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EXPERIMENTAL TUNA PURSE SEINING IN THE CENTRAL PACIFIC

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INTRODUCTION

The general scarcity of live bait in the central Pacific limits live-bait fishing for the available stocks of surface tuna and makes it desirable to develop some alternate method of capture. Attempts to gill net skipjack in the Hawaiian Islands where there is a commercial live-bait fishery have met with little success (Matsumoto 1953). Purse-seine fishing, which accounts for about 12 percent of the California landings of tuna (Godsil 1949, page 17), was tried intensively by the Pacific Oceanic Fishery Investigations of the U. S. Fish and Wildlife Service during the period April 12, 1950, to September 15, 1951. These trials centered around the Phoenix, Line, and Hawaiian Islands (fig. 1, table 1) where surface schools of tuna are commonly found.

DESCRIPTION OF GEAR

The John R. Manning, a West Coast-type purse seiner, was used for all purse seining (fig. 2). The vessel's essential characteristics are:

Length	- 86 feet 6 inches	Beam	- 22 feet 6 inches
Depth	- 12 feet 8 inches	Cruising speed	- 7-3/4 knots
Displacement	- 237 tons		

Three purse seines were used during the John R. Manning's operations. Seine No. 1, a standard West Coast tuna net made of cotton thread in San Diego, Calif., was 360 fathoms long with a lead line measuring 340 fathoms. It had a depth of approximately 31 fathoms. The main body consisted of five strips of No. 48-thread $4\frac{1}{2}$-inch mesh, each 100 meshes deep. The lead-line strip was No. 84-thread 7-inch mesh, 50 meshes deep, and the selvage strip was No. 84-thread $4\frac{1}{2}$-inch mesh, 20

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meshes deep. The lead line was weighted with 32 4-ounce leads per fathom. The cork line contained 20 corks per fathom in the main body. This net was fished during Cruises 1 through 4, April 1950 through December 1950.

After tuna escaped repeatedly, tests showed that the lead line dropped slowly and reached a depth of only 20 fathoms. It was deemed advisable to construct the seine deeper and adjust it to sink more rapidly. Consequently, seine No. 1 was

