in surface catch at night.

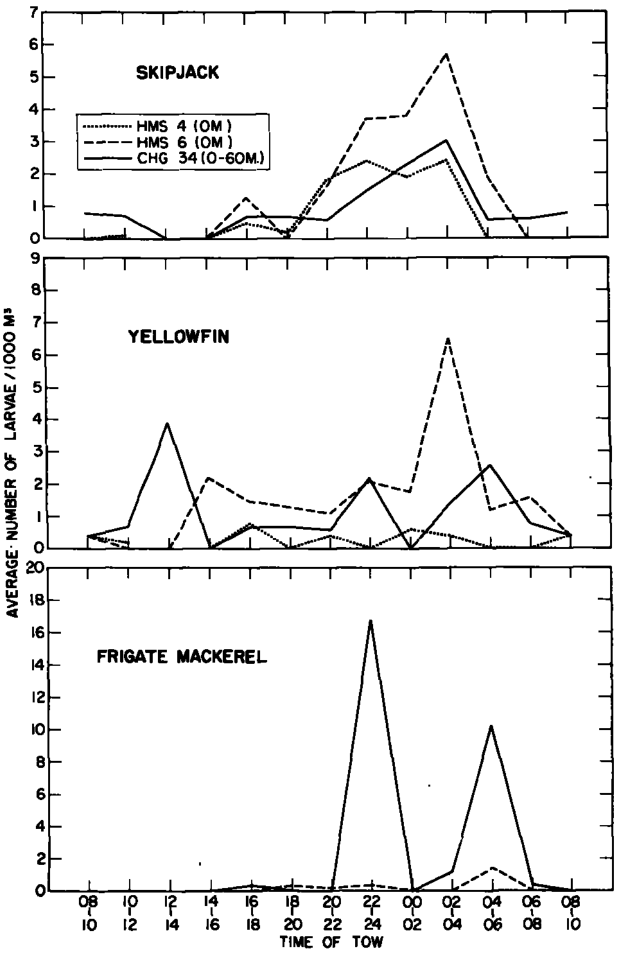

FIGURE 7.—Larval tuna catch by surface and 0–60 m. tows at various times of day. All data are from Hawaiian waters.

Another point illustrated by figure 7 is that surface captures of yellowfin and skipjack commenced in the afternoon, with yellowfin appearing in the catch earlier than skipjack. During the period from 1800–2000 hours, however, both species were uncommon or lacking in the surface catches. This is the time of sunset, and it also marks the beginning of the ascent of the deep-scattering layer and of invertebrate plankton. Subsequent to sunset, the larvae of both tunas increased in the surface catches. In order to investigate the effects of sunset on larval tuna abundance, 6 half-hour surface tows were taken off Oahu just before and after sunset on each of two consecutive days. An EDO depth recorder was used to measure the depth of the various scattering layers, but good traces were obtained by this instrument on only one night. The larval tuna and invertebrate plankton catches made during the two nights, along with the EDO traces obtained on one night, are shown in figure 8. It should be pointed out that in the figure, the plotted times of capture for larval tuna and invertebrate plankton represent the midpoints of the half-hour towing intervals.

The larval tuna catches shown in figure 8 indicate a late afternoon increase in surface abundance for yellowfin but not for skipjack. The invertebrate plankton volumes peaked just after sunset, and declined thereafter. The two deep scattering layer traces obtained became inseparable from each other and from the surface trace at about the time when plankton volumes were greatest and the larval tuna catch the least. It seems evident that the change in environmental conditions accompanying sunset had marked effect on the surface abundance of tuna larvae and invertebrate plankton, and on the position of the deep scattering layer. It is likely that these items are themselves interrelated.

Some contemporary thought holds that euphausiids and other crustacean plankters are the principal components of this layer (Boden 1950, Moore 1950). Our data showing an increase in surface plankton concurrent with the rise of the deep scattering layer are in accord with this idea, although copepods and other small crustacea were considerably more abundant than euphausiids in the samples under consideration. Supposedly these plankters are phototaxic and migrate to maintain position at a weak state of illumination, with their movement to the surface at twilight being a response to fading light (Clarke and Backus, 1956). Although this explanation accounts for the twilight peaking in surface plankton it does not explain the marked decline occurring shortly after sunset. This decline is real, for it was found on two successive days in the present study and has been noted several times by E. L. Nakamura.[1]

The question now arises whether tuna larvae are important constituents of the deep scattering layer. The following lines of evidence indicate that they are not: the surface abundance of larval tuna was complementary to that of the deep scattering layer of invertebrate plankton at sunset; larval skipjack and yellowfin were commonly taken at the surface during the afternoon, well before the deep scattering layer arrived at the surface; and our deep closing net samples indicated extremely scanty abundance of tuna larvae at 140–200 m., so that it is unlikely that they occur at the 350–550 meter depths occupied by the deep scattering layer prior to ascent.

Relation of Larval Tuna to Invertebrate Plankton

It was noted that larval tuna and invertebrate plankton were complementary in abundance at twilight, and it was deemed worthwhile to examine this relation further. A plot of the larval tuna catch (skipjack and yellowfin combined) with the accompanying invertebrate plankton volumes is given in figure 9. The plankton data were obtained from the report of King and Hida (1954) (*Hugh M. Smith* cruises 4 and 6) and from unpublished information in the POFI files (*Hugh M. Smith* cruise 38 and *Charles H. Gilbert* cruises 30, 32, and 34). The dotted line in figure 9 was fitted by eye to enclose the maximal situations of abundance.

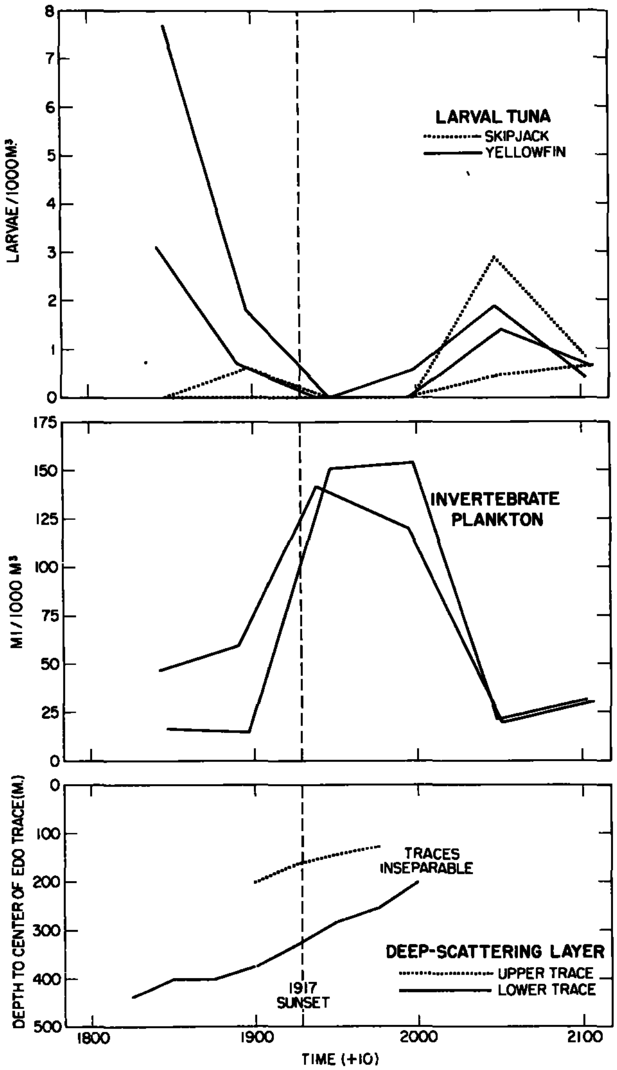

FIGURE 8.—Effect of sunset on larval tuna and invertebrate plankton catches, and depth of deep-scattering layer, as observed on *Charles H. Gilbert* cruise 34, stations 4 and 13, June 21–22, 1957. Plotted time for larval tuna and plankton catches is midpoint of towing interval.

[1] Unpublished data in POFI files. Bureau of Commercial Fisheries Laboratory.

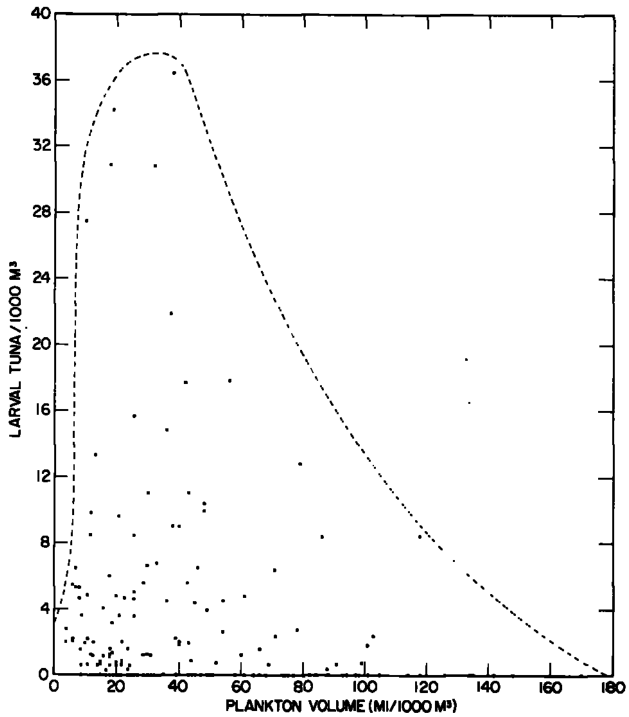

FIGURE 9.—Number of larval skipjack and yellowfin (combined) in relation to accompanying invertebrate plankton volumes. Data derived from 177 samples taken at 0 m. or 0–60 m. between evening and dawn. Curve fitted by eye to include maximal points.

