415

Pacific Tuna Biology Conference

SPECIAL SCIENTIFIC REPORT—FISHERIES No. 415

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

United States Department of the Interior, Stewart Udall, Secretary
Fish and Wildlife Service, Clarence F. Pautzke, Commissioner
Bureau of Commercial Fisheries, Donald L. McKernan, Director

PACIFIC TUNA BIOLOGY CONFERENCE

AUGUST 14-19, 1961

HONOLULU, HAWAII

Edited by

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United States Fish and Wildlife Service
Special Scientific Report: Fisheries No. 415

Washington, D. C.

May 1962

ABSTRACT

A report of the work and results of the Pacific Tuna Biology Conference, held at the University of Hawaii in August 1961 under the auspices of the Bureau of Commercial Fisheries Biological Laboratory, Honolulu, and attended by tuna research workers and fishery experts from 11 countries. The report comprises a general account of the proceedings of the Conference; summaries of the discussions in six general sessions on distribution, migrations, subpopulations, behavior, tuna oceanography, and taxonomy and nomenclature; the reports of two special working groups, on identification of larval and juvenile tunas and on taxonomy and nomenclature; resolutions adopted by the Conference; abstracts of the 50 papers presented; and a list of the participants.

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INTRODUCTION

An informal Pacific Tuna Biology Conference, arranged by the U. S. Bureau of Commercial Fisheries Biological Laboratory at Honolulu, was held at the University of Hawaii, August 14-19, 1961. Fifty papers were contributed to the Conference; 79 persons attended from 11 countries.

The informal nature of the Conference was stressed for at least three reasons: First, so that it would be evident that this was in no sense a government-to-government meeting but rather a gathering of scientists with common interests. Thus, any decisions taken would in no way be binding upon governments but rather would represent working arrangements between individuals or between laboratories. Second, it was hoped that the informal nature of the proceedings would encourage discussion and contribute to the free exchange of ideas. This was either not a real problem or the arrangements achieved their intent, since discussions were spontaneous from the start. Third, the informality allowed me, as organizing chairman, and as a matter of convenience, to draw upon the talents of my colleagues in the preparation and conduct of the Conference, without regard to representation by national groups or by specialties. This would not have been possible under a more formal organization.

Virtually all of the contributed papers were reproduced and distributed to the participants well in advance of the Conference. It was thus not necessary for any papers to be given orally at the Conference. Rather, the papers were grouped according to the following subjects: (1) Distribution, (2) Migrations, (3) Subpopulations, (4) Behavior, (5) Tuna Oceanography, (6) Taxonomy and Nomenclature, and (7) Background Papers, and there were half-day discussions of each subject, except (7). Each discussion group was provided with a Discussion Leader and a Rapporteur. Summary records of each discussion were available on the following day, when they were read, modified if necessary, and accepted by the Conference.

Resolutions were based upon problems and needs identified during the course of the Conference and upon the findings of the two Working Groups, one on Taxonomy and Nomenclature and the other on Identification of Larval and Juvenile Tunas. The Resolutions were read on the last day of the Conference, modified if necessary, and accepted by the Conference.

The physical record of the Conference, i.e., the Discussion Summaries, the Resolutions, and the Abstracts of Contributed Papers, contained in the following pages may be judged on its own merits. It is more difficult to judge the intangible benefits which will accrue over the years from the personal contacts established during the course of the Conference, with resulting improvements in communication between widely separated laboratories.

The success of a Conference of this nature is dependent upon those who participate in it. I wish to express my appreciation to all who found it possible to attend and who contributed so freely to the discussions. I wish also to acknowledge my debt to all of my immediate colleagues in the Bureau, without whom it would have been impossible to arrange and carry out the Conference.

PROGRAM

August 14 - Monday

9:00-10:00	Registration
10:00-10:30	Opening business Chairman: John C. Marr
10:30-12:30	Taxonomy and Nomenclature Discussion Leader: Phil M. Roedel Rapporteur: Walter M. Matsumoto
12:30- 2:00	Lunch
2:00- 5:00	Distribution Discussion Leader: Donald W. Strasburg Rapporteur: Robert T. B. Iversen

August 15 - Tuesday

9:30-12:30	Migrations Discussion Leader: Tamio Otsu Rapporteur: Eugene L. Nakamura
12:30- 2:00	Lunch
2:00- 5:00	Behavior Discussion Leader: John J. Magnuson Rapporteur: Everet C. Jones

August 16 - Wednesday

8:00- 5:00	Demonstration cruise on CHARLES H. GILBERT; live-bait skipjack fishing, underwater observation chambers

August 17 - Thursday

9:30-12:30	Subpopulations Discussion Leader: Lucian M. Sprague Rapporteur: Richard N. Uchida
12:30- 2:00	Lunch
2:00- 5:00	Available for working groups

August 18 - Friday

9:30-12:30	Tuna Oceanography Discussion Leader: Thomas S. Austin Rapporteur: Kenneth D. Waldron
12:30- 2:00	Lunch
2:00- 5:30	Open House, U. S. Bureau of Commercial Fisheries Biological Laboratory. Exhibit of scientific illustrations by Tamotsu Nakata (Room 221)

August 19 - Saturday

9:30-12:30	Closing business Chairman: John C. Marr
5:00-11:00	Luau, U. S. Bureau of Commercial Fisheries Biological Laboratory.

SUMMARY REPORT OF DISCUSSIONS

Taxonomy and Nomenclature

Discussion Leader - Phil M. Roedel
Rapporteur - Walter M. Matsumoto

Reference: Papers No.