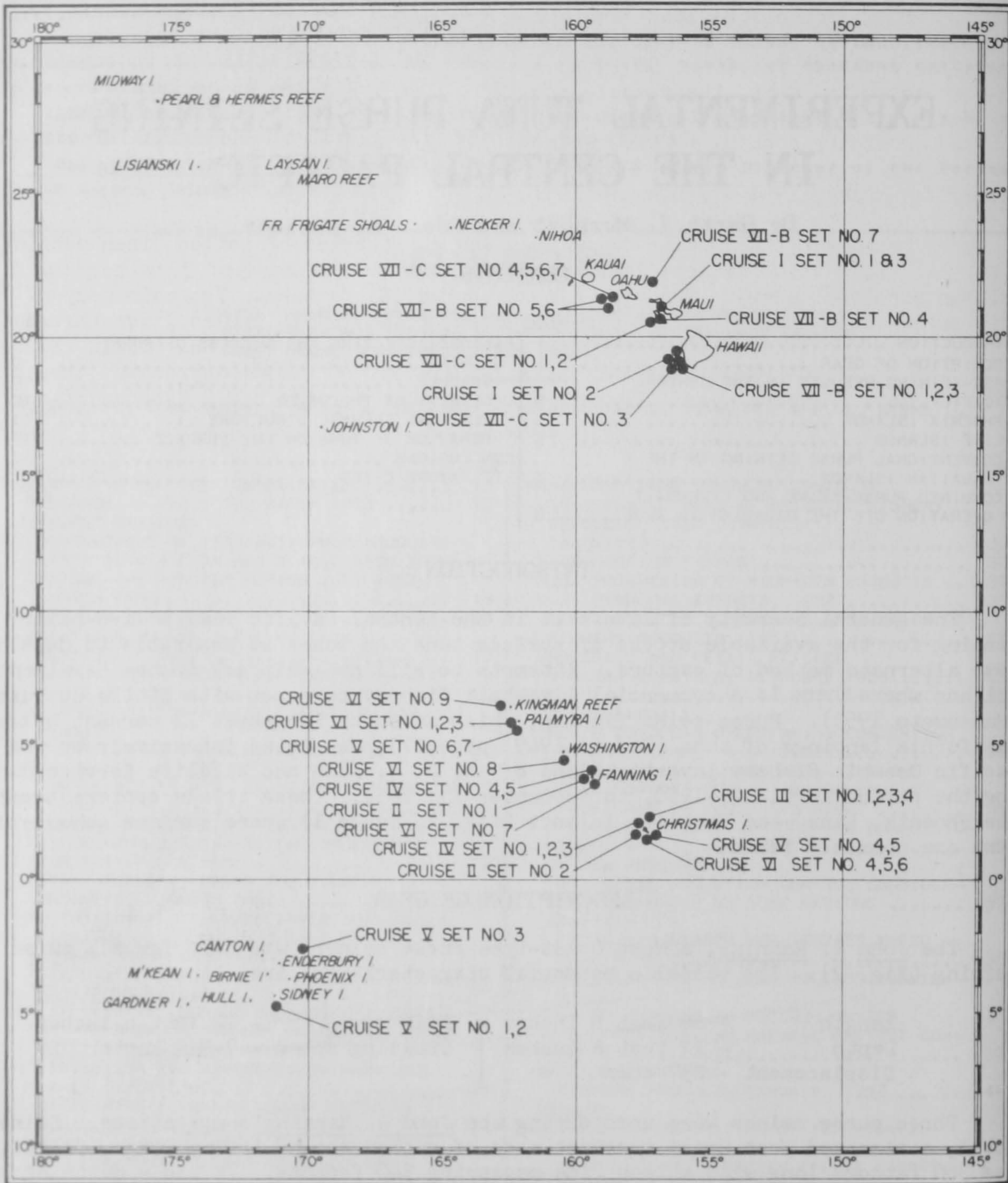

FIG. 1 - THE CENTRAL PACIFIC AREA SHOWING LOCATION OF PURSE-SEINE SETS.

modified by removing one strip of No. 48-thread $4\frac{1}{2}$-inch mesh cotton adjoining the 7-inch heavy mesh lead-line strip and substituting two strips, each 100 meshes deep, of No. 40/16 cabled linen thread, $4\frac{1}{2}$-inch mesh. The theoretical depth of this seine was thereby increased to approximately 36 fathoms. However, drop tests indicated that the modified net reached a maximum depth of only 30 fathoms so the weight on the lead line was increased to $10\frac{1}{2}$ pounds or 42 4-ounce leads per fathom. The first 50 fathoms of the seine to leave the vessel--the bow end of the net--had 44 leads per fathom for faster sinking This seine was used on cruises 5 through 7-A during the period January 1951 through June 1951.

Table 1 - Purse-seining Cruises of the *John R. Manning*

Cruise	Dates	Area
2	4/17-6/14/50	Line Islands
3	7/15-10/2/50	Line & Phoenix Is.
4	10/26-12/6/50	Line Islands
5	1/11-3/2/51	Line & Phoenix Is.
6	3/30-5/17/51	Line Islands
7-A	6/5-6/18/51	Hawaiian Islands
7-B	7/21-8/15/51	Hawaiian Islands
7-C	8/21-9/8/51	Hawaiian Islands

The third and final seine to be used was constructed of boiled linen netting (fig. 3). It was 400 fathoms long with a maximum fishing depth of 39 fathoms (46.7 fathoms stretched mesh). The lead line measured 381 fathoms. The main body of this seine was 7 strips, each 100 meshes deep, of No. 40/16 cabled linen thread $4\frac{1}{2}$-inch mesh. The lead-line strip, 50 meshes deep, was made of No. 6.5/12 cabled linen thread 7-inch mesh. The selvage strip was No. 60 medium-lay cotton thread $4\frac{1}{2}$-inch mesh, 8 meshes deep. The web was hung in the ratio of 10 fathoms of cork

