OBSERVATIONS OF SKIPJACK SCHOOLS IN HAWAIIAN WATERS, 1953

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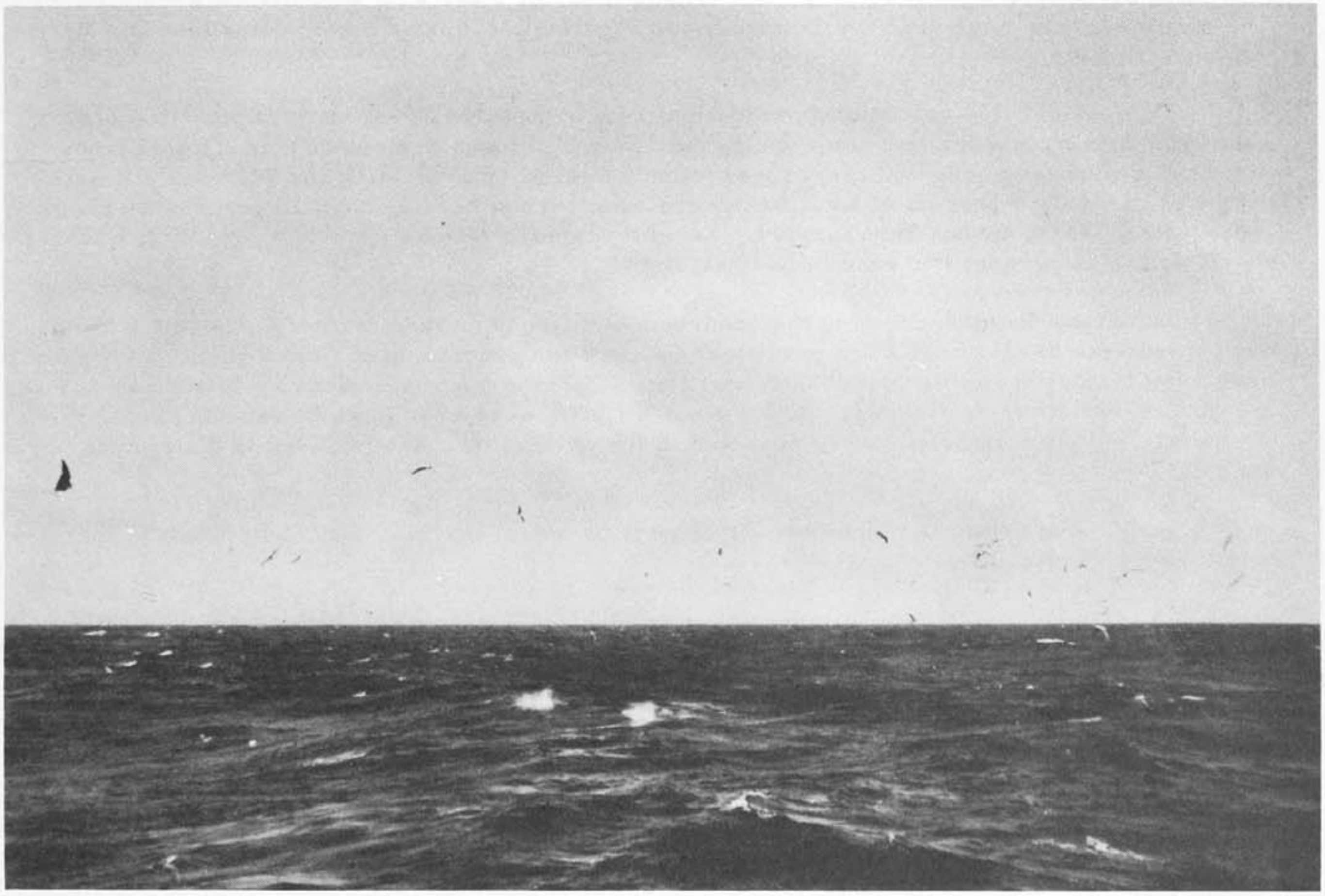

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By

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Pacific Oceanic Fishery Investigations
U. S. Fish and Wildlife Service

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ABSTRACT

On six cruises around the Hawaiian Islands during 1953, 90 days were spent intensively searching for skipjack (aku) schools. Six flights in U. S. Navy PBY amphibians were also made. The purposes were to evaluate and improve the scouting techniques and to determine the distribution of the skipjack.

Skipjack schools are located almost entirely by accompanying birds which flock and maneuver characteristically when working over them. Flocks are seen out to 4 miles from the vessel, but most are seen within 2 miles. A new method of estimating the scanning efficiency indicates that only 6 percent of total flocks are seen beyond 2 miles, and 38 percent between 1 and 2 miles. Many flocks were missed. Careful scanning aft of the vessel on autumn cruises resulted in a 22 percent increase in number sighted.

Numerous factors affecting the occurrence of flocks and the methods of sighting them were investigated. Poor weather conditions reduced the proportion of flocks seen. Large flocks were seen farther from the vessel than small ones. Fishermen maintain consistent watches and are good at estimating distances. In April more flocks were seen in early morning and mid-afternoon: in June more just before noon and in the autumn they were randomly distributed during the day.

Airplane scouting is much less effective than vessel scouting, probably because the dark-colored birds cannot be seen against the water.

The Hawaiian fleet catches three-fourths of its skipjack within 20 miles of land, but schools are not more abundant there. There was no decline in abundance with distance from land out to 230 miles northeast and 350 miles southwest of Oahu.

More schools were seen southwest of Oahu in February, September, October, and November; more to the northeast in April and June.

One location, near an eddy, contained much larger numbers of schools during the September and October cruises. This eddy may enrich the waters, and it will be studied much more intensively.

A peak in the seasonal cycle of number of schools seen occurred in April, not when the catch was greatest in June to August. It is shown that the schools observed in April contained smaller fish and the fishermen fished fewer of them.

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For at least the past two decades the Hawaiian skipjack or "aku", Katsuwonus pelamis (Linnaeus), has provided a major part of Hawaii's fish production. Except for the war years, when there was almost no fishing, the skipjack fleet has consisted of about 20 to 25 boats, which have landed about 10, 000, 000 pounds annually. This comprises from one-half to two-thirds of the total fish production of the Territory (June 1950). Virtually all of the skipjack are taken by chumming the schools of fish with live bait and catching the fish with pole and line from the stern of the vessel.

The nearly constant fleet and the absence of any clear up or down trend in 20 years suggest that it has not been economical to enlarge the fishery. There appear to be two major limiting factors, the first of which is a shortage of the essential live bait. The second is a pronounced seasonal fluctuation, with high catches from about June to September and poor catches during the balance of the year. Clearly, expansion of this fishery involves alleviation of these two limiting factors, and the Pacific Oceanic Fishery Investigations (POFI) has commenced work on both problems. This report presents the results of the first year's study on locating the fish, particularly in areas where and at times when they are not available to the local fishery. In addition a comparison and evaluation of vessel and airplane scouting techniques have been made.

The study got under way in September 1952, using the research vessel CHARLES H. GILBERT, which had been completed in May 1952. After two shakedown cruises, observations on skipjack were begun. Cruises 3, 6, 8, and 12 were made near shore for testing artificial bait or for bait surveys. Some scouting was done on these cruises, but it was incidental to other objectives. On cruise 7, in February 1953, scouting was the principal objective, and a standard scouting technique was developed which was used on cruises 11 and 13, in April and June 1953 respectively. Subsequently the HUGH M. SMITH was used for the standard scouting on cruises 22 to 24 from September to December 1953. The second vital part of the scouting program was made possible by the U. S. Navy, which furnished a PBY amphibian plane for six flights between November 1952 and June 1953.

The authors are greatly indebted to many members of the POFI staff who assisted with the field observations, particularly to John W. Slipp, who was in charge of the skipjack investigation until July 1953 and who standardized the methods of observing the bird flocks and fish schools. Also deserving special mention are Daniel T. Yamashita and Heeny S. H. Yuen, who with Slipp and Otsu served as field party chiefs, and Albert K. Akana, Jr., Robert E. K. D. Lee, and Gordon M. Wilkinson, who captained the vessels on the cruises. We received excellent cooperation from all U. S. Navy personnel concerned with the flights and from Rear Admiral W. K. Phillips, who directed that the aircraft be made available.

Valuable assistance was also received from Mr. Vernon E. Brock, Director of the Division of Fish and Game of the Board of Agriculture and Forestry of the Territory of Hawaii, who made available statistics on the skipjack fishery and who encouraged us in this study.

METHODS

Vessel Scouting

Our principal method of scouting follows the practice of the local skipjack fleet. We employ experienced local fishermen, who maintain a constant watch from the bridge of the vessel while cruising at the normal speed of 9 to 10 knots. These men locate the schools by the presence of bird flocks, and from the species of birds present and their behavior they can make remarkably accurate guesses about the kind and size of fish that are below them. Fortunately for the skipjack fishermen, approximately 90 percent[1/] of the schools of fish which are to be found by the presence of birds in Hawaiian waters are composed of skipjack, the balance being mostly dolphin (mahimahi), small yellowfin or bigeye tuna (ahi), or little tunny (kawakawa). [2/]

Apparently the practice of using bird flocks for locating tuna schools is widespread throughout the Pacific region. According to Cleaver and Shimada (1950), the Japanese live bait fishermen rely heavily on birds for locating skipjack schools when they are in the area where schools are to be expected. The Japanese fishermen also expect to find skipjack schools near floating driftwood and debris, or in the vicinity of whales and basking sharks. In addition they sometimes find fish by seeing the wake of the school or fish actually jumping and rolling on the surface.

In Hawaiian waters the fishermen are almost completely dependent upon the birds for locating tuna. In fact, while they occasionally sight schools not accompanied by birds, on the two principal scouting cruises of the CHARLES H. GILBERT during the spring of 1953, every one of the 253 fish schools sighted was accompanied by birds and was found by means of the birds. Undoubtedly this dependence on birds arises partly from their prevalence and partly also from the almost constantly choppy sea conditions with white caps which make it extremely difficult to see the wake of a school or jumping fish at any considerable distance from the vessel.

Because they rely on the birds, the fishermen adapt their scouting technique to sighting flocks of birds from the deck of the vessel rather than from a crow's nest. Since the Hawaiian sea birds which flock over tuna schools are predominantly dark in color, e.g. wedge-tailed shearwater, sooty and noddy terns[3/], and the ocean is characteristically a very deep blue, they are best seen above the skyline. Fishermen on the bridge of the vessel, when they think they detect a flock of birds at a maximum distance, will frequently take the binoculars down to the deck, where they can see more easily. Apparently this method of scouting is quite different from that which prevails in the American tuna fishery off Central America. According to fishermen who have fished there, they depend primarily upon seeing the wake or shadow of the school or jumping fish. They also find fish by fishing near drift logs, under birds, or near porpoise schools. However, the actual fish school is best sighted at a maximum distance by observing from as high as possible, and the practice is continually to scan the surface from the masthead. No doubt this technique is more effective because of the prevalence of calm water conditions in that area, and also, we suspect, because of larger and denser schools of tuna.

Our system of scouting is designed to secure as continuous a scanning of the horizon by experienced local fishermen as is practicable. The men are assigned 2-hour watches, and each follows the usual fishing practice of making a thorough search of the horizon with the naked eye

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1/ A value which we cannot precisely substantiate. According to fishermen's estimates on the basis of bird behavior, 75 out of 83, or 90 percent, of the schools sighted during GILBERT cruises 11 and 13 were skipjack. We positively identified 55 schools that we tried to chum, and 47, or 85 percent, were either skipjack or a mixture of skipjack with other species.

2/ *Coryphaena hippurus* Linnaeus, *Neothunnus macropterus* (Temminck and Schlegel), *Parathunnus sibi* (Temminck and Schlegel), and *Euthynnus affinis* Cantor in the order named.

3/ *Puffinus pacificus*, *Sterna fuscata*, and *Anous stolidus* in the order named.

and with binoculars about once each 5 minutes. During the first half of 1953 the men concentrated their search on the forward quadrants of the horizon in accordance with their usual practice. Following some study of the data and development of a theory that schools intermittently sound and are not detectable for periods of time, the fishermen were instructed to search the after quadrants of the horizon as carefully as they did the forward quadrants. After finding fair numbers of schools, some of them directly astern of the vessel, the fishermen were convinced of the necessity of this, and we believe that subsequently we achieved uniform attention to all sectors of the horizon.

