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Principal specific international fishery conservation problems of the world .. for the resolution of which international measures and procedures have been instituted ...

In accordance with the advice of experts consulted by the Secretary-General, technical papers on certain items of the provisional agenda were invited from a number of authorities. The Secretary-General has the honour to communicate the following paper by Dr. Milner B. Schaefer, Director of Investigations of the Inter-American Tropical Tuna Commission, La Jolla, California, United States of America. Summaries of this paper will be issued in English, French and Spanish as A/CONF.10/L.11 (Summary).

# SCIENTIFIC INVESTIGATION OF THE TROPICAL TUNA RESOURCES OF THE EASTERN PACIFIC

by

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CONTENTS

## I. INTRODUCTION

1. The tropical tunas which inhabit the high seas off the shores of the Americas from California to Perú and northern Chile constitute the marine resources supporting the most valuable fishery of the Eastern Pacific Ocean. These resources consist of populations of two species, the yellowfin tuna, Thunnus (Neothunnus) macropterus, and the skipjack ("barrelete"), Katsuwonus pelamis. In 1953 there were produced from the Eastern Pacific 274 million pounds of these species, consisting of 140 million pounds of yellowfin and 134 million pounds of skipjack.

2. The preponderate share of the catch is made by fishing vessels based on the West Coast of the United States - very modern, long-range craft constituting one of the most specialized fishing fleets in the world. A small, but appreciable, share of the catch is made by vessels based in Perú, while smaller quantitites are landed in Chile, Ecuador, Panamá, Costa Rica, and México. Most of the landings in other countries than the United States are transshipped frozen to the United States for processing as canned tuna, although small quantities are canned, or otherwise consumed, in the Latin-American countries.

3. The Inter-American Tropical Tuna Commission is engaged in the scientific investigation of the tuna resources supporting this fishery, and of the resources of bait fishes required for their capture by the pole and line fishing method, which accounts for over 80 per cent of the catch. (The remainder is taken by purse seiners).

4. The tunas inhabit the high seas, in contrast to the bait species which occur primarily in inshore waters, and are, therefore, the more pertinent to the subject matter of this conference. I shall, therefore, confine this paper primarily to discussion of our research on the tuna resources.

## II. DEVELOPMENT OF THE FISHERY FOR TROPICAL TUNAS IN THE EASTERN PACIFIC

5. The fishery for tunas in the Eastern Pacific is of comparatively recent origin. Canned tuna was not produced in the United States, or elsewhere in the Americas, until 1903 when there was inaugurated in California a new industry based on the canning of albacore tuna (Thunnus germo), a temperate water species,

captured in the seas off Southern California during the summer months. The albacore canning industry grew rather slowly, but attained by 1917 the utilization of 31 million pounds of these fish. The food demand created during World War I gave impetus to the infant industry. It appears that, simultaneously, about 1918, albacore became rather more scarce in California waters than previously, as a result of which the fishermen and canners turned to the tropical tunas to obtain the required raw material. The northern part of the range of the tropical species reaches to Southern California, where they occur only during the warmer months of the year. By 1925, the industry used 22 million pounds of albacore, 13 million pounds of yellowfin tuna, and 14 million pounds of skipjack.

6. In 1926 there occurred a variation in the local albacore supply, due, presumably, to some oceanographic variation, which motivated the development of the modern, long range fishery for the tropical tunas. In that year the albacore practically disappeared from California and Baja California, only 2.5 million pounds being captured, and it was not until 1938 that the albacore catch again exceeded 10 million pounds. In order to satisfy the demand for tuna for canning, the fishermen began to expand the fishing area for yellowfin and skipjack southward along the Mexican coast, and, with the rapid development of long range craft equipped for refrigerating the cargoes, quickly expanded the fishing area southward to the equator by 1931. Subsequently, the fishery has expanded further southward along the Peruvian coast to almost the southern limit of the distribution, in commercial quantities, of these tropical tuna species.

7. The increase of the harvest of the yellowfin and skipjack tunas from the Eastern Pacific is illustrated in Figure 1. It may be seen that that fishery enjoyed a sustained growth from its inception until 1941. During the early part of World War II, the production, especially of yellowfin tuna, decreased considerably, due to the entry into naval service of most of the long range tuna clippers, and restrictions on the activities of the remainder of the fishing fleet. From 1945 onward, as the fleet was rebuilt, the catch increased very, very rapidly, attaining a peak production of over 350 million pounds by 1950.

8. The greatest share of the catch has, during the years of the modern fishery, always been taken by tuna clippers, or bait boats, which are vessels equipped to

fish for tuna by means of pole and line, using for "bait" live, small fishes, which are cast into the sea to attract the surface-schooling tuna to the boat. A small share of the catch, about 15 per cent, is taken by purse seine nets by vessels especially built for this sort of fishing. In Figure 2, is depicted the landings in California (which constitute most of the total catch) by species and type of fishing gear, illustrating this.

9. The bait-fishes employed in capturing the tunas are several species of small fishes, mostly of the families Clupeidae and Engraulidae, which occur in quantities in inshore waters near to the high-seas areas inhabited by the tunas. In the northern baiting areas, north of about Cape San Lucas, the principal species are California sardines (Sardinops caerulea) and northern anchovies (Engraulis mordax). Similarly, at the southern extremity of the fishery, off Perú, there are available quantities of southern anchovies (Engraulis ringens). In the Galápagos Islands are taken sardines (Sardinops sagax), and smaller quantitites of a spiny rayed fish of the family Xenicthyidae which the fishermen call "salima". In the tropical seas, approximately between Baja California and Cape Blanco, Perú, the principal bait species is a deep-bodied, tropical anchovy (Cetengraulis mysticetus) known to the tuna fishermen as "anchoveta". Quite small quantities of several species of tropical clupeoid fishes, known to the fishermen as "herring", are also taken for tuna-bait from the tropical areas. Bait is measured by the fishermen in "scoops", a scoop being the quantity of fish lifted from the bait seine to the bait tanks of the fishing vessel by means of a small dipnet. A scoop is approximately nine pounds of bait fish. The relative importance of the different kinds of bait is illustrated by Figure 3, which depicts the quantity of bait used, by varieties, by United States clippers for the years 1951, 1952 and 1953.

