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Fish Bulletin No. 33. Fishing Methods for the Bluefin Tuna (Thunnus thynnus) and an Analysis of the Catches

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FISH BULLETIN No. 33
Fishing Methods for the Bluefin Tuna (Thunnus thynnus) and an Analysis of the Catches

By

S. S. WHITEHEAD

Contribution No. 110 from the California State Fisheries Laboratory

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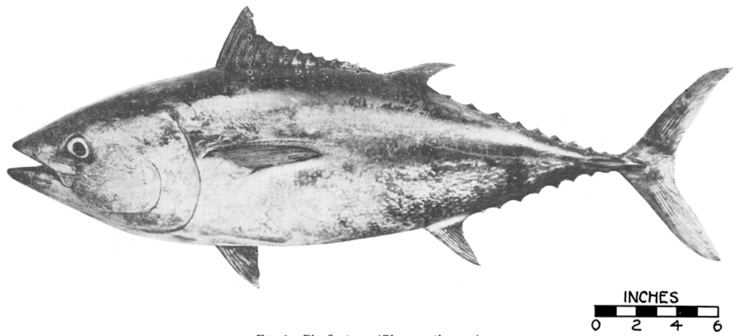

FIG. 1. Bluefin tuna (*Thunnus thynnus*).

FIG. 1. Bluefin tuna (Thunnus thynnus)

1. INTRODUCTION

California is unusually fortunate because among her varied natural resources she has a large marine fish population in the waters along her thousand-mile coast line. Her ocean fisheries rank near the top in the natural wealth of the state.

The value derived from the possession of an extensive fish population of varied species can not be expressed wholly by a monetary standard. Besides supplying food, the fisheries of California have afforded recreation to the people of the state and nation, for every year thousands enjoy the privilege of catching marine fish at the surf or out on the ocean in boats.

The people of California should know the magnitude of their fisheries and to what extent they are being utilized. If a species is being depleted it should be given protection by efficient legislation. It is equally important to know which of the fisheries has no need of protection, so that legislation will not be passed which would hinder the efficient use of that fishery. The following report of the investigation of the bluefin tuna (Thunnus thynnus) has been written to advise the people of California as to this fishery.

The report is divided into three parts: (1) general information about the species, (2) description of the gear and fishing methods of the commercial fishermen, and (3) description of the analysis of boat catches.

The writer wishes to acknowledge his indebtedness to the bluefin tuna fishermen of San Pedro who kindly explained their fishing methods; to Mr. W. L. Scofield, Director of the California State Fisheries Laboratory; to Professor Holbrook Working of Stanford University; and to members of the staff of the California State Fisheries Laboratory, who aided with their constructive criticism the preparation of this report.

No tables substantiating the graphs have been included in this report, but the data are on file at the California State Fisheries Laboratory and are accessible to anyone interested.

December, 1930.

2. GENERAL INFORMATION ABOUT THE SPECIES

2.1. A REVIEW OF PREVIOUS KNOWLEDGE

Some claim that Thunnus thynnus has a world-wide distribution, being found off the coast of Europe, along the east coast of the United States, off California and Lower California, and around Japan. However, other systematists contend that this species is confined only to Europe, and that the tunas of the other regions are of different species. While we have no definite evidence to support the assumption that

Thunnus thynnus is world-wide in distribution, we also have no positive evidence that it is broken up into closely allied species. Though Jordan and Evermann (California Academy of Sciences, Occasional Papers, no. 12, 1926) attempt to differentiate between the European fish and the California species by the longer pectorals of the latter, they throw doubt upon their work by saying, "It (Thunnus saliens) seems to be nearer the European species than the tunny of the Western Atlantic (secundodorsalis), if, indeed, all three are not forms of the same one, the variations due to defects of the artists rather than to peculiarities of the fish." Because of the uncertainty of the validity of this work of Jordan and Evermann, the Division of Fish and Game of California continues to consider the bluefin tuna caught on the north Pacific coast as Thunnus thynnus.

Although the range of bluefin tuna on the Pacific coast is from Lower California (Mexico) to Oregon, the range of commercial activities has been only from Guadalupe Island to Santa Cruz Island. While catches were made at Guadalupe Island (off Mexico) in the 1930 season, in previous years catches were made only in the region from Santa Cruz Island to the California-Mexican boundary line. (See fig. 2 for the 1930 fishing areas of the California fishermen.)

Even though the range in the size of bluefin tuna is from 20 to 250 pounds, most of the commercial catch is made up of fish of 100 pounds or less. The largest fish are caught by the sport fishermen with sport fishing tackle. One bluefin caught by a sportsman in 1908 off Santa Catalina Island weighed 251 pounds, and only once since then has any fish been recorded that weighed more than 200 pounds.

The bluefin generally appear in southern California waters about the first of June, are most plentiful in July, and usually leave between September and November. In some years they arrive around San Diego first, but in other years they first appear in the San Pedro area.

Little is known of the life history of the bluefin tuna. We know that they do not spawn in southern California waters during the fishing season (June to November, inclusive) because at this time the ovaries show no indication of maturity. While we know that the bluefin must spawn sometime between December and May, we do not know where.

2.2. SPORT ANGLING

From the earliest times man has fished for both food and pleasure. As there were many species of fish that were suitable both for food and sport in California waters, it was not exceptional that the early settlers exploited the fish for sport. As early as 1886, a man at Santa Catalina Island took passengers for hire in a dory and rowed by hand to the fishing grounds near the town of Avalon. Bluefin tuna was one of the species that all anglers were anxious to catch. At this early date (1886) and until the early 1900's bluefin tuna could be caught with hand or troll lines. Since 1900, the tuna have become more difficult to catch on the plain trolling tackle.

In 1909, George Farnsworth of Santa Catalina originated an ingenious method of jumping the bait which was very successful. This method was the use of a kite to hold the hook, baited with a flying fish, at the surface of the water so that the bait would appear lifelike.<

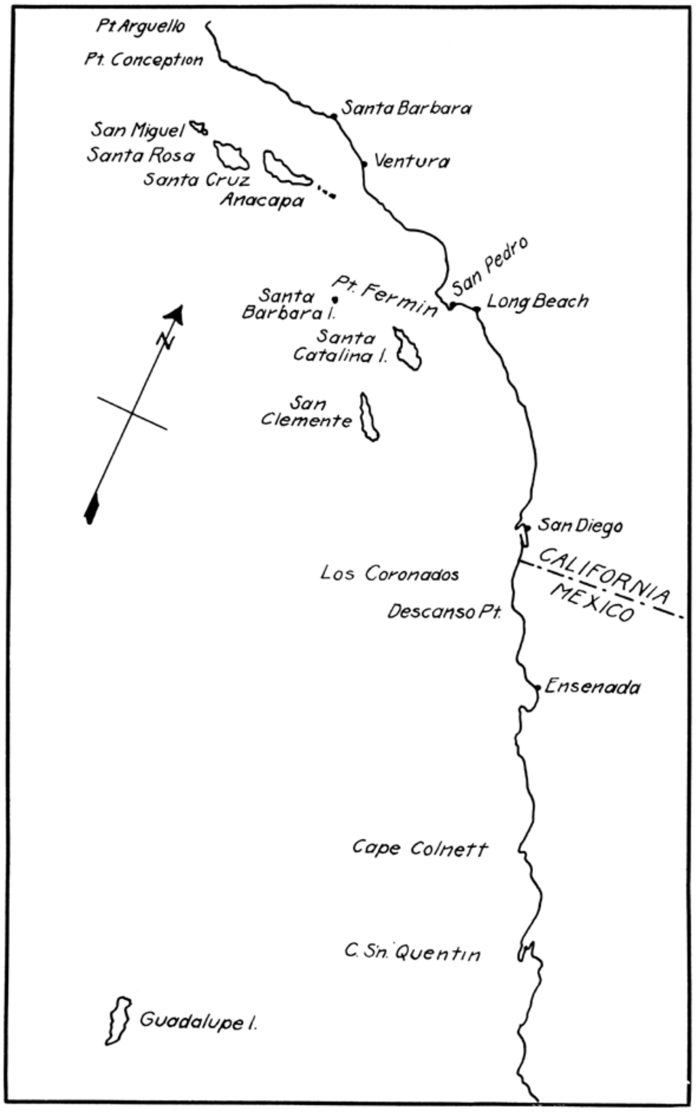

FIG. 2. Areas fished by the bluefin tuna boats in the 1930 season.