Whenever a school of fish accompanied by birds was sighted, the scientist on watch was immediately notified and he maintained a minute-by-minute record of the behavior of the birds, the bearing of the school relative to the course of the vessel, which was never altered until the school was abeam, and the estimated distance of the school from the vessel. After the school was abeam, we frequently approached and fished it, if bait was available.

Estimates of distance over the open sea are expected to be subject to a great deal of error. We are convinced, however, that our fishermen obtain consistent and reasonably accurate estimates of the distances of schools from the vessel. The consistency is evident in data which will be subsequently discussed. The distances were estimated to the nearest 1/4 mile when under about 2 miles and usually to the nearest 1/2 mile from 2 to 4 miles. The smoothness of the frequency curves of schools sighted against distance indicates that there is no important tendency to favor a particular distance over adjoining distances. Various methods of checking the accuracy were tried, including the use of a range finder, a stadimeter, and a sextant. None of the conventional methods for measuring distance under such conditions proved practical, but we did find that with a calm sea large flocks of birds could be detected and their distance accurately measured by radar. On two occasions we obtained radar measurements independent of the fishermen's estimates, and we found good agreement (table 1). Apparently the fishermen have developed a very considerable skill in estimating the distance to birds by relating their appearance to the average time required to run them down.

Table 1.--Comparison of estimated distance and radar distance of bird flocks

a. CHARLES H. GILBERT cruise 12 - May 11, 1953 (about 80 birds in flock)

Time	Fishermen's estimate	Corresponding radar reading[1/]
1142	1 mile	0.8 - 0.9 mile
1143	1 mile	0.5 - 0.7 mile
1144	1/4 mile	0.3 - 0.6 mile
1145	1/3 mile	0.2 - 0.5 mile
1146	1/5 mile	0.1 - 0.4 mile
1147	100 yards	----

b. HUGH M. SMITH cruise 22 - September 8, 1953 (about 300 birds in flock)

Time	Fishermen's estimate	Corresponding radar reading[1/]
1556	1-1/2 miles	2 miles
1600	1-1/2 miles	1-3/4 miles
1601	1	1-3/4 miles
1603	1 mile	1-1/2 miles
1604	1-1/2 miles	1-3/4 miles

1/ The radar readings indicate the spread of the rather diffuse first flock (May 11, 1953) and the middle of the more compact second flock (September 8, 1953).

The areas to be scouted with the vessel were selected to include and extend beyond those fished by the local fleet, but they were, of course, severely limited by the distance that a single vessel could travel. A series of courses in the form of crosses was decided upon, as shown in figure 1. These tracks were followed carefully on GILBERT cruises 11 and 13, which contributed the bulk of our observations for an evaluation of scouting techniques in the subsequent sections. The other GILBERT cruise that provided some data was cruise 7, which followed the track indicated in figure 2. The cross patterns have the advantage of providing replicate coverage of the same area on successive days. They also serve to standardize the heading of the vessel in relation to the sun and to the prevailing seas, which the trade winds usually push from the northeast quadrant. Also, early in the investigation it was expected that the schools of skipjack might be migrating through the areas and that such a pattern of scouting might show a "Doppler effect"[4], which would indicate the direction and speed of the schools. However, no Doppler effect was found, and the cross pattern wasted the time of the vessel during the night because it was not possible to use that period to move the vessel to another scouting location for the following day.

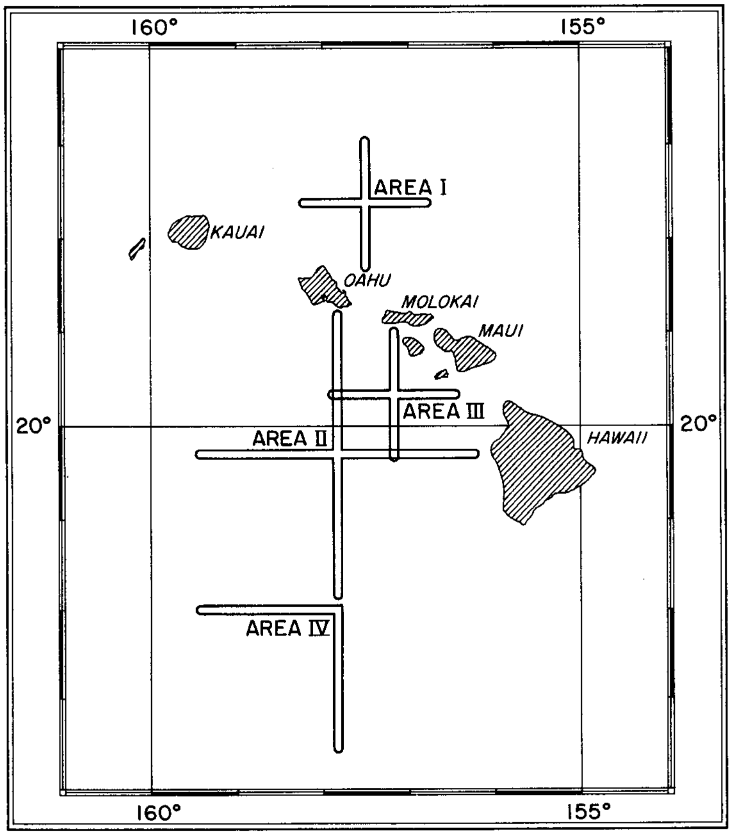

Figure 1.--Scouting plan for GILBERT cruise 11, April 11 to 28, Areas I and II, and for GILBERT cruise 13, June 13, to July 11, all areas.

During the autumn of 1953, a different scouting plan was developed in which a particular area was scouted during a day and then the night was used to move on to another area. This plan consisted of S-shaped courses, as shown in figure 3, which provided an estimate of the number of schools to be sighted within an area in which the schools could be assumed to be randomly distributed. Such an assumption avoided the troublesome problem of deciding whether a concentration of schools sighted during a particular part of a day on a straight run arose from chance variation or for some special reason. It also avoided the troublesome west to east run on which the prevailing northeasterly tradewinds frequently caused the vessel to take spray over the bridge, resulting in poor scouting conditions. The length of this S-shaped section was 95 miles or about 10 hours' running time. With about 12 hours of daylight this left 2 hours for fishing schools and experimenting with them. Night was then almost fully utilized in the run to the next station. This plan resulted in covering areas out to 230 miles northeast and 350 miles south and west of Oahu.

[4] The name is given to the physical effect of an apparent change in the frequency of sound or light where observer and source are approaching or separating. A similar difference might be expected if a given number of fish schools were meeting or traveling with the vessel.

Airplane Scouting

Airplanes have come into increasingly common use for locating fish in various parts of the world. Harrison (1931) reported that planes were successfully used for locating schools of menhaden off the North Carolina coast. Cushing et al. (1952) discussed the use of planes and helicopters, particularly in the American tuna fishery, where they reported that schools of tuna more than 20 miles away have been spotted from the air and that under usual conditions much more can be seen from the plane above altitudes of 600 feet. However, Sette (1949) felt that the method was not satisfactory for locating pilchard off California, where the scouting was done by day, the fishing by night. Blackburn and Tubb (1950) found that planes aided in exploratory work in Australia, but the observations left much to be desired over waters where many different species were schooling. Then, too, planes have been previously used for locating skipjack in Hawaiian waters, although it was reported to us that the trials were not extensive enough to demonstrate their value. Clearly, plane scouting was a likely method of locating skipjack and we undertook to test it.

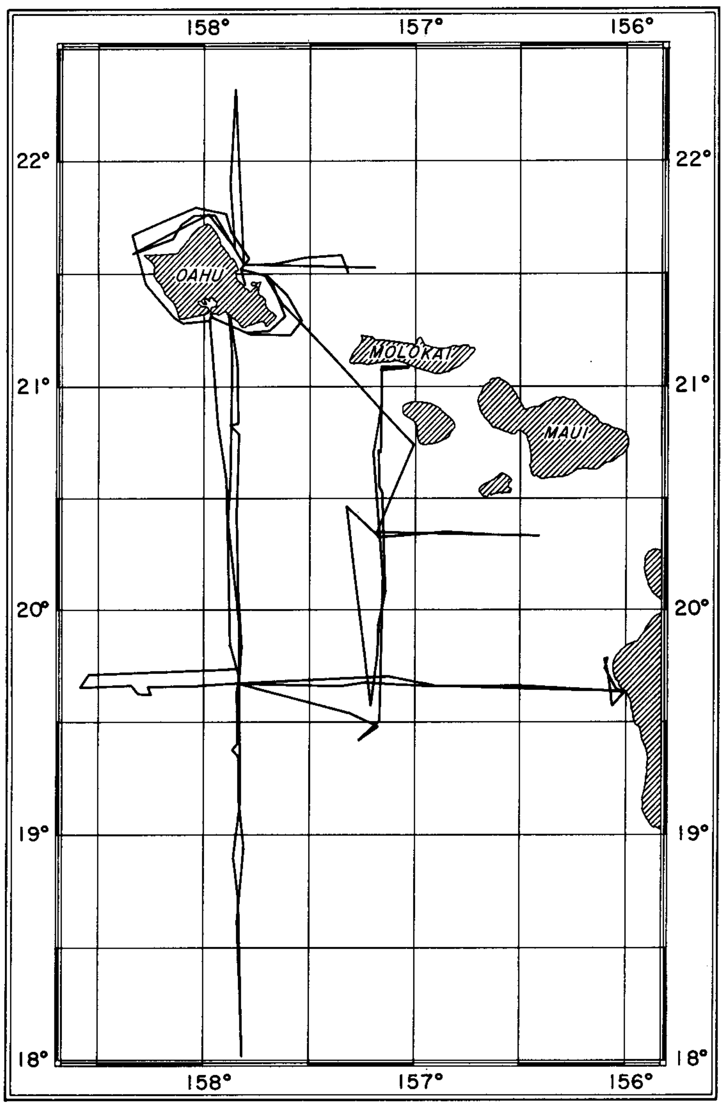

Figure 2.--Track chart, GILBERT cruise 7, in February.

Through the cooperation of the United States Navy at Barbers Point, Oahu, six flights were made between November 14, 1952 and June 15, 1953. These flights were made in an amphibious PBY plane, which was ideal for our aerial scouting because it had a relatively low cruising speed of approximately 100 knots and it had large blisters, where four observers could conveniently be located, on the fuselage just forward of the tail assembly.

Since this was our first attempt at aerial scouting, the scouting procedure was necessarily modified several times before a more standardized technique could be developed. Following is a summary of the procedures employed:

The first method was to have each observer work independently throughout the entire flight and record his own observations. This method sometimes produced confusing records in which it was impossible to determine whether two observers had recorded the same object or whether they had recorded separate objects at the same time.

An improved method was to divide the observers into two teams, placing a team of two on each side of the plane. A member of each team scanned from a point directly below the plane to an angle of about 30° from vertical on one side, the other outward from this point.