## III. THE INTER-AMERICAN TROPICAL TUNA COMMISSION

10. The very rapid postwar increase in the fishery for yellowfin and skipjack tunas in the Eastern Pacific gave rise to concern as to the effects of fishing on the tuna resources, as well as on the bait resources. Very little scientific information was available respecting these species of fish, and no one had any idea about the current status of the fishery with respect to the condition which would provide maximum sustained yield. In order to make possible the scientific

investigation of the tunas and bait fishes, and the effects of the fishery on them, there was consummated in 1949, and ratified in 1950, a Convention between Costa Rica and the United States of America establishing the Inter-American Tropical Tuna Commission. Under the terms of the Convention, the purpose of the Commission is to gather and interpret factual information required to facilitate maintaining, at a level which will permit maximum sustained catches year after year, the populations of yellowfin and skipjack tunas, and of other kinds of fishes taken by tuna fishing vessels in the Eastern Pacific Ocean.

11. The Commission is directed, and authorized, by the Convention to undertake necessary scientific investigations for this purpose and, on the basis of these investigations, to recommend proposals for joint action designed to keep the populations of fishes covered by the Convention at the levels of abundance which will permit maximum sustained catches.

12. The Convention contains a provision whereby any other nations having an interest in the tuna fishery may adhere by a simple exchange of correspondence with the existing members. Panamá thus adhered to the Convention in the autumn of 1953.

13. The Commission commenced its investigations in 1951 with a small scientific staff, which since has been augmented by additional scientific and technical personnel. This staff has, during the last four years, made rather good progress on gathering the scientific information required for the purpose of the Convention. At the outset both the biology and ecology of the tunas, and the condition of the stocks was almost entirely unknown. A very great deal yet remains to be learned, but, as will be seen, we are, after four years of study, approaching possession of sufficient information to assess the general status of the fishery, and to provide a part of the scientific information required as a basis of future conservation action by the member Governments.

14. The Inter-American Tropical Tuna Commission is unusual in that it has been able to commence its investigations at a stage in the development of the fishery when serious overfishing has not yet occurred. Very often adequate scientific research on a fishery resource is not undertaken until economic distress, resulting from overfishing, makes such research imperative. We have here an opportunity to provide the scientific basis of <u>maintaining</u> the harvest from the resource, and preventing serious overfishing <u>before</u> it occurs.

## IV. SCIENTIFIC INFORMATION RESPECTING THE TROPICAL TUNAS

### A. Geographical distribution

15. Yellowfin and skipjack tunas are found in the Pacific in a broad band across the ocean, extending on either side of the equator, bounded, approximately, by the surface isotherms of 20° C. In addition to the commercial fishery in the Eastern Pacific, off the coast of the Americas, there is a sizable fishery, pursued primarily by Japanese fishing craft, on the western side of the Pacific, extending eastward among the islands of the Central Pacific to the longitude of Hawaii. Both species, together with the bigeye tuna (Parathunnus sibi) are fished commercially in the seas surrounding the Hawaiian Islands, and this fishery is expanding southward along the Line Islands to the vicinity of the equator. They are also known to exist in commercial abundance in the vicinity of the Marquesas and Society Islands. Exploratory fishing by the United States Fish and Wildlife Service has shown that yellowfin tuna occur at various longitudes between the American mainland and the Central Pacific.

16. In the high seas off the shores of the Americas, the yellowfin and skipjack tuna occur in commercial abundance from approximately latitude 32° N. to 20° S. At the northern and southern extremes of the range, these fish appear only during the warmer months of the year, but in the middle part of the range they are present at all times. Skipjack, apparently, tolerate slightly lower temperature than yellowfin, their range extending slightly further to the north and south; skipjack are sometimes taken commercially during the warmest months of the year, off Southern California on the north, and off Copiapó, Chile, on the south. The present range of the fishery by means of modern, high seas fishing craft, covers almost the complete span of latitides, extending from the northern extremity to about Callao, Perú. The commercial fishing area extends offshore from the mainland about 300 miles, except where there are outlying islands (Revillagigedos, Clipperton, Cocos, Galápagos) where it reaches out even farther to include the seas near to such islands.

17. Within this range, the tunas are not found everywhere in equal abundance, but are found concentrated in certain localities which, as will be explained later, appear to be particularly favourable feeding areas, determined by the oceanic circulation.

18. The geographical distribution of the catch from the Eastern Pacific, and the areas of concentrations, may be illustrated by the catches made by the tuna clippers based in the United States, which keep accurate logbook records of their operations for the Tuna Commission, for the year 1953. The levels of production of yellowfin and skipjack tuna by these vessels during that year are shown in Figure 4 for each one degree square in which fishing was done. While there is some variation from year to year, the main centres of production have remained nearly the same for the recent years for which such detailed records are available.

B. Population relationships

19. Since the yellowfin and skipjack tunas occur completely across the Pacific, it is important to know whether the fish captured in the Eastern Pacific fishery are members of populations confined to that region, or whether they are representatives of larger populations which migrate freely throughout the trans-oceanic range of each species. Knowledge of whether the members of these species in the Eastern Pacific belong to populations distinct from those further to the westward is of importance to (1) considering the magnitude of the catch in relation to the magnitude of the resources; (2) determining the region in which it is necessary to conduct research; and (3) determining the geographical extent of jurisdictional areas which may be required for conservation management.

20. With respect to yellowfin tuna, it has been tentatively concluded that the resource supporting the American fishery is distinct from those further to the westward. Three lines of evidence support this: (1) morphometric comparisons of specimens from the American area with specimens from French Polynesia and with specimens from Hawaii reveal rather large differences in fin lengths and body proportions; (2) tagging (by the California State Fisheries Laboratory) of yellowfin off the Americas has resulted in no recoveries from the commercial fisheries to the westward, and (3) analysis of statistics of fishing intensity and population abundance (which will be discussed later) indicate that the changes in fishing intensity have measurably affected the abundance, which would be unlikely if the fishery were supported by a large, trans-oceanic population which is unfished throughout much of its range.