In figure 9 it is seen that all of the large catches of tuna larvae were accompanied by small or moderate volumes of invertebrate plankton (roughly 10 to 60 ml./1000 cubic meters). The catches lowest in plankton contained few larvae, as did those richest in plankton. A similar but more marked situation obtained for frigate mackerel (not shown). It might be hypothesized that the low plankton concentrations were associated with either low-nutrient water or with enriched water so new to the euphotic zone that it had not been exploited biologically. In neither case would larval tuna be expected to abound. At the other extreme, large numbers of invertebrate plankters could represent both successful biological exploitation and a low level of grazing by higher forms. Many plankton feeders, such as small fish, squid, and crustaceans are of value to adult tuna as food (Reintjes and King, 1953; King and Ikehara, 1956), so that in their absence few adult tuna would be present, and logically there would be a paucity of tuna larvae (unless tuna spawn in areas of poor forage).

The shape and skewness of the dotted line (fig. 9) were evident in the data segregated by species and by cruise, and pooling was only done to emphasize the maximal (limiting?) situations. The nearly vertical ascent of the left limb stood in contrast to the gradual descent of the right. Whether the right-hand slope represents invertebrates grazing on larval tuna is not known, but there is some evidence that the left slope does not depict tuna larvae feeding on invertebrates. Clemens (1956) found that juvenile tunas rejected invertebrate plankters as food but avidly fed on softer-bodied larval fish, and the single larval tuna containing food, an 8 mm. skipjack, dissected by the writer had eaten a fish larva one-third its length.

The apparent incompatability between larval tuna and invertebrate plankton reminds one of the exclusion hypothesis of Hardy (1935). In the present investigation, it would seem more likely that the two groups of animals are showing a differential response to some stimulus, such as light intensity, rather than actively avoiding each other.

Length Distribution of Larval Tuna by Depth and Time

Knowledge of the relative abundance of various size groups is of considerable importance in the problem of sampling larval tuna. It is desirable to know the minimum size which can be captured by a given mesh, and the maximum size which can be taken at a certain towing speed. From the standpoint of tuna biology, relative size abundance provides information on growth and mortality.

For this report, size was expressed in terms of length, and total length was selected from the several length measurements used for fish (p. 233). Length was measured with the aid of a binocular dissecting microscope fitted with an ocular micrometer. Measurements were made to the nearest micrometer unit (0.095 mm.), and then converted to millimeters and tenths of millimeters. Because of body distortion and frayed fins these measurements were sometimes overly precise, but this has been remedied by grouping the fish in 1-mm. length categories.

The percentage frequency of occurrence by 1-mm. length groups of skipjack and yellowfin is shown in figure 10 for specimens collected on *Hugh M. Smith* cruises 4, 6, 31, and 33, and

Charles H. Gilbert cruise 34. Larvae between 3.0 and 5.9 mm. dominated the catch of both species. Since tuna larvae are thought to measure between 2.4 and 3.0 mm. at hatching (Matsumoto 1958) one would expect the 2.0–2.9 mm. category to predominate, and the fact that it did not do so indicates either an erroneous impression of hatching size, a different habitat for this group, or, more likely, escapement through the net meshes. These factors may also apply to the 3.0–3.9 mm. group, for it was exceeded in number by the 4.0–4.9 mm. category in most instances. The nets employed in capturing these fish had aperture widths of 0.66 mm. (body) and 0.31 mm. (rear section and bag). Large larvae (> 5 mm.) comprised only a small portion of the catch, and although this stems in part from their being fewer in number, it also reflects their increased agility and net-dodging powers.

Although the surface, 0–60 and 70–130 m. tows yielded similar length frequency distributions for yellowfin they did not do so for skipjack. The 0–60 m. samples contained more large skipjack larvae than those from the surface, whereas the 70–130 m. collections had more small skipjack larvae than either shallow tow. In the case of the 70–130 m. data, however, the small sample size tends to discredit any conclusions drawn.

Because samples from deeper than 60 m. contained few tuna larvae of any kind, the discussion of the temporal aspects of length distribution is limited to the surface and the 0–60 m. catches. These were segregated into day and night hauls and replotted as figure 11. Except for the yellowfin surface data the day samples contained few fish, and the slight contrasts may not be real. In general terms there appeared to be little difference between the day and night length distributions of the surface catches, but in the 0–60 m. data the two species were more variable. Here there was a tendency for more large skipjack to be taken at night than during the day, whereas in yellowfin the reverse was true. If these phenomena are not sampling artifacts they may represent behavior having to do with differential vertical migration and net-dodging. Some evidence points to the existence of different migrational patterns between skipjack and yellowfin, for in figure 7 it was shown that yellowfin were more commonly caught at the surface during the day than skipjack. These captures could also

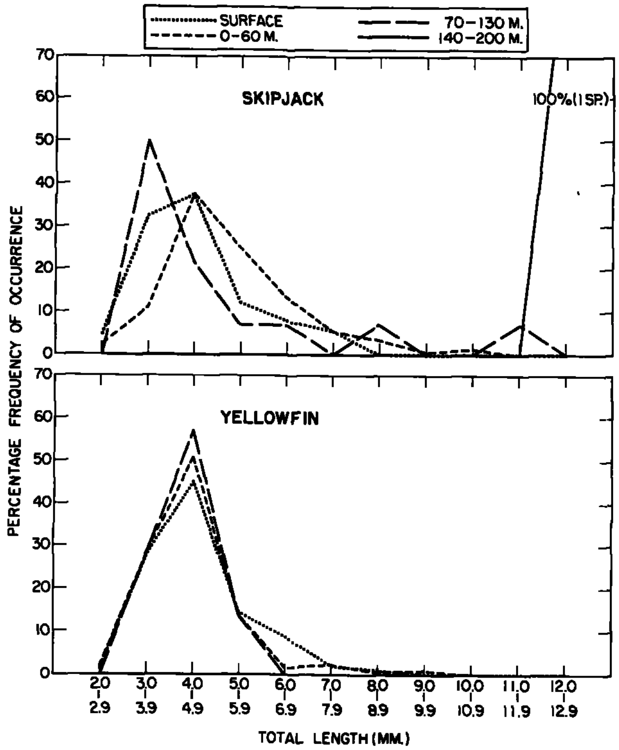

FIGURE 10.—Size variation of skipjack and yellowfin larvae in samples taken at various towing depths. Samples were collected at all times of day; percentages derived from the following catches: skipjack, 190 at 0 m.; 172 at 0–60 m.; 14 at 70–130 m.; and 1 at 140–200 m.; yellowfin, 311 at 0 m.; 183 at 0–60 m.; 7 at 70–130 m.; and 0 at 140–200 m.

have resulted from yellowfin being less adept at net-dodging, although this variable is difficult to assay.

Of the maximal sizes captured by surface tows, yellowfin were generally larger than skipjack (fig. 12); the difference in length between the yellowfin and skipjack larvae was fairly constant with various sampling times; and larger sizes of both species were taken with the advent of night. The last point indicates less successful dodging after dark, while the first two show that at a given time of day larger yellowfin than the skipjack can be captured, thus implying that yellowfin are slightly, but consistently, poorer dodgers. On the basis of casual observations of the adult swimming speeds, larval yellowfin may be slower swimmers than skipjack. The 0–60 m. data vary irregularly with sampling time but generally point out the diminishing effects of dodging as greater (darker) depths are sampled.