VI - 1. Collette, B. B. - A preliminary review of the tunas of the genus *Thunnus*

2. Roedel, P. M., and J. E. Fitch - Taxonomy and nomenclature of the Pacific tunas

In spite of the tremendous amount of attention given the tunas in recent years, the basic problems of taxonomy and nomenclature are still unresolved. Several things have contributed to this; for example, many of the past descriptions are too brief, the localities of capture are often vague, and the taxonomy of the group is often approached from a geographically narrow point of view. As a result, a multitude of names exist for fish which could well be of the same species but were simply taken in different parts of an ocean or in different oceans. To further complicate matters there are today two schools of thought among taxonomists with regard to the tunas: (1) those who recognize the existence of numerous species in different parts of the world and (2) those who contend that there are only a few species widely distributed throughout the world.

The purpose of the open discussion was to identify the various problems concerning the taxonomy of the tunas and to find solutions to these problems or decide upon the best means by which they could be solved.

Several problems, two in the form of questions, were brought out during the discussion:

1. How many genera are there among the tunas?
2. How many species comprise the tuna?
3. Difficulty in defining genus.

1. It was pointed out and generally accepted that there is no reason to split the tunas taxonomically to the point where each species is given a generic name. This means that such generic names as Parathunnus, Neothunnus, and Kishinoella should be replaced by Thunnus. Other genera (Euthynnus, Katsuwonus, and Auxis) were not discussed.

2. The single-species concept was strongly advocated for yellowfin, bigeye, albacore, and skipjack. It was also felt that T. tonggol and T. atlanticus are valid species. One exception to this single-species concept was pointed out in the bluefins. The Pacific T. orientalis and the Atlantic T. thynnus were suggested to be subspecies on the basis of gillraker counts. Here again, species of two other genera, Euthynnus and Auxis, were not discussed.

3. While it was clearly recognized that the problem is extremely subjective and, therefore, difficult for researchers to come to any agreement on, it was pointed out that some degree of objectivity was possible in taxonomic works. In the case of species there may be evidence of reproductive isolation. The use of serology in separating tunas on the generic level was suggested. It was felt that this technique has some possibility, even though the problem is not solvable at this time.

Although there was general agreement on the greater portion of the species and genera discussed, evidence of some reservations was clearly displayed when suggestions for carrying out further work in clarifying the taxonomic problem were offered. The consensus was to appoint a well-qualified person or committee to prepare a thorough background paper for the FAO World Tuna Conference and to determine whether or not there is need for more data.

In connection with the need for more data, Hiroshi Nakamura kindly offered his cooperation in collecting specimens of various species of tunas from all oceans of the world in which Japanese fishing operations are being carried on at the present time.

At this point, with further work to be done on some of the problems and in order to formulate recommendations wherever needed, a working group was appointed consisting of Phil M. Roedel, Chairman, John C. Marr, Hiroshi Nakamura, and Robert H. Gibbs, Jr.

Distribution

Discussion Leader - Donald W. Strasburg
Rapporteur - Robert T. B. Iversen

Reference: Papers No.

I - 1. Nakamura, H. - An outline of the tuna longline grounds in the Pacific

2. Kamimura, T., and M. Honma - Distribution of yellowfin in the longline fishing ground in the Pacific Ocean, especially on the regional variation of the density in each size group

3. Mimura, K. - Studies on Indo-maguro
4. Clemens, H. B. - The distribution of California bluefin tuna in the eastern North Pacific
5. Clemens, H. B. - The distribution of albacore in the North Pacific

The initial discussion centered on longline fishing in the Pacific and Indian Oceans. It was brought out that the Pacific Ocean in general is marked by a series of current systems extending in an east-west direction. These current systems are characterized as distinct environments with distinctive fisheries. For example, the North Pacific Current north of 28° N. is noted for heavy catches of albacore, while the area from 5° N. to 10° S. (parts of the Equatorial Countercurrent and the South Equatorial Current) is noted for heavy catches of yellowfin. Migrations of tunas in these current systems were hypothesized as occurring (a) within current systems, where the movements are slow and easy to follow, and (b) between current systems, where they are rapid and difficult to follow. Evidence for (b) is the abrupt seasonal change in the size composition of the catch.

The next phase of the discussion pointed out there was considerable variation in the abundance of tunas according to years. For example, the 1953 catch of albacore was good, relative to the catch in an average year, and catches of bigeye tuna were also good then. The 1953 catch was attributed in part to the dominance of 5-year-old albacore. It was also noted that 1953 was an atypical year in many other ways. El Niño off western South America was well developed, tuna catches in the eastern Pacific were affected, the Equatorial Countercurrent was weak, Chinook and sockeye salmon catches were poor, and the eastern Pacific was abnormally warm.

North-south hemispheric differences were shown to exist in longline catches. In general, catches of tunas and marlins were heaviest in the Southern Hemisphere. The significance of this is unknown.

The discussion then shifted to the length distribution of yellowfin in various regions of the Pacific longline grounds. Catch data were classified by length, area, and season. Yellowfin smaller than 120 cm. were largely restricted to waters of east longitude, while fish larger than 140 cm. were mostly distributed in waters of west longitude. Intermediate-sized fish, 121-140 cm., were widely distributed, showing a relative shift in abundance to the east when compared to the small fish. This shift in size was present throughout the year, with no marked seasonal differences. Three possible artificial causes for it were evaluated: effect of fishing, gear selectivity, and the location of the fishing grounds with respect to land masses. The difference in size groups was hypothesized as a migration of the smaller yellowfin from west to east. It was suggested that the shoaling thermocline to the east in equatorial waters may be responsible for bringing the larger yellowfin into the depth range of the longline. It was further pointed out that returns from tagging in the western Pacific have been mostly short term (i.e., 1 year or less).