FIG. 2. Areas fished by the bluefin tuna boats in the 1930 season

The following description of gear used is quoted from "Fishing at Santa Catalina Island: Its development and methods," by Dwight D. French (California Fish and Game, vol. 2, p. 15–16, 1916): “Two persons are required in the use of the kite, the boatman manipulating the boat and kite, the angler the bait. From 500 to 1000 feet of kite line are necessary. The method of putting out the kite is as follows: The boatman puts the kite in the air and plays out about 200 feet of line or more, as circumstances require; a similar cord from ten to twenty feet in length is then tied to the kite line and to the free end of this cord is tied a short piece of line that will break at about twelve pounds strain. The end of this line is then fastened to the wire leader of the angler's line. The boatman and angler then play out line together. In this manner the bait can be carried to any distance from that boat that is desired, the kite holding all lines clear of the water and allowing only the bait to touch the surface. On hooking a fish the light line between the kite line and the angler's line breaks, thus letting the angler free to fight the fish and the boatman to reel in the kite.” “"No glue is used in these kites, consequently they are little affected by water. Two kites are necessary, one that can be used in a heavy wind, and one that can be flown in a very light breeze or by the speed of the boat alone. These kites must be so constructed and have such lifting powers that the bait is seldom raised more than three feet above the surface of the water.” “"With experience this bait can be made to skip and jump in the school of tuna, and to all appearances to act as if it were making frantic efforts to escape. The skipping is accomplished by raising and lowering the rod in a jerky manner. Tuna seem unable to resist these actions of the bait and often three or four will make their lightning-like strike for it. It matters not whether the bait is on the surface of the water or three feet above, they seem possessed with the mad desire to have the bait."”

Relatively few people angle for bluefin tuna because the necessary equipment is too expensive. The launch and the experienced boatman, who maneuvers the boat and flies the kite, are generally hired by the day or week, and very few of the mass of anglers have the means to hire the boat and equipment. The number of people angling for bluefin tuna can not be compared with the thousands of people that fish for barracuda, mackerel, bonito and halibut on the pleasure barges and smaller boats.

2.3. COMMERCIAL FISHING

Prior to 1918 the commercial catch of bluefin was negligible, for the fishermen had not found a method of fishing by which they could catch the fish in large enough quantities to pay for the trip. While kite fishing was successful for the sportsmen, it would not pay commercially.

Bluefin tuna congregate in schools of considerable numbers of individuals so that if they would not bite on a hook voluntarily they might be impounded within a net involuntarily. In 1915 the purse seine (described later), a net which impounds the fish, was being used on other species with success, consequently this gear was tried for bluefin tuna and found to be very successful. In 1918, about 6,000,000 pounds were caught and in 1919 approximately 15,000,000 pounds. Figure 3 presents graphically the commercial bluefin catch since 1919.

The high catch of 1919 was probably due to two factors: a great war-time demand, and an exceedingly abundant supply of fish available to the fishermen. In 1921 the low catch was the result of the post-war slump and possibly a decrease in the availability of fish. At this time (1921 and 1922) many boat owners went bankrupt or left southern California waters for other fishing grounds because the cost of catching the fish was too high. There were two reasons for the high cost: (1) A decrease in demand caused a similar decrease in price, and (2) the price of supplies the fishermen used did not decrease proportionately with the price of fish. After 1923 economic conditions improved, and the increased demand for bluefin tuna made the fishing more profitable.

The greatest part of the bluefin catch is landed at San Pedro and Long Beach. In 1922 a few of the San Pedro boats landed some of their catches at San Diego. From then on the boats continued delivering occasional catches to San Diego canneries, especially when the bluefin were caught in that vicinity, but all the bluefin boats make Los Angeles Harbor their home port.

With the exception of a small amount sold in the fresh state, the majority of the bluefin is canned in half-pound cans, with small quantities being put in quarter-pound and one-pound cans. Canned bluefin tuna sells under different trade names, such as light meat tuna, bluefin tuna, and sometimes tonno.

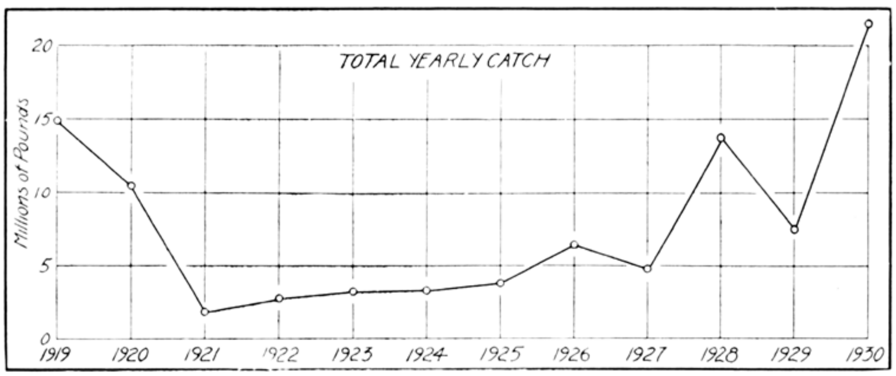

FIG. 3. Annual bluefin tuna catch in California. Although the point for 1930 was plotted from catches made through August, very few fish were delivered after September.

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3. DESCRIPTION OF GEAR AND FISHING METHODS OF THE COMMERCIAL FISHERMEN

3.1. BOATS

3.1.1. Description

All of the boats used in catching bluefin tuna have the same characteristics, namely: they carry the net at the stern of the boat on a turntable, and lay out and pull in the net in the same manner. The only major difference between the boats is their size which varies from 54 to 85 feet in length. Most of the boats that have been built since 1928 are more than 70 feet long.

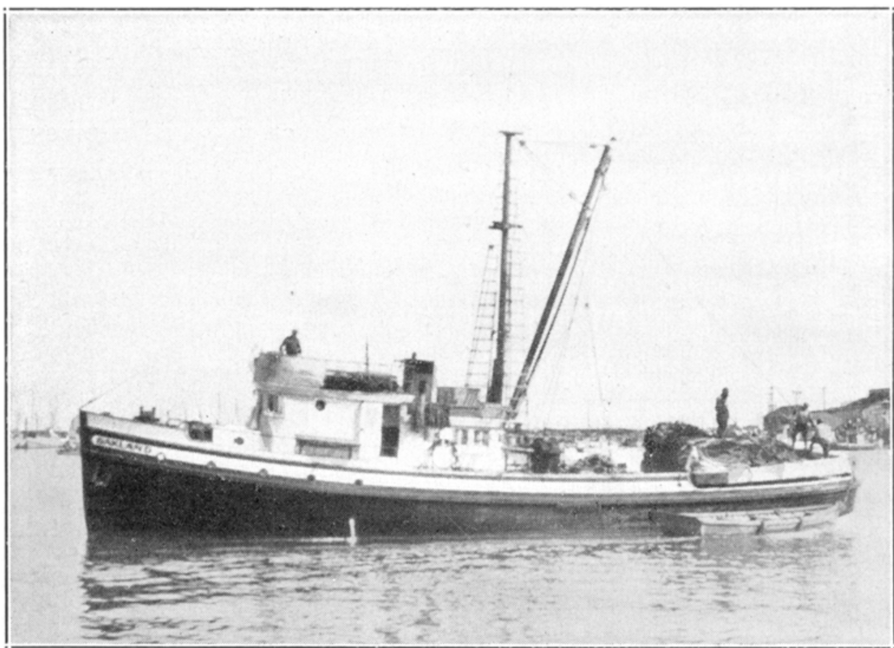

FIG. 4. A bluefin tuna boat of the larger type. 1930. Photo by R. S. Croker.

FIG. 4. A bluefin tuna boat of the larger type. 1930. Photo by R. S. Croker

Figures 5 and 6 are drawings of the deck plan and side elevation of a typical purse seine boat 75 feet long and 18½ feet wide.

The crew's quarters are located in the bow of the boat under the fore deck, which is 2 feet higher than the main deck. The hatch just forward of the wheelhouse, and the portholes on the side of the bow, are the sources of light and ventilation for the quarters.

The engine (180-horsepower Diesel) together with the auxiliary machinery such as a small gas engine, electric generator, and pumps, is in a separate compartment or room aft of the crew's quarters. The engine room may be entered either through a door in the bulkhead separating the crew's quarters from the engine room or down through a passageway from the main deck.

Full engine controls, a pilot wheel, and an accurate compass are installed in the wheelhouse, which is 13 feet back from the bow. The

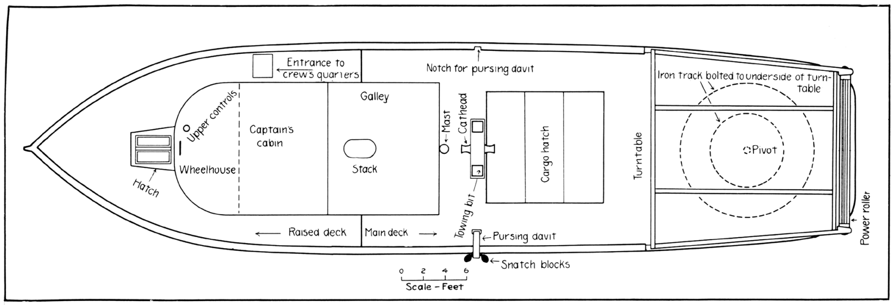

Fig. 5. Deck plan of a typical purse seine boat.

FIG. 5. Deck plan of a typical purse seine boat

captain's cabin, containing two bunks, is immediately aft, and is entered by an inside door from the wheelhouse.