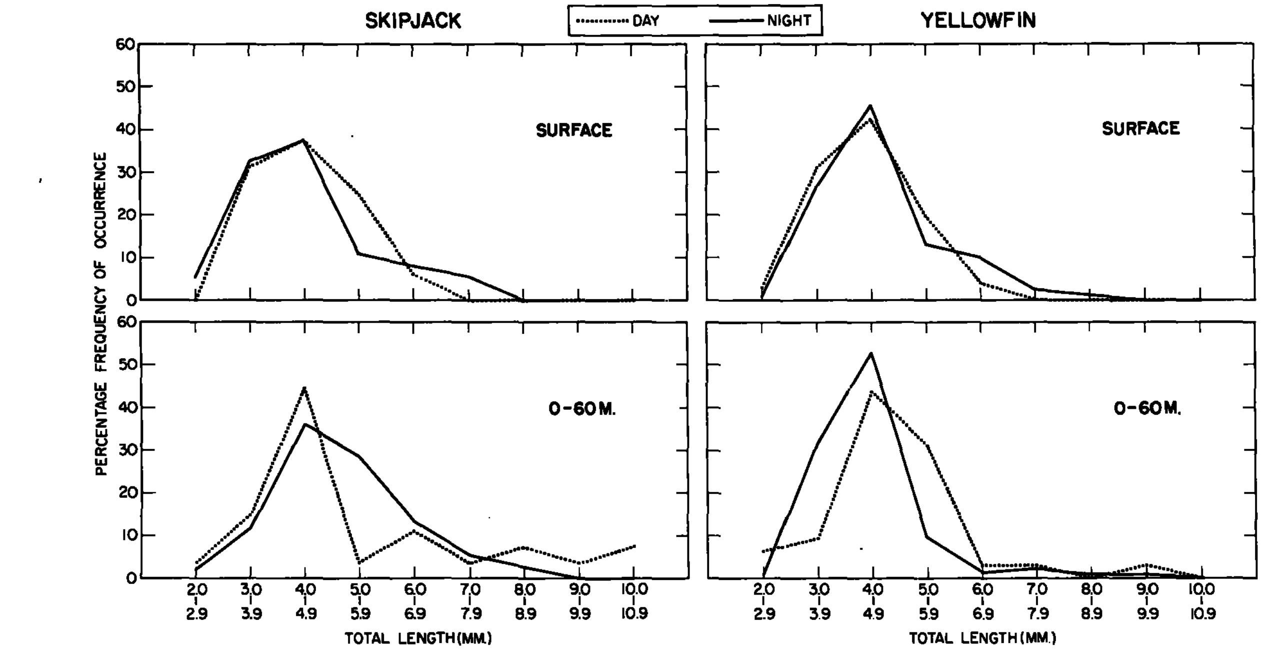

FIGURE 11.—Size variation of skipjack and yellowfin larvae in relation to time of sampling. Data derived from following catches: surface tows (skipjack) 16 day, 174 night; (yellowfin) 71 day, 239 night; 0–60 m. tows (skipjack) 27 day, 147 night; (yellowfin) 32 day, 144 night.

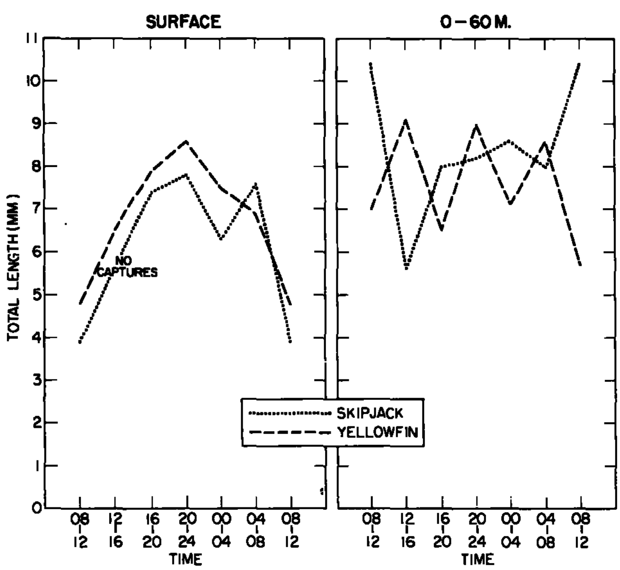

FIGURE 12.—Maximum length of tuna larvae captured at various times of day. Data derived from following catches: Surface tows, 190 skipjack and 311 yellowfin; 0–60 m. tows, 200 skipjack and 179 yellowfin.

ADULT VERSUS LARVAL TUNA ABUNDANCE

The determination of a numerical larval-adult tuna relation is of considerable practical value, for if a definite numerical relation could be established it might result in the substitution of plankton nets for poles and longlines to provide estimates of abundance in exploratory fishing. An obvious limitation of this approach is that larvae contribute information only about the presence of spawning fish. In calculations of the larva/adult ratio particular attention must therefore be paid to the size of the adults caught, for it would be pointless to correlate the presence of larvae and immature adults.

It was shown earlier that of the various plankton tows employed, the 0–200 m. tow was the only one which sampled the entire vertical range of larval tuna. Where possible this sampling method has been used to provide estimates of larval abundance, with the catches being converted to the number of larvae beneath 10 square meters of sea surface, and the day and night samples being considered of equal reliability.

Yellowfin are sexually mature in appreciable numbers only at lengths greater than 120 cm. (Yuen and June, 1957); fish of this size are deep-swimming and best sampled by longlining (Murphy and Shomura, 1953). For yellowfin, therefore, only longline captures were considered, and these were expressed as catch per hundred hooks. The data examined were taken from the reports of Murphy and Shomura (1953, 1955) dealing with the catches made on cruises 5, 7, 11, and 18 of the *Hugh M. Smith*. During these four cruises longline stations were accompanied by a 0–200 m. plankton tow on 55 occasions (see Matsumoto 1958). At 13 of these stations both larval and adult yellowfin were captured, at 25 stations only adults were taken, at 3 stations only larvae were captured, and at 14 stations neither larvae nor adults were taken. Only the 13 stations yielding both adults and larvae were analyzed, as it was reasoned that the absence of larvae might connote non-spawning (the absence of adults in the presence of larvae was infrequent and is not presently explicable). The data examined are presented in table 4. As previously shown, the larval data are skewed, and as pointed out by Murphy and Elliott (1954), so are those for adult yellowfin captured by longline. The data in table 4 were made approximately normal by transforming them logarithmically, and were analyzed by correlation methods which yielded a non-significant r-value of 0.422 ($r_{.05}=0.553$, Snedecor 1946: 149). It would appear from this, that for yellowfin either the larva/adult relation is not well defined, or that the individual catches are not reliable estimates of abundance.

TABLE 4.—*Larval and adult yellowfin captured at the same station*

Hugh M. Smith, cruise No.	Station	Larvae per 10 m²	Adults per 100 hooks
5	2	1.5	3.2
7	16	0.9	2.3
7	24	1.3	3.4
11	4	2.9	1.2
11	6	1.4	0.8
11	8	5.2	9.5
11	9	4.1	5.0
11	10	5.7	15.7
11	11	8.2	10.3
11	12	2.1	7.9
11	22	4.6	29.3
11	23	1.5	13.0
18	4	3.2	0.4

Considerable difficulty was experienced in relating the abundance of larval and adult skipjack. The adults are essentially surface fish, so that it was necessary to derive abundance figures from the techniques peculiar to a live-bait fishery. This fishery provides two measures of abundance, one based on catch, the other on the number of schools sighted during scouting. Adult-larval catch correlations could not be calculated because of a lack of plankton data, for in scouting, those observations attended by adequate plankton tows were generally secondary to other work programs. The available abundance estimates furnished by scouting thus suffer from inconsistency of effort and insufficient data on the number of fish comprising a school.

Despite these inadequacies there seemed to exist a rough relation between the numbers of larvae captured and schools seen, an example of which is shown in figure 13. The data used in this figure were derived from *Hugh M. Smith* cruises 33 and 38 (both primarily oceanographic) and *Charles H. Gilbert* cruise 32 (live-bait fishing). All three cruises investigated the waters of French Oceania and the central equatorial Pacific in January-March, the local skipjack season. For this study the region was divided into 13 areas (fig. 13) in accordance with the vessel tracks and certain oceanographic features. The number of hours of scouting and number of skipjack schools sighted were recorded by area, and from these figures a measure of abundance, expressed as the average number of skipjack schools sighted per 100 hours, was obtained. The data on adult abundance resulted from a total of 1,035 scouting hours in which 140 definitely identified skipjack schools were seen.

It would have been desirable to extract larval skipjack abundance figures from the captures made by 0–200 m. plankton tows, but unfortunately these tows were infrequent on the above cruises. As a consequence it was necessary to use the night catches of the 0 m. and 0–60 m. tows, both of which yielded about the same numbers of larval skipjack per station (see appendix tables 7, 8, and 10). As with the adult calculations, larval catch and effort were summarized by area, providing abundance estimates in terms of the average number of skipjack larvae per 1,000 cubic meters strained. The larval tuna data were based on a total of 406 skipjack larvae captured by straining 149,408 cubic meters of water.

The occurrence of larval skipjack coincided with that of adult schools, except for areas 6 and 11 (fig. 13). In addition, there was a general proportionality between the two variables, so that area 8 had large numbers of adults and larvae, the surrounding areas had small or moderate