Indian Ocean bluefin tuna, fished by the Japanese in waters north and west of Australia, have recently become the object of an important longline fishery. There are two grounds for these bluefin, clearly separated from each other. The Old Fishing Ground is located between the Lesser Sunda Islands and Australia and, since 1958, the New Fishing Ground off the Australian west coast from 20° S. - 30° S. No bluefin have been found peripheral to these grounds, and only scattered fish are found on the grounds outside the months of September through April. The catch rate in the Old Fishing Ground has two peaks, one in September - October and the other in February. On the New Fishing Ground the single peak occurs in January - February and is twice as great as those of the Old Fishing Ground. The size of bluefin taken on the Old Fishing Ground is uniformly large throughout the season, while on the New Fishing Ground their size decreases at the height of the season. Bluefin on the Old Fishing Ground have relatively large gonads (1,000 - 4,000 g.) throughout the season, while fish on the New Fishing Ground have gonads mostly smaller than 1,500 g., with a change in relative size at various times during the season. It was pointed out that gonads from large western Atlantic bluefin are difficult to evaluate by the method of gonad weight because they contain a large amount of fat. Western Atlantic bluefin make a seasonal migration, a situation also hypothesized for these two groups of Australian bluefin.

The bluefin tuna of the eastern North Pacific is taken primarily in coastal waters, in contrast to the North Pacific albacore, which is primarily a pelagic species. Both species range from Baja California to Alaska, and both are the object of seasonal fisheries off the west coast of the United States and Baja California. The size of bluefin caught in the last 50 years has changed considerably. In the early 1900's, many large bluefin (200 - 300 lb.) were caught by sports fishermen. During the last 20 years the catch has been mostly fish of 25 - 30 lb. or less. Since 1958, some large bluefin (>100 lb.) have reappeared in the catch. California bluefin may inhabit either warm, high-saline water, such as is normally occupied by yellowfin, or the cold, low-saline water characteristically inhabited by albacore, but they occur mostly in water with temperature-salinity characteristics intermediate between these two. In years when ocean temperatures are unusually warm, the California bluefin ranges hundreds of miles farther north. It was agreed that a cause-and-effect relationship between distribution and ocean temperature should not be postulated without further investigation.

It was stated that bluefin leave the California coastal area for spawning, since there is an absence of sexually mature adults, eggs, and larvae in this area. H. Nakamura presented evidence for a possible continuous distribution of bluefin across the Pacific.

To further our understanding of tuna distribution, it was felt that increased emphasis should be given to tagging of small tunas in the western and North Pacific, of albacore off South America, and of southern Australian bluefin. The design of exploratory fishing surveys utilizing special equipment was recommended. We can expect further knowledge to result from studies on migration, subpopulations, behavior, and oceanography, all of which relate to distribution.

Migrations

Discussion Leader - Tamio Otsu
Rapporteur - Eugene L. Nakamura

Reference: Papers No.

II - 1. Otsu, T., and R. N. Uchida - A model of the migration of albacore in the North Pacific Ocean

2. Clemens, H. B. - Migration, age and growth, and spawning studies of the North Pacific albacore (Thunnus germo)

A model was presented of the migration of albacore in the North Pacific Ocean, based on tag recovery data, age and growth data, and distribution and size frequency data from the three major albacore fisheries: the Japanese live-bait fishery, the Japanese longline fishery, and the American west coast trolling and live-bait fishery. This model is consistent with the hypothesis that there is a single population of albacore throughout the North Pacific Ocean.

Discussion of the albacore tagging data brought forth remarks that young bluefin in Australian waters ought to be tagged to see if they would appear in the Japanese longline fishery in equatorial waters. Agreement was expressed by others with further remarks concerning the desirability of tagging the young of all species of tuna to help solve distributional, growth, and taxonomic problems of the various species.

Further discussion about small albacore centered around the 35-cm. modal group. It was stressed that one should be aware of the fact that even though 35-cm. fish are present they may not be fished for economic reasons, particularly if larger fish are available.

A suggestion was made that in view of the amount of information available from the various laboratories studying albacore, a joint effort should be made to define more clearly the problem of assigning absolute ages to modal groups.

The view was expressed that there may be some danger in assuming that recruitment occurs only in the eastern Pacific. There was general agreement that the major spawning area is in subtropical waters, but which way do the newly hatched fish go? What size are they when they enter the postulated migratory routes? Attention should be directed toward the smaller fish, particularly the 35-cm. modal group. These fish have been reported in the area of the Japanese live-bait fishery by fishermen who do not catch them for economic reasons. So perhaps it may be better to hypothesize that recruitment occurs in both the Japanese and American fisheries. Plans are being made by the Japanese to use special gear for catching these small fish in the future.

The statement was then made that perhaps discussions of recruitment involve a semantic problem. One use means recruitment into the fishery while the other means recruitment into the temperate North Pacific Ocean.

The question of tagging small fish arose again. It seems desirable to tag small albacore. It was suggested that the salmon investigators might be encountering small albacore in their gill nets. However, it was believed that the mesh sizes used for salmon were too big to catch small albacore.

Serological evidence supports the hypothesis that a single reproductive population of albacore exists in the North Pacific Ocean.

The subject of depth of albacore occurrence was discussed next. In both the Japanese live-bait fishery and the American fishery, the fish are caught at the surface. In the longline fishery, the albacore are caught with gear fishing down to 100 meters. The depth of occurrence may be associated with the depth of the mixed layer. Japanese longline fishermen adjust the depths of the hooks depending upon the area fished.

In connection with depth of occurrence, the suggestion was made to further develop the idea of a depth gauge which could be attached directly to the fish. If a miniature type of bathythermograph could be developed, it could help solve problems of vertical distribution. Such depth gauges, which must be inexpensive, small, and calibrated after recovery, were worked upon by Bureau of Commercial Fisheries technicians at Seattle, but lack of interest and research funds brought an end to the project.

A method that has been used in Japan to determine the depth of fish occurrence was described. The gear consisted of a float attached to each branch line. It was implied that the fish could not have been caught at a depth deeper than the length of the line. In the Celebes Sea, yellowfin were caught as deep as 160 m., but most were caught at 100 m. Marlin catches were best at 70 to 80 m., and shark catches at 30 m. However, the work of gear handling was increased greatly so that not as many units could be fished as normally.