Another set of controls and a wheel are built on top of the wheelhouse (bridge) as shown in figures 5 and 6. The boat is operated from here while scouting for fish and during the making of the haul. In fact, the controls in the wheelhouse are only used during rough weather or when an accurate compass is needed to keep the boat on the course.

Cooking is done in the galley, which is on the main deck aft of the captain's cabin. The crew eat and lounge in here when it is too uncomfortable out on deck.

A mast and boom, used in hauling the net and loading and unloading the fish, are built up against the back end of the galley. Unlike those on sailing vessels the masts do not extend down through the deck to the keel. The "crow's nest," a pipe frame covered on the front side with canvas, back left open, bottom a wooden platform, used in scouting for schools of fish, is built at the top of the mast. (See fig. 6.)

Two snatch blocks (see fig. 5) fastened on a straight wooden davit and a winch are used in drawing the bottom of the net together (pursing) after the circle is made. Position of the winch and the pursing davit can be seen in figure 5. The two towing bits are used to support the two catheads which are connected by a steel shaft with a sprocket in the center. Power is applied to the catheads by a chain connecting the cathead sprocket to another sprocket driven from the engine. A control is arranged on deck so that the sprockets may be engaged or disengaged without going down into the engine room to do it. By taking three or four wraps of the line around a cathead and pulling on the free end of the line, enough power can be exerted to purse the net quickly or unload the cargo of fish. Each end of the purse line is passed through a snatch block in order to reduce the friction as the line passes over the side of the boat. The position of the davit and snatch blocks may be seen in figure 5. The lower end of the davit is placed in a socket on deck, one and a half feet from the side of the boat, and then fitted in the notch cut in the top of the guard railing. The davit is made long enough so that when put in position the blocks will clear the railings. A wooden brace (not shown in the figures) runs from a notch in the upper end of the davit to another notch at the deck in one of the winch timbers. The brace is necessary to keep the davit from slipping out of position while pursing.

The hold for the stowage of fish takes up the rest of the space under the decks from the engine room aft where 100 tons of uniced fish or 75 tons of iced fish can be stowed. Boxes or compartments with removable sides which hold from 3 to 7 tons of fish each, are built throughout the hold. These compartments are used mainly when the fish are iced. Fish are put into the hold through the cargo hatch as shown in figure 5.

The turntable (see fig. 5) which is four feet aft of the cargo hatch, not only carries the net but expedites its handling. In the process of making the haul, the power roller is used as an aid in pulling the net up on the turntable. The roller is a foot in diameter with strips of hardwood fastened along its length to increase the friction as the net is pulled on board. The side opposite the power roller is one foot high and four inches thick, while the two adjacent sides, also four inches thick, increase in height to two feet at the ends that form the bearings for the power roller. Two circular tracks, as shown by the dotted lines in figure 5, and the pivot are bolted to the underside of the bottom which is made of two-inch planks. Sets of rollers to fit the tracks and a socket to fit the pivot are mounted on the deck of the boat so that the turntable can be easily turned yet remain rigid. Power for the roller is furnished with a shaft which is mounted along the guard rail and is connected to the winch by a chain that runs from a sprocket on the shaft to a sprocket on one of the catheads. By revolving the turntable a quarter of a turn, one of the ends of the power roller can be connected to the power shaft by means of a universal joint. When the net is not being piled the sprocket is removed from the cathead and the chain tied up to one side.

3.1.2. Engines

Prior to 1922 all of the purse seine boats were powered with gasoline engines. In 1922 one or two boat captains tried diesel engines and found them very successful. Since then all new boats and several old boats have installed diesels. The chief advantage of the diesel engine over the gasoline engine is the economy of operation, as cheap

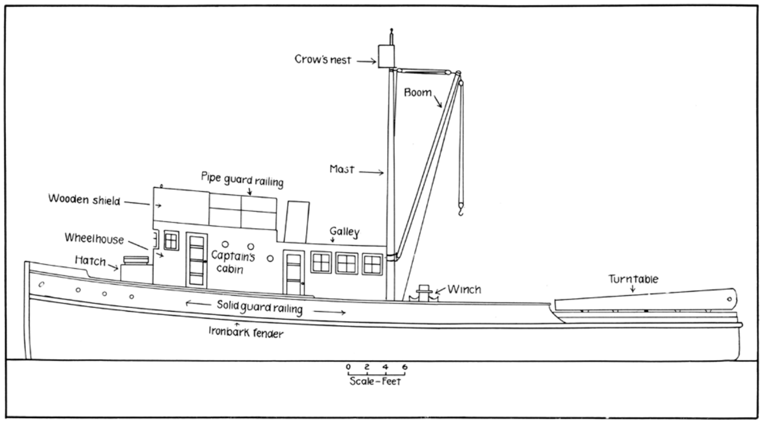

Fig. 6. Side elevation of a typical purse seine boat.

FIG. 6. Side elevation of a typical purse seine boat

crude oil may be used instead of the more expensive gasoline or distillate. It costs about one-tenth as much to operate a diesel as it does for a gasoline engine of equal horsepower. Moreover, crude oil as a fuel greatly reduces the fire hazard since it is much less inflammable than gasoline.

At present (1930) there are about 6 gasoline engines and over 75 diesels in purse seine boats. The boats using gasoline engines are 55 to 60 feet long and are powered with 45- to 65-horsepower engines. Boats using crude oil as fuel range from 60 to 85 feet long and have 90- to 225-horsepower engines.

3.1.3. Insulation of the Holds

The holds are not insulated in the majority of the purse seine boats. Uninsulated boats depend upon the deck, the hull of the boat, and the bulkhead between the hold and the engine room, to exclude the warm air from the hold. Since ice melts quickly in an uninsulated hold, the fish can not be kept very long without spoiling. The holds of a few of the large purse seine boats are insulated by lining the underside of the deck, the inside of the hull around the hold and the bulkhead separating the hold from the engine room, with slabs of ground cork dipped in asphalt.

3.2. NETS

3.2.1. General Description of a Purse Seine

A purse seine when stretched out has the appearance of a long, shallow blanket of 4- to 7-inch mesh webbing. The top of the net is buoyed by corks strung on a strong rope (cork line) which is fastened to the webbing. The cork line is looped at each of the upper corners of the net and then fastened along the ends of the webbing. Some fishermen call the continuation of the cork line, on which corks are not strung, the "up-and-down" lines. A light rope, strung with lead sinkers (lead line), is fastened to the bottom of the net. Purse rings are fastened at regular intervals along the lead line with short ropes called "bridle" lines. The purse line, which is used in drawing the bottom of the net together (pursing), passes through each of the purse rings. Each end of the purse line is tied to the loop at the upper corners of the net. During the haul it is necessary to lift the lead line to the cork line by pulling up a line (brail line) which is fastened at the bottom of the net and passed through rings that are attached to the up-and-down lines. (See figs. 7a.) This process is called brailing. One end of the net (skiff end) is tied to the skiff with a heavy line 12 fathoms long that is tied to the loop at the upper corner of the webbing. The other end of the net (haul end) is tied to the boat with a heavy line, 100 fathoms long, that is fastened to the other loop. (See fig. 7b, which is a sketch to scale of the purse seine, purse seine boat and skiff.) The landing bag is always at the haul end of the net.

3.2.2. Size of Nets

In 1929 the bluefin nets were from 275 to 350 fathoms long and 28 to 34 fathoms deep. About 1922[1] the nets were approximately 250 to 290 fathoms long and 25 to 30 fathoms deep.

[1] Skogsberg, Tage. Preliminary investigation of the purse seine industry of southern California. California Fish and Game Commission, Fish Bull. no. 9, p. 88, 1925.