21. With respect to skipjack tuna, we cannot yet draw similar conclusions. Morphometric studies do show indications of differentiation between American fish and specimens from further westward, but the data in hand are not yet adequate for firm conclusions. Tagging, again, has resulted in no recoveries from outside the range of the American fishery, but such negative evidence is not, by itself, a sufficient basis for conclusions. Analysis of statistics of fishing intensity and abundance of skipjack, unlike the yellowfin, do not reveal any measurable effect of fishing on the abundance. The question, for this species, is therefore, still open.

22. It is, of course, of very great importance also to determine whether within the region of the East Pacific fishery these specias are further subdivided into distinct or semi-distinct populations, or stocks, which should be considered as separate biological units in the management of the fishery. Preliminary investigation of this problem by means of comparison of morphometric data indicates that this technique may not be adequate, because of the inability, for technical reasons, to be able to distinguish small anatomical differences. Satisfactory results may be obtained from tagging, to determine the range of migrations of specimens tagged in different locations, and so determine the degree of intermingling. The California State Fisheries Laboratory has, during the past two years, commenced such tagging experiments, with encouraging results, but it is yet too soon for any definitive conclusions. Migrations of up to six and seven hundred miles have been recorded for some specimens at liberty in the neighbourhood of a year. Many specimens have, however, shown rather short movements in the same interval of time. It appears that these tunas do not diffuse rapidly throughout the range of the fishery, but this does not preclude complete mixing throughout at a slower rate.

23. Information from size composition of catches may also be brought to bear on this problem, since, if the stocks are heterogeneous, consistent differences in size composition, persisting in a geographical subregion may be taken as evidence that separation of populations is being maintained. Here, again, not enough data have yet been gathered along this line for such purpose.

24. Pending the solution to these problems, we are collecting the data on fishing effort, yield, and tuna abundance by the smallest practicable

geographical sub-areas, so that they may be recombined according to such natural boundaries as may exist.

C. <u>Information on life history, ecology, and behaviour</u>

25. The yellowfin and skipjack tunas are creatures of the high seas. They lead a completely pelagic existence throughout their lives. Due to their completely oceanic habitat, the study of their biology and life history is technically difficult, and expensive, in consequence of which, until recent years, very little has been known concerning them. During the past decade, however, some fisheries scientists of the United States, Japan, and other countries have devoted rather intensive efforts to this group of fishes, so that our former ignorance is being replaced by some knowledge of the more important aspects of their biology.

26. The yellowfin and skipjack tunas, during their early years of life at least, aggregate into schools near the surface. This behaviour is the basis of the fishery in the Eastern Pacific, since both the live-bait and the purse-seine methods of fishing, depend, for their efficient capture, on the occurrence of sizable schools. Skipjack tuna in the commercial catch range in size from about three to thirty-five pounds. Yellowfin tuna in the catch range in size from about six to two hundred pounds, most of the catch consisting of fish of less than about forty pounds. Analysis of size frequencies indicates that, for both species, the bulk of the catch consists of members of only three or four age classes, the youngest fish being probably in their first or second years of life.

27. The smallest sizes are not represented in the catch in proportion to their abundance in the sea, both because of selectivity of fishing method at very small sizes, and because of a legal requirement in the State of California (where the bulk of the catch is landed) that skipjack be over 4 pounds (46 cms.) and yellowfin be over 7 1/2 pounds (57 cms.). At very large sizes, the yellowfin tuna become partially unavailable to the surface fishing methods in use in the Eastern Pacific, due to a vertical migration to greater depths. In the Western Pacific and in the vicinity of Hawaii these large fish are captured commercially by means of pelagic long lines, fishing as deep as 90 fathoms,

No commercial fishery by this method has been developed in the Eastern Pacific. Experimental fishing by the Tuna Commission, the Scripps Institution of Oceanography, the California State Fisheries Laboratory, and other agencies has shown, however, that, particularly in the vicinity of the equator, these large sub-surface yellowfin also occur in the Eastern Pacific. There is no evidence that the skipjack behave similarly, since this species is not taken, except infrequently, on longline gear. This, however, might be due to selectivity of the gear rather than absence of the species in sub-surface layers of the sea.

28. It has been shown that the tunas tend to school by sizes, so that the members of a school are more similar in size than in a random sample of the population. Sampling of the landings, to obtain a representative sample of the catch involves, therefore, drawing samples from a sufficiently large number of different schools to average out this source of statistical error. This is done by taking samples from the catch of several different vessels, and for several different fishing days for each vessel, for each geographical area and time period considered. The Tuna Commission, in co-operation with the California State Fisheries Laboratory, has in routine operation a programme of sampling of the landings to determine the size composition of the catch for each month of the year for six geographical regions of the fishery. These data are expected to yield information on age and growth, on total mortality rates, and on the population structure of the resources. The programme has not been in operation long enough to draw conclusions respecting the latter two matters, but some information respecting growth rates is forthcoming.

29. It appears, from the occurrence and time progression of modes in the length-frequencies, that both the yellowfin and skipjack tunas are relatively rapidly growing species, the commercial catch being composed primarily of only about three age groups in each case. Determination of age is yet tentative, since aging by marks on hard parts has not, so far, proven successful. From the positions of the modes of the size frequencies, however, it appears certain that the youngest age group of yellowfin tuna in the commercial catch cannot be over two years old and is probably but one year old. Determination of age at first capture of skipjack is less certain from presently available date, but it tentatively appears that the youngest age group is two years old. It appears, therfore, that, for both species, growth, and turnover of population, is very rapid.

30. Spawning of the tropical tunas occurs over a wide geographical range, and the spawning season is quite long. Indeed, in the vicinity of the equator, investigations, both by the Tuna Commission and by the United States Fish and Wildlife Service unit operating from Hawaii, indicate that some spawning takes place throughout the entire year. Under these circumstances, large variations in year class strength are less likely than for species having a restricted spawning area and a short spawning season.

31. A avery large number of eggs is spawned by each female. Investigations in Hawaii have found, for example, that a 100 pound yellowfin produces over two million eggs at a single spawning, and that each fish may spawn more than once during the year. Material for fecundity determinations for both yellowfin and skipjack from the Eastern Pacific have been collected, but have not yet been analysed.