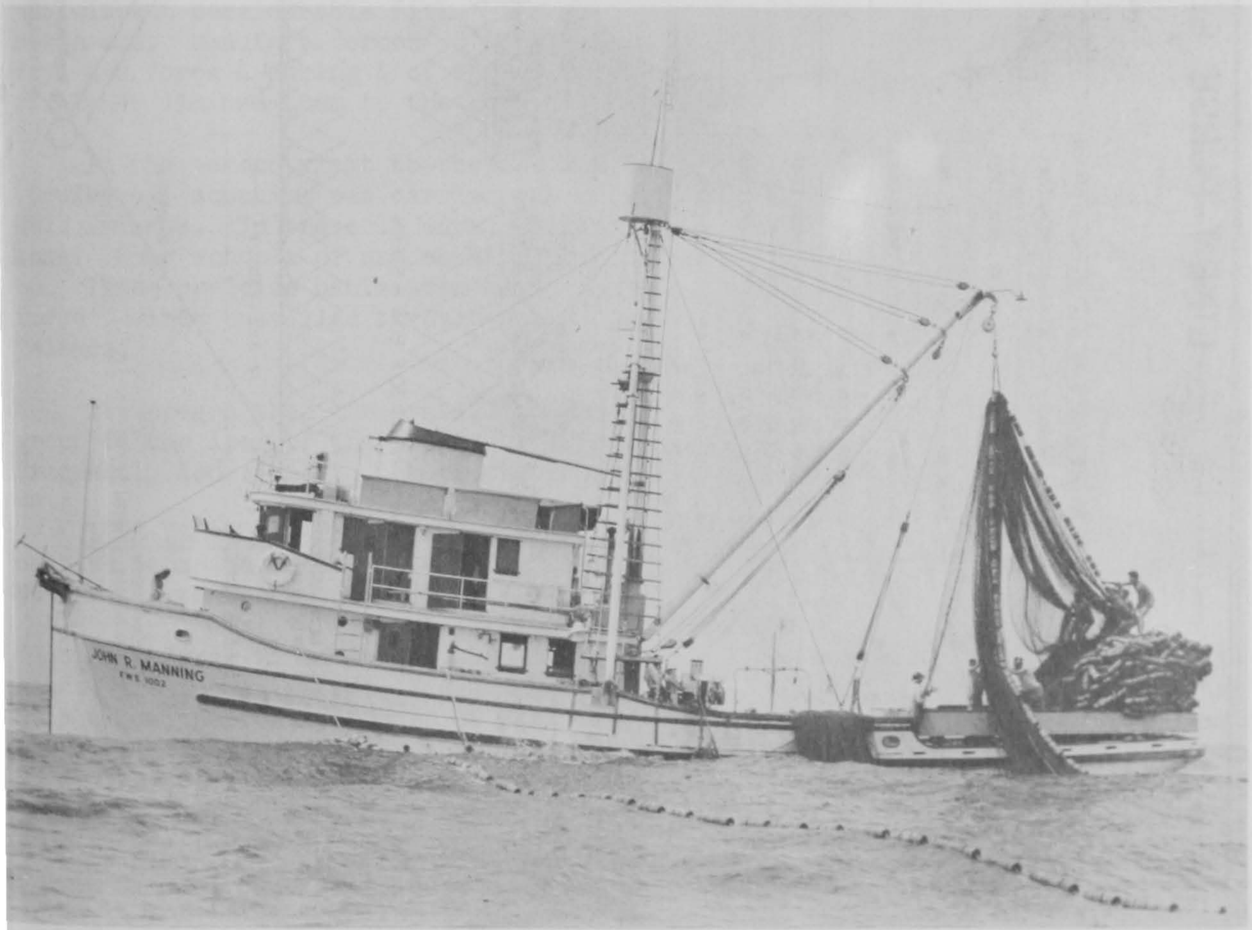

FIG. 2 - THE JOHN R. MANNING, EXPERIMENTAL PURSE SEINER OF THE PACIFIC OCEANIC FISHERY INVESTIGATIONS.