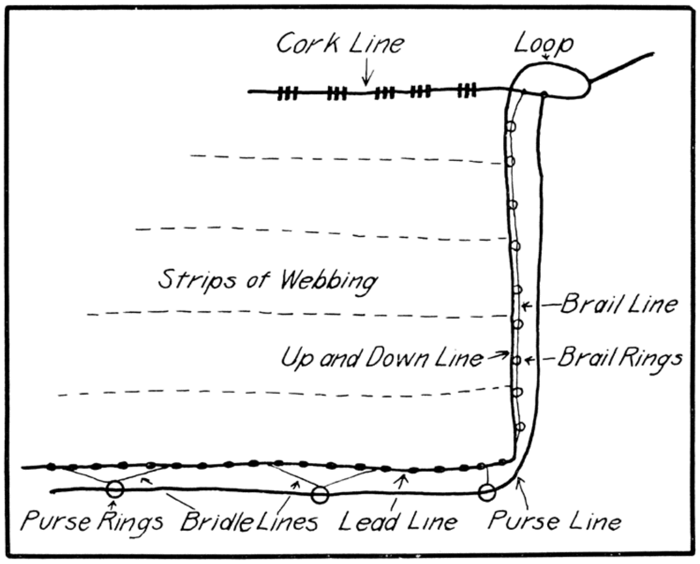

FIG. 7a. A sketch (not drawn to scale) of the end of a purse seine showing the relative positions of the different lines and rings. The brail and the purse lines and either the haul or the skiff line are tied to the loop

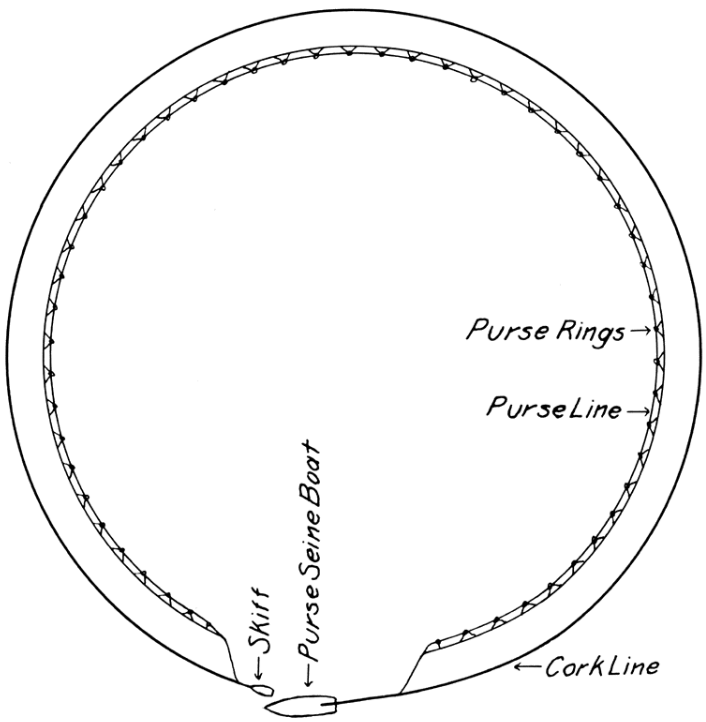

FIG. 7b. Diagram showing the relative sizes of the net, purse seine boat and skiff

3.2.3. Webbing

The web (material which impounds the fish) of the net is generally made up of five horizontal strips, which when laced together, form a large rectangle. Before the new strips are combined they are tarred to protect the webbing from fish slime which rots unprotected webbing very quickly. About thirteen barrels of tar are used for a 350-fathom seine. In putting the strips together, much skill is required especially for two strips of different size mesh. The strips must hang evenly from end to end, not hang full in one place and tight in another. The fact that the small mesh webbing shrinks more than the large mesh during the first few weeks of use must also be taken into consideration when the net is constructed.

3.2.4. Size of Mesh

The size of mesh of the webbing is quite variable in nets used for bluefin tuna. If the net is to be used exclusively for bluefin and yellowfin, the mesh at the top of the net may be 6 or 7 inches (stretched mesh). However, if the net is also to be used for skipjack and bonito, the size of mesh at the top must be about 4½ inches. Too many bonito and skipjack would gill if 6- or 7-inch mesh were used in the two top strips because their head would slip through the mesh and become entangled. Although the mesh of bluefin and yellowfin nets is fairly uniform, it has a tendency to be larger at the bottom than at the top. In a net with 4½-inch mesh webbing for the top strip, the mesh size of each lower strip increases to 6 or 8 inches in the bottom strip. Fishermen use the largest size practicable, because they find that the larger the mesh is the more easily the net is handled. There is no standardization of mesh sizes as each net owner has his own ideas about the size of mesh and combination of the strips.

The webbing of the net is made of cotton seine twine, manufactured in the United States. Most of the webbing of the 6-inch mesh is made of No. 48 twine, while the 4- and 5-inch mesh is made of No. 36 to 48 twine. (The number of twine corresponds to the number of threads used in the making.) As a bluefin seine is made of heavy twine, it is not necessary to use a heavier material at the place in the net where the fish are concentrated during brailing operations.

3.2.5. Lead Line and Cork Line

In most of the bluefin seines the cork line is of 21-thread manila rope in the center of the net and is spliced to 27-thread manila rope at the ends of the web of the last 40 to 60 fathoms. The ends of the cork line receive more of the strain in the hauling of the net than the center and therefore must be heavier. The lead line is smaller than the cork line, being 12- to 15-thread manila rope.

Most of the fishermen make the cork line a trifle shorter than the webbing, and the lead line ten per cent shorter than the cork line. As the webbing is longer than either the lead line or the cork line, it must be gathered when fastened to the two lines. The continuation of the cork line down the ends of the net (up and down lines) is generally only half as long as the stretched-out web.

The number of corks used to buoy the nets is quite variable, depending on the size of the net. Generally there are 14 to 20 corks to the fathom. These corks are disc-like in shape (6 inches in diameter and 2 inches thick) with a hole in the center for the cork line.

The leads or sinkers, which are uniformly distributed along the line, are used to sink the bottom of the net quickly as the school of fish is being encircled. They weigh about four ounces apiece, and are supplied with a hole through which the line passes. About seven pounds of lead per fathom are used so that in a 350-fathom net about 2400 pounds of lead are used in the sinkers.

3.2.6. Pursing Arrangement

Purse rings, through which the purse line runs, are fastened along the whole length of the lead line. Each purse ring is fastened to the lead line with a bridle line which is of 15-thread manila rope and 14 to 16 feet long. The purse ring is made fast to the center of the bridle line which is fastened at each end to the lead line. The distance on the lead line from each of the fastenings of the bridle line is such that the purse ring will drop about two feet when the lead line is stretched tight. For example: if a 16-foot bridle line were used, the distance between fastenings would be 15½ feet. The distance between the bridles is the same as the distance between the bridle fastenings of one ring. The purse rings are made of galvanized iron or brass, 6 inches in diameter and half an inch thick.

In large seines, rope of 4 inches in circumference, is used in the center section (40–50 fathoms) with 3¼- or 3½-inch rope at the ends. In a relatively short seine (under 275 fathoms) the purse line is of one size throughout, either 3¼- or 3½-inch rope. Every purse line is divided into two or three parts of equal length with a link at each end and connected with a "swinging link." These link connections are for convenience in coiling the purse line when the net is being piled during a haul. The ends of the purse line are tied to the loops at each of the upper corners of the seine.

3.2.7. Skiff

The skiff is an important part of the gear of a purse seiner, for besides being used to hold one end of the seine as the circle is being made, it is used to buoy part of the net after the fish have been encircled and the actual hauling commences. It is built similar to a small flat-bottom skiff except that it is of much heavier material and is wider in proportion to its length. A skiff, 20 feet long, has an 8½-foot beam. In 1930 the biggest skiff used was 26 feet long and the smallest was 16.

3.2.8. Brailer

The brailer, a dip net, 4 feet in diameter and 4 feet deep, with a long handle, is used to transfer the fish from the net into the hold of the boat after a haul is made. It is attached to the hook on the cargo boom line with three ropes of equal length fastened at equal intervals around the top of the net. The fish are released through a hole in the bottom of the net which has several 1½-inch rings fastened around the edges. A chain is run through the rings and pulled tight, closing the hole. When the chain is slackened the weight of the fish opens the hole, allowing the fish to drop out.

3.2.9. Scares

After the circle has been made and while the purse line is being drawn in, there is a triangular area around the boat through which the fish can escape. To prevent this, the fish must be frightened back into the net to keep them away from the opening. This is accomplished by plunging the scare into the water at the opening and pulling it out, repeating the operation until the opening is closed. The scare is a wooden pole, 15 feet long and 1½ inches in diameter, with a wooden cylindrical shell, 10 inches long and 6 inches in diameter, fastened to the end of the pole. The top of the shell is closed and the bottom open. When the cylinder is driven down in the water it scares the fish by churning the water into a white streak.

In making a haul in the dark (such as is done at Guadalupe Island) an electric light, enclosed in a glass globe with water-tight fittings, connected to rubber-covered wires, is often used. The light is sunk about 20 fathoms in the water and intermittently turned on and off, so that the flickering rays frighten and keep the fish away from the opening.

3.3. LOCALITIES FISHED AND TIME OF CAPTURE

3.3.1. Localities

Until the 1930 season all of the commercial fishing for bluefin tuna was done off southern California (Point Conception to the Mexican boundary line). Generally the season started with the boats fishing off San Diego and as the season progressed they worked northward to the northern channel islands. From 1924 to 1929 no change was made in the fishing localities. In June, 1930, it was discovered that bluefin tuna could be caught around Guadalupe Island and about two-fifths of the 1930 catch came from this region. (See fig. 8 for fishing area prior to the 1930 season.)

3.3.2. Time of Capture

Local fish are caught during the daylight hours. Fishermen say the best time of fishing is from noon until sundown. Fishing around Guadalupe Island is done at night during the dark of the moon. The water is so clear around the island that in the daytime the fish can see the net. At night, during the dark of the moon, the fish are not frightened into sounding when encircled by the net.