32. The pelagic eggs hatch in less than 48 hours. The eggs and larval stages are taken from the surface to at least 200 metres depth in plankton net hauls. Juveniles from about 1 to 10 centimetres have been collected by light and dip-net, at night, at oceanic stations off the Central American coast, and elsewhere, and have also been collected among the stomach contents of adult tunas and other pelagic carnivorous fishes.

33. With respect to feeding habits, investigations by our staff in the Eastern Pacific, and by investigators of other agencies in other parts of the Pacific, indicate that the tunas feed quite omnivorously on all forms of pelagic animals encountered on the high seas which are of suitable size, ranging from Euphausids and Squilla larvae, to fairly large Cephalopods and fishes.

34. Migration patterns of tunas in the Eastern Pacific are not yet elucidated. Extensive tagging experiments have been instituted by the California State Fisheries Laboratory, and these will be augmented by the Tuna Commission in the near future. Results as yet are insufficient to determine seasonal migration patterns.

35. As has been illustrated by Figure 4, showing the geographical distribution of catches by tunas clippers during 1953, the tunas are concentrated in certain areas. There are such regions of concentration off Baja California, in the vicinity of the Gulf of Tehuantepec (which occurs during the early part of the year only), off the coast of Central America, in the region lying off the coast of the northern

part of South America, and in the vicinity of the Galápagos Islands. These regions of concentration correspond, in general, with regions of high production of food organisms, as indicated by the volume of zooplankton per unit volume of water. This is illustrated by Figure 5, showing the distribution of plankton volumes obtained on a recent oceanographic expedition. The zooplankton is, in major part, a step lower in the food chain than the animals which are fed on by the tunas, but it is expected that the organisms on which the tuna feed will be most abundant in regions of high standing crop of zooplankton. It further appears that these regions of high production of zooplankton organisms are also regions where the surface waters are enriched by basic nutrients brought up from the deeper layers by upwelling, or by mixing along major current boundaries. It seems logical to hypothesize that regions which are fertilized by these physical processes support an abundant growth of primary (plant) producers, which in turn support an abundance of organisms higher in the food chain, culminating in the tunas, which are harvested by man. Since the oceanographic regime, to which the tunas seem to be so closely related, is not constant, but is subject to variations between seasons and years, it is important to achieve understanding of the details of the oceanic circulation, and the causes of its variations. This is, of course, a very large problem on which only a beginning has been made.

D. Effects of fishing on the resource and current status

36. The central problem of the Inter-American Tropical Tuna Commission is the determination of the effect of amount of fishing on the tuna resources, with particular reference to determining whether the present level of exploitation is above or below that level corresponding to maximum sustainable harvest. Fundamental to the investigation of these matters is the measurement, over a series of years encompassing different levels of fishing intensity, of the abundance of the tunas, the intensity of fishing, and the total catch. Such measurements are most conveniently obtained from the detailed records of the fishery itself. A very great part of the labours of the staff has, therefore, been directed toward collection and compilation, on a continuing basis, of detailed information regarding the amount caught of each species, dates and locations of fishing, and effort required to make the catches. Since data from a considerable series of

years are required for proper analysis and interpretation, we have bent our efforts to obtaining pertinent data not only for current years, but also for past years, before the establishment of the Commission.

37. Information respecting the total catch of each species from the Eastern Pacific is available, since the very early days of the fishery, from the records of tuna canners and of Government agencies in the United States and other countries where fish are landed. We have compiled these statistics for past years (Figure 1) and we collect them currently on a continuing basis.

38. In order to measure the relative abundance of each species of tuna, as encountered by the fishermen, two kinds of measurements are available, the catch-per-day's-absence-from-port and the catch-per-day-of-tuna-fishing. From records of quantities of tuna landed and number of days absence from port, which we obtain from nearly the entire fleet of vessels landing their catches in the United States (which account, currently, for about 90 per cent of the total catch) it is possible to compute the average catch-per-day-of-absence-from-port. For seiners this provides a measure of the abundance of the tunas, since they fish for the tunas directly witn nets. For clippers, however, this statistic measures the combination of apparent abundance of tunas and prior success in catching the live-bait employed in this fishing method. If, however, the percentage of the time absent from port which is spent in tuna fishing is relatively constant, the catch-per-day's-absence will measure the apparent abundance of the tunas. Fortunately, as will be shown, this appears to be the case. The catch-per-day's-absence has the great practical virtue that we have available records from which to compute it for nearly all vessels engaged in the fishery over the past twenty years, so that it may be employed to study major changes which have occurred as the intensity of fishing has changed over that period.

39. A more exact measurement of average abundance of tunas, as encountered by the fishermen, is provided by the catch-per-day-of-tuna-fishing. This is computed from logbook records of days actually spent fishing for tunas, and the resulting catch. Current data are gathered by means of logbooks, especially designed, provided free to fishing captains by the Commission. A specimen page of such a logbook is shown in Figure 6. Since 1951, when we commenced our investigations, over 80 per cent of all trips made by vessels landing in the United States have been covered by

such logbooks. For earlier years, fortunately, a number of vessel masters had kept logbook records for their own purposes, which they have kindly made available to us. A fairly adequate sample of the landings are covered by such logbooks since 1947, and some logbooks are available back to 1930.

40. Because the efficiency of fishing varies with size of vessel, we compile the basic data respecting catch per unit of effort by six size categories, based on tuna-carrying capacity. From comparison of records of vessels of different sizes during the same years, it is possible to derive correction factors, so that the catch per unit of effort (catch-per-day's-fishing or catch-per-day's-absence) may be expressed in standard units (i.e. the catch per unit of effort in terms of a size category taken as standard) to correct for changes in the size composition of the fishing fleet over the years.

41. From the catch-per-day's-fishing, based on clipper logbook records, compared with the catch-per-day's-absence of the same trips, for records available from 1936-1953, it has been possible to show that there is a rather constant relationship between the two. This is illustrated in Figure 7. In the lower panel, we show, for yellowfin tuna, as abscissae, the mean catch-per-day's-fishing and, as ordinates, the mean catch-per-day's-absence, for each vessel category for each year during which a specified number of trips were available for calculating both averages. It may be seen that the points cluster fairly closely about a trend line. This indicates that the catch-per-day's absence may be taken as a reasonably good estimator of the catch-per-day's-fishing and, therefore, is also probably a fairly good estimator of the apparent abundance of this species as encountered by the fishermen. In the upper panel, the same sort of information is shown for skipjack tuna, with similar results. For skipjack we employ only the four smallest size-categories of vessels, omitting the two largest classes. This has been done because analysis of relationships between landings of the two species has shown that, for the two largest classes of vessels, the amount of time spent fishing for skipjack is influenced by abundance of yellowfin, whereas this does not appear to be true for the smaller vessel size classes.