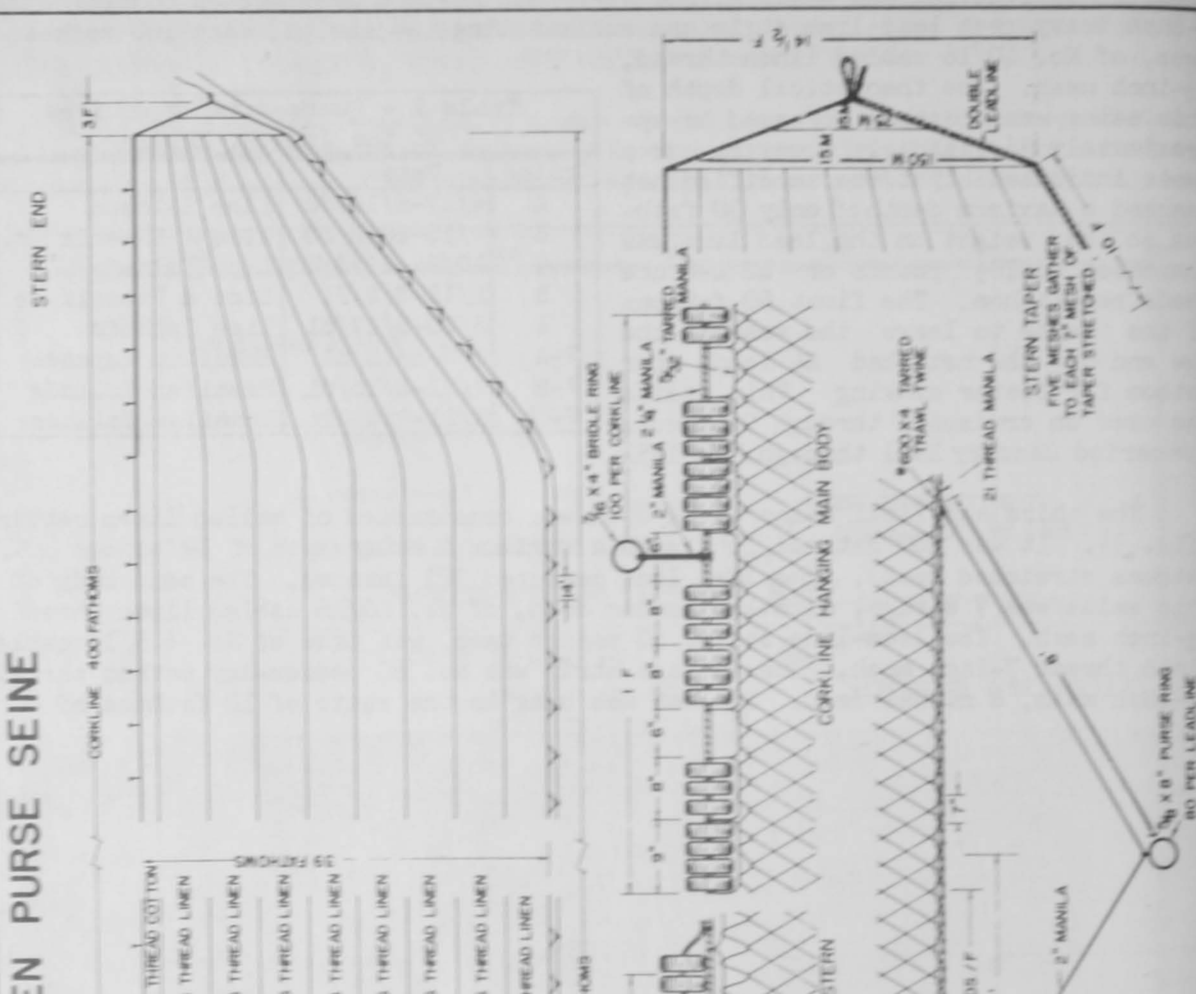

FIG. 3 - DIAGRAM OF THE LINEN PURSE SEINE USED BY THE PACIFIC OCEANIC FISHERY INVESTIGATIONS.

line to 9½ fathoms of lead line, with the exception of the stern 10 fathoms of the seine which were hung in a 10:10 ratio. Nine extra meshes per 10 fathoms of netting were allowed as slack on the cork line.

The cork line of the linen seine contained 22 6-inch diameter cork per fathom in the main body of the net. At each extremity of the seine there were 14 corks per fathom for a distance of 30 fathoms. The lead line was weighted with 17 8-ounce leads per fathom throughout. For ten fathoms on each end, the lead line was reinforced with 21-thread manila rope. The taper on the towing end of the linen seine was made in the form of a 45° angle and differed from that in the cotton seine which was in the form of a 25° angle. The breast-line hanging was essentially the same as for the cotton seine. This linen seine[1] was fished only during the final stages of the purse-seine program in the Hawaiian Islands area (July-August 1951).

PURSE-SEINING RESULTS IN THE CENTRAL PACIFIC

PHOENIX ISLANDS: The John R. Manning visited the Phoenix Islands on two occasions. During the first period, July 24 to September 1, 1950 (Cruise 3), parts of 16 days were devoted to scouting for tuna. This activity centered around the islands of Canton, Birnie, Sidney, Phoenix, Enderbury, McKean, Gardner, and Hull, and Carondelet Reef. During the 64 hours of actual scouting, 11 schools of tuna were sighted--4 of shipjack, 2 of yellowfin, and 5 unidentified. These schools either outran the vessel or were too close to coral reefs to permit setting the net without considerable risk. The greatest handicap during this period was the rough sea. Beaufort force[2] 5 or stronger winds prevailed during 18 of the 40 days and force 4 during 4 of the 40 days. This either precluded operations entirely or limited them to the lees of the islands.

In the second visit to the Phoenix Islands, January 24 to February 5, 1951 (Cruise 5), scouting was carried out at Canton, Enderbury, Phoenix, Sidney, and Hull Islands. In these 13 days, 29 hours of 9 days were devoted to searching for tuna. Four schools of unidentified tuna were sighted, but they could not be set on. Three practice hauls were made, however, during this period. Force 4 and force 5 winds prevailed through the period, limiting operations to the lees of the islands.

It appears that the prevailing high winds limit purse seining in the Phoenix group to the lees of the islands. Here schools of tuna are relatively scarce and frequently too close to the reefs for sets to be made without great hazard.

LINE ISLANDS: The purse-seining potential of the Line Islands was surveyed on five separate occasions: April 22 to June 7, 1950; September 2 to 19, 1950; November 1 to December 1, 1950; February 11 to 23, and April 5 to May 12, 1951.

From April 22 to June 7, 1950 (Cruise 2), waters adjoining the following islands were investigated: Kingman Reef, Palmyra, Washington, and Fanning. During this 47-day period, parts of 38 days--a total of 310 hours--were devoted to actual scouting for tuna. Twenty-eight schools of tuna were sighted, including 12 of yellowfin, 8 of skipjack, 5 unidentified, and 3 of mixed species. Two sets were made. On May 8, 1950, a set on a school of yellowfin off Fanning Island was un-

1/THE LINEN SEINE WAS DIFFICULT TO USE BECAUSE SKIPJACK HAD A TENDENCY TO CATCH ON THE ROUGH LINEN THREAD (FIG. 4), NECESSITATING INDIVIDUAL HANDLING OF A LARGE PORTION OF THE CATCH. SOME OF THE SKIPJACK RAISED WITH THE NET CREATED A WORKING HAZARD WHEN THEY FELL ON DECK, AND IN SO DOING FREQUENTLY BROKE THE RELATIVELY SMALL-DIAMETER LINEN TWINE. THESE PROBLEMS MIGHT HAVE BEEN LESS SERIOUS IF THE LINEN HAD BEEN TARRED, MATTING DOWN THE LOOSE FIBERS.