3.4. METHOD OF FISHING

3.4.1. Locating the Fish

When the desired locality is reached, a member of the crew goes up to the crow's nest in the mast and watches for schools of fish. When he sights them he signals to the man at the wheel to steer in the direction of the fish. Schools are located by the ripples made in the water as the fish swim near the surface. With experience different species can be differentiated by the kind and size of ripple made. When the bluefin tuna are located the captain climbs up in the crow's nest and looks the situation over to determine: (a) the size of the school; (b) direction and speed it is traveling; and (c) chances of making a successful haul. If the school is too large to be entirely encircled the head of the school is picked out as the best part to enclose. The fish are generally frightened into sounding when the center or side of a large school is encircled.

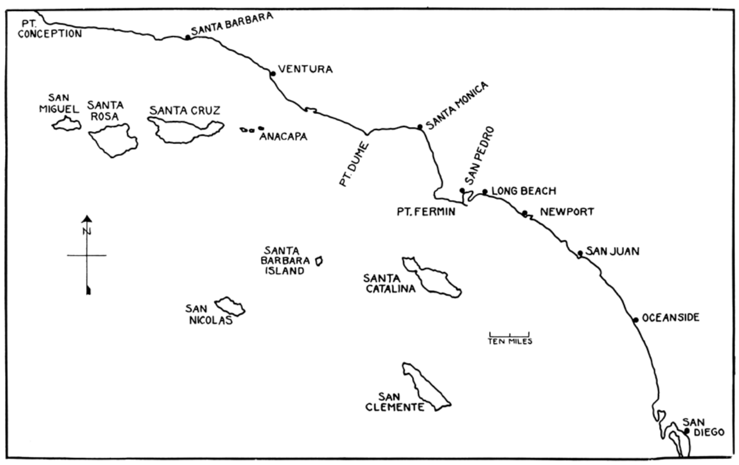

FIG. 8. Area fished by the bluefin tuna boats prior to the 1930 season.

— 19 —

FIG. 8. Area fished by the bluefin tuna boats prior to the 1930 season

3.4.2. Encircling the School

When the captain is satisfied that the chances of capture are certain he gives the signal "let the skiff go." (See fig. 9.) Two men stay in the skiff, one to hold the skiff in position with the oars and the other

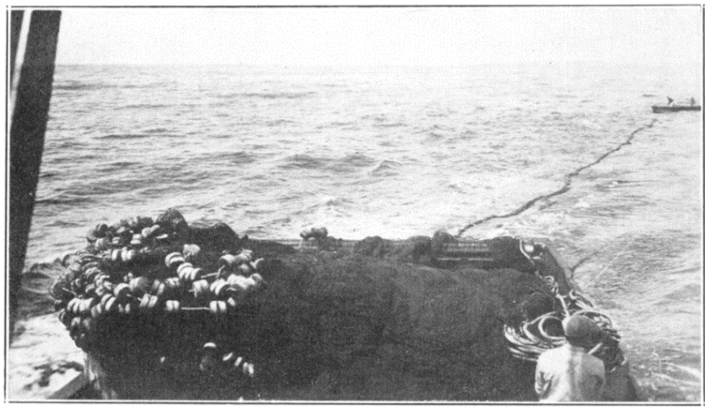

FIG. 9. Paying out the net. 1930. Photo by author

man to throw the skiff line on to the purse seine boat after the fish have been enclosed. The man in the bow of the skiff of figure 10 is getting ready to throw the skiff line. The purse seine boat moves ahead at full speed with the net paying off the stern, puts the net around the school and returns to the skiff, thus encircling the school.

FIG. 10. Picking up the skiff end of the net after the school has been enclosed. 1930. Photo by author

3.4.3. Pursing

After the skiff is reached, the loop on the skiff end is pulled back to the pursing davits amidships, with the skiff line, and the loop placed over a peg on the davit. Then the lead line is pulled up on the deck by means of the brail line. The turntable is turned so that the power roller is on the hauling side and connected to the powered shaft. If the haul line was paid out, it is drawn in with the winch until the loop on the haul end can be placed over the same peg with the skiff-end loop. The lead line of the haul end is also pulled up on the deck by the brail line. As each loop is drawn to the davit, each end of the purse line is untied from its loop, run through a snatch block, passed to a cathead on the winch, and then pursing commences. (See fig. 11) During all of this time and until the net is completely pursed a man keeps driving the scare down into the water to keep the fish away from the open area around the boat. As each end of the purse line is hauled in, the purse rings are drawn closer until they are all concentrated at the pursing davit. Next, a sling is wrapped around all of the bridle lines just under the purse rings, and is then attached to a block from the power boom, after which the purse rings are lifted high enough so that when dropped all of the rings, bridle lines, and the lead line are on deck. (See fig. 12.) When the purse rings are on deck the fish are impounded in the net with no chance for escape except over the cork line.

3.4.4. Piling the Net

The cork line is bunched together along its entire length and made fast at intervals with short ropes either to the skiff or the big boat to keep the fish from sinking the net and escaping over the cork line. Bunching and tying also keep the

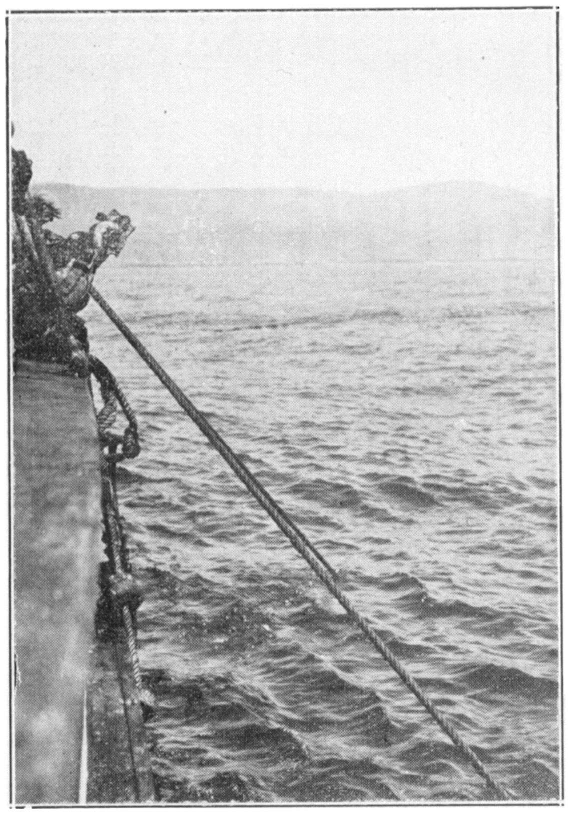

FIG. 11. Pursing the net. 1930. Photo by author

cork line from surrounding the purse seine boat and becoming entangled. After the cork line is properly tied, the haul end pulled on the turntable and the roller started revolving, the men start to pile the net on the turntable. (See fig. 13.) Because the men generally can not pull the seine by hand when more than 10 tons of fish are in the net, a mechanical device, the power-boom, is used for this purpose. The turntable is revolved a quarter of a revolution so that the roller extends along the deck, the net is bunched together (lead and cork lines together), a sling is bent around the net, and the net is pulled up high with the boom and winch. Figure 14 shows the net being lifted. After 20 to 25 feet of net is raised, it is lowered slowly and piled by the men on the turntable. As the net is piled, the size of the net impounding the fish is reduced until the catch is concentrated in a small bag-like area. One side of the bag is fastened to the skiff and the other to the purse seine boat. (See fig. 15.)

3.4.5. Brailing

The dip net is attached to the line of the boom and lowered into the midst of the fish. One man standing in the skiff guides the dip net with the long handle. Another fisherman (also in the skiff) keeps the opening in the dip net closed by pulling hard on the draw chain. When a sufficient number of fish is scooped with the dip net, the brailer is lifted with the cargo boom and winch, and is dropped over the cargo hatch, after which the draw chain is slackened, and the fish in the dip net are dropped down into the hold. (See figs. 16 and 17.) These operations are repeated until all the fish are brailed into the hold.