42. Compilation of information has been completed respecting total catch of both species of tunas from the Eastern Pacific, and the catch-per-day's-absence for an adequately large sample of the fleet from 1934 through 1953. From the catch-per-day's-absence, in standard units, and the total catch may also be computed the total relative intensity of fishing for each year.

43. These series of statistical measurements of amount of fishing, yield, and apparent abundance, considering as a whole the populations of each tuna species for the entire Eastern Pacific give results of importance. In Figure 8 are shown for yellowfin tuna: (1) total landings by all vessels and all types of gear, a measurement of yield; (2) catch-per-day's-absence of a large sample of United States clippers, standardized to a class IV clipper, a measurement of abundance; (3) calculated amount of total fishing effort, in terms of number of day's absence from port of a standard class IV clipper. It may be seen that, as the amount of fishing increased from 1934 to the time of the United States's entry into World War II, the catch increased, but the catch per unit of effort declined rather steadily. With the decrease in fishing effort during the early war years, yield declined, but abundance increased sharply. Beginning in 1945, the amount of fishing increased rapidly for a few years, resulting in increased yield but decreased abundance. In recent years, intensity of fishing exhibits a slight upward trend, while the corresponding downward trend of abundance is likewise small. The fishery appears to be stabilizing, with a yield somewhat below the peak yield of 1950.

44. It seems to be valid to conclude from these data that the intensity of fishing has been sufficiently great to affect the average abundance of the yellowfin tuna. This is, of course, the inevitable result of effective exploitation of a fish population, and indicates only that the rate of catching is at a sufficiently high level measurably to affect the average size of the standing crop. In itself, it tells nothing about the relation of present level of exploitation to level of maximum sustainable yield.

45. To obtain some idea about this latter point, we have in Figure 9, plotted the total catch against the fishing intensity (the same data as in Figure 8). We have also plotted on this same graph a theoretical curve of equilibrium catch (average sustainable yield) against fishing intensity, based on the assumptions that the yellowfin tuna population aggregate considered here has a population growth curve of the form of the Verhulst-Pearl logistic, and that the mean equilibrium population is linearly related to the amount of fishing effort. It should be noted that these assumptions may be only approximately true, and also that, due to the rather large variability of catches from 1947-1953, the

theoretical curve may not prove to be quite correctly fitted. With these reservations, however, it may be seen that it appears that the present level of fishing intensity for yellowfin tuna in the Eastern Pacific is, in the aggregate, near, or perhaps slightly beyond the level corresponding to maximum sustainable yield.

46. While the foregoing conclusions are valid for the aggregate of all yellowfin in the Eastern Pacific, if it turns out that there are, in truth, several separate populations involved, it is possible, and indeed probable, that they might be in quite different stages of exploitation; some of them might be underfished while others are overfished.

47. Although the fishery in 1953 appears to have, for yellowfin, reached a level of intensity near to the level of maximum sustainable yield, there is no likely imminent danger of serious overfishing. Due to economic conditions, the intensity of fishing has decreased in 1954, and does not promise to increase in 1955. Financial returns from the fishery are such that building of new vessels to replace normal losses is not economically attractive, as a result of which the fishing fleet has been shrinking since 1951 (Figure 10). In 1952 and 1953 the intensity of fishing was maintained by fuller use of existing vessels, but by 1954 the actual intensity decreased, and no increase is expected in 1955.

48. Similar statistical data for skipjack present quite a different picture. In Figure 11 are charted for this species measurements of yield, fishing effort, and apparent abundance, again considering the entire Eastern Pacific as a single unit. It may be seen that, for this species, apparent abundance has exhibited very wide fluctuations not related to the amount of fishing. General level of catch-per-day's-absence in recent years, with very much greater fishing effort and total catch than prewar, is as high as formerly. Biological data are not now adequate to determine whether the variations in apparent abundance are due to variations in availability to the fishery, or to variations in the actual abundance in the sea. Whatever the causes of the variations, it appears from Figure 11 that effects of fishing, at present levels, on the abundance of skipjack are so small that they cannot be detected in the presence of variations due to other factors. It would appear that the skipjack resource being tapped by the Eastern Pacific fishery can support a greater intensity of fishing before reaching the point of maximum average sustained yield.

E. Simultaneous occurrence of yellowfin and skipjack

49. The two tuna species occur very generally at the same places at the same times. Sometimes they are found in mixed schools, containing a mixture of members of the two species of similar size. Often, however, the species are schooled separately.

50. It appears likely, from our investigations to date, that the yellowfin tuna resource is in a more advanced stage of exploitation than the skipjack resource and that, therefore, in an unregulated fishery the level of fishing giving maximum sustained yield of yellowfin will be passed before that for skipjack is attained.

51. Two courses of action are possible at such time as it becomes necessary to establish conservation regulations: (1) action to maximize the sustained average catch of each species individually, or (2) action to maximize the sustained average catch of the aggregate of both species. The first course of action would result in a greater total sustained average catch than the latter, providing that it is possible, in practice, to design regulatory measures such that fishing for yellowfin is controlled differentially from fishing for skipjack. The practicality of such measures involves consideration of considerable complexity, both with respect to the behaviour of the fish and with respect to juridical, political, and economic matters. The scientific staff of the Commission is not, at this time, prepared to make recommendations on this subject, since the scientific information respecting the behaviour of the fish is as yet inadequate for this purpose.