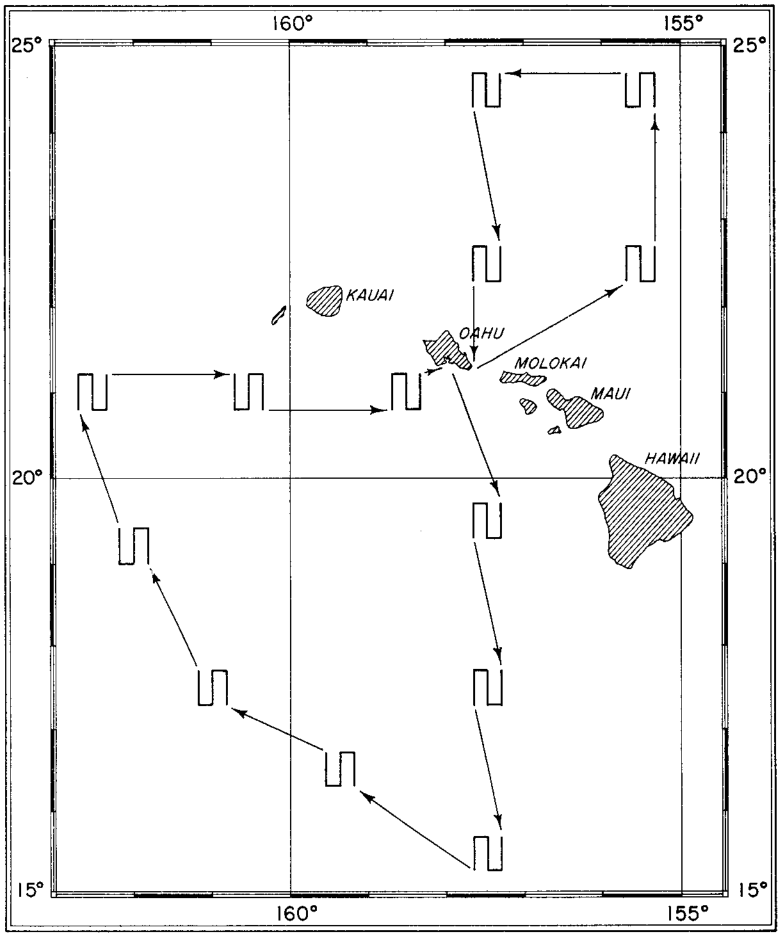

Figure 3.--Scouting plan for cruises 22, 23, and 24 of the HUGH M. SMITH in September, October, and November.

These inner and outer zones were exchanged between observers each 20 minutes. The observer scanning the outer zone was also charged with the responsibility of keeping the team's records as well as making periodic observations of weather and sea conditions. Unfortunately, communication between observer and recorder was a serious problem in the noisy interior of the plane. This problem was alleviated when each observer was required to keep his own record. During the last flight each observer was also required to measure and record the angle from vertical of each object sighted.

The flights were about 4-1/2 hours long and covered a distance of approximately 450 miles. The flight track was usually laid out over an area which was being scouted by the CHARLES H. GILBERT and, in addition, covered areas where skipjack were likely to occur (fig. 4). The plane flew at altitudes between 500 and 2,000 feet on the various flights, but a constant altitude was maintained during each flight except occasionally, when the plane descended to lower elevations to examine objects more closely or repeatedly. On several flights a Navy photographer accompanied the plane to photograph objects of special interest. Records were maintained of the time and sighting of all fish, birds, and aquatic mammals and also the condition of the sea surface. Since frequent navigational fixes were obtained by the Navy crew, it was possible to construct a detailed chart combining track and sightings.

Despite the minor differences in techniques, we believe that we maintained a very high scanning efficiency on all flights. Usually the personnel included someone experienced in searching for skipjack schools from a vessel. There was much interest in making the flights and they were short enough to avoid undue fatigue and eye strain.

Behavior of Birds in Relation to Fish

Terns and shearwaters are most commonly seen in association with skipjack schools in the Hawaiian waters and the fishermen consider both to be indicators of skipjack's presence (table 2). Among the terns, the noddies and the sooty tern are the species most commonly seen. The noddies are generally more abundant near the islands while the sooty terns range as far as we have searched. The shearwaters and petrels are a difficult group of birds to identify in flight, but the wedge-tailed shearwaters have been found to be very common. These also are found to the limit of our scouting area.

The most obvious difference in the composition of the bird flocks in our scouting area was the presence of boobies (Sula dactylatra) close to land. In our scouting in April and June 1953 (table 2) none were found in area IV or the southern part of area II, both of which are beyond 100 miles from land. White terns may be more abundant farther from land, but the numbers seen were too small to be important. The other principal groups--terns, shearwaters, and frigate birds--appear in the flocks without regard to the distance from land in our scouting area.

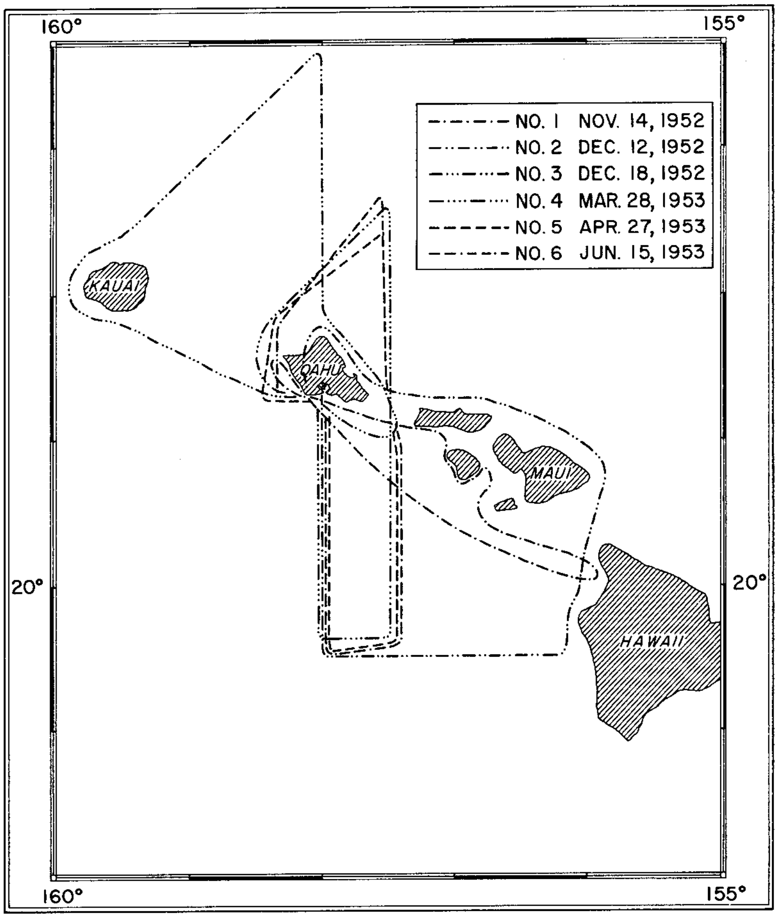

Figure 4.--Tracks of airplane scouting flights.

The terns are believed by the fishermen to be the most important species as they are considered to be the "leaders" of the flock; their movements closely paralleling those of the fish. The captain of a fishing boat generally observes the behavior of the terns in order to intercept the head of the school successfully.

Bird behavior is thought to give a generally reliable indication of whether a school is composed of tunas or of dolphin (mahimahi), the number in the school, and the size of the fish. Birds which alternately fly very high, then low, diving almost vertically to the surface and then rising just as steeply to great heights, continuing this behavior, suggest--to the fishermen--the presence of a dolphin (mahimahi) school. This behavior appears to be independent of the species of birds involved, as terns, shearwaters, and boobies all show it. Other behavior suggests tuna schools, the great majority of which, in Hawaiian waters, are skipjack with only occasional yellowfin, bigeye, or little tuna schools. The size of the fish in a school may also be indicated by birds, for they are thought to dive and circle faster and more erratically over small fish, perhaps because the small tuna have a shorter turning radius.

The size of the fish schools is judged by the spread of the bird flock rather than by the number of birds involved. A small school is expected with a compact group of birds. A flock scattered over a large area or broken up to form several smaller groups near each other suggests a large school. In Japanese waters..."as a rule the size of the fish school is thought to be proportional to the number of accompanying birds; the greater the number of fish, the larger the flock" (Cleaver and Shimada 1950).

A high-flying flock is believed to indicate a fast-moving school which is not actively feeding at the surface. An actively feeding school is characterized by "working" birds which are seen continuously diving in amongst the fish. (Fishermen often forgo schools with inactive high-flying birds without making any attempt to fish them, and select schools with "working" birds.) A school may intermittently sound to greater depths after feeding actively for a while. This is generally shown by the birds, which stop "working" whenever the school sounds. Occasionally, when a school is completely lost, the birds rest on the surface of the water. Such resting birds are believed to signify fish at greater depths.

Table 2.--Composition of bird flocks on two CHARLES H. GILBERT scouting cruises

Cruise	Area	Number of flocks	Number of flocks with						
			Noddy and sooty terns	Shearwaters	Boobies	Tropic birds	Frigate birds	Albatrosses	White terns
GILBERT 11, April 1953	I	46	46	46	33	1	7	-	-
	II	59	54	59	15[1]	2	18	1	4
GILBERT 13, June 1953	I	47	47	43	17	1	12	-	-
	II	53	53	53	12[1]	3	11	-	5
	III	5	5	5	2	-	2	-	-
	IV	31	31	31	-	3	14	-	1

1/ None in southern part of area.

In addition to the terns and shearwaters, the frigate bird (Fregata minor), which usually does not flock, is also a species important to the Hawaiian fishery. One to five of these birds frequently hover high over a flock of terns and shearwaters, and the fishermen believe that their presence indicates a good-sized skipjack school which can be successfully fished. In any event these large (wing spread 5 to 7 feet), high-flying birds can be seen great distances, and on several occasions we have discovered low-flying flocks after noticing a high-flying frigate bird.

In addition to the flocks of oceanic birds which were obviously feeding or "working", some migrating flocks were seen. At the two westernmost stations on the November cruise (SMITH cruise 24) a total of 10 tightly clustered flocks were sighted flying near the sea surface. They were all headed about southwest at carefully estimated speeds of 40 to 60 knots. None were captured or seen closely enough to establish positive identification, but they were tentatively identified as a species of shearwater other than the common wedge-tailed one. These flocks, of course, were not included in our counts of "working" flocks.

EVALUATION OF VESSEL SCOUTING[5]

Distance and Bearing of Flocks from Vessel

Our fishermen, who are accustomed to looking for bird flocks, can spot them as much as 4 miles from the vessel, and even without the assistance of binoculars they can see birds 2 to 3 miles away. However, on GILBERT cruises 11 and 13 the vast majority of the flocks were first seen within 2 miles of the vessel and many were not seen until a half mile or less from the vessel (table 3).

The relation among the numbers sighted at the various distances when first seen provides an estimate of the efficiency of sighting. We have in table 3 the actual number seen in each successive, concentric, half-mile-wide, semicircular segment of the scanning area ahead of the vessel. If we transform these to the number per unit area (a square mile is convenient) and imagine that the unit area is approached repeatedly, then we have a series showing the number of

5/ Most of this analysis was prepared immediately after GILBERT cruise 13 in order to provide a basis for planning SMITH cruises 22, 23, and 24. On these latter cruises only 94 more flocks were seen, which add little to the evaluation of many factors affecting the scouting. Consequently the SMITH cruises are considered only where the data make a significant contribution.

schools seen when the vessel was at various distances from the unit area (fig. 5). A simple accumulation of these may be transformed to a percentage of the total number seen in that area. Thus only 0.2 percent were seen in the most distant zone, including 3-3/4 and 4 miles, 5.9 percent had been seen when the vessel had approached within 2-1/4 miles, and only 42.4 percent of the total number seen had been seen when the vessel approached to less than 1-1/4 miles.

Table 3.--Relation of distance from vessel and number of flocks seen on GILBERT cruises 11 and 13[1/]

Estimated distance miles	Number seen[2/]	Square miles of scanning area[3/]	Number seen per square mile	Cumulated number per square mile	Cumulated percent seen
3-3/4, 4	2	6.082	0.3	0.3	0.2
3-1/4, 3-1/2	3	5.301	0.6	0.9	0.6
2-3/4, 3	5	4.516	1.1	2.0	1.3
2-1/4, 2-1/2	26	3.731	7.0	9.0	5.9
1-3/4, 2	44	2.945	14.9	23.9	15.7
1-1/4, 1-1/2	88	2.160	40.7	64.6	42.4
3/4, 1	51	1.374	37.1	101.7	66.8
1/4, 1/2	31	.614	50.5	152.2	100.0
Total	250				

1/ Three flocks omitted because of incomplete data.

2/ Three seen in after-quadrants. The entries in this column are the sums of the schools sighted at quarter-mile intervals listed in the stub.

3/ In two forward quadrants only.