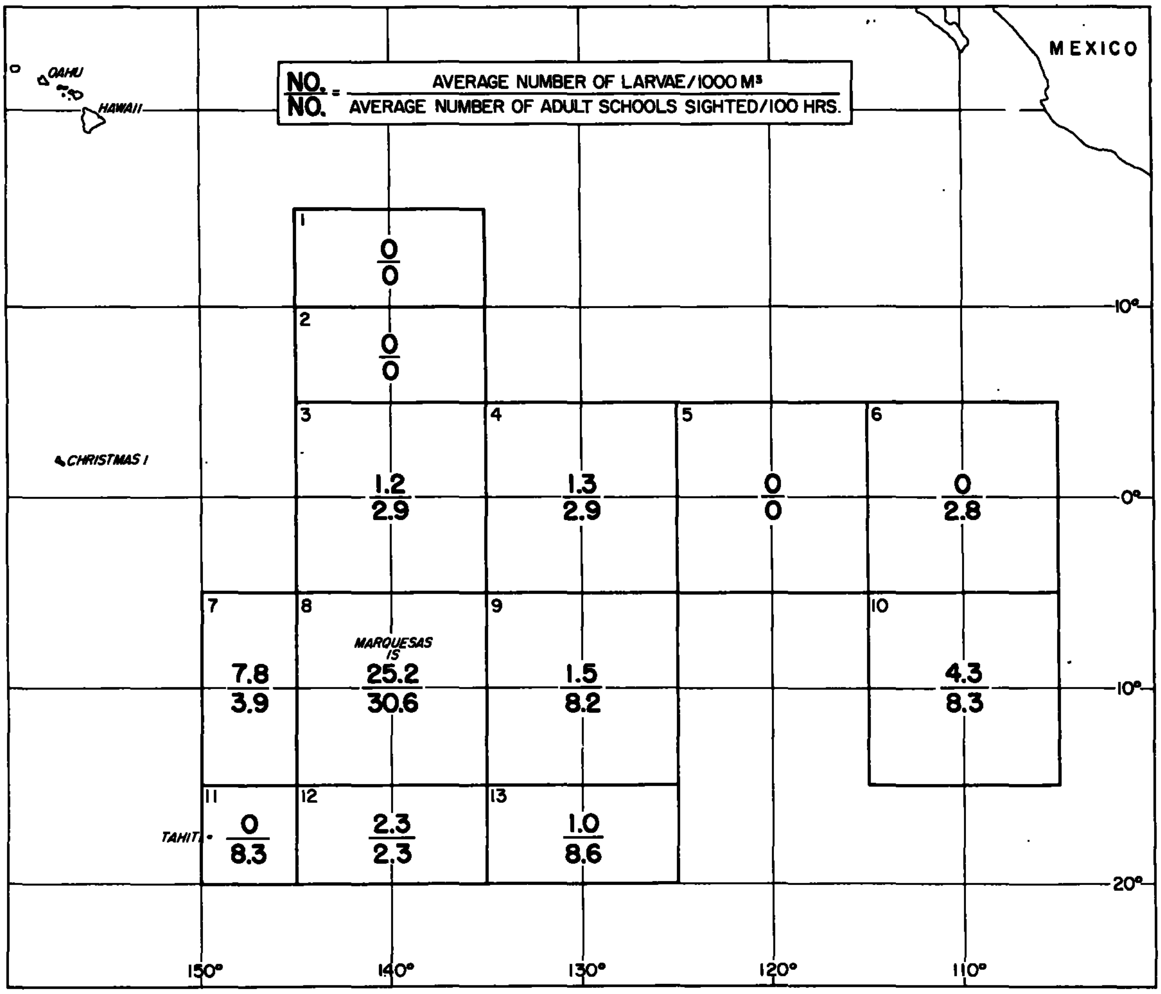

FIGURE 13.—Relation between numbers of larval and adult skipjack. Data from *Hugh M. Smith* cruises 33 and 38 and *Charles H. Gilbert* cruise 32. See text for details.

numbers of each, and the peripheral areas frequently lacked both. As with yellowfin, the data were transformed logarithmically and analyzed by correlation methods. Ignoring the zero records, a non-significant r-value of 0.611 was obtained ($r_{.05} = 0.754$, Snedecor 1946: 149). Again it could not be determined whether the lack of correlation resulted from a real lack of inter-relation or merely reflected the inadequacy of the estimates.

SUMMARY

(1) As a prelude to the collection and interpretation of data on larval tuna abundance, it was considered necessary to know the reliability of the sampling methods, to standardize the time and depth of sampling for comparative purposes, and to understand certain facies of larval tuna behavior. This report deals with these problems by an analysis of the larval tuna catches made by 0, 0–60, 70–130, 140–200, and 0–200 m. plankton tows. These tows were taken during 15 POFI cruises in the waters of the Hawaiian Islands, the equatorial Pacific, and French Oceania.

(2) The use of paired plankton nets showed that the catch made by a single net could be duplicated and was therefore reliable within the limitations of the sampling method.

(3) Most tuna larvae were captured between the surface and 60 m. depth, with about 20–25 percent of the catch between 70 and 130 m., and

practically none between 140 and 200 m. There were marked night-day differences in catch at the surface but these became less as greater depths were sampled, and were not present in the 0–200 m. catches. Diurnal catch differences were attributed to migration to the surface at night and to dodging the nets during the day, with the former being of greater importance to the catch. Some evidence suggested that the 60°F. isotherm may be limiting to the occurrence of tuna larvae.

(4) When larval tuna catches were referred to areal units of sea surface it appeared that the 0–200 m. plankton tow, by sampling the complete vertical distribution of the fish, produced the most reliable abundance estimates. There was no apparent relation between the catch of this tow and of shallower tows made at the same time.

(5) Catch data from 0 and 0–60 m. tows showed that skipjack and frigate mackerel larvae were rarely captured during the day but were common at night. This tendency was less marked for yellowfin, particularly in the 0–60 m. tows.

(6) Both skipjack and yellowfin began to appear in the surface catch in the afternoon, but practically none were caught near sunset. Their temporary disappearance was correlated with the evening rise of the deep scattering layer and its associated invertebrate plankton. Further study showed an inverse relation between the numbers of larval tuna and invertebrate plankton volumes. Larval tuna did not appear to be constituents of the deep scattering layer.

(7) Measurements of larval tuna demonstrated that the dominant length group in the catch was from 4.0 to 4.9 mm. in total length. This size range predominated at each depth sampled, with slight non-modal shifts between day and night and between certain depths. Many larvae of the 2.0–2.9 mm. group may have passed through the net meshes, as may some of the 3.0–3.9 mm. category, and fish larger than 5 mm. were not common. Evidence derived from the larger larvae indicated that yellowfin were poorer dodgers than skipjack.

(8) No significant relation was found between the number of yellowfin taken by longline and the number of their larvae captured by 0–200 m. plankton tows. Similarly no significant relation was obtained between the number of skipjack schools sighted per 100 hours scouting and the number of larvae taken by 0 m. and 0–60 m. tows.

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APPENDIX

TABLE 5.—*Larval tuna collected from surface hauls of one-hour duration on cruise 4 of the* Hugh M. Smith *in Hawaiian waters*

[All data except for larval tuna are from King and Hida, 1954; only skipjack and yellowfin larvae considered]

Station No.	Position: North latitude	Position: West longitude	Date	Time started	Water strained (m^3)	Number of fish in sample: Skipjack	Yellowfin	Total
1	23°31′	161°07′	5/16/50	0934	2,255.3	0	1	1
1a	22°40′	161°15′	5/16/50	1722	2,604.7	6	7	13
2	21°52.5′	161°07′	5/17/50	0240	2,504.5	0	0	0
3	21°06′	161°05.5′	5/17/50	0925	2,699.9	0	2	2
4	20°14.5′	161°07.5′	5/17/50	1640	2,124.9	0	0	0
5	19°23.8′	161°06.3′	5/18/50	0028	2,231.5	2	0	2
6	19°25′	159°50′	5/18/50	1048	2,271.9	0	0	0
7	20°14.5′	159°50′	5/18/50	1835	2,967.4	0	0	0
8	21°05′	159°50′	5/19/50	0255	2,472.3	5	4	9
9	21°47.7′	159°51′	5/19/50	1000	2,585.2	1	1	2
10	22°40′	159°50′	5/15/50	1456	2,742.2	0	0	0
11	23°30′	159°50′	5/15/50	2316	2,704.2	12	0	12
12	22°40′	158°30′	5/15/50	0503	2,642.3	0	0	0
13	21°51′	158°29′	5/21/50	0150	2,906.2	16	0	16
14	20°58′	158°26′	5/21/50	1005	2,265.3	0	0	0
15	20°12.3′	158°30′	5/21/50	1610	2,950.2	0	0	0
16	19°22′	158°28′	5/21/50	2253	3,017.4	2	0	2
17	18°32.5′	158°27.8′	5/22/50	0546	2,594.0	0	0	0
18	18°32′	157°05′	5/22/50	1531	2,768.9	0	2	2
19	19°24.3′	157°10′	5/23/50	0018	3,097.3	0	0	0
20	20°14′	157°03.5′	5/23/50	0911	3,346.3	0	1	1
21	20°58.7′	157°10.2′	5/23/50	1648	2,739.9	0	1	1
22	21°53′	157°08.5′	5/24/50	0120	2,705.6	13	5	18
23	22°40′	157°10′	5/14/50	1852	2,191.5	2	0	2
24	22°45′	155°49′	5/14/50	0820	1,254.7	0	0	0
25	21°54′	155°48.2′	5/24/50	1333	2,644.7	0	0	0
26	21°02.5′	155°45.5′	5/24/50	2107	2,815.1	5	1	6
27	20°30′	155°45′	5/25/50	0214	3,098.8	5	0	5
28	18°33.5′	155°48′	5/25/50	1740	3,169.4	0	0	0

TABLE 6.—*Larval tuna collected by 3-level closing nets on cruise 31 of the* Hugh M. Smith *(numerous samples not processed)*

[All data, except larval counts, from King and others, 1957]

Station No.	Depth of tow (meters)	Position: Latitude	Position: Longitude	Date 1955	Time started	Water strained (m^3)	Number of fish in sample: Skipjack	Yellowfin	Frigate mackerel	Unidentified	Total
Test 1	0–41 [1]	20°38′ N	157°49′ W	9/23	1501(+10)	592.9	0	1	0	0	1
	59–89 [1]					661.8	0	0	0	0	0
Test 2	0–51 [1]	17°46′ N	157°09′ W	9/24	1418	686.6	0	1	0	0	1
	56–110 [1]					458.9	0	0	0	0	0
1	0–92	12°02′ N	156°14′ W	9/26	0939	814.1	0	0	0	0	0
	101–206					514.8	0	0	0	0	0
	226–403					562.1	0	0	0	0	0
3	0–77	10°42′ N	156°04′ W	9/26	2222	1,537.0	0	0	0	3	3
	52–137					1,083.0	0	0	0	0	0
4	0–63	09°24′ N	155°50′ W	9/27	1005	1,113.6	1	0	0	0	1
	61–127					921.5	0	0	0	0	0
	137–240					1,482.9	0	0	0	0	0
6	0–74	07°50′ N	155°16′ W	9/27	2309	1,480.7	2	4	0	0	6
7	0–76	06°42′ N	154°54′ W	9/28	0948	1,577.7	1	0	2	0	3
	68–160					933.7	0	0	0	0	0
	151–306					360.4	0	0	0	0	0
9	0–74	05°26′ N	154°52′ W	9/28	2215	1,681.7	1	0	0	0	1
	76–158					984.4	2	3	0	0	5
10	72–133	05°26′ N	154°22′ W	9/29	0933	508.2	0	0	0	0	0
12	0–60	06°30′ N	153°18′ W	9/29	2218	1,542.9	0	0	0	0	0
13	0–63	07°30′ N	152°07′ W	9/30	0928	1,298.4	5	0	0	0	5

[1] Data not reported by King et al. because of damage or malfunctioning of gear or other reasons. Most of these data not incorporated in present analysis.