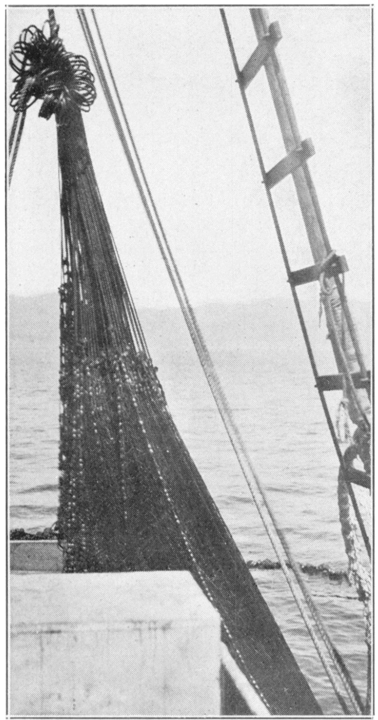

FIG. 12. Lifting the purse rings and lead line onto the deck. 1930. Photo by author

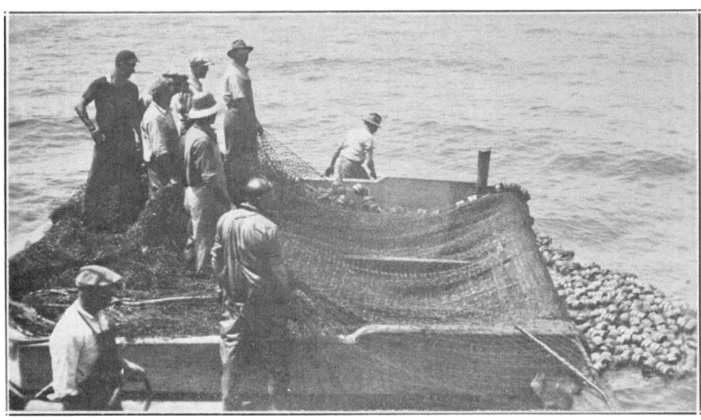

FIG. 13. Piling the net by hand with the aid of the power roller. 1930. Photo by author

3.4.6. Time Taken to Make the Haul

Direction and strength of the tide and wind, quantity of fish in the net, and the condition of the sea, affect the length of time necessary to make a haul. To make the circle prior to pursing requires from 1½ to 2½ minutes, depending upon the size of the net and the speed of the boat. This time is fairly constant in haul after haul with the same boat and net. Pursing takes about 10 minutes. From this point on the time varies greatly. If few or no fish are in the net it necessitates about an hour to make the complete haul, but if several tons (10 or more) are in the net it takes 3 or more hours. On one occasion, with a wind blowing, rough sea and 80 tons of fish in the net, the fishermen had to work 36 hours before completing the haul.

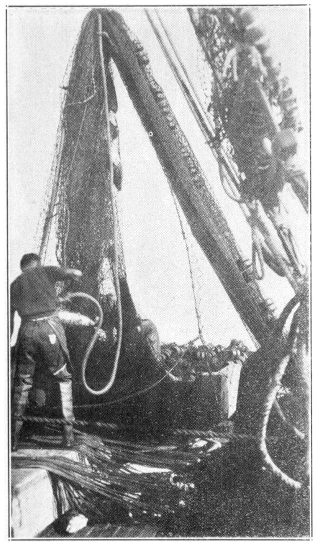

FIG. 14. Piling the net with the aid of the power boom and tackle. 1930. Photo by author

FIG. 15. Showing the small bag in which the fish are concentrated during the brailing. 1930. Photo by author

3.4.7. Disposal of Fish After Catching

Bluefin tuna are always delivered uncleaned to the canneries and fresh fish markets. Until the 1930 season, immediately after a successful haul the boat would return to port and deliver the catch to the cannery or to the fresh fish markets. As the distance was fairly short and the fish were fresh, no ice was necessary. However, during the 1930 season when the boats fished in the region of Guadalupe Island, the increased distance between the fishing grounds and the canneries necessitated the use of ice to prevent spoilage. As the trip to Guadalupe is expensive, the boats try to bring back as near a capacity load as possible.

FIG. 16. Scooping the fish with the dip net (brailing). 1930. Photo by author

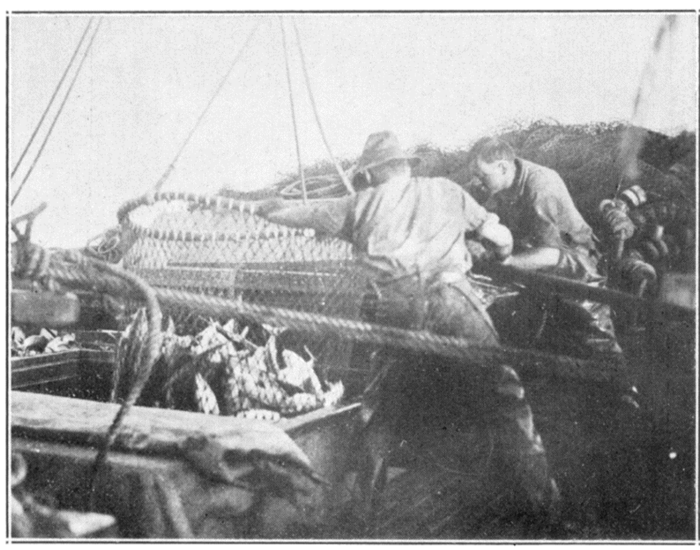

FIG. 17. Dropping the fish into the hold. 1930. Photo by author

4. DESCRIPTION OF THE ANALYSIS OF CATCH

4.1. STATISTICAL DATA

The backbone of the fisheries statistics of California is a collection of the records made since 1918 by the Bureau of Commercial Fisheries. The law requires that each fish buyer record in triplicate in a receipt book issued by the Division of Fish and Game, the quantity of each species purchased, the price, port of delivery, fisherman's name, boat name, boat number, and the date of delivery. One of the three receipts is retained by the Bureau of Commercial Fisheries. The total catch of a species, catch of an individual boat, number of boats engaged in catching a certain species, and number of deliveries of certain species a boat makes can be calculated from these receipts.

Although data were collected prior to 1924, they were not considered trustworthy because some of the fish buyers had not differentiated between yellowfin and bluefin tuna on the purchase receipts. For this reason, the period of investigation for the bluefin tuna fishery is from 1924 to 1930, inclusive. By going through the statistical records of the boat catches the number of boats that fished bluefin in each year was chosen. Boats that made less than five catches in a season were arbitrarily discarded as atypical because of their infrequent catches. The number of boats which could be used in the analysis for each year is shown in the following table:

	1924	*1925*	*1926*	*1927*	*1928*	*1929*	*1930*
Number of boats[1]	15	15	19	18	35	24	26

These boats, with their tabulated individual catches, formed the groundwork for the analysis of the boat catches.

Inasmuch as some of the catches of 35 of the 61 boats that fished bluefin in 1930 were made in a new fishing area (Guadalupe Island), they were incomparable to the catches made in former years in local waters. If a boat made any catches at Guadalupe Island it was discarded from the 1930 data because its monthly catch would not be comparable with the monthly catch of a boat that made all of its catches in local waters. In 1930 there were 26 boats that made 5 deliveries or over of bluefin tuna and which fished entirely in local waters.

4.2. TOTAL YEARLY CATCH AND AVERAGE YEARLY BOAT CATCH

4.2.1. Total Yearly Catch

Since total catch is greatly affected by the yearly changes in fishing effort, it is not a dependable criterion of the availability of fish to the fishermen. The number of boats engaged in the fishery greatly affects the total catch. often a decrease or an increase in the total catch from one year to another is directly correlated with a similar decrease or increase in the number of boats that fished in each year. Likewise an increase or decrease in the amount of time spent fishing from year to year is often directly correlated with total catch. Inasmuch as the number of boats fishing for bluefin tuna has varied

[1] Number of bluefin boats that could be used in the analysis each year. All boats which made less than five catches in a season were discarded.

from year to year, total catch is not a reliable criterion of availability of fish. The number of individuals which are available in the bluefin tuna population should be the only factor affecting the catches of the boats. The object of this section of the report will be to discount all factors other than changes in the fish population which would affect the boat catches. In order to discount these extraneous factors properly, fishing methods and gear must have been studied.

4.2.2. Average Yearly Boat Catch

The effect of a different number of boats fishing from year to year can be discounted by using an average catch per boat. For example, in one year the total catch with 50 boats operating is 1,000,000 pounds, while the second year the total catch is 2,000,000 pounds with 100 boats fishing. That the total catch indicates that the fishermen were doubly successful in the second year is refuted by the fact that average catch per boat was the same for both years; or in other words, twice as much effort was expended in the second year.

Average boat catch per year is an accurate criterion only when the number of fishing days is constant from year to year. For example, one year the boats fish 90 days or 3 months, and in the second year the boats operate 60 days or 2 months. The boats in the first year will catch more fish because they exert more effort. In order to discount an unequal length of season from year to year, a catch per unit of time that would be constant from year to year should be used, such as catch per day or catch per month.

4.3. SELECTION OF THE TYPE OF DATA

Very few of the boats fished every year over the period of investigation. of the 15 boats that operated in 1924 only 5 had fished continuously until 1930. The catches of 5 boats do not form a sufficient sample to represent the catches of the entire fleet that fished each year.

If the catches of the 5 boats that fished continuously are not sufficient data, the alternative will be to use all the boats that made more than the arbitrary 5 catches a season. There are chances that using different boats each year may introduce an error by the change in the size of nets. If the size of nets used affects the size of catch, an introduction of bigger nets will make for an increase in size of catch not necessarily indicative of availability. Since the factor of increase or decrease in size of nets has an important bearing upon the analysis, a scatter diagram of the size of nets and size of catches was constructed as in figure 18. The sizes of the catches and nets for 23 boats in 1928 were used in constructing the diagram. As the dots scatter over the diagram with no uniformity, there is no indication of any correlation. In order to determine mathematically the amount of correlation, the Pearsonian coefficient of correlation was found to be +.05±.14, an insignificant amount indeed.[2] We can safely assume that, in this fishery, an increase or decrease in the size of nets used from year to year will have no serious effect on the amount of fish caught. Skill and hard work are the most likely reasons why some boats catch more fish than others.