2/BEAUFORT FORCE IS THE STANDARD MARINE EXPRESSION OF WIND VELOCITY. FORCE 1 IS 1 TO 3 KNOTS; FORCE 2 IS 4 TO 6 KNOTS; FORCE 3 IS 7 TO 10 KNOTS; FORCE 4 IS 11 TO 16 KNOTS; FORCE 5 IS 17 TO 21 KNOTS, ETC.

successful. The second set was made off Christmas Island on May 13, 1950, on a mixed school of yellowfin and skipjack and was also unsuccessful, although fish were in the net when pursing began.

Throughout this period (April 22–June 7, 1950) the weather was generally favorable. No winds over force 4 were encountered. Chiefly force 3 and lesser winds prevailed with force 4 winds encountered only for five days.

FIG. 4 - SKIPJACK CAUGHT IN THE LINEN SEINE. AUGUST 23, 1951.

During the period September 2-19, 1950 (Cruise 3), the following islands were scouted: Jarvis, Christmas, Palmyra, and Kingman Reef. Scouting for tuna was done during 85 hours of 9 days. Sighted were 8 schools of yellowfin and 6 schools of unidentified tuna. One set was made off Christmas Island on September 9 on "breezing" tuna, but no fish were captured. Another set was made on September 10 under bird signs, and again no fish were taken. Sets were also made on September 11 and on September 12 off Christmas Island. Both of these were on yellowfin tuna and on both sets fish were still inside the net when pursing commenced, but they apparently sounded out of the net.

During this 18-day period, Beaufort force 5 winds prevailed on 4 days, force 4 on 5 days, and force 3 or less prevailed for the balance.

The John R. Manning scouted areas near Kingman Reef, Christmas, Fanning, Washington, and Palmyra islands from November 1 to December 1, 1950 (Cruise 4). During 226 hours of actual scouting distributed over 18 days, 9 schools of yellowfin tuna, 7 schools of skipjack, and 6 schools of unidentified tuna were sighted. Although most of these schools were either too close to the reefs or too elusive to permit a set, one unsuccessful attempt was made at Fanning Island on a school of yellowfin. During the set the fish sounded and escaped after pursing began. Four practice sets were made in the area.

High winds were a considerable handicap largely limiting operations to the lees of the islands. For 18 days force 5 or stronger winds prevailed; force 4 winds blew on 4 days; and lesser winds blew for 9 days.

The waters off the islands of Jarvis, Christmas, Fanning, Washington, Palmyra, and Kingman Reef were prospected February 11 to 23, 1951 (Cruise 5). During 104 hours of actual scouting, only 1 school of yellowfin, 2 of skipjack, and 2 of mixed yellowfin and skipjack were seen. Only one was large, and it could not be set on because of the proximity of the Fanning Island reef. The other schools were very small and outran the vessel. Four sets were made on this cruise, two for practice and two on milkfish (Chanos chanos). The latter two were unsuccessful.

For 6 days of the period, force 5 winds prevailed, for 5 days force 4, and for only 2 days force 3. These winds, of course, limited operations to the lees of the islands.

The final attempt at purse seining in the Line Islands (Cruise 6) was made April 5 to May 12, 1951, when waters in the vicinity of Kingman Reef, Palmyra, Fanning, Christmas, and Washington islands were explored. Parts of 28 days--208 hours--were devoted to scouting for fish. Schools sighted were 2 of yellowfin, 2 of skipjack, and 2 of unidentified tuna. Five practice sets were made--2 on visible fish, 1 under bird signs, 1 on porpoises, and 1 on fathometer indications. No fish were taken, but fish were still in the net as pursing began on the May 1 set on yellowfin off Christmas Island and the May 5 set on unidentified tuna. Evidently these fish sounded.

During this survey, force 5 or stronger winds blew on 19 days, force 4 winds blew on 7 days, and lesser winds blew on 13 days.

In summary, 5 trips distributed over one 12-month period were made to these islands (fig. 1). During these trips, 933 hours were devoted to scouting for tuna. Strong winds frequently limited operations to the small lees of the individual islands. Sighted were 75 schools of tuna, but either because of the wildness of the fish or the proximity of reefs, it was possible to set on only 8 of them. On six of these sets fish were in the circle as pursing began, but sounded out before pursing was completed. Tuna purse seining in the Line Islands, therefore, appears to be a problematical venture.

CONVENTIONAL PURSE SEINING IN THE HAWAIIAN ISLANDS: The initial survey of the Hawaiian Islands area was undertaken June 5 to June 18, 1951. During 122 hours of actual scouting, 6 schools of skipjack were located, but because of their speed and erratic behavior the *John R. Manning* was able to approach only one and this was not set on.

More extensive trials were made from July 21 to August 15, 1951. During this and subsequent cruises the linen seine was substituted for the cotton net used previously. In order to insure maximum efficiency in handling the gear, the captain, a skilled California purse-seine fisherman, was engaged for this and the subsequent tests. A total of 213 hours distributed over 23 days was devoted to scouting for tuna. This activity occurred in the lees of Hawaii, Maui, Lanai, Oahu, and Kauai, with the exception of August 14-15 when weather conditions permitted scouting off the windward (NE.) side of Oahu. Sixty schools of tuna were sighted on this cruise, and with the exception of 4 schools of yellowfin sighted off the lee of Hawaii, all were identified as skipjack. The localities of these schools are given in table 2.