TABLE 6.—*Larval tuna collected by 3-level closing nets on cruise 31 of the* Hugh M. Smith *(numerous samples not processed)*—Continued

[All data, except larval counts, from King and others, 1957]

Station No.	Depth of tow (meters)	Position		Date 1955	Time started	Water strained (m^3)	Number of fish in sample				
		Latitude	Longitude				Skipjack	Yellowfin	Frigate mackerel	Unidentified	Total
15	66–132	08°26′ N	150°54′ W	9/30	2157	833.0	2	0	0	0	2
16	0–64	09°13′ N	149°48′ W	10/1	0932	1,285.6	0	0	0	0	0
	52–145					1,026.8	0	0	0	0	0
19	115–346	11°32′ N	148°13′ W	10/2	0845	1,008.5	0	0	0	0	0
21	0–59	10°55′ N	147°10′ W	10/2	2200	1,503.2	0	2	0	0	2
21	161–300					360.4	0	0	0	0	0
22	171–315	10°16′ N	146°08′ W	10/3	0929	851.8	0	0	0	0	0
24	0–68	09°40′ N	144°54′ W	10/3	2153	1,502.7	0	1	1	0	2
	141–259					1,197.1	0	0	0	0	0
25	0–75	09°02′ N	143°57′ W	10/4	0918	1,298.2	0	0	2	0	2
27	0–71	08°34′ N	142°34′ W	10/4	2201	1,502.2	0	2	0	1	3
	47–132					1,772.8	0	0	0	0	0
28	0–57	08°06′ N	141°24′ W	10/5	0923(+9)	1,500.9	0	4	0	0	4
	63–135					1,310.3	0	0	0	0	0
30	0–68	08°55′ N	140°02′ W	10/5	2155	1,349.1	3	2	0	2	7
	59–137					1,740.8	0	0	0	0	0
	131–259					1,408.7	0	0	0	0	0
33	80–129 [1]	10°29′ N	137°43′ W	10/6	2155		0	0	0	0	0
34	90–128 [1]	11°16′ N	136°30′ W	10/7	0931		0	0	0	0	0
	141–303					1,077.3	0	0	0	0	0
36	59–160	10°45′ N	135°36′ W	10/7	2152	335.7	0	0	0	0	0
37	0–79	10°10′ N	134°12′ W	10/8	0931	1,374.7	0	1	0	0	1
	61–152					1,019.6	0	0	0	0	0
42	66–143	09°31′ N	129°53′ W	10/9	2155	737.7	0	0	0	0	0
	147–279					1,195.7	0	0	0	0	0
43	80–170	10°03′ N	128°18′ W	10/10	0938	521.0	0	0	0	0	0
	180–334					760.5	0	0	0	0	0
45	54–167	10°30′ N	127°16′ W	10/10	2156(+8)	825.4	0	0	0	0	0
46	184–305	10°55′ N	126°12′ W	10/11	0937	404.4	0	0	0	0	0
48	0–60	11°36′ N	125°00′ W	10/11	2142	1,201.7	0	0	2	0	2
	61–143					545.2	0	0	0	0	0
49	0–68	12°11′ N	123°48′ W	10/12	0933	1,426.4	0	0	0	0	0
	66–141					882.6	0	0	0	0	0
	147–256					916.6	0	0	0	0	0
51	0–41	11°20′ N	122°28′ W	10/12	2137	1,432.6	0	0	6	0	6
	61–130					988.3	0	0	0	0	0
	137–276					882.2	0	0	0	0	0
52	0–59	10°19′ N	121°13′ W	10/13	0927	1,715.2	0	1	2	0	3
	137–300					648.2	0	0	0	0	0
54	0–61	09°26′ N	119°58′ W	10/13	2137	1,438.7	0	0	0	0	0
	66–152					972.5	0	0	0	0	0
55	61–140	08°38′ N	118°53′ W	10/14	0934	265.9	0	0	0	0	0
	137–259					934.4	0	0	0	0	0
57	137–257	09°14′ N	117°28′ W	10/14	2138	1,222.4	0	0	0	0	0
58	0–82	09°56′ N	115°55′ W	10/15	0930	1,547.1	0	0	1	0	1
	61–162					1,176.5	0	0	0	0	0
	137–302					717.4	0	0	0	0	0
60	0–43	10°40′ N	114°34′ W	10/15	2142	1,160.4	0	1	0	0	1
	161–263					581.7	0	0	0	0	0
61	0–43	11°30′ N	113°30′ W	10/16	0925	1,332.8	0	2	0	0	2
	68–121					959.8	0	0	0	0	0
	151–259					842.4	0	0	0	0	0
63	42–156	12°22′ N	112°27′ W	10/16	2138(+7)	1,283.9	0	0	0	0	0
	94–315					1,039.7	0	0	0	0	0
65	61–126	07°00′ N	108°37′ W	10/27	2151	1,039.2	0	0	0	0	0
68	0–48	04°34′ N	109°24′ W	10/28	2123	1,372.7	0	0	0	0	0
	161–245					943.5	0	0	0	0	0
69	0–43	03°10′ N	110°12′ W	10/29	1027	1,178.2	0	0	0	1	1
	74–126					967.6	0	0	0	0	0
	165–263					955.7	0	0	0	0	0
71	0–45	02°10′ N	110°54′ W	10/29	2320	1,347.6	0	0	0	4	4
74	76–135	00°14′ S	112°20′ W	10/30	2127	475.2	0	0	0	0	0
	171–277					586.4	0	0	0	0	0
75	0–48	01°23′ S	112°46′ W	10/31	0922(+8)	1,335.9	0	0	0	1	1
	54–122					413.6	0	0	0	0	0
83	0–47	07°42′ S	114°52′ W	11/2	2127	1,264.4	0	0	0	0	0
	56–120 [1]					92.8	0	0	0	0	0
85	157–276	07°56′ S	120°04′ W	11/4	0926	686.8	0	0	0	0	0
87	80–135	06°44′ S	119°59′ W	11/4	2144	554.5	0	0	0	0	0
88	66–124	05°16′ S	120°04′ W	11/5	1024	804.3	0	0	0	0	0
90	59–139	04°15′ S	120°00′ W	11/5	2138	1,198.9	0	0	0	0	0
	68–295					1,334.0	0	0	0	0	0
91	0–40	02°48′ S	120°06′ W	11/6	0925	1,410.1	0	0	0	0	0
	74–126					437.2	0	0	0	0	0
	165–269					720.7	0	0	0	0	0
93	145–204 [1]	01°35′ S	119°59′ W	11/6	2141	429.2	0	0	0	0	0
108	0–47	04°32′ N	119°49′ W	11/9	0920	1,055.2	1	0	0	0	1
	78–136					1,006.7	0	0	0	0	0
	175–284					205.9	0	0	0	0	0
110	0–47	05°49′ N	120°00′ W	11/9	2122	1,390.8	4	0	0	0	4
	76–136					833.7	0	0	0	0	0
	171–284					781.1	0	0	0	0	0
111	66–127	05°10′ N	121°20′ W	11/10	0920	715.7	0	0	0	0	0
	147–257					1,060.5	0	0	0	0	0

[1] Data not reported by King et al. because of damage or malfunctioning of gear or other reasons. Most of these data not incorporated in present analysis.