The use of echo sounders for determining hook depths was mentioned, and a design for a sonic reflector tag for skipjack was described.

Vertical distribution of tuna in relation to oceanographic factors was also discussed, such factors being internal waves, the deep scattering layer, and temperature discontinuities.

It was pointed out that there was basic agreement between the two reference papers and that the major difference was in the assignment of absolute ages to the various modal groups. Another difference was that Clemens' paper postulated that some albacore of all sizes remain in the central Pacific without migrating either eastward or westward. The paper by Otsu and Uchida does not so postulate, although available data would tend to support Clemens.

Clemens' estimation of albacore age is 1 year less than that of Otsu and Uchida. The possibility of the difference being due to a different assumed spawning season was expressed. Clemens believes that the youngest fish entering the American fishery are really about 15 or 16 months old. In addition to other data, Clemens read scales from near the caudal peduncle to estimate age. Slides were shown of albacore scales from the peduncle of a 59-cm. fish which had one annulus, a 69-cm. fish with two annuli, and a 75-cm. fish with three annuli. It was stated that scale readings of albacore in Japan were in agreement with the California studies. The opinion was also expressed that because scales in the peduncular area are the last to develop in a young fish, the first annulus may be so compact and small in radius that it may be overlooked. A comparison was made of the albacore growth curves of Clemens and of Otsu, and both are nearly identical for fish sizes above 50 cm. A statement was made that in the Atlantic yellowfin and bluefin the first year's growth is in the neighborhood of 30 cm.

The discussion then turned to triggering mechanisms for migration. Two areas of search for this triggering mechanism were suggested: in the environment and within the organism. It was then suggested that the two probably interact, that an environmental mechanism (extrinsic factor) interacts with an internal mechanism (intrinsic factor). That extrinsic factors may be temperature or length of daylight was discussed. An example of the importance of length of daylight was given for the maturation of the ayu in Japan. It was suggested that the intrinsic factor is possibly associated with the endocrine system, as has been shown in salmonids.

The final discussion involved the use of commercial landings as indicators of presence or absence of albacore. It was pointed out that lack of commercial landings need not mean the absence of albacore, but rather the lack of encounter between fishermen and fish, whether it be due to inclement weather or something else.

Behavior

Discussion Leader - John J. Magnuson
Rapporteur - Everet C. Jones

Reference: Papers No.

IV - 1. Strasburg, D. W. - An aerating device for salt well water

2. Nakamura, E. L. - The establishment and behavior of skipjack tuna (*Katsuwonus pelamis*) in captivity

3. Yuen, H. S. H. - Experiments on the feeding behavior of skipjack at sea

Behavior has been defined as the total movements of an intact animal. More recently the field has been broadened to include the study of these movements relative to physiology, ecology, and phylogeny. From a practical viewpoint, behavior studies may provide information useful in developing fishing gear, in predicting a tuna's location in time and space, and in understanding behavioral mechanisms which have consequences in population dynamics.

Observations of skipjack both in captivity and in the field indicate that certain color changes and fin movements are associated with feeding. Transient vertical bars observed on skipjack appear to result from the contraction of melanophores in vertically oriented zones on the sides of the fish, producing a pattern of alternate light and dark bars. The speed of these changes indicates nervous control rather than endocrinal control. Such transient vertical bars have been observed on other large pelagic fishes in the living state, but fade on dead or dying fishes. Vertical bars are a common non-transient pattern on juveniles of many fish species.

Various people have observed reddish colored skipjack; perhaps this is a spawning coloration. A more commonly observed pattern is one of bright blue horizontal streaks on the dorso-lateral surface. It was suggested that these blue streaks may be fluorescent or luminescent. Since this color is not observed on dead fish the possibility of iridescence was questioned. Transient color patterns, together with erection of the first dorsal fin (resulting in the prominent display of the white leading edge) and opening of the mouth (resulting in the display of the silvery tongue), may be social releasers. The possibility that these changes are involved in communication among fish opens up new fields of research. Avenues of investigation included the use of artificial skipjack painted in appropriate colors to test the reactions of both captive and wild fish.

The feeding response of skipjack at sea appears to be influenced by the quality of the stimulus, i.e., the characteristics of the bait species used. It is possible that a sufficiently attractive bait fish might actually attract the tuna away from the hooks and result in a lower biting rate. Experiments have been conducted in Hawaii using dead bait fish because of the scarcity of live bait. Both the catch rate and feeding response of skipjack were less with dead bait than with live bait, but yellowfin tuna in the eastern Pacific react to such inanimate material as macaroni, rice, or nails. The Galapagos fishery was started on dead bait.

Large schools of many species of pelagic fishes, including the tunas, have often been observed to be associated with floating logs, boxes, or driftwood. In the Atlantic, blackfin tuna have been observed associated with whale sharks, and various tunas in the Pacific have been observed associated with porpoises. It is a common practice of fishermen to investigate floating material to locate schools of tuna. In Japan, skipjack did not aggregate under driftwood which was planted at sea for that purpose. A hypothesis put forward to explain the association between fish schools and logs or driftwood was that the floating object attracted small fish which were preyed upon by the large fish of the school. Objections to this idea centered about the observation that the schools of predaceous fish under floating objects were often too large to be attracted by a few small fish. A counter suggestion was made that we do not know the rate at which small fish accumulate and that it may be greater than presently expected.

Skipjack schools in the Japanese fishery have been observed to extend from 100 to as much as 1,000 meters from the driftwood and to move in and out from it. In Hawaii, 3 months of investigation of floating wood resulted in no observed association with skipjack. Dolphin (*Coryphaena*) were often seen in such association, but examination of stomach contents indicated that they were not feeding on *Kyphosus*, the small fish most often found under driftwood, but were feeding on trunkfish and flying fish.