Table 2 - Tuna Schools Sighted from the *John R. Manning* in the Hawaiian Islands Area, 1951

Locality	Number of Schools	Date
Lee of Hawaii	29	July 22-26
Lee of Lanai	17	July 30-Aug. 1
Lee of Oahu	7	August 5
Lee of Kauai	4	August 6-7
Lee of Oahu	2	August 9-13
52 mi. NE. Oahu	11	August 14-15

The behavior of the schools was very erratic so that even though a serious attempt was made to set on 57 of them, it was possible to "shoot" the net on only 7 schools--1 of yellowfin tuna and 6 of skipjack. Some of the 57 schools sounded on approach, some changed course so frequently it was impossible to maneuver into a setting position, some schools scattered on approach, and some merely outran the vessel. The most pertinent data on the seven sets made in Hawaiian waters are given in table 3.

COMBINED PURSE-SEINE AND LIVE-BAIT OPERATION OFF THE HAWAIIAN ISLANDS: A cruise to test the feasibility of seining Hawaiian tuna in cooperation with a live-bait boat was made August 21 to September 8, 1951. A small Honolulu sampan, the *Momi*, was engaged as a chum boat. Seven days were devoted to catching bait, 6 to fishing for tuna, and 5 to travel between baiting and fishing localities.

The fishing procedure followed a regular pattern. After locating a school, the *Momi* attempted to concentrate the fish with chum. If this was successful, her speed was reduced so that a set could be made by the *John R. Manning*. (According to Hawaiian fishermen the local skipjack will disperse despite the throwing of chum unless a speed of approximately 2 knots is maintained.) When the captain of the of the *Momi* considered that the school was concentrated and holding, he signalled the *John R. Manning* to set. The set was started at the earliest moment the vessel could maneuver into a proper downwind position from the *Momi*. During the course of the set the *Momi* cruised in a circle inside the seine, chumming continuously. When the net was pursed, the *Momi* ceased chumming, gunned her engine, then cut it off and coasted over the cork line. The rest of the operation constituted a normal purse. Eleven schools of skipjack were located during the fishing. One of these was abandoned because of rough seas, 3 did not respond to the chum, and 7 were set on.

Table 3 - Results of Conventional Purse-Seine Sets on Tuna in Hawaiian Waters, 1951

Set Number	Date	Location	Behavior of Fish
1	July 23	Lee of Hawaii	Unknown.
2	July 23	Lee of Hawaii	Sounded out of net.
3	July 24	Lee of Hawaii	Probably sounded out of net.
4	July 30	Lee of Lanai	Followed forage out of net before circle closed.
5	August 5	Lee of Oahu	Some swam out on surface before net closed. Others sounded.
6	August 10	Lee of Oahu	Probably sounded.
7	August 14	NE. of Oahu	Probably sounded.

The results of the 7 sets are given in table 4. The amounts of bait shown in the table are the actual catches less the estimated amounts lost between capture and utilization. Losses were inordinately high, chiefly because time could not be spared to rest the bait after capture. It is evident from table 4 that the chumming rate varied considerably. This came about because the chief aim was to investigate the general method, not to work out minimum chumming rates, and consequently no effort was made to economize on bait. Also there was a distinct tendency on the part of the fishermen to chum more heavily when ample bait was in the wells.

The catch for the successful sets, with the exception of the fourth and sixth, represents the entire school. On the fourth the *Momi* appeared to have held only part of the school. The school for the sixth set was completely chummed, but a large segment of the school disengaged and sounded before the net could be pursed. A number of controllable factors contributed to this: (1) there was too long a period between chumming the school and pursing the net; (2) too much tow line was let out, thus increasing the pursing time; (3) the wilder iao (*Pranesus insularum*) were used as chum instead of the nehu (*Stolephorus purpureus*) normally used. This latter species, in contrast to the iao, remains very close to the boat after being thrown in the water.

It appears that by skillful handling of both the chum boat and purse seiner entire schools of Hawaiian skipjack can be captured. With our present information it is not possible to state whether this type of fishing is economically feasible.

Table 4 - Purse Seine-Chum Boat Sets, Hawaiian Waters, 1951

Set Number	Date	Skipjack Caught (In Pounds) Manning[1]	Momi[1]	Total	Buckets[2] of Bait Used	Buckets of Bait Per Ton of Catch	Notes
1	Aug. 23	1,125	700	1,825	36	24	Entire school taken.
2	Aug. 23	810	500	1,310			
3	Aug. 26	0	0	0	10	-	Momi fouled cork line before pursing was well started and had to stop chumming. School sounded out of net.
4	Aug. 29	7,490	500	8,440	9	2	Only part of school responded to chum.
5	Sept. 2	6	0	6	7	-	Fish ceased responding to chum and sounded out of net.
6	Sept. 6	2,500	1,400	3,900	21	11	Part of school taken.
7	Sept. 8	900	700	1,600	9	6	-
Total		13,281	3,800	17,081	82[3]	10[4]	