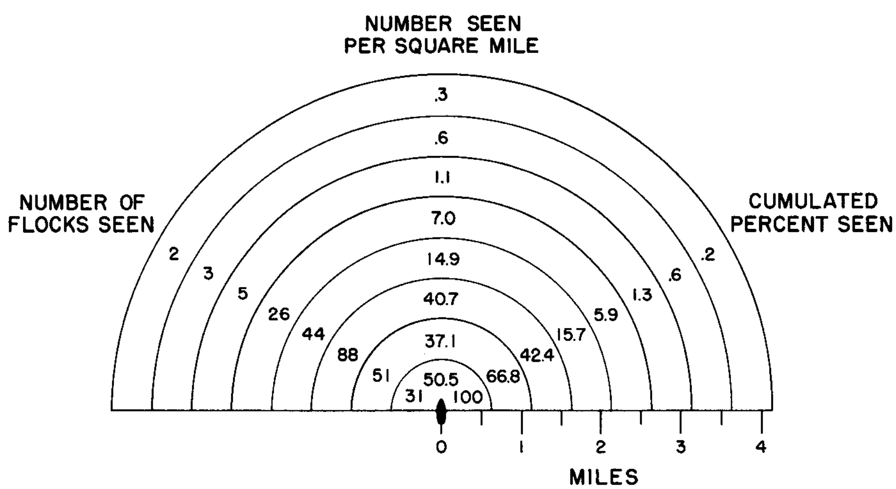

Figure 5.--Flocks seen in concentric segments of the scanning area on GILBERT cruises 11 and 13.

If we consider these percentages to be estimates of efficiency, several assumptions must be made. First, movement of schools in and out of the scanning area before detection must have been equal. Second, it is necessary to assume that the speed and course of the fish schools and accompanying bird flocks were unrelated to the speed and course of the vessel. Since the skipjack are suspected of considerable annual migrations, which it was thought, when the scouting patterns were planned, might be detectable by a "Doppler effect", this assumption may appear unjustified. However, our data, which will be presented in the section on migration of skipjack schools, indicate that no such effect was detectable and that the movement of schools while being watched approximated a random motion.

Another necessary assumption which appears to be well justified is random distribution of schools in the scanning area. The totals seen in the starboard and port forward quadrants on runs in the various directions during GILBERT cruises 11 and 13 are shown in table 4. The data suggest a tendency toward more sightings in the starboard quadrant, but the difference between starboard and port quadrants is not statistically significant by a chi-square test. The total number of flocks seen according to the relative bearing from the bow did show a significant tendency to increase at bearings between 30° and 60° during the spring scouting (table 5). However, this appears to be associated with characteristics of the vessel and habits of the fishermen. The GILBERT has a rather high bow and a mast and shrouds forward of the bridge, where the observer stands, which tend to obscure vision directly ahead of the vessel. Also, the fishermen perhaps pay somewhat less attention to the area directly ahead of the vessel, because they believe that any flocks in that area will be approached by the vessel and be seen eventually. Quite likely these two factors resulted in a lesser number seen directly ahead of the vessel and a somewhat greater number in the 30° to 60° sector.

Table 4.--Number of flocks sighted in forward quadrants by course run on GILBERT cruises 11 and 13[1/]

Side	Direction								Total
	East to west		West to east		North to south		South to north		
	CHG-11	CHG-13	CHG-11	CHG-13	CHG-11	CHG-13	CHG-11	CHG-13	
Starboard	16	36	11	18	20	10	14	10	135
Port	13	31	8	14	16	9	7	15	113

1/ A total of 5 flocks (3 seen in after-quadrants, 2 with incomplete data) omitted from this tabulation.

Table 5.--Number of flocks by relative bearing from bow

Relative bearing[1/]	GILBERT cruises 11 and 13	SMITH cruises 22-24
0° - 30°	73	23
30° - 60°	103	25
60° - 90°	72	29
90° - 120°	1	6
120° - 150°	2	2
150° - 180°	0	9
Unrecorded	2	0

1/ Starboard and port sides combined.

Finally, it is necessary to assume that all of the flocks and schools within 1/2 mile of the vessel were seen. Unquestionably this is true of the bird flocks, but the flocks habitually assemble and disperse while accompanying fish schools, and the assumption that all of the fish schools which approached within a half-mile of the vessel were accompanied by bird flocks at that particular time may not be justified. The ease with which a considerable flock of birds is seen at a distance of 2 miles is not compatible with an estimate that an average of only 5.9 percent of the flocks are seen beyond that distance. Unquestionably the birds are missed to a major extent because they are not assembled into a flock and behaving as they do when they are chasing a fish school. This suggests that considerable numbers of fish schools are completely escaping attention because they are neither visible on the surface nor accompanied by birds. If this is the case, then our estimates of efficiency are maximal.

Suspecting that schools were being missed, we instructed the fishermen to take special pains to watch all parts of the horizon - astern as well as ahead. Soon after these instructions were issued a large school was located only about a half-mile behind the vessel--directly in its wake--which emphasized the need for looking astern. Consequently, during the fall scouting with the SMITH, 17 of 94 schools were seen off the quarter, and if we assume that these would have been missed by our previous technique, then we saw 22 percent more schools. We note also that the distribution of schools in the forward section is nearly uniform, which is gratifying because vision from the bridge of the SMITH is unobstructed forward and therefore the distribution is approximately as expected.

Size of Flocks

If we consider that the flocks accompanying the skipjack schools vary in size from less than 10 to several hundred birds, it appears probable that the size of the flock will affect the efficiency of sighting it. Our data support this probability. In table 6 we have tabulated the number of flocks seen at each distance according to whether they were large (more than 100 birds), medium (50 to 100 birds), or small (less than 50 birds). The data indicate that large flocks were seen farther from the vessel and much more efficiently at distances from 1 to 2 miles. Medium-sized flocks were seen at medium efficiencies, but perhaps most striking is the comparatively large proportion of small flocks (47.9 percent) which were first seen within a half-mile or less from the vessel.

Table 6.--Comparison of numbers of flocks of various sizes seen on GILBERT cruises 11 and 13[1/]

Estimated distance (miles)	Large (100 or more birds)		Medium (50-100 birds)		Small (50 or less birds)	
	Number of flocks seen	Cumulated percent seen	Number of flocks seen	Cumulated percent seen	Number of flocks seen	Cumulated percent seen
3-3/4, 4	1	0.7	1	0.3	0	0.0
3-1/4, 3-1/2	1	1.4	1	0.6	1	0.3
2-3/4, 3	1	2.1	3	1.8	1	0.7
2-1/4, 2-1/2	10	11.5	10	6.1	6	3.3
1-3/4, 2	13	26.8	22	18.1	9	8.3
1-1/4, 1-1/2	16	52.6	41	48.4	31	31.9
3/4, 1	12	82.9	22	74.0	17	52.1
1/4, 1/2	3	100.0	10	100.0	18	100.0
Total	57		110		83	

[1/] Three flocks omitted from table because of incomplete data.

Weather and Sea

In Hawaiian waters visibility and sea conditions are remarkably uniform. Visibility is almost always excellent, though reduced occasionally by haze, which is troublesome at distances of more than 8 to 10 miles, and by rain squalls, which are almost always temporary. Neither of these troubles had any important effect on scouting conditions, and it is possible to consider that visibility is essentially constant. The sea conditions, however, are usually choppy and affect vision according to the amount of spray thrown over the vessel. This, of course, also depends on the vessel's course in relation to the wind and sea, and since the wind is usually from the northeast quadrant, certain compass courses are habitually affected more than others.

Scouting conditions were classified as follows:

Good- good visibility in all directions, vessel not taking any spray on bridge and sailing smoothly, binoculars usable regularly.

Fair- good visibility in all directions but occasional spray, usually from one side of the vessel, hampering regular use of binoculars on that side; one door on bridge usually closed because of spray, vessel with moderate pitch or roll.

Poor- fairly continuous spray over bow to bridge deck, impossible to use binoculars, heavy pitching and rolling of vessel.

The relation of scouting conditions to direction of travel of vessel is shown in table 7, which shows the scouting performed on GILBERT cruises 11 and 13 along the courses shown in figure 1. In executing these patterns the day's run was always toward one of the cardinal points of the compass. The east to west runs were almost always performed under good conditions whereas the west to east runs encountered almost all of the poor conditions. Both northward and southward runs were performed under about equal amounts of good and fair conditions.

Table 7.--Summary of hours scouted and flocks seen under good, fair, and poor conditions on GILBERT cruises 11 and 13

Direction of travel	Hours	Condition		
		Good	Fair	Poor
West	85	82	1	2
East	84	13	20	51
South	84	45	35	4
North	86	43	43	0
Total hours	339	183	99	57
Total flocks	253	158	65	30
Flocks per 10-hour day		8.6	6.6	5.3

The scouting conditions have surprisingly little effect on the relative efficiency with which schools are sighted at varying distances. Table 8 shows the number seen under each condition of scouting at various distances and the estimated percentages. The estimated percentages seen under good and fair conditions are not significantly different at any distance. However, no schools were seen under poor conditions beyond 2 miles, and the numbers seen at the shorter distances are small enough to introduce a large variability due to chance.

A further comparison of the average number seen per day (table 7) indicates that 38 percent fewer schools were seen under poor conditions than under good conditions, and the fair conditions were but little better than the poor. These differences are large enough to be expected by chance (as indicated by a chi-square test) only about once in 50 times; hence they are statistically significant. Since the variation in conditions arose almost wholly from the heading of the vessel relative to the northeasterly trade winds, differences in the number seen must either have been due to visibility or to a Doppler effect resulting from a migratory movement of the fish in one generally consistent direction. It will be shown in a later section that the latter was probably not responsible.

Table 8.--Comparison of number of flocks seen under various scouting conditions on GILBERT cruises 11 and 13[1]

Estimated distance (miles)	Good[2]		Fair		Poor	
	Number seen	Cumulated percent seen	Number seen	Cumulated percent seen	Number seen	Cumulated percent seen
3-3/4, 4	2	0.3	0	0.0	0	0.0
3-1/4, 3-1/2	2	0.8	1	0.5	0	0.0
2-3/4, 3	2	1.2	3	2.4	0	0.0
2-1/4, 2-1/2	15	5.5	11	10.2	0	0.0
1-3/4, 2	29	16.0	11	20.0	4	6.6
1-1/4, 1-1/2	57	44.3	18	42.2	13	34.7
3/4, 1	29	66.9	14	69.5	8	62.0
1/4, 1/2	19	100.0	7	100.0	5	100.0
Total	155		65		30	

1/ Three flocks seen under good conditions were omitted from the table because of incomplete data.

2/ See page 5 for definition of conditions and explanation of calculations.

Time of Day

It is the general belief amongst Hawaiian fishermen that more bird flocks are to be spotted early in the morning and in late afternoon than during the middle daylight hours. This belief is borne out by the numbers sighted per hour on GILBERT cruise 11 during April 1953, which are plotted in figure 6. There was a peak between 7 and 8 a.m. and a decline until noon, with an increase to another peak between 2 and 4 p.m.

This daily pattern of behavior is not constant, however, because on GILBERT cruise 13 in June 1953 the greatest number of flocks was sighted between 11 a.m. and noon, with goodly numbers sighted at all hours between 7 a.m. and 5 p.m. (fig. 6). The distribution continued to be about the same during the three Smith cruises in the fall months. We have no knowledge at this time as to why this pattern changed after April. It might have been caused by a change in the behavior either of the birds or of the fish. We do note that the schools seen in April were predominantly small schools of small fish, whereas those seen during the June and autumn cruises included more large fish.

Differences Among Observers

The maintenance of a continuous watch implies maintaining it at constant efficiency, and of course this was essential in the study. The tedium and eye strain of searching and the normal ship's routine of activities require changing the fishermen on watch every 2 hours. Furthermore, for various reasons there were changes in the crew list between cruises and even in the midst of cruises. Consequently it is vital to our study to determine whether the different fishermen observed uniformly.