In the Philippine fishey, floating objects are used to help "lure" or guide skipjack toward the mouth of large traps. This practice appears to be associated with the presence of deep, narrow channels between islands.

Techniques of observation must be related to whether the investigator is studying the behavior of individual fish or the behavior of schools of fish. For the former, direct observation of a detailed image is necessary; the use of movies appears to be the best technique because it allows more detailed analyses. For studying fast-moving tuna, fast shutter speeds and fast film are required to prevent blurring. The desirability of securing much more footage of movies of tuna was pointed out. Vessels having underwater viewing facilities are particularly useful in this work.

In the observations of fish schools, sonar instruments are useful. Other possibilities include the use of aerial observations with movies of schools being fished. Airplanes are standard equipment in the North American west coast fisheries. In Hawaii, attempts to use aircraft for scouting have not been successful because of sea surface glitter and rough seas. In the Atlantic, movies of tuna schools have been taken from a slow-flying aircraft flying at 20 feet and at 30 - 35 miles per hour.

Relating the studies of anatomy and behavior appears to be a useful approach, particularly in the case of fishes that are difficult to observe directly. Examples mentioned included the hypothesis that the ratio of rods and cones in the retina may be related to the amount of light in the usual environment; that the presence or absence of a swim bladder may be related to diving behavior; and that the presence of vascular anastomoses may be a mechanism of blood flow control related to diving behavior.

Studies of the internal body temperature taken in live tuna indicate that it is consistently 1 to 5° C. higher than the water temperature. Just what part of this difference is associated with the unusual exertions of being caught and what part is normal has not been determined. Because it is difficult to take thermometer observations of "normal" fish, the use of infrared heat detection was suggested as a useful tool.

Subpopulations

Discussion Leader - Lucian M. Sprague
Rapporteur - Richard N. Uchida

Reference: Papers No.

III - 1. Legand, M. - Biometric data on yellowtin tuna in New Caledonia

2. Suzuki, A. - Blood types in tuna

3. Fujii, Y., K. Mimoto, and S. Higasa - Biochemical studies on the races of tuna base composition of testis deoxyribonucleic acid (DNA)

4. Marr, J. C., and L. M. Sprague - The use of blood group characteristics in studying subpopulations of fishes

5. Ridgway, G. J. - Distinction of tuna species by immunochemical methods

6. Royce, W. F. - A morphometric study of yellowfin tuna Thunnus albacares (Bonnaterre)

7. Hiyama, Y., and K. Kurogane - Morphometrical comparisons of tuna from areas in the Pacific and Indian Oceans

8. Sprague, L. M., and L. I. Nakashima - A comparative study of the erythrocyte antigens of certain tuna species (Abstract)

9. Sprague, L. M., and L. I. Nakashima - Studies on the erythrocyte antigens of the skipjack tuna (Katsuwonus pelamis)

10. Sprague, L. M. - Blood group studies of albacore (Germo alalunga) tuna from the Pacific Ocean

11. Legand, M. - Some biometric data on the albacore of the region west of New Caledonia

The discussion was divided into three main categories depending on the methodology:

A. Chemical methods

1. Biochemical

2. Immunochemical

B. Morphometrical methods

C. Serological methods

A. (1) Discussion centered on the biochemical studies on the races of tuna by analysis of the base composition of testis DNA (deoxyribonucleic acid). It was brought out that DNA is implicated as the substance primarily responsible for the transmission of hereditary characteristics at the molecular level. In most samples of DNA, four heterocyclic bases predominate. For the purines, these are adenine and guanine, and for the pyrimidines, they are thymine and cytosine. These bases are bound together on a chain of deoxyribose sugar together with certain phosphate residues, and the chain forms the chemical backbone of the DNA molecule.

It has been demonstrated that the values of the base pairs adenine and thymine divided by the values of the base pairs guanine and cytosine yield ratios which are quite different for some tunas. Studies on bigeye, yellowfin, Indo-maguro and Goshu-maguro yielded ratios which ranged from 1.26 to 1.75.

The conclusion was reached that the ratio of the base pairs of the DNA molecule may in the future provide an indication of the racial relationships of the tunas.

It was noted that a similar study of differentiating the racial stocks of tuna by electron-micrographic comparisons of tuna spermatozoa was being carried on by the Inter-American Tropical Tuna Commission. In this study the potentiality of telling racial stocks apart depends on differences in sperm morphology.

Cushing endorsed further exploration on the subject of DNA as a tool for differentiating subpopulations of tunas. A paper model of the DNA molecule was shown the conferees, and its structure was briefly explained.

A. (2) Discussion centered on the immunochemical method. The study involved development of a suitable method for use in the identification of larval forms of tuna. The study has shown that the method of diffusion precipitin analysis demonstrated the presence of species-specific differences in serum antigens of adult tuna.

The study has revealed that there is at least one distinctive antigen which may be used as a diagnostic antigen for individual species of tuna.

The conclusion was reached that there are definite possibilities in the application of immunochemical methods to the problem of identifying larval forms. The usefulness of this method, however, depends on the development of species specificity in antigenic constitution early in embryological development.

Discussion brought out that immunochemical methods may be useful in studying the taxonomic relations between species of fishes. Their use may provide additional information in distinguishing species and, when combined with red blood cell studies, may be a very sensitive and useful tool in taxonomic studies.

The question was raised whether this method would be useful in distinguishing the tuna larvae, which have only a very small amount of blood. It was stated that there are refined techniques for dealing with organisms with a small amount of blood, but the techniques are very time-consuming and expensive. It was stated that fresh specimens should be used in immunochemical studies, and sample size should be as large as possible so that statistical tests can be made.

The conclusion was reached that serological studies can be useful in verifying the conclusions reached by systematic studies. The suggestion was made that a study of the American and European eel problem be carried out by these methods.