1/THE POUNDAGE OF THE CATCH ON THE JOHN R. MANNING AND THE MOMI WAS ESTIMATED BY MULTIPLYING THE NUMBER OF FISH BY THE MEAN WEIGHT OF THE INDIVIDUAL SKIPJACK. ACCURATE COUNTS WERE NOT OBTAINED FOR THE MOMI CATCH ON SETS 1, 2, AND 4, NOR FOR THE JOHN R. MANNING ON SET 6. THE MOMI CATCH WAS MADE BY FISHERMEN WITH JIGS WHILE CHUMMING THE SCHOOL.
2/ONE BUCKET OF BAIT IS ROUGHLY 10 POUNDS.
3/BAIT USED ON SET 3 IS NOT INCLUDED.
4/IN 1948 THE HAWAIIAN FLEET AVERAGED 14 BUCKETS OF BAIT PER TON OF FISH LANDED.

In order for the operation to be profitable, the cost of producing fish in terms of capital outlay, personnel, and consumption of bait must be no higher than that experienced by the present commercial fleet. The POFI operation, being an experimental one, was expensive, but some economies appear to be possible. The most practical methods are listed below.

1. Design netting gear that can be used in rough seas in order to overcome the present restriction to the lees of the islands.

2. Design a small chum boat that can be carried and launched by the seiner when a school is sighted. Bait reserves could be carried on the seiner.

3. Economize on bait by:

   a. Reducing chumming rate to a minimum
   b. Reducing the chumming period by:

      (1) determining how long before the net is pursed chumming can cease;
      (2) reducing preset chumming to a minimum by skillful boat handling;
      (3) using the smallest possible net and fast winches to reduce pursing time (this might also reduce the capital outlay).

4. Use boat time more efficiently by:

   a. Having bait boat locate a second school while the net boat is completing a set.
   b. Providing a supply of bait so that the equipment is not held up when catching bait.

FACTORS AFFECTING THE SUCCESS OF PURSE SEINING

WEATHER: As already intimated, conventional purse seining in the central Pacific is severely handicapped by prevailing high winds. This is indicated by the prevalence of Beaufort force 4 (11 to 16 knots) or higher winds in the various island areas (table 5). According to Bigelow and Edmondson (1947), 5- to 8-foot seas are associated with force 4 winds, and 5-foot seas in our experience are near the maximum for effective use of conventional purse-seine gear. These wind conditions are compared (table 5) with those experienced off Cape San Lucas, Baja California, where force 4 winds are rarely experienced.

Strong winds particularly handicap purse-seine operations in the Hawaiian Islands area as they are most prevalent during the period when tuna are most abundant (May to October). Off the Line and Phoenix Islands winds are less severe, but nevertheless preclude any systematic effort to operate a purse seine.

Table 5 - Percentage of Force 4 or Higher Winds (From U. S. Pilot Charts for 1951)

Month	Hawaiian Islands	Cape San Lucas, Baja California	Line Islands	Phoenix Islands
Jan.	63	0	16	46
Feb.	36	0	91	41
Mar.	67	0	25	4
Apr.	29	0	22	0
May	49	0	11	0
June	82	0	41	0
July	91	0	32	15
Aug.	89	0	0	32
Sept.	84	4	94	0
Oct.	46	2	22	10
Nov.	44	0	11	55
Dec.	76	0	50	17

Because of the generally unfavorable sea and weather conditions of the central Pacific, purse seining must generally be carried on in the lees of the islands. With the exception of the Island of Hawaii, the lees are quite small, thus greatly limiting operations.

CLARITY OF THE WATER: Clarity of the water is a factor that affects the efficiency of many types of nets, e.g., gill nets. Generally, as the water becomes clearer the nets become less efficient. Increased clarity of the water might affect a purse seine by allowing the tuna to see it at a considerable distance, stimulating them to dive under the net.

Purse seines are constructed so that they belly somewhat when laid in the water. As soon as pursing is started this is accentuated so that very early in the set a shelf of webbing is formed under the vertical sections of the net. If the water were turbid so that a fish did not sight the net until it was within 10 feet of the web, a 10- or 15-foot shelf might stop it from sounding if it became panicky and dashed about at random after finding its downward path blocked. If it perceived the net at 100 feet, a shelf extending at least 100 feet into the center of the net would be needed to turn back the fish. Further, in very clear water a fish sounding and striking a shelf of netting might actually perceive the edge of the shelf and swim towards it.

There are few data available on the relative turbidity of the Central Pacific and West Coast of North America, but according to Jerlof (1951) surface transmission of blue light was 76 percent per meter south of the Galapagos Islands and 92 percent per meter south of the Hawaiian Islands. This unit is not particularly meaningful for purposes of comparison because light intensity decreases logarithmically with distance. More useful is the extinction coefficient (Sverdrup et al 1949, p. 82), which is a linear measure of water clarity. The extinction coefficient for Jerlof's Galapagos station is 0.0833, and for the Hawaiian station 0.2754. In other words, the water south of the Galapogos is about 3.3 times as turbid as water south of the Hawaiian Islands. Therefore, a fish could theoretically see a net 3-1/3 times as far in Hawaiian waters.