TABLE 6.—*Larval tuna collected by 3-level closing nets on cruise 31 of the* Hugh M. Smith (*numerous samples not processed*)—Continued

[All data, except larval counts, from King and others, 1957]

Station No.	Depth of tow (meters)	Position: Latitude	Position: Longitude	Date 1955	Time started	Water strained (m³)	Number of fish in sample: Skipjack	Yellowfin	Frigate mackerel	Unidentified	Total
113	0-46	04°05′ N	122°31′ W	11/10	2124	1,365.4	0	0	0	0	0
	54-118					1,105.2	0	0	0	0	0
114	0-46	03°01′ N	123°47′ W	11/11	0919	1,785.6	0	2	0	1	3
	102-124					155.3	0	0	0	0	0
119	141-284	00°22′ N	127°08′ W	11/12	2137	697.8	0	0	0	0	0
123	0-41 [1]	02°04′ S	130°48′ W	11/14	0947(+9)	1,080.6	0	0	0	1	1
	165-262					884.1	0	0	0	0	0
125	0-47	01°00′ S	131°42′ W	11/14	2130	1,552.6	0	0	0	1	1
	66-136					234.6	0	0	0	0	0
	147-284					955.9	0	0	0	0	0
126	0-48	00°10′ N	133°10′ W	11/15	0921	1,590.3	0	0	0	0	0
	61-122					1,137.3	0	0	0	0	0
	140-187 [1]					1,539.3	0	0	0	0	0
134	0-54	05°36′ N	139°12′ W	11/17	2230	1,192.9	1	1	0	0	2
	40-134					905.4	0	0	0	0	0
	89-269					494.2	0	0	0	0	0
135	0-40	04°32′ N	139°11′ W	11/18	1010	1,357.3	0	1	0	0	1
	66-116					1,034.1	0	0	0	0	0
	147-256					960.3	0	0	0	0	0
137	0-40	03°27′ N	139°11′ W	11/18	2128	1,502.7	0	0	0	1	1
	161-240					480.6	0	0	0	0	0
139	0-45	02°27′ N	139°13′ W	11/19	0908	1,696.3	0	1	0	4	5
	70-130					716.3	0	0	0	0	0
	179-207 [1]					444.1	0	0	0	0	0
142	0-49	01°14′ N	139°27′ W	11/19	2129	1,718.1	0	0	0	0	0
	54-143					469.7	0	0	0	0	0
144	61-122	00°16′ N	140°12′ W	11/20	1005	38.0	0	0	0	0	0
147	0-42	01°05′ S	140°00′ W	11/20	2130	1,465.9	0	0	0	0	0
149	0-46	02°43′ S	139°46′ W	11/21	0906	1,340.0	0	0	0	0	0
	61-118					878.6	0	0	0	0	0
	137-237					824.6	0	0	0	0	0
152	141-271	04°03′ S	139°42′ W	11/21	2117	621.5	0	0	0	0	0
153	0-43	05°31′ S	139°54′ W	11/22	1008	1,339.8	0	0	0	0	0
	63-126					966.4	0	0	0	0	0
	141-268					761.9	0	0	0	0	0
155	147-248	06°33′ S	139°26′ W	11/22	2128	987.9	0	0	0	0	0
185	0-53	00°35′ N	157°47′ W	12/8	2121(+10)	1,463.0	0	0	0	0	0

[1] Data not reported by King et al. because of damage or malfunctioning of gear or other reasons. Most of these data not incorporated in present analysis.

TABLE 7.—*Larval tuna collected on* Hugh M. Smith *cruise 33 in equatorial waters*

Station No.	Approximate depth of tow (meters)	Position: Latitude	Position: Longitude	Date 1956	Time started (+10)	Water strained (m³)	Number of fish in sample: Skipjack	Yellowfin	Frigate mackerel	Unidentified	Total
2	0-60	11°54.9′ N	140°02′ W	3/9	1019	2,020	0	0	0	0	0
	70-130					924	0	0	0	0	0
	140-200					1,303	0	0	1	0	1
3	0-60	10°52′ N	139°57′ W	3/9	2127	2,598	0	0	7	0	7
	70-130 [1]					1,547	0	0	8	0	8
	140-200 [1]					1,700	0	0	4	0	4
	0	10°51′ N	139°58′ W	3/9	2246	2,352	0	0	19	0	19
4	0-60	09°35′ N	140°05′ W	3/10	0908	1,512	0	0	4	0	4
	70-130					1,171	0	0	0	0	0
	140-200					1,265	0	0	0	0	0
5	0-60	08°36.5′ N	140°09′ W	3/10	2118	[2] 1,600	0	0	2	0	2
	70-130					1,295	0	0	0	0	0
	140-200					1,333	0	0	0	0	0
	0				2224	1,895	0	1	3	0	4
6	0-60	07°22′ N	140°01′ W	3/11	0916	1,282	0	1	3	0	4
	70-130						0	0	0	0	0
	140-200					302	0	0	0	0	0
7	0-60	06°28.5′ N	139°56′ W	3/11	2113	1,407	0	1	4	0	5
	70-130					1,206	0	0	0	0	0
	0				2225	1,974	0	0	6	0	6
8	0-60	05°10′ N	139°51′ W	3/12	0917	1,283	0	1	0	0	1
	70-130					1,890	0	0	0	0	0
	140-200					1,247	0	0	0	0	0
9	0-60	04°06′ N	140°00′ W	3/12	2200	2,342	0	0	0	0	0
	70-130					1,627	0	4	0	0	4
	140-200					202	0	0	0	0	0

See footnotes at end of table.

TABLE 7.—*Larval tuna collected on* Hugh M. Smith *cruise 33 in equatorial waters*—Continued

Station No.	Approximate depth of tow (meters)	Position		Date 1956	Time started (+10)	Water strained (m³)	Number of fish in sample				
		Latitude	Longitude				Skipjack	Yellowfin	Frigate mackerel	Unidentified	Total
10	0-60	02°45′ N	140°07′ W	3/13	0934	1,588	0	0	0	0	0
	70-130					945	0	0	0	0	0
	140-200					1,442	0	0	0	0	0
11	0-60	01°48′ N	140°13′ W	3/13	2117	1,316	0	0	0	0	0
	70-130					1,155	0	0	0	0	0
	140-200					1,354	0	0	0	0	0
	0				2228	1,953	0	0	0	0	0
12	0-60	00°29′ N	140°06′ W	3/14	0928	1,775	5	0	0	0	5
	70-130					103	0	0	0	0	0
	140-200					2,639	0	0	0	0	0
13	0-60	00°40′ S	140°07′ W	3/14	2115	1,435	0	0	0	0	0
	70-130					811	0	0	0	0	0
	140-200					2,175	0	0	0	0	0
	0				2219	2,356	0	0	1	0	1
14	0-60	01°58′ S	139°46′ W	3/15	0924	1,361	0	3	0	0	3
	70-130					1,540	0	0	0	0	0
	140-200					2,632	0	0	0	0	0
15	0-60	03°00′S	139°54′ W	3/15	2112	1,786	0	0	0	0	0
	70-130					1,062	0	0	0	0	0
	140-200					8	0	0	0	0	0
	0				2220	2,394	0	2	0	0	2
16	0-60	04°03′ S	140°07′ W	3/16	0848	1,848	1	4	0	0	5
	70-130					1,012	0	0	0	0	0
	140-200					756	0	0	0	0	0
17	0-60	05°03′ S	140°16′ W	3/16	1949	1,583	64	5	4	0	73
	70-130					1,082	1	0	0	0	1
	140-200					628	0	0	0	0	0
	0				2059	2,663	39	5	1	0	45
18	0-60	00°11′ N	139°53′ W	3/18	2134	4,706	0	0	0	0	0
	70-130					2,364	4	0	0	1	5
	140-200					4,983	0	0	0	0	0
	0-200				2245	1,633	0	1	0	0	1
19	0-60	00°06′ N	139°37′ W	3/19	1041	1,753	0	0	0	0	0
	70-130					1,382	0	0	0	0	0
	140-200					2,598	0	0	0	0	0
20	0-60	00°00.6′ N	139°25.4′ W	3/19	2118	2,043	0	1	0	0	1
	70-130					1,618	0	0	0	0	0
	140-200					2,796	1	0	0	0	1
	0-200				2235	1,914	0	0	0	0	0
21	0-60	01°07′ N	140°07′ W	3/20	2125	2,375	0	0	0	0	0
	70-130					542	0	0	0	0	0
	140-200						0	0	0	0	0
	0-200				2238	2,519	0	0	0	0	0
22	0-60	01°06.4′ N	140°03.8′ W	3/21	0941	1,830	0	0	0	0	0
	70-130						0	0	0	0	0
	140-200					1,053	0	0	0	0	0
	332-127	01°05′ N	140°03′ W	3/21	1048	1,461	0	0	0	0	0
23	0-60	01°06′ N	140°05′ W	3/22	0924	2,114	1	0	0	0	1
	70-130					734	0	0	0	0	0
	140-200					1,185	0	0	0	0	0
	812-355				1030	1,353	0	0	0	0	0
24	0-60	01°06.2′ N	140°10′ W	3/22	2125	1,506	1	0	0	0	1
	70-130					1,731	3	0	0	0	3
	140-200					1,583	0	0	0	0	0
26	0-60	01°09.2′ N	140°30.4′ W	3/23	2121	1,946	0	3	0	0	3
	70-130					867	0	0	0	0	0
	140-200					1,073	0	0	0	0	0
	0				2314	2,934	1	0	1	0	2
	0-200				2239	2,487	3	0	0	0	3
27	0-60	01°11.7′ N	140°32.9′ W	3/24	1055	2,055	0	1	2	0	3
	70-130					1,049	0	0	0	0	0
	140-200					2,319	0	0	0	0	0
28	0-60	01°13.9′ N	140°35.4′ W	3/24	2122	2,558	3	0	0	0	3
	70-130					1,561	0	0	0	0	0
	140-200					624	0	0	0	0	0
	0-200				2234	1,874	2	1	0	0	3

[1] Nets came in open.
[2] Estimated.