B. Hiyama noted that there were only small differences in the body characters of the northwest Pacific albacore which form the basis of the Japanese winter longline and summer live-bait fishery. When northwest Pacific albacore were compared to the albacore from the equatorial and southwest Pacific areas, there were distinct differences. The albacore from the equatorial and southwest Pacific were morphometrically similar. The Indian Ocean albacore were found to be distinct from the northwest

Pacific albacore; however, the conclusion was that there was possibly some mixing between the Indian Ocean and southwest Pacific albacore.

In respect to yellowfin, Hiyama concluded that morphometrically there are at least three independent populations in the equatorial Pacific between 130° W. and 130° E. Yellowfin in waters adjacent to the Lesser Sunda Islands were found to be distinct from fish of the equatorial Indian Ocean.

No conclusions were made on population differences in bigeye because of insufficient data.

Discussion brought out that the albacore has the widest distribution of any of the tunas in the Pacific and also the smallest differences between populations. The yellowfin apparently has small independent populations scattered over the Pacific; the bigeye distribution is larger than the yellowfin but smaller than the albacore distribution.

Royce compared yellowfin samples from the Pacific, Atlantic, and Indian Oceans. In the yellowfin along the Pacific Equator from the eastern Pacific to the Caroline Islands, the existence of a cline or character gradient was noted. A sample from the Atlantic closely resembled a sample taken between Costa Rica and the Line Islands. The Somaliland sample was the most diverse, the specimens showing particularly short fins, a deep body, and a long distance from the snout to the insertion of the ventrals.

The conclusion was that east-west migration is limited, because the overlap of samples from along the Pacific Equator is inversely related to distance between samples; the average overlap between samples 1,500 miles apart was less than 50 percent, 3,000 miles less than 25 percent, and 6,000 miles less than 6 percent.

Royce concluded that the name for the yellowfin should be Thunnus albacares (Bonnaterre) 1788, because the yellowfin has a continuous distribution and also because the full range of characters which have been used to distinguish species occurs in the series of samples from the Pacific Equator.

Discussion on yellowfin subpopulations brought out that among the yellowfin in the eastern Pacific, ranging from Baja California to Chile, there is evidence of isolation among the stock, with intermixing on the order of about 20 to 25 percent. North of latitude 15° N., the stock responds differently from stock to the south of 15° N. An example noted was that the northern stock spawns in summer while the equatorial stock spawns in winter.

Discussion brought out that plastic phenotypic characters can be modified by diet and temperature. Conditions that modify growth may change not only from place to place, but also from year to year. As a result, we may be measuring the changes in the fish or changes in the environment. It was remarked, unfortunately, there is no way to separate morphological changes due to genetic factors from those due to the environment. However, even if the characters are phenotypic, there is still an indication that intermingling between fish from one area and those of another area is highly unlikely.

It was stated that knowledge of the subpopulations of the tunas is essential, since each population unit will respond, perhaps uniquely, to fishing effort. Such knowledge of the population pattern can help materially in the management of the fishery resources.

Discussion on genetic exchange brought out that there may be intermingling between surface and subsurface aggregations and also during the early years of life. Yellowfin were noted to be responsive to oceanographic changes and, under conditions of abnormal warming or cooling, they may move to other areas. Thus exchange of genetic material may occur through the movements of a few fish. Further evidence of possible genetic isolation was cited. Along the Equator from 120° E. to 110° W. there does not appear to be much variation in spawning. Size at maturity appears to be at about 110 cm., although a few individuals between 80 to 110 cm. may be mature. Off the American coast, however, a very large percentage of fish over 80 cm. were found to be mature. Therefore, one might possibly conclude that the fish in the eastern part of the Pacific are of a different population than those of the western part.

Diversity of opinion was noted among some contributors as to the extent of intermingling of yellowfin population units in the equatorial Pacific. Because of the possible need for management in some yellowfin fisheries in the near future, it was thought that the investigators concerned should make special effort to resolve this problem.

Discussion brought out that the term subpopulation should refer to reproductive units, and that the use of this term for aggregates of individuals apart from this framework would lead to confusion.

Legand summarized his biometrical analysis of yellowfin and albacore taken in the region of New Caledonia. He remarked that insufficient studies have been made on yellowfin to differentiate the sexes by biometric data. There are, nevertheless, indications that the length of the pectoral fin may differ significantly. This possibility should be considered particularly in a serious study of the population by morphometric characters. Thus in New Caledonia, yellowfin tunas tend to have smaller heads and larger second dorsal and anal fins than fish caught farther east.

For albacore, it was concluded that results similar to those of Kurogane and Hiyama were obtained from data on the northern Coral Sea, but results were different from those obtained in the northwest Pacific. Both phenotypic and genotypic differences have been observed in the number of anal rays and vertebrae in the medaka (*Aplocheilus latipes*).

C. Antigens discussed in this section were defined as molecules on the surface of the erythrocyte, or red blood cell, detected by immunological methods.

Serological comparisons of North Atlantic and North Pacific albacore have demonstrated that serological techniques can distinguish reproductively isolated tuna populations.

Two blood group systems in the skipjack are recognized, namely the A and C system. The C system has been found in all tuna species thus far investigated. The A system was also present in all the tunas except the yellowfin.

Systems such as the A and C system in the tunas would be comparable to the A-B-O and M-N blood groups found in man.

Students of skipjack population units in the Pacific recognize at least two reproductively isolated units. There is good evidence that the North American and Samoan stocks of albacore are reproductively isolated.

Discussion of serological studies on Pacific, Atlantic, and Indian Ocean albacore disclosed that the Atlantic forms had a very high percentage of positive reactions with bigeye-antigen-3. Samples from the eastern Pacific and Indian Ocean had a significantly lower percent of positive reactions. It was indicated that further research will be carried out.

A background study on serology and its implications to tuna research was discussed. It was pointed out that this is just one of the useful tools for identifying population units. Further discussion focused on possible exchange of material from various parts of the world to help in determining whether similar population units such as those that are now being discovered for some of the tunas can be isolated.