Fortunately it appears that the numbers of schools sighted by the different fishermen are sufficiently uniform to indicate that we have been maintaining essentially a constant watch. In table 9 we list the numbers sighted by various fishermen according to distance from the vessel and cruises in which they participated. Fishermen B, E, F, and H were considered the most experienced. There appears to be no tendency for any one man to sight flocks closer or farther than the others. In particular areas on different cruises there is a tendency for certain men to sight more flocks, but it is to be noticed that fisherman E, who sighted the most flocks on GILBERT 11 in Area I, sighted the least on GILBERT 13 in Areas II, III, and IV, and fisherman

D, who sighted the least on GILBERT 11 in Areas I and II, sighted the most on GILBERT 13 in Area I. We believe that the variations in the total number sighted indicate no difference in effort, the differences being due rather to a somewhat greater than random variation in conditions. This may well occur, because groups of schools were sometimes sighted in quick succession in a small area. We conclude that these differences between observers are not significant and that the changes in personnel did not affect our results.

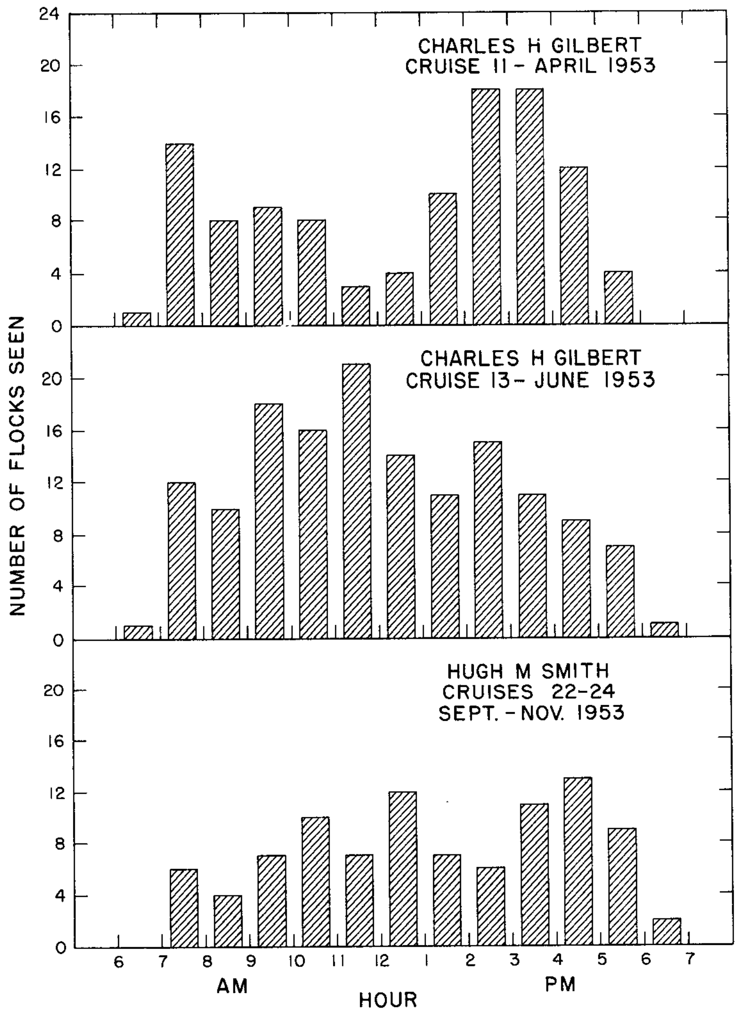

Figure 6.--Diurnal variation in the frequency of sightings of bird flocks on GILBERT cruises 11 and 13 and SMITH cruises 22-24.

EVALUATION OF AIRPLANE SCOUTING

With the exception of Flight No. 2, on which eight fish schools were sighted, the results of the six flights were very poor from the standpoint of giving information on the abundance and distribution of skipjack in the Hawaiian area. Although the flights were made at different times of the year and covered periods of relatively heavy skipjack catches by the commercial fleet as well as the off-season months, the aerial survey results did not indicate such seasonal fluctuations (table 10). On the contrary, the largest number (8) of fish schools and bird flocks seen was during the flight in December 1952, a month of low skipjack catch in the Hawaiian fishery. The flight made during June 1953, a month of good skipjack catches, resulted in the sighting of only one bird flock. Furthermore, on all flights the number of flocks seen per 100 miles was far less than the number seen from our vessel scouting the same area simultaneously.

It appears that our aerial scouting was greatly affected by weather and sea conditions. For example, during Flight No. 2 the weather was excellent with superb visibility. The sea was flat calm with only breeze patches in most areas. This flight resulted in the sighting of four schools (three skipjack and one yellowfin) not associated with any birds and four other schools attended by birds. Two of the flights (Flights 1 and 3) were made under generally adverse scouting conditions, with occasional rain squalls, overcast skies, and poor visibility. The seas were choppy with numerous white caps, making observations difficult. Flight No. 1 resulted in the sighting of three flocks, while on Flight No. 3 only one flock was seen. Somewhat more discouraging are the poor results of the last three flights (4, 5, and 6) which were made in typical, that is generally good, weather with moderately choppy seas. Only eight flocks were seen on all three flights. On these same three days the GILBERT was scouting and reported 31 flocks.

Table 9.--Number and distance of flocks sighted by various fishermen

CHG 11 - Area I - 4/25-28					
Miles from Vessel	Fishermen				
	A	B	C	D	E
1/4 - 1	2	1	4	1	8
1-1/4 - 2	6	4	4	3	8
2-1/4 - 3	1	1	0	1	1
3-1/4 - 4	0	1	0	0	0
Distance unrecorded	0	0	0	1	0
Total	9	7	8	6	17

CHG 11 - Area II - 4/11-21				
Miles from Vessel	Fishermen			
	C	D	F	G
1/4 - 1	5	2	5	7
1-1/4 - 2	1	4	13	9
2-1/4 - 3	3	3	2	3
3-1/4 - 4	0	0	2	1
Distance unrecorded	0	0	0	0
Total	9	9	22	20

CHG 13 - Area I - 6/13-16				
Miles from Vessel	Fishermen			
	B	D	E	F
1/4 - 1	5	15	7	3
1-1/4 - 2	4	3	5	6
2-1/4 - 3	1	0	1	0
3-1/4 - 4	0	0	0	1
Distance unrecorded	0	0	0	0
Total	10	18	13	10

CHG 13 - Areas II, III IV - 6/22-7/11				
Miles from Vessel	Fishermen			
	B	E	F	H
1/4 - 1	4	4	4	5
1-1/4 - 2	19	7	19	17
2-1/4 - 3	5	2	2	5
3-1/4 - 4	0	0	0	0
Distance unrecorded	0	1	1	0
Total	28	14	26	27

In addition to the weather conditions, the visibility of the bird flocks which we are using as indicators greatly influenced our results. In the Hawaiian area the sea birds are mostly dark-plumaged and difficult to see against the background of the water. This effect is noticeable from the vessel but is minimized by observing from close to the water where the birds are seen against the sky. On the other hand, the difficulty is so great when observing from the plane that we saw bird flocks of different composition than those seen from the vessel. Of 15 flocks sighted during the 6 flights, 11 consisted predominantly or solely of white boobies, while only 4 flocks were of the dark-colored terns and shearwaters. Vessel scouting at nearly the same times produced sightings of 39 bird flocks, of which only 1 was white boobies; 19 contained no white-plumaged birds at all, while the remaining 19 contained a few white birds. We conclude that many flocks of dark-colored birds were overlooked by the observers on the plane.

This is surprising because it is easy to see individual flying fish from the plane at an altitude of 1,000 feet or more. When they leave the water they attract attention by the glitter of the sun on their wet bodies. However, they were not seen beyond about 1,600 feet from the track of the plane and most of them between 200 and 400 feet. During the last flight (Flight No. 6, June 15, 1953, at 800 feet altitude) the angles from vertical were recorded for 152 objects sighted, which were mostly flying fish and scattered birds. Tabulation showed that 52 percent were between 15° and 30° from vertical on both sides of the plane. Between 0° (directly beneath the plane) and 15° there were 17 percent, between 30° and 45°, 13 percent, and between 45° and 60°, 18 percent of the total sightings. The small percentage recorded directly below the plane was probably a result of its being somewhat of a "blind spot" to the observers, who experienced some difficulty in vertical scanning. Thus for objects of this kind the effective scanning radius of the plane is only about 1/3 mile or less. Of course, large flocks of birds might be seen at greater distances, but we saw so few that we have no estimate of how far they might be seen.

Table 10.--Comparison of plane and vessel scouting

Plane						Vessel				
Flight No.	Date	Hours Scouted	Miles scouted	Flocks and schools seen		Date	Hours scouted	Miles scouted	Flocks and schools seen	
				Total	Per 100 miles				Total	Per 100 miles
1	11/14/52	3.6	355	3	0.85	11/13/52	8	75	2	2.67
2	12/12/52	4.7	450	8	1.78	12/12/52	10	90	5	5.56
3	12/18/52	4.7	470	1	0.21	12/18/52	10.5	85	3	3.53
4	3/28/53	4.4	430	4	0.93	3/27/53[1/]	7.0	50	6	12.00
5	4/27/53	4.7	440	3	0.68	4/27/53	11.7	90	12	13.33
6	6/15/53	4.5	440	1	0.23	6/15/53	10.8	90	13	14.44

1/ Incidental scouting while vessel was enroute to hydrographic section in Kaiwi Channel--some flocks seen at station.

Another factor which may lessen the efficiency of the plane is the tendency of the bird flocks to assemble and disperse while following a school. Hence, more schools will be seen if an area is watched for a longer time. If we take 1/3 mile as the effective scanning radius of the plane, as suggested by the observations in the preceding paragraph, it will be possible to observe a particular spot of ocean not more than the time required to fly 2/3 of a mile, or 24 seconds in a plane flying at 100 knots. On the other hand, a similarly effective scanning radius for the vessel may be 2 miles, which would permit watching a spot up to 24 minutes from a vessel moving at 10 knots.

Despite the small number of flocks and schools sighted on most flights, it is significant that four of the eight fish schools seen on Flight No. 2 were not accompanied by birds. Such a discovery of an unaccompanied fish school was never made from the vessels during the following year. This suggests that when conditions are right for fish schools to be spotted directly (as they were on Flight No. 2), the airplane is effective in locating them, as has been reported by Harrison (1931) and Cushing et al. (1952). However, when the sea has white caps, as it usually does around Hawaii, and the fish schools must be located by the accompanying birds, the airplane is not as effective as a vessel.

MOVEMENT OF SKIPJACK SCHOOLS

The seasonal appearance and disappearance of the skipjack schools as well as the seasonal change in the average size suggest that the species is migratory, coming and going with the seasons, and that there may be different populations moving through the area at different times. Our data offer little conclusive evidence of any migrations of the skipjack but do provide some information regarding the seasonal distribution of schools and the movements of schools during limited periods of observations.

Perhaps most conclusive is the seasonal shift in abundance between the northeast and southwest sectors off Oahu. The results of the standardized scouting from February to November (table 11) indicate that in the northeast sector the skipjack were less abundant in February and during the fall months of September through November than in April and June. This is the kind of change in distribution that might be expected if the fish move south in the winter, and the absence of schools in the northeast sector during the 4 days of scouting in November suggests that Hawaii may be near the northern limit of the skipjack in the winter months.

There also are shifts of schools from one locality to another around the islands during the fishing season. This is well known to the fishermen and is evident in the statistics of fluctuating catch by area. It is also indicated in our scouting data by the very low number of schools per day seen in Area III during June, when they were abundant in other localities. Our data are too scant to provide any further information about these shifts, but since they do occur, it clearly is necessary to plan the scouting to include a considerable area around the islands if our results are to be comparable with those of the local fishing fleet.

Table 11.--Abundance of skipjack schools by area

Cruise	Month	Number of skipjack schools per 100 miles scouted			
		Northeast sector	Southwest sector		
		Area I	Area II	Area III	Area IV
GILBERT 7	Feb.	1.8 [1]	5.8	8.1	
GILBERT 11	April	13.1	8.3		
GILBERT 13	June	14.4	7.8	1.7	8.9
SMITH 22	Sept.	2.4		4.8	
SMITH 23	Oct.	0.5		3.3	
SMITH 24	Nov.	0.0		1.6	

1/ The scouting of the northeast sector during GILBERT cruise 7 was not on the regular arms of Area I (see fig. 2)

When the cross-like patterns of scouting were laid out for the February, April, and June cruises, it was thought that any concerted movement of schools through the area might be detectable by a "Doppler effect" and by means of vector analysis the direction of movement might be determined. The number of schools sighted on certain arms of the areas scouted do indeed suggest a Doppler effect (fig. 7). For example, in Area I during April we found 8 schools while traveling west and only 3 on our return towards the east. On the south arm we found 12 schools while heading south and 7 while proceeding back toward the center. Similar results were obtained in the south and west arms of Area II in April, and during June on the east and west arms of Area I, on the west arm of Area II, and on the west arm of Area IV. These all show that more schools were sighted on runs toward the south and west than were seen on the reciprocal runs toward the north and east. If this could be ascribed to a Doppler effect, then the schools would have been moving toward the northeast; a vessel meeting the schools would encounter more of them than a vessel proceeding in the same direction as the schools.