TABLE 8.—*Larval tuna collected on* Hugh M. Smith *cruise 38 in equatorial waters and near French Oceania*

Station No.	Approximate depth of tow (meters)	Position		Date 1957	Time started	Water strained (m³)	Number of fish in sample					
		Latitude	Longitude				Skipjack	Yellowfin	Frigate mackerel	Little tunny	Unidentified	Total
2	0–200	00°02′N	124°56′W	1/22	2000(+8)	1,490	0	0	0	0	0	0
	0–60					619	0	0	0	0	0	0
	0	00°02′N	124°54′W		2042	1,939	0	0	0	0	0	0
	0				2110	1,892	0	0	0	0	0	0
5	0–200	00°13′N	121°46′W	1/23	2000	1,697	0	0	0	0	0	0
	0–60					984	0	0	0	0	0	0
	0	00°12′N	121°44′W		2050	2,614	0	0	0	0	0	0
	0				2119	2,214	0	0	0	0	0	0
8	0–200	00°13′N	118°49′W	1/24	2005(+7)	1,925	0	0	0	0	0	0
	0–60					913	0	0	0	0	0	0
	0	00°11′N	118°46′W		2050	2,168	0	0	0	0	0	0
	0				2117	2,101	0	0	0	0	0	0
11	0–200	00°08′S	115°32′W	1/25	2000	2,975	0	0	0	0	0	0
	0–60					569	0	0	0	0	0	0
	0	00°06′S	115°30′W		2045	1,944	0	0	0	0	0	0
	0				2111	1,877	0	0	0	0	0	0
14	0–200	00°01′S	112°14′W	1/26	2005	2,707	0	0	0	0	0	0
	0–60					615	0	0	0	0	0	0
	0	00°03′S	112°14′W		2050	1,772	0	0	0	0	0	0
	0				2116	1,829	0	0	0	0	0	0
16	0–200	01°23′S	110°06′W	1/27	2000	1,893	0	0	0	0	0	0
	0–60					615	0	0	0	0	0	0
	0	01°23′S	110°04′W		2040	1,896	0	0	0	0	0	0
	0				2110	1,680	0	0	0	0	0	0
19	0–200	04°43′S	109°45′W	1/28	2015	1,702	0	0	0	0	0	0
	0–60					849	0	0	0	0	0	0
	0	04°45′S	109°44′W		2055	1,578	0	0	0	0	0	0
	0				2121	1,518	0	0	0	0	0	0
23	0–200	07°53′S	110°04′W	1/29	2005	2,370	3	0	0	0	0	3
	0–60					621	2	1	0	0	0	3
	0	07°55′S	110°02′W		2055	1,535	3	0	0	1	5	9
	0				2122	1,449	13	0	0	0	5	18
45	0–200	02°58′S	129°55′W	2/25	2000(+9)	2,465	2	3	0	1	0	6
	0–60					860	2	0	0	0	0	2
	0	03°00′S	129°52′W		2100	1,814	1	0	0	0	1	2
	0				2128	1,723	0	0	0	0	0	0
47	0–200	06°32′S	130°04′W	2/26	2120	2,277	3	1	0	0	0	4
	0–60					781	0	2	0	0	0	2
	0	06°33′S	130°01′W		2210	1,750	10	1	0	0	0	11
	0				2235	1,706	4	0	0	0	0	4
49	0–200	10°00′S	130°00′W	2/27	2115	2,554	0	0	0	0	0	0
	0–60					767	3	0	0	0	0	3
	0	10°00′S	129°58′W		2200	1,601	0	0	0	0	0	0
	0				2225	1,592	1	1	0	0	0	2
51	0–200	13°27′S	130°01′W	2/28	2130	2,726	0	0	0	0	0	0
	0–60					925	1	1	0	0	0	2
	0	13°30′S	130°00′W		2215	1,815	0	0	0	0	0	0
	0				2240	1,724	0	0	0	0	0	0
54	0–200	16°30′S	130°04′W	3/1	2000	2,825	0	0	0	0	0	0
	0–60					884	3	1	0	0	0	4
	0	16°35′S	130°04′W		2050	1,473	0	4	0	0	0	4
	0				2115	1,481	0	1	0	0	0	1
57	0–200	18°03′S	131°53′W	3/2	2040	2,026	0	1	0	0	0	1
	0–60					645	0	2	0	0	0	2
	0	18°01′S	131°54′W		2120	1,511	0	7	0	0	0	7
	0				2145	1,521	0	47	0	0	0	47
59	0–200	17°50′S	135°06′W	3/3	2000	1,404	0	1	0	0	0	1
	0–60					462	3	0	0	0	1	4
	0	17°48′S	135°06′W		2035	1,180	8	5	0	0	0	13
	0				2100	1,188	6	15	0	0	0	21
64	0–200	17°56′S	140°28′W	3/5	2030	1,967	1	1	0	0	0	2
	0–60					625	3	3	0	0	0	6
	0	17°55′S	140°25′W		2115	1,391	0	2	0	0	0	2
	0				2139	1,509	0	1	0	0	0	1
66	0–200	17°55′S	142°28′W	3/6	2030(+10)	2,061	0	1	0	0	0	1
	0–60					1,022	0	2	0	0	0	2
	0	17°56′S	142°35′W		2115	1,570	0	3	0	0	0	3
	0				2140	1,622	1	0	0	0	0	1
68	0–200	18°03′S	145°30′W	3/7	2000	2,184	0	0	0	0	0	0
	0–60					968	0	0	0	0	0	0
	0	18°02′S	145°31′W		2040	1,682	0	0	0	0	0	0
	0				2105	1,705	0	0	0	0	0	0
75	0–200	11°18′S	145°02′W	3/15	2020	1,930	3	1	0	0	0	4
	0–60					557	0	1	0	0	0	1
	0	11°18′S	144°59′W		2105	1,515	0	2	0	0	0	2
	0				2130	1,209	0	2	0	0	0	2
79	0–200	08°12′S	145°12′W	3/16	2020	2,478	2	1	0	0	0	3
	0–60					955	4	4	0	0	0	8
	0	08°09′S	145°12′W		2103	1,642	14	2	0	0	0	16
	0				2129	1,599	3	0	0	1	0	4
82	0–200	05°00′S	145°00′W	3/17	2100	2,932	2	1	0	0	0	3
	0–60					1,010	10	8	0	0	0	18
	0	05°01′S	144°57′W		2147	1,785	54	1	1	0	0	56
	0				2212	1,678	60	1	0	0	0	61
85	0–200	02°04′S	144°56′W	3/18	2020	2,327	3	2	0	0	0	5
	0–60					936	10	2	0	0	1	13
	0	02°06′S	144°54′W		2108	1,445	7	1	2	0	0	10
	0				2134	1,451	9	4	0	0	0	13

TABLE 9.—*Larval tuna collected on* Charles H. Gilbert *cruise 30 in French Oceania*

[All tows were at the surface and of a half-hour's duration]