[2] The size of boats and the size of catches also were plotted as a scatter diagram, which indicated as little correlation between the two values as between the size of nets and the size of catches.

There is a possibility that with different boats fishing from year to year, a greater proportion of skillful or poor fishermen may be fishing in one year than another. This error which may be caused by a change in proportion of good to poor fishermen can not be eliminated from the data. Since this error will probably be very small due to the fact that the exceedingly successful crews in each year will be offset by the poorer crews, the writer felt justified in disregarding it.

Inasmuch as the size of boat and net did not affect the size of catch, the writer decided to use the catches of all the boats that made 5 or more catches of bluefin tuna in a year.

4.4. Selection of a Time Interval

The deliveries for each boat were tabulated for each season (June–August, inclusive) of the period 1924 to 1930. Catches after August were discarded because of their infrequency in some years. After the

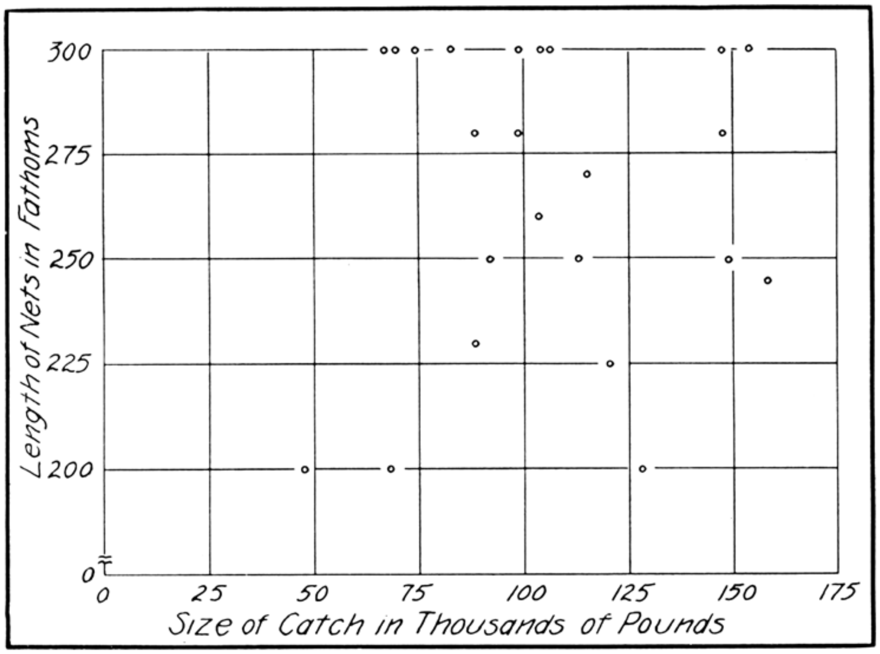

FIG. 18. Relation between the size of catch and length of net.

FIG. 18. Relation between the size of catch and length of net

catches were tabulated, the amount of fish each boat caught a trip, month, or season could be calculated.

4.4.1. Average Catch per Trip

Average boat catch per trip for each year was determined by totaling all the catches for the year and dividing by the total number of trips made in that year. The trend of average boat catch per trip is presented graphically in figure 19.

Before average catch per trip can be accepted as a criterion of the fishing success of the fishermen, the changes in the amount of fishing effort per trip must be determined. If the trips were of longer duration in 1930 than in 1924, more effort was expended per trip in 1930 than in 1924. Since there is no information available which furnishes the exact length of time that each boat spent in fishing per trip, an estimation of the relative length of fishing trips must be made.

4.4.2. Changes in Relative Length of Trips from Year to Year

Average number of deliveries per month would be an accurate criterion of the relative length of the trips if the fishing time per month remains constant from year to year. A small number of deliveries made in a month means that a longer time was required to catch the fish in that month than in months in which more deliveries were made. The next step will be to determine whether or not the fishing time per month has changed.

If the boats stayed in port more in one year than in another, the decline in the number of trips would not be due to a longer duration of fishing time, but to a longer elapse of time between the trips. According to information given by the fishermen, they only spent sufficient time in port each year to unload the fish and make repairs to the boat or net. Thus, this period in port would tend to be constant from year to year.

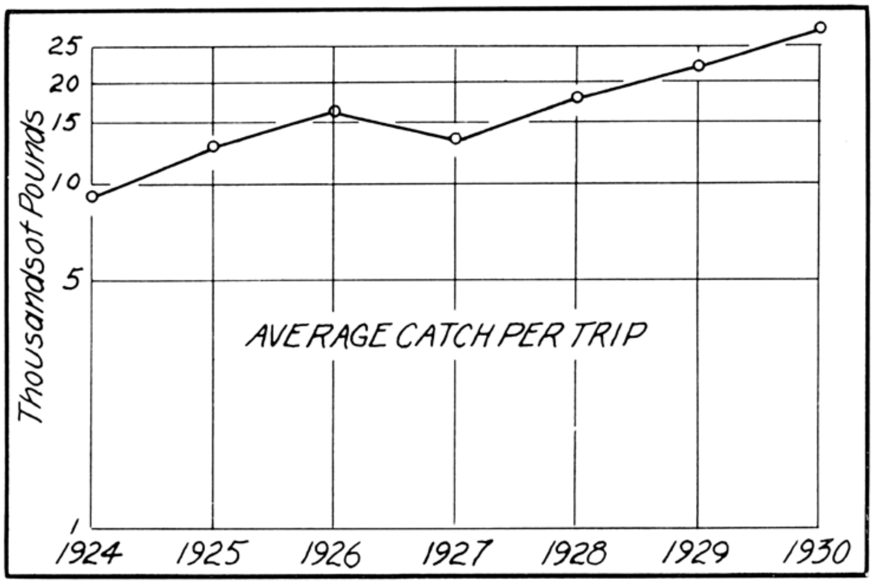

FIG. 19. Average catch per trip, calculated from all of the bluefin tuna boats usable in the analysis, plotted on a semi-logarithmic scale.

FIG. 19. Average catch per trip, calculated from all of the bluefin tuna boats usable in the analysis, plotted on a semi-logarithmic scale

Another factor that would make for fewer deliveries of bluefin tuna would be for the fishermen to have caught other species of fish. In order to see whether this happened, the proportion of the number of bluefin catches to the total number of all catches made by the bluefin boats in a season (June–August) for each year was calculated. The trend of these proportions expressed as percentages is shown graphically in figure 20. The number of bluefin catches was divided by the total number of all catches for each year. If the fishermen had been exerting more time in each succeeding year on some other species, the curve of figure 20 would have been downward. The trend, which is practically horizontal except for 1928, indicates that the fishermen have not been expending more effort on other species of fish. In each season the number of bluefin catches has been about 80 per cent of the total. This horizontal trend, coupled with the fact that the fishermen spent a constant amount of time in port, shows that the fishermen have exerted a constant amount of fishing time per month each year.

Since the fishing time per month has been constant, the average number of deliveries per month indicates the relative amount of time spent each year on the fishing trips. The graph of the average number of trips per month is presented in figure 21. The total number of trips made in a season was divided by the number of months fished in that season. From 1924 to 1930 the trend of the average number of trips per month was slightly downward, indicating that a greater length of time was spent on fishing trips. In 1927 and 1929 much more time was spent in catching the fish than in the other years, as indicated by the relatively low average number of trips per month. As

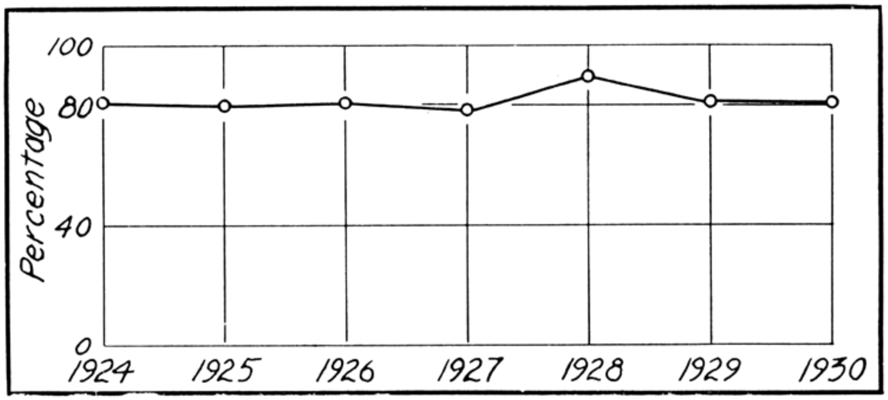

FIG. 20. The proportions of the number of bluefin catches to the total number of all catches for each season, expressed in percentages.