It was recommended that a working group be formed to attack one particular problem from the standpoint of biochemical, morphological, and serological methods and to present results at the World Tuna Conference in 1962.

Tuna Oceanography

Discussion Leader - Thomas S. Austin
Rapporteur - Kenneth D. Waldron

Reference: Papers No.

V - 1. Rosa, H., Jr., and T. Laevastu - World distribution of tunas and tuna fisheries in relation to environment

2. Alverson, D. L. - Ocean temperatures and their relationship to albacore tuna (*Thunnus germo*) distribution in waters off the coast of the States of Oregon, Washington, and the Province of British Columbia

3. Inoue, M. - Relation of sea condition and ecology of albacore in the northwest Pacific Ocean. Parts I and II

4. Blackburn, M. - Distribution and abundance of eastern tropical Pacific tunas in relation to ocean properties and features

5. Yamanaka, H., and N. Anraku - Relation between the distribution of tunas and water masses of the North and South Pacific Oceans west of 160° W.

6. Johnson, J. H. - Sea temperatures and the availability of albacore (Thunnus germo) off the coasts of Oregon and Washington

7. Uda, M. - Cyclical fluctuation of the Pacific tuna fisheries in response to cold and warm water intrusions

8. Uda, M. - Localized concentration of tunas in the eddies along oceanic fronts

9. Austin, T. S., and R. A. Barkley - Use of oceanographic stations in fishery research

10. Seckel, G. R., and T. S. Austin - The association between Hawaiian skipjack landings and the oceanographic climate

11. Brown, R. P., and K. Sherman - Oceanographic observations and skipjack distribution in the North Central Pacific

In the past, and to a lesser extent at present, only a knowledge of the broad-scale oceanographic features was needed to study the distribution of tunas. Our present need for more detailed knowledge of both the horizontal and vertical distribution of tunas requires a more detailed knowledge of oceanographic features and the processes involved. Two aspects of tuna oceanography can be considered: (1) distribution, population size, and environment of tunas, and (2) prediction techniques using oceanographic data.

On a worldwide basis there is need for more information concerning the distribution of the different tunas. Exploitation of new fishing grounds and extensive exploratory fishing, together with re-examination of taxonomic problems, requires continued evaluation and revision of charts showing distribution. Parathunnus obesus probably occurs in the western as well as the eastern Atlantic; Euthynnus lineatus has a continuous distribution in the eastern Pacific within the limits shown; and both Sarda chilensis and S. orientalis occur in the eastern Pacific, with a break in the distribution between about latitudes 7° N. and 15° N. Suggestions as to the distribution of the different species would aid in the completion of a world distribution paper being prepared by FAO for the World Tuna Conference in 1962.

In the western half of the Pacific, temperature-chlorinity curves for the upper 200 meters were useful in identifying water mass subtypes and the associated distribution of tunas and marlins. Water mass characteristics, identified by temperature-salinity relationships, are useful not only on an oceanwide basis, but also for studies within the area of a fishery. There is need for some means of portraying temperature-salinity relationships as a single index of water type on a time-space basis. An approach worth considering would be the use of the discriminant function analysis. However, since temperature and salinity, as measured at the sea surface, are not conservative properties, it appears necessary to isolate the conservative portion of each, i.e., that portion not due to sea-atmosphere interaction processes at the sea surface.

Availability and abundance of tunas are related in various ways to different aspects of temperature in the ocean. Processes in the atmospheric pressure system exert an influence on the temperature distribution in the ocean. Skipjack, albacore, and bluefin tuna in the western and eastern Pacific show certain variations in abundance and availability which may be temperature-controlled. Cyclical changes in catch and temperature in the western and eastern Pacific appear to vary in a reciprocal manner. The proposed reciprocal relationship, particularly with respect to a potential prediction technique, should consider the total American west coast landings of albacore. The reciprocal trend in temperature has been observed in data from monitoring stations. Commerical catch records show that in some years the reciprocal trend in catch does not pertain, i.e., there may be good catches in both the American and the Japanese fisheries. However, caution must be exercised in using commercial catch records because of changes in the economics and technology of a fishery. As an example, the poor albacore catch off Oregon and Washington in 1957 can be accounted for by a glut of this tuna in the American and world market, resulting in a dearth of buyers for American albacore.

A study of the possible influence of the waters of the Equatorial Countercurrent in stabilizing the biota and environment in the eastern Pacific yellowfin and skipjack fisheries would be valuable.

In the western Pacific, tuna are to be found along fronts, localized in cool or warm eddies, and in zones of upwelling. Variations in concentration and location of these tuna are associated with the growth, decay, and change in position of the eddies. Such eddies are found to be associated with the Polar Front, Subtropical Convergence, and near the Equator. Individual eddies are probably more or less transient, but may form and disappear in a regular progression. Certain areas may be classed as "eddy-prone." These areas vary with latitude and with position of the North Pacific High. In the eastern Pacific, there are very interesting fronts, such as the one off Cape San Lucas at the tip of Baja California, in which the temperature change is much more rapid than in the large frontal zones described for the western Pacific. While the Cape San Lucas Front is semipermanent, many other such sharp temperature discontinuities are very transient. One explanation for the aggregation of tunas in frontal zones is that the tuna have converged to feed on forage organisms associated with these surface features.

Skipjack and yellowfin of the eastern Pacific usually occur in waters warmer than 21° C. Skipjack may also be excluded from areas in which the temperature is greater than 28° C. Annual changes in the position of the 21° C. isotherm produce corresponding changes in the extent of the fishery in the northern (California) and southern (Chile) extremes. The central area of the fishery (roughly latitudes 5° S. to 22° N.) is characterized by a shoal thermocline, and skipjack and yellowfin are present, with some seasonal variation, throughout the year. Island groups located at some distance from the mainland form other areas of good tuna fishing with some degree of seasonal variation.