Station No.	Position		Date 1956	Time started (+9)	Water strained (m³)	Number of fish in sample					
	Latitude	Longitude				Skipjack	Yellowfin	Frigate mackerel	Little tunny	Unidentified	Total
1	01°24.5'N	133°49'W	8/16	0959	1,804	0	0	0	0	0	0
2	00°24.5'N	133°09'W	8/17	0750	1,774	0	1	0	0	0	1
3	00°01'S	133°02'W		2000	1,570	0	1	0	0	0	1
					1,597	0	0	3	0	0	3
				2041	1,571	0	0	1	1	0	2
					1,533	0	0	1	0	0	1
4	00°54'S	132°22'W	8/18	0752	1,872	0	0	0	0	0	0
5	01°29'S	132°03'W		2003	1,572	0	0	0	0	0	0
					1,309	0	0	0	0	0	0
				2039	1,548	0	0	0	0	0	0
					1,555	0	0	0	0	0	0
6	02°44'S	131°42'W	8/19	0744	1,541	0	0	0	0	1	1
7	03°08'S	131°35'W		1959	1,562	0	0	0	0	1	1
					1,688	0	0	0	0	1	1
				2037	1,373	0	0	0	0	2	2
					1,320	0	0	0	0	0	0
8	04°25.5'S	131°39'W	8/20	0746	1,670	0	0	0	0	0	0
9	04°49'S	131°48.5'W		2000	1,567	0	0	0	0	0	0
					1,548	0	0	1	0	0	1
				2038	1,610	0	0	0	0	0	0
					1,597	0	0	0	0	0	0
10	06°01.5'S	132°17'W	8/21	0746	1,678	0	0	0	0	0	0
11	06°19.5'S	132°10'W		1958	1,409	0	0	0	0	0	0
					1,392	0	0	0	0	0	0
				2037	1,410	0	0	0	0	0	0
					1,413	0	0	0	0	0	0
12	07°32'S	132°05'W	8/22	0754	1,452	0	0	0	0	0	0
13	08°01.5'S	132°03'W		1957	1,775	1	0	0	0	0	1
					1,732	0	2	0	0	0	2
				2035	1,563	2	0	0	0	0	2
					1,552	1	0	0	0	0	1
14	09°22'S	132°09.5'W	8/23	0747	1,670	0	0	0	0	0	0
15	09°48'S	132°07'W		1954	1,672	0	1	0	0	0	1
					1,649	0	0	0	0	0	0
				2034	1,271	0	0	0	0	0	0
					1,249	0	0	0	0	0	0
16	10°51'S	132°00'W	8/24	0740	1,741	0	0	0	0	0	0
17	11°10'S	131°56'W		1957	1,705	0	0	0	0	0	0
					1,627	0	0	0	0	0	0
				2035	1,776	1	0	0	0	0	1
					1,726	0	0	0	0	0	0
18	12°12.5'S	132°05'W	8/25	0750	1,891	0	0	0	0	0	0
19	12°31'S	132°04'W		1956	1,843	2	0	0	2	0	4
				2033	1,755	0	0	0	0	0	0
						1	0	0	0	0	1
20	13°30'S	132°15.5'W	8/26	0749	1,697	0	0	0	0	0	0
21	13°02.5'S	132°31'W		2002	1,540	17	0	0	0	0	17
					1,533	13	0	0	0	1	14
				2040	1,687	25	0	0	0	1	26
					1,634	11	0	0	0	2	13
22	12°18'S	133°18'W	8/27	0749	1,418	0	0	0	0	1	1
23	12°02.5'S	133°33.5'W		2001	1,677	2	0	0	0	0	2
					1,561	2	0	0	0	2	4
				2040	1,615	1	0	0	0	0	1
					1,587	1	0	0	0	0	1
24	11°33'S	134°33'W	8/28	0742	1,706	0	0	0	0	0	0
25	11°09.5'S	134°45.5'W		2002	1,737	1	1	0	0	0	2
					1,646	0	0	0	0	0	0
				2040	1,545	0	0	0	0	0	0
					1,450	0	0	0	0	0	0
26	10°35'S	135°38.5'W	8/29	0800	1,706	0	0	0	0	0	0
27	10°17'S	135°52'W		1955	1,151	0	0	0	0	0	0
					1,107	0	0	0	0	0	0
				2033	1,322	0	0	0	0	0	0
					1,474	0	0	0	0	0	0
28	09°36.5'S	136°45'W	8/30	0801	1,562	0	0	0	0	0	0
29	09°21.5'S	137°01'W		2000	1,505	0	0	0	0	0	0
					1,462	0	0	0	0	0	0
				2038	1,306	0	0	0	0	0	0
					1,216	0	0	0	0	0	0
30	08°43'S	137°52'W	8/31	0802	1,747	0	0	0	0	0	0
31	07°32'S	138°54'W	9/1	0756	2,021	0	0	0	0	0	0
32	07°39'S	138°56'W		1957	1,682	1	0	0	0	0	1
					1,866	4	0	0	0	1	5
				2035	1,826	4	0	0	0	0	4
					1,521	2	0	0	0	0	2
33	08°50'S	139°08'W	9/2	0750	1,380	0	0	0	0	1	1
34	09°12'S	139°12'W		2005	1,457	1	0	0	0	0	1
					1,450	0	0	0	0	0	0
35	10°28'S	139°38'W	9/3	0754	1,188	0	0	0	0	0	0
36	10°00'S	139°41'W		1959	1,325	0	0	0	0	0	0
				2034	1,281	0	0	0	0	0	0

TABLE 10.—*Larval tuna collected on* Charles H. Gilbert *cruise 32 in French Oceania; all tows were at the surface and of a half-hour's duration*

Station No.	Position: Latitude	Position: Longitude	Date 1957	Time started (+10)	Water strained (m³)	Number of fish in sample: Skipjack	Yellowfin	Frigate mackerel	Little tunny	Unidentified	Total
53	14°57′ S	146°20′ W	2/19	1937	1,490	36	15	0	2	0	53
54	14°17.5′ S	145°31.5′ W	2/20	0347	1,881	11	5	0	0	2	18
55	12°48.5′ S	143°55′ W	2/20	1941	1,834	0	1	0	0	0	1
56	12°05′ S	143°06.5′ W	2/21	0346	1,738	5	1	0	0	0	6
57	10°39′ S	141°33′ W	2/21	1933	1,760	4	4	0	0	0	8
58	09°55.5′ S	141°03′ W	2/22	0345	1,842	17	2	0	0	0	19
66	09°22.5′ S	139°37′ W	2/27	1936	1,467	6	0	0	0	0	6
71	08°57′ S	139°54′ W	3/2	2121	1,068	1	8	2	0	0	11

TABLE 11.—*Larval tuna collected on* Charles H. Gilbert *cruise 34 in Hawaiian waters*

[All tows were of a half-hour's duration]

Station No.	Approximate depth of tow (meters)	Position: North latitude	Position: West longitude	Date 1957	Time started (+10)	Water strained (m³)	Number of fish in sample: Skipjack	Yellowfin	Frigate mackerel	Little tunny	Unidentified	Total
1	0–60	21°10′	158°19′	6/21	1240	1,538	0	6	0	0	0	6
3	0–60	21°09′	158°19′		1500	1,189	0	0	0	0	0	0
4	0–60	21°12.5′	158°21′		1742	1,644	2	4	0	0	0	6
	0	21°11.5′	158°20.5′		1813	1,282	0	4	0	0	0	4
	0	21°10.5′	158°20′		1840	1,377	0	1	0	0	0	1
	0	21°10′	158°19.5′		1909	1,504	0	0	0	0	0	0
	0	21°09′	158°19′		1942	2,061	0	0	0	0	0	0
	0	21°10.5′	158°20′		2015	2,156	1	3	0	0	0	4
	0	21°12′	158°20.5′		2049	1,540	1	1	0	0	0	2
	0–60	21°11.5′	158°20′		2121	1,616	0	0	0	0	0	0
6	0–60	21°11′	158°19′	6/22	0013	1,742	1	0	0	0	0	1
7	0–60	21°11.5′	158°21′		0300	1,681	1	0	0	0	0	1
8	0–60	21°10′	158°19.5′		0622	1,933	2	0	0	0	0	2
9	0–60	21°10.8′	158°19.5′		0906	1,719	3	0	0	0	0	3
11	0–60	21°10′	158°18′		1154	1,371	1	1	0	0	0	2
12	0–60	21°12′	158°20.5′		1459	1,663	0	0	0	0	0	0
13	0–60	21°11.5′	158°19′		1743	1,553	1	0	0	0	0	1
	0	21°11′	158°18.5′		1814	1,426	0	11	0	0	0	11
	0	21°11′	158°17.5′		1844	1,665	1	3	0	1	0	5
	0	21°10.5′	158°17′		1914	1,593	0	0	0	0	0	0
	0	21°10.5′	158°16′		1945	1,870	0	1	0	0	0	1
	0	21°11′	158°16.5′		2015	2,060	6	4	0	0	1	11
	0	21°11.3′	158°18.4′		2045	2,454	2	1	0	0	0	3
	0–60	21°11′	158°20.7′		2121	1,616	2	2	0	0	0	4
15	0–60	21°10.6′	158°19.5′	6/23	0001	1,724	7	0	0	0	0	7
16	0–60	21°11.3′	158°20.6′		0259	1,485	4	1	0	0	0	5
17	0–60	21°10′	158°20′		0603	1,543	0	0	0	0	0	0
18	0–60	21°10.5′	158°19.8′		0859	1,412	0	2	0	0	0	2
21	0–60	20°56′	157°50′		1652	1,253	1	0	0	0	0	1
22	0–60	21°10′	157°50′		1902	1,412	1	1	0	0	1	3
24	0–60	21°25′	157°21′		2305	1,354	4	0	41	1	0	46
26	0–60	21°37′	157°46.5′	6/24	0324	1,618	5	0	8	0	0	13
27	0–60	21°59′	157°45′		0621	1,570	1	4	2	0	0	7
28	0–60	22°20′	157°46′		0930	1,645	1	0	0	0	0	1
32	0–60	21°47′	158°13′		1642	1,325	0	0	2	0	0	2
36	0–60	21°24.5′	159°00′		2337	1,385	0	6	5	1	0	12
37	0–60	21°24.5′	158°40′	6/25	0228	1,621	9	8	0	0	0	17
38	0–60	21°25′	158°17′		0526	1,566	1	4	16	0	0	21
64	0	20°43.8′	156°58′	7/11	1924	2,496	0	4	77	0	0	81
65	0	20°42.9′	156°56.5′		2059	2,230	2	10	284	0	7	303
66A	0	20°42.1′	156°55.1′		2301	2,400	0	5	140	0	1	146
66B	0	20°42.1′	156°55.1′		2337	2,864	0	8	173	0	0	181
67	0	20°42.0′	156°53.0′	7/12	0100	2,312	0	5	96	0	0	101
68	0	20°42.0′	156°51.9′		0300	2,343	1	4	65	0	0	70
69	0	20°40.7′	156°50.6′		0501	1,786	4	24	210	0	0	238
71	0–60	20°43.8′	156°55.4′		2001	1,215	0	4	43	0	0	47
72	0	20°42.8′	156°55.5′		2046	2,339	1	22	1,557	0	0	1,580
73	0–60	20°42.2′	156°55.5′		2201	1,626	4	36	186	0	1	227
74A	0	20°42.2′	156°55.6′		2233	2,370	0	11	182	0	0	193
74B	0	20°42.1′	156°56.6′		2306	2,295	4	59	234	0	0	297
75	0–60	20°42.4′	156°58.5′	7/12	2349	1,754	9	11	11	0	4	35
76	0–60	20°44.2′	156°58.3′	7/13	0035	1,587	6	17	138	0	0	161
77	0–60	20°47.2′	157°01.0′		0133	1,434	3	10	36	0	0	49
78	0–60	20°47.1′	157°02.0′		0221	1,646	11	21	65	0	0	97

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