FIG. 20. The proportions of the number of bluefin catches to the total number of all catches for each season, expressed in percentages

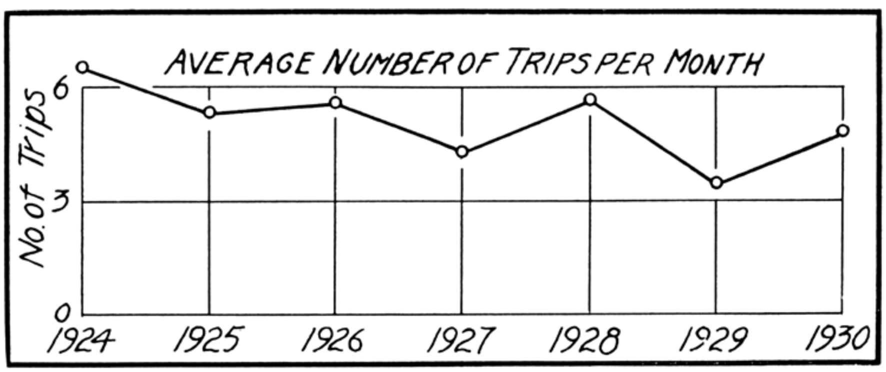

FIG. 21. Average number of trips per month made by all the boats usable in the analysis.

FIG. 21. Average number of trips per month made by all the boats usable in the analysis

the length of time per trip for each year has increased, the average catch per trip is a poor criterion of fishing success.

In 1929 the average catch per trip was slightly higher than in 1928. It is possible that even though there were fewer schools of fish present in 1929, the fishermen were able to obtain in one haul as many fish as they obtained in a single haul in 1928.

4.5. AVERAGE CATCH PER MONTH

Because the gear has not affected the catches, and the fishing time per month has been constant, average boat catch per month is the most accurate criterion of fishing success. Figure 22 shows the trend of average boat catch per month. As the deliveries had already been tabulated, the amounts caught by each boat in each month were calculated. These monthly catches were averaged arithmetically for each season (June–August) of the period 1924 to 1930. Months in which only one delivery was made were discarded from the data.

4.5.1. Arithmetic Mean in Preference to Other Means

Inasmuch as the plain arithmetic mean expressed the true conditions of the fishery as accurately as any other method of averaging, and was the easiest to calculate, it was used in preference to any other mean. The dispersion of the catches was such that there was no definite mode at any unit of amount. In other words there were as many large monthly catches as there were small and medium monthly catches.

If the catches of some of the boats had been consistently larger than the catches of others, the trend indicated by the arithmetic means

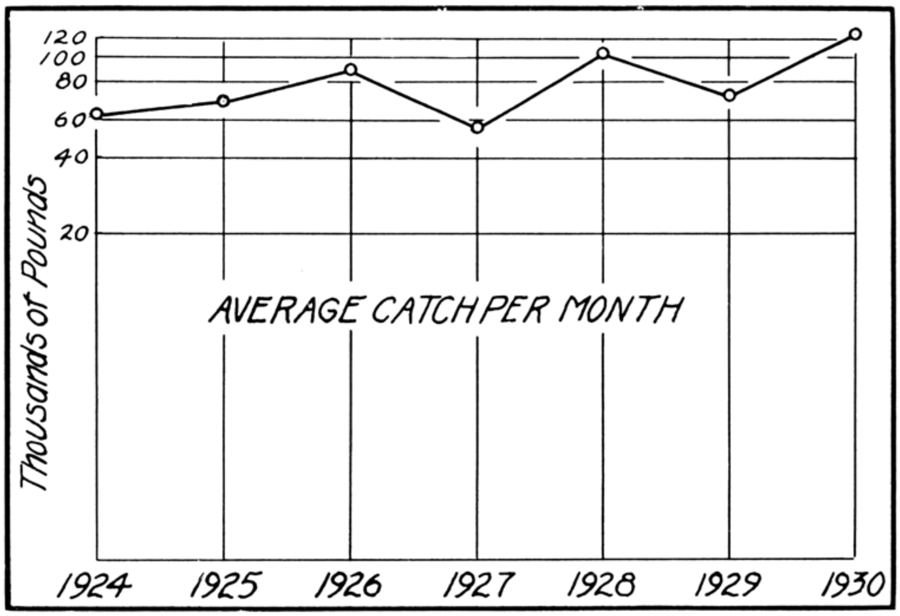

Fig. 22. Average boat catch per month, calculated from the data of all the boats usable in the analysis, plotted on a semi-logarithmic scale.

FIG. 22. Average boat catch per month, calculated from the data of all the boats usable in the analysis, plotted on a semi-logarithmic scale

might not be representative of the fishing success of the entire group of boats. The changes in the larger catches from year to year might overshadow the changes in the smaller catches. If there had been consistent differences in the sizes of the catches, the geometric mean would be the better average, as it puts the yearly changes of each boat's catches on a proportional basis. As there were no consistently higher catches, the geometric mean was unnecessary and the arithmetic mean was used.[3]

4.5.2. Significance of the Means

In order to test the significance of the trend of average monthly boat catches (as shown in fig. 22), the standard error of the means

[3] The geometric means were calculated and were nearly identical with the arithmetic means in rate of change from year to year. Similar parts of each season were compared for all the years of the period, and the time of the largest and smallest catches was found to be consistent from year to year.

and the standard error of the difference between the means was calculated by the formulae

$$\sigma_M = \frac{\sigma}{\sqrt{N}}$$

EQUATION

, and

$$\sigma_{(M_1-M_2)} = \sqrt{(\sigma_{M_1})^2 + (\sigma_{M_2})^2},$$

EQUATION

where M is the arithmetic mean; [o], the standard of deviation; N, the number of monthly catches; and [o] $_{M}$, the standard error of the mean for each year. These results are shown in the following table:

	M or Means	σ_M	$\frac{M}{\sigma_M}$	*Difference between the means*	*Standard error of difference*	$\frac{M_1-M_2}{\sigma_{(M_1-M_2)}}$
1924	61,726	8,459	7.3			
				5,494	11,434	.5
1925	67,220	7,693	8.7			
				20,024	12,091	1.6
1926	87,244	9,328	9.3			
				32,026	11,917	2.7
1927	55,218	7,417	7.4			
				47,865	11,422	4.2
1928	103,083	8,686	11.9			
				29,990	11,704	2.6
1929	73,093	7,845	9.3			
				52,685	12,374	4.3
1930	125,778	9,570	13.1			

EQUATION

Since the means of the monthly catches of bluefin tuna are at least seven times greater than their standard errors, they may be accepted as significant of the fishing success for each year. That the differences in the average catch per month from 1924 to 1926 are probably not denotative of the changes in the availability of fish, is indicated by the relatively high values of [o] $_{(M1–M2)}$. On the other hand, the relatively low values of [o] $_{(M1–M2)}$ for the differences between the means from 1926 to 1930 suggests an appreciable fluctuation in abundance from year to year. In other words, while the changes from 1924 to 1926 do not reflect a fluctuating population of available fish, differences from 1926 to 1930 do.

4.6. CONDITION OF THE FISHERY

While the graph (fig. 22), showing average boat catch per month, reveals an upward trend, it is not definitely significant because of the wide variations in average monthly catch from year to year. Also, if the point for 1930 had been unusually low, as it could have been, the direction of the trend would have been horizontal or slightly downward. There are too few years in the series to say definitely that the trend is upward, since one year can change the direction of the trend. The standard error of the slope of a straight line fitted to the averages was ±.0201, while the slope of the line was+.0383. (Since a semi-logarithmic scale was used, the slope and standard error were computed in logarithms.) From R. A. Fisher's "Table of 't'",[4] the chances were found to be 1 in 9.25 that another slope calculated from the same type of data would be greater or less than a 0 to +.0766[5] slope, and 1 chance in 18.5 that another slope would be negative. Since the chances are small of a possible negative slope, we can safely assume that there has been no downward trend over the period 1924 to 1930. On the other hand, since the upward trend of the catch is defined principally by the 1930 season's data, we can not say there has been an increase in fishing returns. In other words, the availability of bluefin tuna has been relatively constant over the period of investigation.

[4] "t" is the ratio of the measure being tested to its standard error.

[5] This range is the calculated slope plus and minus "t" times the standard error.

There are too many factors which might affect the population of this species for us to be certain that average boat catch reflects the relative changes in the numbers of the entire bluefin tuna population. The fishermen catch only certain sizes of this fish which apparently migrate into California waters. A change in water temperatures or food in one year or a series of years may subject a greater or lesser number of fish to exploitation by the fishermen. Average boat catches indicate only the relative yearly changes in the numbers of fish that were available to the fishermen.

4.7. CONCLUSION

While we can not assume that the entire population of bluefin tuna has remained fairly constant over the period, we can assume that the numbers of fish have been sufficient to support the fishing operations over the period 1924 to 1930, inclusive. Therefore, no protective legislation is needed at the present time (1930). However, a continuation of the analysis of boat catches should be made in the future in order that protection may be given if found necessary.