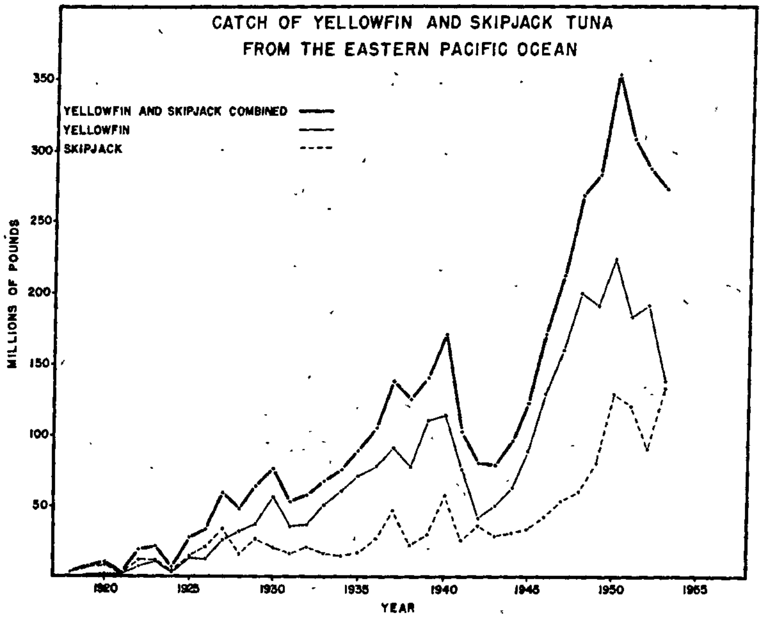



FIGURE 1. Total catch of yellowfin and skipjack tuna from the Eastern Pacific, 1918-1953.

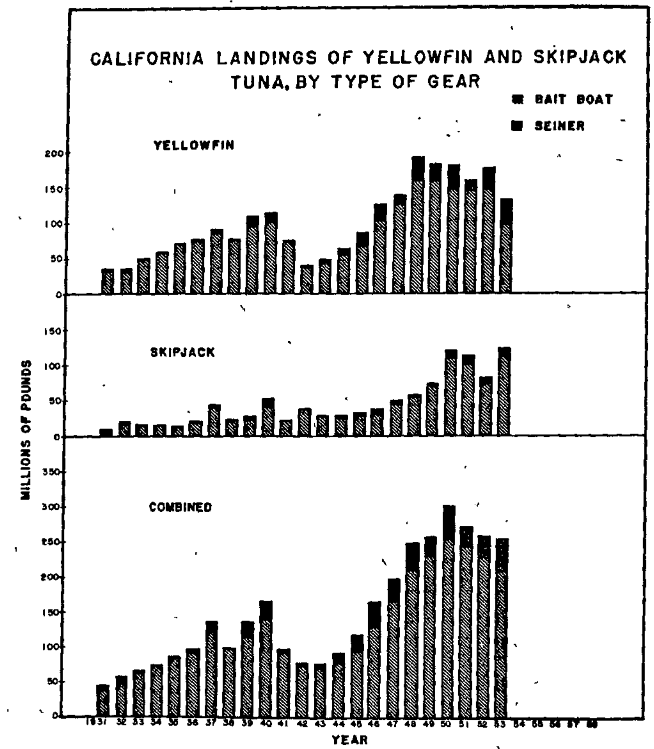



FIGURE 2. Landings in California of tropical tunas, by species and type of fishing gear, 1931-1953.

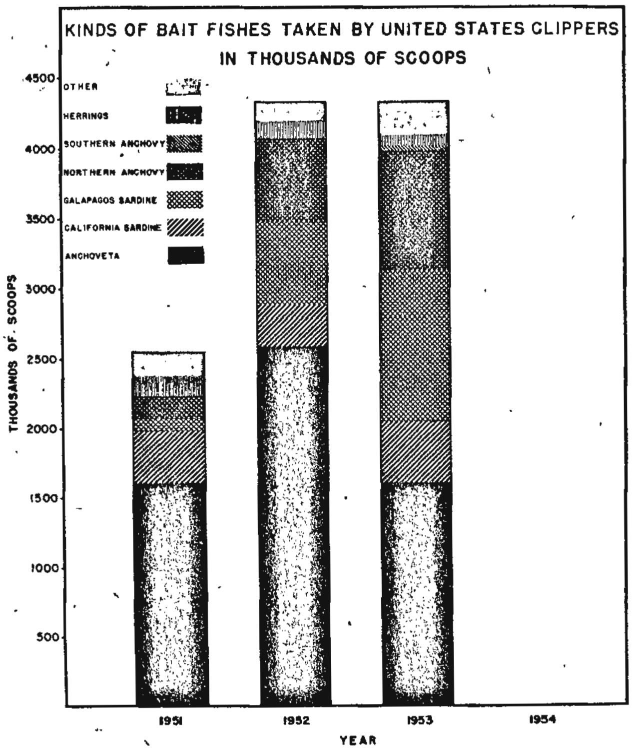



FIGURE 3. Quantities of bait fishes, by kinds, taken by U.S.Clippers 1951-1953.

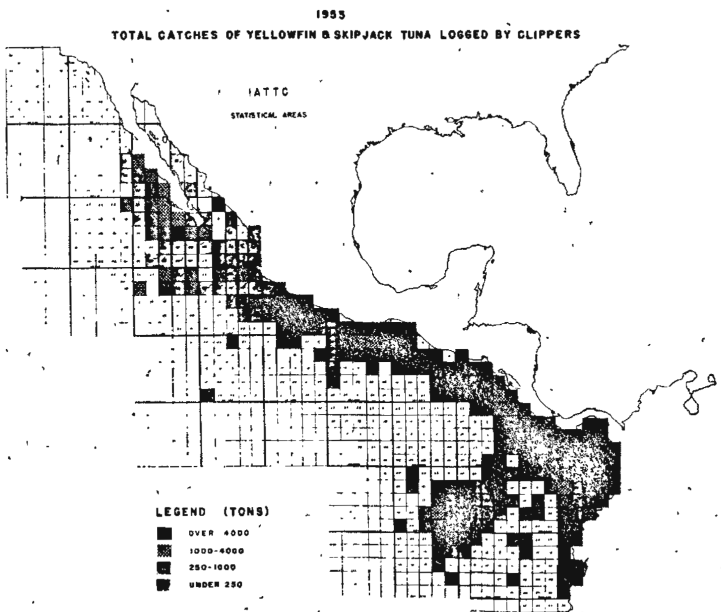



FIGURE 4. Geographical distribution of tuna catches by Clippers in 1953.