On the other hand, tuna may not become alarmed and sound wildly on sighting a net. They may simply swim to it and follow it down to the lead line like sheep following a fence. In this event water clarity would have little effect on the efficiency of a purse seine because, unless the fish were motionless, the differenc in time (during which pursing might be proceeding) between the perceiving of the net at 100 feet and at 30 feet would be inconsequential.

Skipjack tuna are not inherently "afraid" of a boat or net, for schools of skipjack have been observed swimming close alongside our vessels. Whether this occurs in those rare instances when the course of the vessel and the course of the school coincide, or is the result of a definite attraction, has not been determined. Further, when skipjack were pursuing the live-bait chum, they were observed swimming or foraging within a foot or two of the net without showing alarm. They would even swim by the unclosed gap in the purse seine and within 15 feet of the boat with its throbbing machinery without showing alarm or attempting to escape.

These observations lead to the conclusion that tuna leave a purse seine not because of inherent fear of foreign bodies in the water, but rather because on encountering a wall of netting in their course they simply avoid the obstacle by diving under it. If this is true, perhaps purse-seine sets are not particularly successful unless some other factor prevents the fish from diving under the net.

VERTICAL THERMAL STRUCTURE: It is entirely possible that the vertical temperature structure of the water can influence the success of a purse-seine set, for if the lead line extends into cold water, yellowfin tuna and skipjack might be deterred from sounding out of the net.

The experimental sets in the Central Pacific have shown rather conclusively that tuna, even when corralled by the net, readily and quickly sound out of it. This occurred even when tuna were seen in the net several minutes after pursing began. Observations on the purse seines used by POFI showed that the lead line reached a depth of approximately 200 feet. At this depth the water in the Central Pacific, including Hawaiian waters, is generally only 2° to 5° F. cooler than the surface water temperature of about 80° F. It is difficult to imagine this temperature difference and the high absolute temperatures at the lead line acting to prevent fish from sounding out of the net. In contrast, bathythermograms from off Cape San Lucas, Las Tres Marias, and San Benedicto Island (West Coast purse-seine grounds) having surface temperatures from 74° to 87° F., show a 4° to 22° differential between the surface and 200 feet. In this area not only the difference between surface and lead line but the low temperature at 200 feet might frequently act as a deterrent to sounding out of the net.

Breder (1951) found that *Jenkinsia stolifera* reacted very positively to a temperature gradient; the fish, even when frightened, turned back when they encountered a particular temperature. Sounding tuna might well react in a similar manner, particularly if they were not under a strong stimulus such as fright, and there is reason to believe tuna are not greatly alarmed by the net.

BEHAVIOR OF TUNA ON THE SURFACE: The rapid, erratic swimming of tuna schools in the Central Pacific, particularly of the Hawaiian skipjack, has already been noted. Since the same species tend to swim slowly and are readily caught off Central America, there must be some factor in the Central Pacific environment that accounts for their behavior.

It is possible that the behavior of tuna while feeding is in large part a function of the behavior of their forage. It has been observed on the west coast of Central America that forage fishes will frequently "ball up" into a compact mass when attacked by tuna. This tends to produce a relatively stationary school of fish, an easy prey for a purse seiner. This sort of behavior has never been observed in the Central Pacific to the knowledge of the writers. The local forage species when attacked flee rapidly as a school or scatter with the tunas in pursuit.

Further evidence that forage-fish behavior controls tuna behavior on the feeding grounds is afforded by the behavior of the skipjack when the purse seiner-chum boat combination was used to capture them. By the simple expedient of introducing the docile nehu, a species not normally found where tuna are feeding, the behavior of the skipjack is markedly changed. The speed of the schools can be slowed to 2 knots and they can be led into a circle inside a purse seine, all in response to a different food supply.

Reintjes and King (1953) have shown that yellowfin tuna in the Central Pacific are rarely gorged. The average volume of the stomach contents is such that the fish may have to forage rather constantly in order to obtain an adequate daily ration. Presumably this would result in continuous movement of the tuna schools.

CONCLUSIONS

Tuna purse seining shows little promise of success in Central Pacific waters. On our trials we found that:

1. The area and period of operations were greatly limited by prevailing wind and sea. Even in the lees of the islands operations were hindered by the coral reefs and the few schools present.

2. The tuna schools swam wildly and rapidly, frequently outrunning the vessel, and of course making it extremely difficult to set on them.

3. Tuna surrounded in the conventional manner dove under the seine. These tuna may do this easier than off the American coast because the water is much clearer and also warm to a greater depth. Cold water which might be a barrier to sounding, occurs below the lead line of even an extra-deep seine in the Central Pacific.

4. Live-bait chum would hold a tuna school while it was being surrounded by the purse seine. Small, but apparently entire schools, were captured in this way. Commercial operation in this manner is questionable because there is no proof that this method--using an expensive purse seine--would catch more tuna than pole-and-line fishing with live bait.

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