However, the weather is definitely a factor here because of the prevailing northeasterly winds, which made the scouting conditions poorer on the runs toward the east and, to a lesser

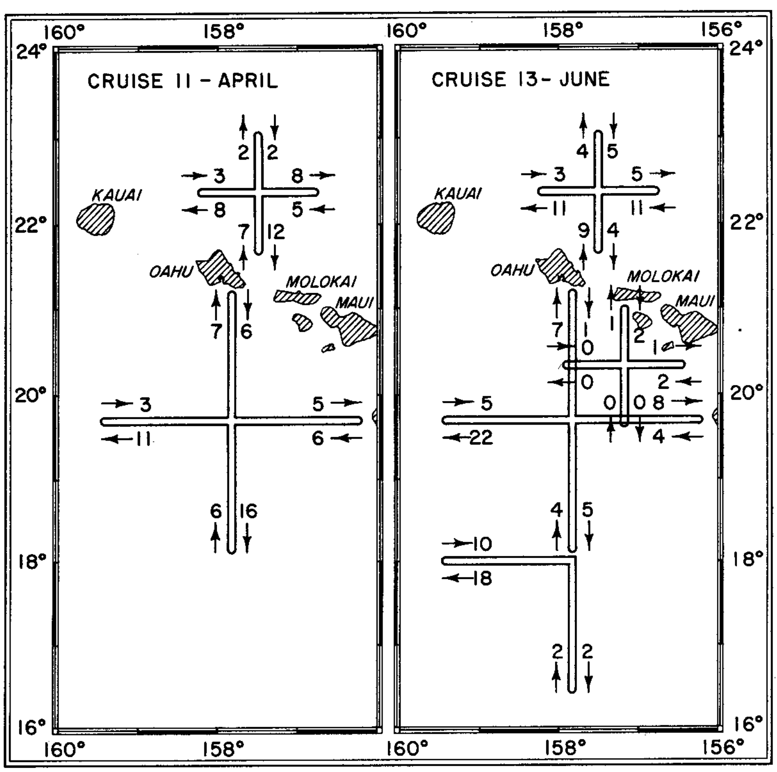

Figure 7.--Numbers of schools seen during systematic scouting on the April and June cruises of the CHARLES H. GILBERT.

degree, on those toward the north. It has previously been pointed out that almost all of the scouting conditions classified as poor were encountered on runs toward the east and the highest proportion of good conditions was found on the runs towards the west. Since the weather was quite steady, we have no way of separating a possible Doppler effect from the weather effect with these data.

But we do have direct observations on the schools, which frequently moved considerable distances while they were being observed from the ship. It is reasonable to assume that any collective migration of these schools would be evident in the average movement of the individual schools during the 5 to 15 minutes for which they were watched. (It will be recalled that when schools were sighted, a minute-by-minute record of the ship's course and the relative bearing and distance of the school was maintained. This permits reconstructing a track chart of the school while it was under observation, though it is subject to some inaccuracies due to the problems of estimating distance.) When the movements of these schools during the first 10 minutes of observation are plotted, it is found that less than half of them show definite movement. Usually the schools were milling about in one place, but at times they were moving and sometimes at speeds of 10 to 15 knots. When we plot the movement of the schools which were seen to move during a 10-minute period on all runs where the relative numbers of schools suggest the Doppler effect (fig. 8), we find that the movement of the schools is almost a random one except on the south arm of Area II in April, where most of the schools were moving southwesterly, on the east and the west arms of Area I in June, where they were moving westerly, and on the west arm of Area IV, cruise 13, where they were moving northerly. Since the apparent Doppler effect suggests a northeasterly movement and there is not a single instance of the concerted movement of the schools while under observation substantiating this, we conclude that the apparent Doppler effect is due entirely to weather and to the inevitable fluctuations of rather small numbers.

The plots of figure 8 do suggest that at times the movement of schools is concerted rather than random, and this may be further evidence of the tendency of schools to vacate or appear in limited localities.

ABUNDANCE OF SCHOOLS IN RELATION TO LAND AND TO THE FISHING AREA OF THE FLEET

The Hawaiian skipjack fleet habitually operates within 20 miles of land and from 1948 to 1952 took 74.5 percent of its catch in that zone (fig. 9). However, this does not mean that the vessels operate within 20 miles of port because some may range much farther by operating along other than their home islands. Since the fishermen can be expected to know where the fish are easiest to locate and can easily range 100 miles or more from land, the fact that most of the catch came from within 20 miles might mean that skipjack are more abundant in this zone. Moreover, such abundance would be expected because of general observations that fish of many species are more abundant near the reef.

However, during our spring scouting more tuna schools per day were seen outside the zone extending to 19 miles from shore (table 12). They were most abundant in the zone from 20 to 39 miles from shore, but to the limit of scouting, about 300 miles south of Oahu, they remained slightly more abundant than in the inshore zone during most cruises. These small differences are probably not significant, because much of the inshore scouting was performed on runs to hydrographic stations or while on other missions when scouting was incidental. Furthermore, the areas scouted were mostly between Oahu and Maui, or north and south of these islands. This area is near the center of the fishery but is not representative of the entire fishing area in the zones specified. We consider the data to indicate that the schools were nearly randomly distributed in the area scouted but with local changes as indicated by the scarcity of schools in Area III in June, and with a shift in relative abundance between the north and south sides of the islands.

After the discovery that the schools were abundant beyond the customary range of the fleet and probably beyond the range of our spring scouting, we planned our fall scouting to encompass two larger sectors, one northeast and one southwest of Oahu (figs. 3 and 10). In these sectors scouting was done out to 350 miles southwest and to 230 miles northeast of Oahu. On all three of the cruises, with the exception of one station, the schools were about equally abundant

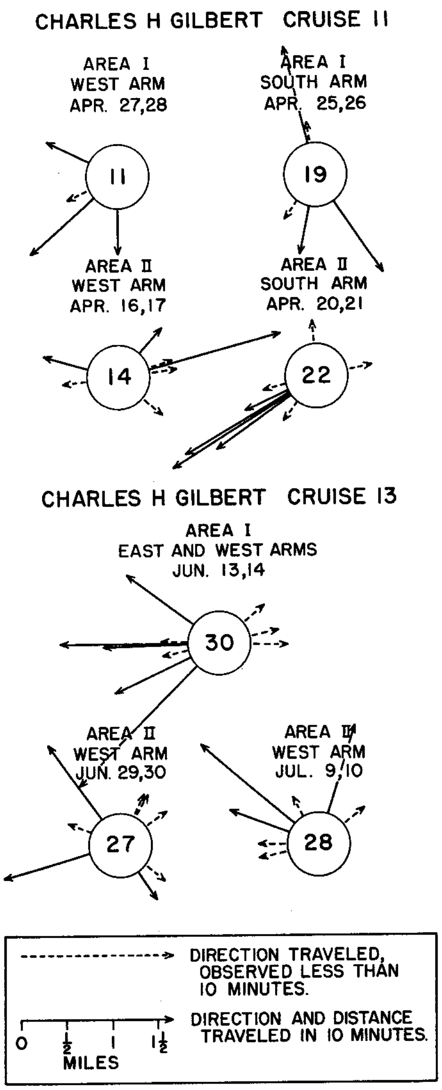

Figure 8.--Direction and distance moved in 10 minutes by schools seen on runs where a Doppler effect was suspected during the April and June cruises. The number in the center is the total number of schools seen; the number of arrows indicates the number of schools which moved. Distances are indicated from the circle, not its center.

in all parts of each sector, but they were consistently less abundant to the northeast. Also, the abundance decreased from month to month.

The exceptional station where more schools were sighted on the September and October cruises was located about 80 miles west of Hawaii and 110 miles south of Oahu. The abundance of tuna here seems the more significant because it is near an eddy which is indicated in our preliminary analysis of oceanographic observations. This eddy, which is now being made the subject of more detailed study, is a counterclockwise one, in the center of which the thermocline rises to less than 100 feet of the surface. It is suspected that this eddy may somewhat enrich the waters and indirectly create more food for the skipjack.

SEASONAL TREND

The seasonal trend in the landings of skipjack is fairly constant and is well known to everyone in the local fishing industry. With minor variations, the low landings of the winter months increase gradually to a peak in the summer and decline again to a low in the winter. The pattern during 1953 was nearly typical, with a peak in June and a secondary peak in August. Therefore, when our scouting results indicate a markedly different seasonal pattern of abundance (fig. 11), with a peak in April and much lower abundance during the fall months, it would appear to be a matter for further study.

First, we must consider the reliability of the estimates of abundance from our scouting results, and since in most cases a considerable amount of scouting was done, the question appears to become one of whether the areas covered by our scouting were representative of the areas being fished by the fleet. The cruises from which we have scouting data have varied considerably in length, the scouting frequently has been incidental to other operations, and the areas covered have varied considerably among cruises. However, on the cruises in February, April, June, September, October, and November scouting was the major objective and large areas were covered. This scouting extended far outside the range of the fleet, but it revealed a fairly uniform geographic distribution of schools and the results should be similar to the experience of the fleet. Also, the seasonal pattern indicated by these major cruises is supported by the scouting results of GILBERT cruises 3, 6, 8, and 12, during which scouting was incidental and much more restricted in area.

Therefore, it seems clear that our scouting results are representative, and yet they differ markedly from the trends in the commercial catch. The principal and most significant difference is the peak in abundance indicated by the April scouting, which does not correspond to a peak in the catch, and for an explanation we turn to more detailed data from the commercial fishery itself during the periods of GILBERT cruises 11 and 13 in April and June. Table 13 is a summary of data from interviews with captains obtained by the Division of Fish and Game, Board of Commissioners of Agriculture and Forestry, Territory of Hawaii. These records show that the commercial fishermen also saw slightly more schools per day during April, but these schools were mostly small fish and a much smaller percentage of them was fished by the fishermen. We suspect that they were not fished partly because they were small fish and also partly because they may have been smaller and wilder schools. In either case the fishermen are reluctant to waste bait if there is a fair possibility of encountering a big school of large fish during the next few hours. The fishermen also avoid small fish, even though they sell them for the same price per pound, because the buyers prefer the larger fish and threaten to pay less or not buy if large quantities of small fish are landed.