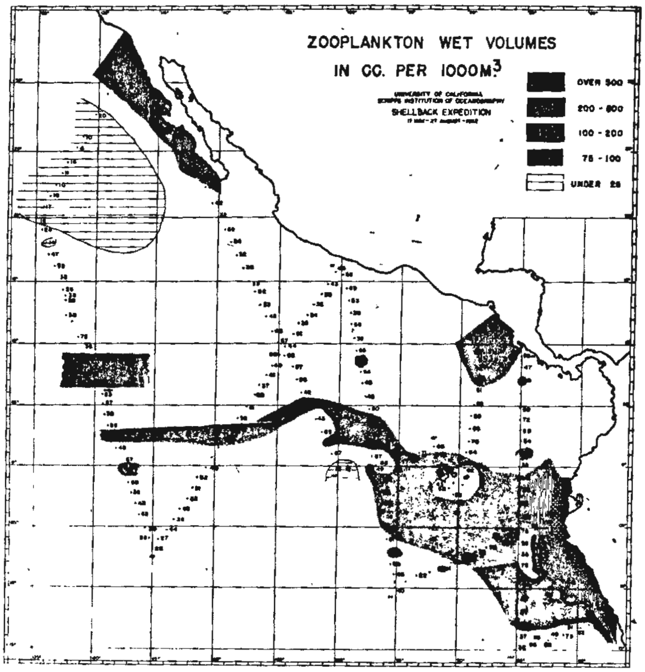
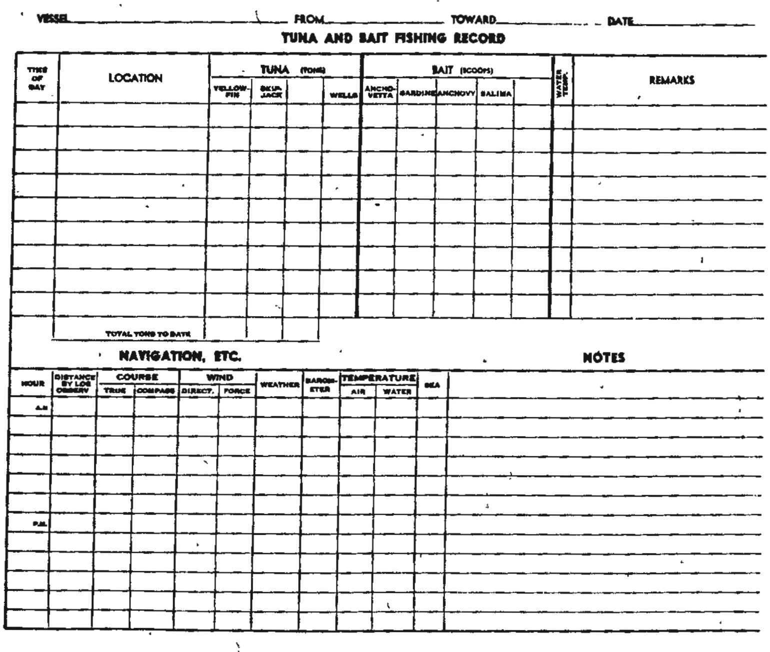



FIGURE 5. Relative abundance of zooplankton organisms in the Eastern tropical Pacific May-August, 1952.



VESSEL ______ FROM ______ TOWARD ______ DATE ______

TUNA AND BAIT FISHING RECORD

| TIME OF DAY | LOCATION | TUNA (TONS) | | | | BAIT (SCOOPS) | | | | | WATER TEMP. | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | YELLOW-FIN | SKIP-JACK | | WELLS | ANCHO-VETTA | SARDINE | ANCHOVY | SALIMA | | | |
| | TOTAL TONS TO DATE | | | | | | | | | | | |

NAVIGATION, ETC.

| HOUR | DISTANCE BY LOG OBSERV. | COURSE | | WIND | | WEATHER | BAROM-ETER | TEMPERATURE | | SEA | NOTES |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | TRUE | COMPASS | DIRECT. | FORCE | | | AIR | WATER | | |
| A.M. | | | | | | | | | | | |
| P.M. | | | | | | | | | | | |

FIGURE 6. Specimen page from tuna-clipper logbook.

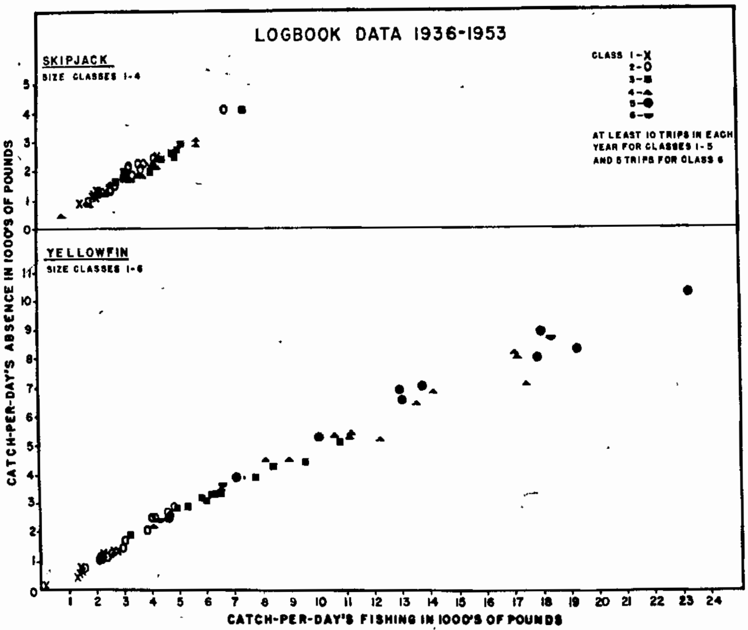



FIGURE 7. Relationship between catch-per-day's-absence and catch-per-day's-fishing, 1936-1953.