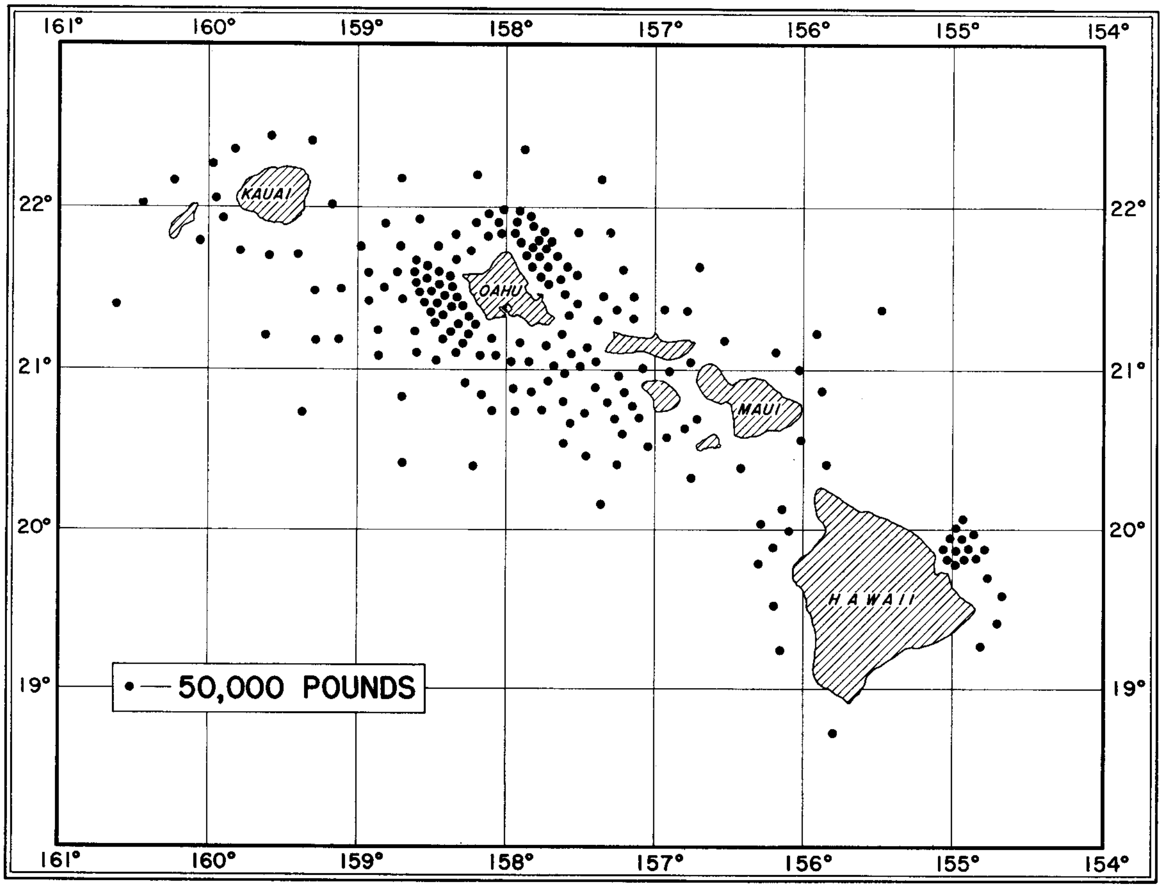

Figure 9.--Location of the average year's catch of skipjack from 1948 to 1952. Data compiled from records of the Division of Fish and Game, Board of Commissioners of Agriculture and Forestry, Territory of Hawaii.

In spite of seeing fewer schools per day in June, the fishermen were much more successful, as is indicated by the catch per day in table 13. Thus the success of the fishery depends on the size and behavior of the fish as well as their abundance, and there are seasonal cycles in all of these factors.

RESULTS OF LIVE BAIT FISHING

The amount of live bait fishing which we were able to accomplish on our cruises was limited, but in general our experience was similar to that of the commercial fishermen during the same period in that we encountered smaller fish during the spring months and larger ones during the autumn.

Table 12.--Abundance of bird flocks in relation to distance from land[1/]

Cruise	Date scouted 1953	Distance (miles)	Hours scouted	Number of flocks sighted	Number of flocks per 10-hour day
GILBERT 7	Jan. 26-Feb. 14	0 - 19	76.0	28	3.7
		20 - 39	22.0	18	8.2
		40 - 59	18.5	21	11.4
		over 60	28.5	6	2.1
GILBERT 11	Mar. 27-Apr. 29	0 - 19	60.5	52	8.6
		20 - 39	39.0	36	9.2
		40 - 59	32.0	22	6.9
		over 60	68.0	48	7.1
GILBERT 13	June 5-July 5	0 - 19	90.0	41	4.6
		20 - 39	44.0	34	7.7
		40 - 59	38.5	20	5.2
		over 60	106.0	85	8.0
Sum		0 - 19	226.5	121	5.34
		20 - 39	105.0	88	8.38
		40 - 59	89.0	63	7.08
		over 60	202.5	139	6.86

[1/] Includes incidental as well as systematic scouting results.

Live bait fishing by itself was never a major objective of the cruises. It was carried on in conjunction with tests of tuna attractants, which were usually performed in the calm leeward waters where the tuna were easy to observe. On scouting runs live bait was available only a small part of the time and it was used to sample as many schools as possible.

Our relative success in fishing schools may be judged only by the percentage of schools from which we caught fish. In no instance was our catch indicative of what might have been taken by a commercial fisherman, because we regularly stopped fishing as soon as a sample of the school was obtained. Of a total of 83 schools chummed, 36 or 43 percent were successfully fished (table 14). The failures were those which did not respond at all or which did not approach the vessel after rising to the surface for the chum. No consideration was given the number of passes made in the school or the number of fish taken. There were some variations in the percentage of success during the various cruises, but the numbers are so small that the differences are not statistically significant.

Our sampling bore out what is common knowledge among the fishermen--that the skipjack school by sizes. The length and weight frequencies of skipjack taken are given in table 15. Many of our samples are too small to be indicative of the range of sizes in the school, but in some of the schools of small fish from which adequate samples were obtained the range was as narrow as from 2-3/4 to 3-3/4 pounds (on April 28 and July 5). Other schools were more mixed, the one fished on June 8 ranging from about 2-1/4 to 9-1/2 pounds and another, on June 9, from about 1-3/4 to 12 pounds. The larger fish were always by themselves, and with an average size of about 20 pounds they commonly included a range of 10 or 12 pounds. Brock (1954) also found skipjack to school by sizes, and he reported the mean range in length of fish in a school (based on 120 school samples taken in 1950) to be 11.3 cm. compared to the range of 47 cm. for fish in the landings as a whole.

The proportion of schools of large skipjack (over 10 pounds) which we fished appears to be similar to that reported by the fishery, except during June [6], when only one of the eight schools we sampled was large. During April one of nine schools was large, and during September all of the six schools sampled were composed of large fish.

SUMMARY

Three scouting cruises of the CHARLES H. GILBERT were made in February, April, and June 1953. These were followed by three cruises of the HUGH M. SMITH in September, October, and November 1953. Cruises primarily for other purposes but on which some scouting was done were made in November and December 1952, and in late February and May 1953.

Six scouting flights were made in U. S. Navy PBY amphibian planes between November 1952 and June 1953.

Skipjack schools are located almost entirely by accompanying bird flocks, which frequently by their behavior indicate the size of schools and species of the fish. The flocks are chiefly composed of dark-colored terns and shearwaters.

Bird flocks were located up to 4 miles from the vessel, but most were seen within 2 miles. The average proportion spotted at 4 miles was only 0.2 percent of the schools estimated to be present. At 2 miles only 5.9 percent had been seen and at 1 mile 42.4 percent. Flocks were seen at nearly random bearings in the quadrants forward of the vessel.

Few were seen astern of the vessel in the spring scouting but after instructions to search astern as much as ahead, in the fall scouting the fishermen located 22 percent more flocks.

Larger bird flocks were seen at greater distances from the vessel.

Poor scouting conditions were mostly due to spray over the bridge, which interfered with the use of binoculars. Thirty-eight percent less schools per hour were seen under poor conditions than under good and none were seen beyond 2 miles under poor conditions.

The hours of the day during which most flocks were seen varied somewhat with the season. In April more were spotted between 7 and 8 a.m. and between 2 and 4 p.m.; in June most between 9 a.m. and noon; during the autumn the distribution was nearly random.

A fairly constant scouting efficiency was maintained despite frequent changes in personnel.

Airplane scouting revealed far fewer fish schools per unit of distance than vessel scouting. The principal reasons probably are the prevailing choppiness of Hawaiian waters and the difficulty of locating dark-colored birds against the background of the ocean.

Skipjack schools were more abundant northeast than southwest of the islands in April and June. In February, September, October, and November they were more abundant to the southwest, and in November none were seen in 4 days of scouting to the northeast. This suggests a seasonal migration.

The movements of schools, while being observed from the vessel, suggested in some cases a concerted movement which might lead to local abundance or scarcity, but there was no evidence of a general movement of the schools sufficient to cause a "Doppler effect".

The Hawaiian skipjack fleet obtained three-fourths of its catch from 1948 to 1952 within 20 miles of land, but both our spring and fall scouting indicated that skipjack schools were about equally abundant out several hundred miles to the limit of scouting, except for the difference between the northeast and southwest sectors, and except for a single station where on two of the three fall cruises substantially greater numbers of schools were located.

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[6] At this time the catch of the fishery was about 93 percent large fish.

This exceptional station was located in an area where oceanographic studies indicate upwelling may occur, which would enrich the water and provide more food for the skipjack. A more intensive study in this area will be made.

The seasonal peak in April of the number of schools sighted per day did not correspond with the summer peak in the catch of the fishery. This was due to a predominance in April of schools of smaller fish, which the fleet took in markedly less quantity than the fewer larger fish found in the summer months.

Forty-three percent of the fish schools which were approached and chummed with live bait came close enough to the vessel for some fish to take the hook.

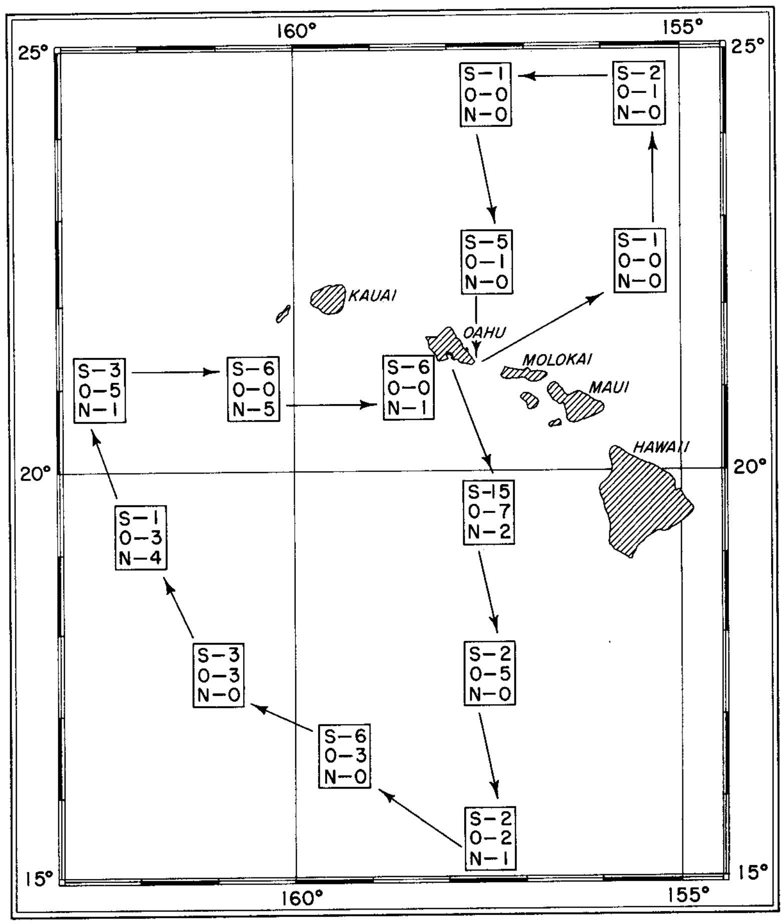

Figure 10.--Number of schools sighted on the autumn cruises of the HUGH M. SMITH. From top to bottom, cruise 22 in September, 23 in October, and 24 in November.

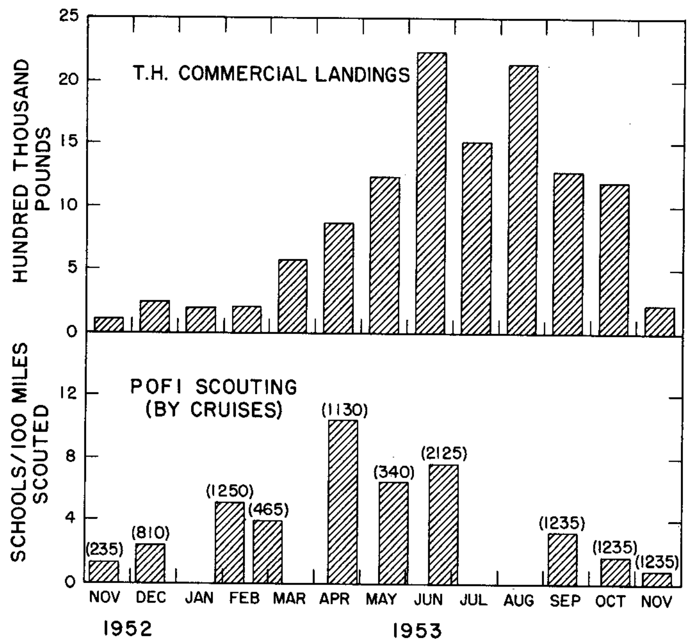

Figure 11. --Seasonal distribution of skipjack school sightings on POFI cruises compared with monthly landings of the commercial fishery. Upper--landings by months from statistics of the Division of Fish and Game, Board of Commissioners of Agriculture and Forestry, Territory of Hawaii: lower--numbers of schools sighted per 100 miles scouted, by cruises. The figures in parentheses are the total number of miles scouted on each cruise.

Table 13. --Summary of results of commercial fishing during periods of GILBERT cruises 11 and 13 1/

Period	Apr. 13-Apr. 28	June 8-July 11
Number of boat-days	18	83
Number of schools sighted but not fished		
Small fish	47	25
Large fish	3	41
Size undetermined	0	1
Total	50	67
Number of schools fished		
Small fish	13	22
Large fish	20	238
Size unrecorded	0	12
Total	33	272
Percent of schools fished	40	80
Average production per school (pounds)	1,549	2,096
Number of schools seen per day	4.6	4.0
Average catch per boat-day 2/	2,406	6,743
Percent of fish larger than 10 pounds in catch 2/	63	93

1/ From interview records provided by the Territory of Hawaii, Division of Fish and Game.

2/ Based on 41 boat-days between April 12 and May 2, and 88 boat-days between June 7 and July 11.

Table 14.--Results of live bait fishing

Cruise	Total number of schools fished	Number successes		Number failures	
		Skipjack[1]	Others	Skipjack	Others[2]
GILBERT 7	10	1	0	4	5
GILBERT 11	19	9	1	5	4
GILBERT 12	19	4	3	4	8
GILBERT 13	17	8	0	2	7
SMITH 22	16	6	4	4	2
SMITH 23[3]	2	0	0	0	2
Total	83	28	8	19	28

1/ Includes mixed schools of skipjack and other tunas.

2/ Unidentified schools, some of which may have been skipjack.

3/ The 2 schools in this cruise were chummed first with artificial bait and subsequently with live bait.

Table 15.--Length-frequencies of skipjack taken by live bait fishing (each school tabulated separately)

Length (cm.)	Corresponding weight (lbs.)	C. H. GILBERT 11									C.H. GILBERT 12				C. H. GILBERT 13								H. M. SMITH 22						C.H. GILBERT 7
		April									May	June			June						July		Sept.						February
		11	12	12	20	25	26	26	26	28	12	1	1	1	8	8	9	24	25	29	5	6	5	7	12	14	17	18	2
30	1.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
31	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
32	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
33	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
34	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
35	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
36	2.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
37	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
38	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
39	2.5	-	1	-	-	-	-	-	-	-	3	-	-	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-
40	-	-	2	-	-	-	-	3	1	2	3	-	-	-	-	-	-	1	11	-	5	2	-	-	-	-	-	-	-
41	3.0	-	4	-	-	3	-	3	-	16	8	-	-	-	-	-	-	-	13	-	24	11	-	-	-	-	-	-	-
42	-	-	7	-	-	5	-	3	-	28	11	-	1	-	-	1	-	-	21	-	25	26	-	-	-	-	-	-	-
43	-	-	1	-	-	-	-	1	-	8	-	-	1	1	-	2	-	-	6	-	6	13	-	-	-	-	-	-	-
44	-	-	-	-	-	2	-	-	-	2	-	-	1	1	-	6	1	3	3	-	-	5	-	-	-	-	-	-	-
45	4.0	-	-	-	-	-	-	-	-	-	-	1	-	1	1	5	4	4	1	-	-	1	-	-	-	-	-	-	-
46	-	-	-	-	-	-	1	-	-	-	-	3	1	1	1	16	4	8	-	-	-	1	-	-	-	-	-	-	2
47	-	-	-	-	-	-	-	-	-	-	-	1	1	2	4	14	3	6	-	-	-	-	-	-	-	-	-	-	1
48	5.0	-	-	-	-	-	-	-	-	-	-	1	-	-	2	16	8	15	-	-	-	-	-	-	-	-	-	-	-
49	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	20	5	10	-	-	-	-	-	-	-	-	-	-	-
50	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	13	6	3	-	-	-	-	-	-	-	-	-	-	-
51	6.0	-	-	4	-	-	-	-	-	-	-	-	-	-	-	9	7	1	-	-	-	-	-	-	-	-	-	-	1
52	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	7	6	1	-	-	-	-	-	-	-	-	-	-	-
53	7.0	-	-	2	-	-	1	-	-	-	-	-	-	-	-	1	2	2	-	-	-	-	-	-	-	-	-	-	-
54	-	-	-	3	-	-	1	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-
55	8.0	-	-	4	-	-	1	-	-	-	-	-	-	-	-	2	5	1	-	-	-	-	-	-	-	-	-	-	-
56	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-
57	9.0	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	2	1	-	-	-	-	-	-	-	-	-	-	-
58	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	2	3	-	-	-	-	-	-	-	-	-	-	-	-
59	10.0	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-
60	10.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-

Table 15.--Length-frequencies of skipjack taken by live bait fishing (each school tabulated separately) - Continued

Length (cm.)	Corresponding weight (lbs.)	C. H. GILBERT 11									C.H. GILBERT 12				C. H. GILBERT 13								H. M. SMITH 22						C.H. GILBERT 7
		April									May	June			June						July		Sept.						February
		11	12	12	20	25	26	26	26	28	12	1	1	1	8	8	9	24	25	29	5	6	5	7	12	14	17	18	2
61	11.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
62	12.0	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
63	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
64	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
65	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
66	15.0	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	1	-	-	-	-
67	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-	-	-	-
68	-	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	2	1	4	-	-	1	-
69	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	-	-	1	3	4	1	-	-	-
70	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	-	-	2	8	5	-	2	3	-
71	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-	6	12	10	2	1	3	-
72	20.0	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	2	32	7	6	2	3	-
73	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	3	23	4	2	1	7	-
74	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	3	21	2	2	1	19	-
75	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	7	1	1	2	8	-
76	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	1	7	-
77	25.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-
78	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	6	-
79	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-
80	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
81	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-
82	30.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
83	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
84	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
85	35.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Measured:		60	16	25	1	10	7	10	1	56	25	6	5	6	8	115	71	57	55	53	60	60	19	114	40	14	10	68	4

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APPENDIX

Cruise itineraries. The dates given are only those on which some scouting was performed.

CHARLES H. GILBERT cruise 3, 1952

November 11	Honolulu Harbor to Kaunakakai, Molokai, via Kaumalapau, Lanai. Tuna scouting and fishing enroute. Offshore work not possible because of rough seas.
November 12	Kaunakakai to Brown's Camp, Oahu, via Penguin Banks. Tuna scouting and fishing enroute.
November 13	Brown's Camp to Pearl Harbor. Tuna scouting and fishing 1-10 miles offshore between Kaena Point and Barbers Point, Oahu.

ITINERARY

CHARLES H. GILBERT cruise 6, 1952

December 9	Departed Honolulu for tuna scouting and fishing following a southerly course 1 02 miles offshore.
December 10	Tuna scouting and fishing easterly 115 miles to Kailua, and Kauna Pt., Hawaii. Night-baiting at Kailua.
December 11	Tuna scouting and fishing 2 to 10 miles offshore between Kailua and Kauna Pt., Hawaii. Night-baiting at Kealakekua Bay.
December 12	Tuna scouting and fishing 3 to 17 miles offshore between Kealakekua Bay and Kawaihae, Hawaii. Night-baiting at Kealakekua Bay.
December 13	Enroute to Hilo, Hawaii. Night-baiting at Hilo.
December 14	Tuna scouting and fishing 2 to 12 miles offshore between Hilo Bay and Cape Kumukahi, Hawaii. Night-baiting at Hilo.
December 15	Enroute to Kahului, Maui. Night-baiting at Kahului.
December 16	Enroute to Kaneohe Bay, Oahu. Night-baiting at Kaneohe Bay.
December 17	Enroute to Nawiliwili, Kauai. Night-baiting at Nawiliwili Bay.
December 18	Tuna scouting and fishing between Kauai and Niihau area. Night-baiting at Port Allen, Kauai.

CHARLES H. GILBERT cruise 7, 1953

January 26-28	Operated around Kaneohe Bay, testing scouting methods, and conducting diffusion tests of fluorescein introduced from moving vessel.
January 29-30	Scouted for fish along Kaneohe-Kahuku-Kaena shoreline of Oahu. Conducted sea tests of fluorescein-fish extract mixture; also bait tank aeration test.
February 2	Scouted part of west arm then returned to Hub II.
February 3	Scouted east arm of Area II to Kailua, Kona.
February 4	Scouted off Kailua and north to Keahole Pt. Attempted sound tests.
February 5	Scouted east arm to Hub II.
February 6	Scouted north arm of Area II to Oahu.
February 8	Scouted north arm to Hub II.
February 9-10	Scouted south arm of Area II.
February 11-13	Scouted, north, south, and east arms of Area III.
February 14	Returned to Pearl Harbor.

CHARLES H. GILBERT cruise 8, 1953

February 25	Left Waianae anchorage and sailed to Nawiliwili, Kauai. Ran from Nawiliwili to Port Allen and anchored there overnight. Mission: To test tuna attractants and to study live bait fishing techniques from the *C. H. GILBERT*.
February 26	Left Port Allen at 0640 and cruised off Kauai and Niihau throughout the day, anchoring off the lee of the island of Niihau.
February 27	Cruised throughout the day off Niihau and Kauai, starting for Pearl Harbor at dusk.
March 1	Departed Pearl Harbor for Kaumalapau, Lanai.
March 2	Left harbor on Lanai, going to Maalaea Bay on Maui to search for bait and to Lahaina, Maui.
March 3	Scouted for fish west of Lanai, tested artificial bait and hydrophone. Returned to Pearl Harbor at night.

CHARLES H. GILBERT cruise 11, 1953

March 27-28	Executed hydrographic section in Kaiwi Channel.
April 1-2	Executed hydrographic section.
April 8-9	Executed hydrographic section.
April 11-12	Scouted north arm, Area II.
April 14-15	Executed hydrographic section.
April 16-17	Scouted west arm, Area II.
April 18-19	Scouted east arm, Area II.
April 20-21	Scouted south arm, Area II.
April 22-23	Executed hydrographic section.
April 25-26	Scouted south and north arms, Area I.
April 27-28	Scouted east and west arms, Area I.
April 29-30	Executed hydrographic section.

CHARLES H. GILBERT cruise 12, 1953

May 11-13	Tested fish attractant solutions at sea.
June 1-3	Tested fish attractant solutions at sea.

CHARLES H. GILBERT cruise 13, 1953

June 4-5	Executed hydrographic section.
June 8-9	Tested chemical and visual fish attractants at sea.
June 11-12	Executed hydrographic section.
June 13-16	Scouted Area I.
June 18-19	Executed hydrographic section.
June 22-23	Scouted north and south arms, Area III.
June 24-25	Tested chemical and visual fish attractants at sea.
June 27-28	Scouted west and east arms, Area III.
June 29-30	Scouted west arm. Area II.
July 1	Scouted north arm, Area II to Honolulu.
July 3	Scouted north arm to Hub II.
July 4-6	Scouted east and south arms, Area II.
July 7-10	Scouted south and west arms, Area IV.
July 11	Scouted northward on south arm, Area II.
July 12	Returned to Pearl Harbor.

HUGH M. SMITH cruise 22, 1953

September 3-7	Scouted north and east of Oahu.
September 11-21	Scouted south and west of Oahu.

HUGH M. SMITH cruise 23, 1953

October 9-17	Scouted south and west of Oahu.
October 23-26	Scouted north and east of Oahu.

HUGH M. SMITH cruise 24, 1953

November 6-15	Scouted south and west of Oahu.
November 19-22	Scouted north and east of Oahu.