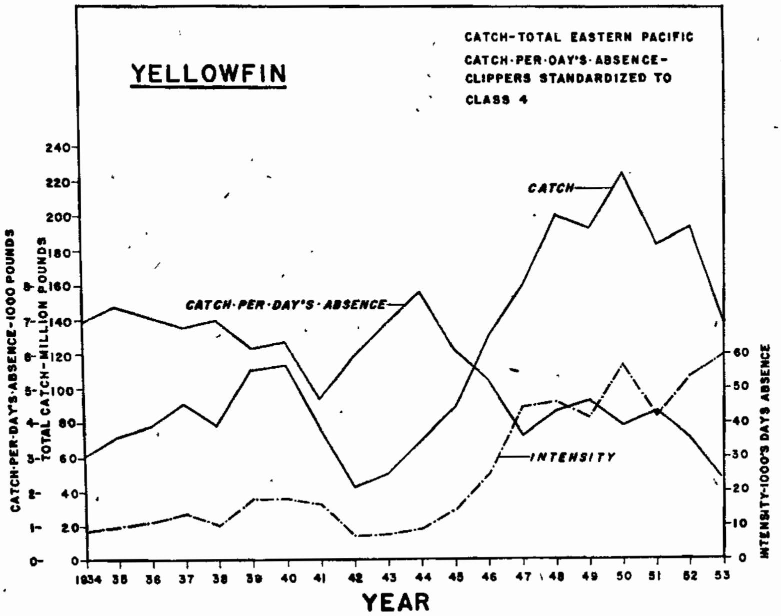



FIGURE 8. Catch, catch-per-day's-absence, and fishing intensity for yellowfin tuna 1934-1953.

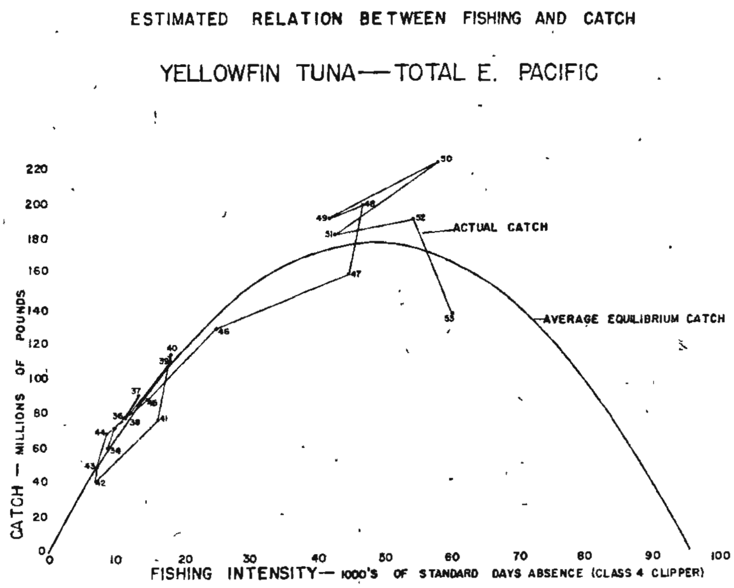



FIGURE 9. Relationship between fishing intensity and total catch, with estimated relation between fishing intensity and average equilibrium catch, yellowfin tuna, 1934-1953.

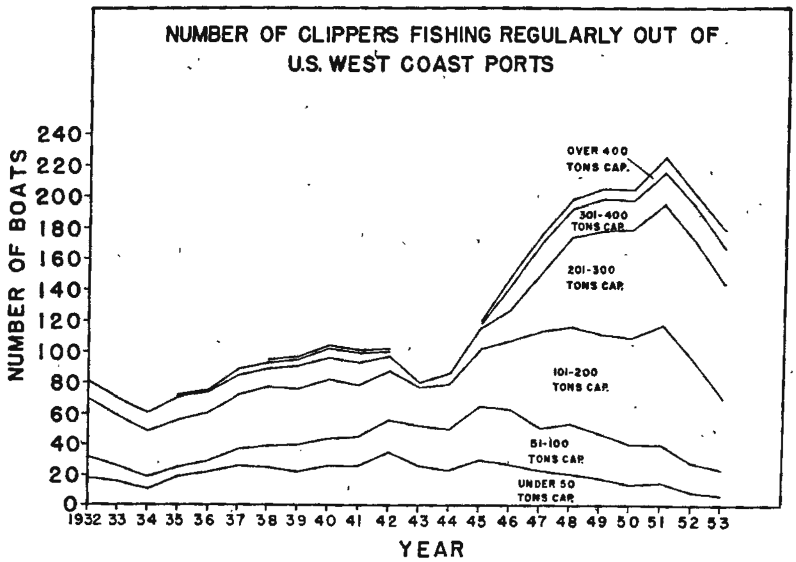



FIGURE 10. Number of clippers fishing from U.S. West Coast ports, 1932-1953.

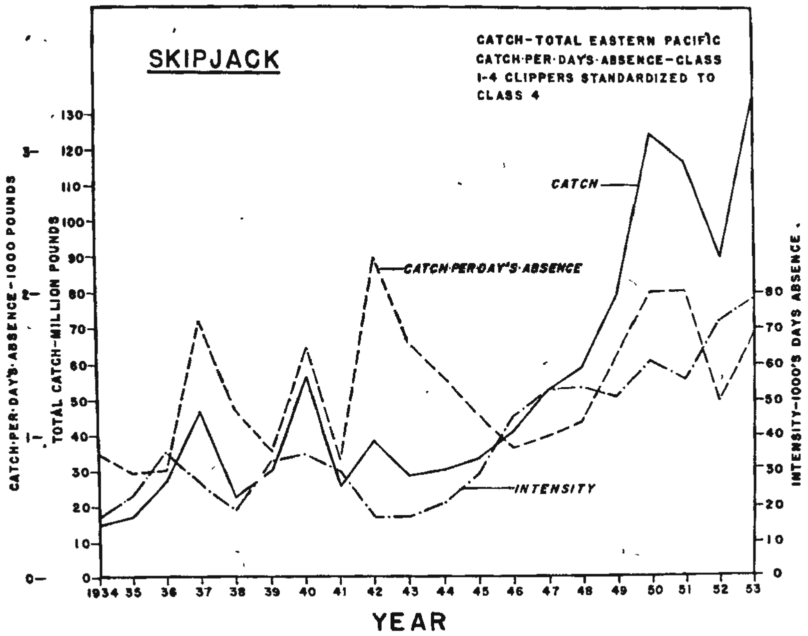



FIGURE 11. Catch, catch-per-day's-absence, and fishing intensity for skipjack tur 1934-1953.

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