The reasons for the aggregation of tuna near islands are not known. There is some evidence that at Clarion Island tuna may forage on detritus-feeders such as galatheid crabs, and on trunk fish (Lactoria). Also near Clarion Island in close inshore waters there is no significant correlation between phytoplankton and zooplankton such as is found in other areas of the eastern Pacific. Near the Marquesas and certain eastern Pacific islands, zooplankton abundance increases with proximity to the island. This may be associated with the lack of a surrounding reef, which would tend to filter the runoff and remove a significant portion of the nutrients. Correlation among PO4, carbon-14, zooplankton, and climax predators may not be apparent unless the total standing crop of climax predators is included, rather than that of a single species or group of species.

When using commercial catch records to evaluate productivity in a fishery it is necessary, as was previously pointed out, to consider change in fishing methods. As an example, certain islands and areas in the eastern Pacific are not suitable purse seine grounds because of the presence of sharks, strong currents, or other reasons, but they are suitable for live-bait fishing.

During the summer, albacore off Oregon, Washington, and British Columbia (latitudes 42° N. to 50° N.) are normally found in waters with temperatures between 54° and 63° F. (12° and 17° C.), with the greatest concentration between 58° and 61° F. (14° and 16° C.), and in areas where the top of the thermocline is 50 to 75 feet (15 to 23 m.) below the surface. Within these general limits, the distribution of albacore may be associated with feed or other biological determinants. Control of distribution within rather broad temperature limits by factors other than temperature applies not only to albacore in temperate waters but also to tunas in tropical waters. To the south, off California, albacore are found in waters with temperatures between 57° and 70° F. (14° and 21° C.), with albacore less than 20 pounds in weight most abundant in 57° to 65° F. (14° to 18° C.) water, and those above 20 pounds most abundant in 65° to 70° F. (18° to 21° C.) water. Thus the upper distributional limit of albacore in 62° F. (17° C.) water in the northern area merely indicates a lack of warmer waters. However, reduced commercial catches during years of favorable water temperatures, 58° F. (14° C.) or above, in the northern waters should not always be construed to indicate a scarcity of albacore. Economic or market conditions may act to prevent or discourage the formation of a fishery when albacore may in fact be abundant. A particular problem concerning the use of commercial catch statistics is that such records often indicate only the port of landing, not the actual catch area, which may be hundreds of miles away, e.g., albacore caught off California may be landed in Oregon or Washington.

The shallow thermocline mentioned above may act as a physical barrier limiting the vertical migration of albacore. It is likely that gill nets and purse seines are most successful under such conditions. In certain areas, as in the eastern tropical Pacific, temperature may not be the only barrier to vertical migration. Reduced oxygen content of thermocline waters may also have an effect in inhibiting the descent

Working Group Report on Identification of Larvae and Juveniles

W. M. Matsumoto - Chairman
S. Ueyanagi
W. Klawe
M. Watson (Mrs.)
H. Nakamura, Observer
W. G. Van Campen, Interpreter

Reference: Papers No.

VII - 6. Yabe, H., and S. Ueyanagi - Contributions to the study of the early life history of the tunas

9. Matsumoto, W. M. - Identification of larvae of four species of tuna from the Indo-Pacific region. I.

13. Watson, M. E., and F. J. Mather, III - Species identification of juvenile tunas (genus Thunnus) from the Straits of Messina, Northwestern Atlantic, and the Gulf of Mexico

Perhaps the phase of tuna life history about which we have the least information is the period beginning with spawning and ending prior to the time the young enter the fishery. In order to fill this gap, studies of tuna eggs, larvae, and juveniles are undertaken. A prerequisite of these studies is the positive identification of species at the various stages of development. The purpose of the Working Group meeting, therefore, was to discuss the validity of species identification of larval and juvenile tunas as presented in the several papers, to point out differences of opinion, and to make recommendations regarding these differences. It was also the intention of the committee to delve into the methods and gear for collecting tuna in the early stages of growth.

Identification of Larvae

It was pointed out that the two papers on larval tuna identification were not in agreement concerning two species, albacore and bigeye. Of the species which were described in both papers, general agreement was found for one species, T. orientalis. Concerning the point of difference, the authors of the first paper felt that two types of larvae (A and B) could be distinguished from among the larvae which had no pigment spots either on the dorsal or ventral edges of the trunk (similar to yellowfin), primarily by the locality (between 10° N. and 25° N.) and time of capture, relative body width, and pigmentation on the tips of the jaws.

Regarding locality and time of capture, it was suggested that care should be taken not to rely too heavily on latitudinal distance from the Equator as a determining factor in species identification, because surface water temperature in the western Pacific is high even in high latitudes during summer and fall, so that, if spawning or larval survival were dependent upon temperature in any way, then latitudinal designation might become meaningless.

The second paper had for identifying the various species a different approach. Identification was based on locality and time of capture and the number of spawning species present, as represented in longline catches for similar months. Pigmentation on the dorsal and ventral edges of the trunk and the position of the second dorsal fin insertion, in the case of two species (T. orientalis and T. tonggol), also were used.

Results of X-ray technique failed, of course, to corroborate either view regarding the presence or absence of pigment spots on the trunk. Since a large percentage of specimens had no pigment spots and about 25 percent had either one spot on the dorsal edge, or one spot on the ventral edge, or one spot each on both dorsal and ventral edges of the trunk, it was felt that, although pigmentation is useful in identifying larvae, there may be enough variation so that other characters should also be used.

Hindcasting proved this technique to be valid for an 8-year period. In addition the magnitude of the catch has been successfully predicted for 3 years. Since fishing success seems to be associated with the dynamics of the circulation system in Hawaiian waters, it is not surprising that an index based on the first derivative curve of the temperature has been the most reliable.

Background Papers

Reference: Papers No.

VII - 1. King, J. E., and R. T. B. Iversen - Midwater trawling for forage organisms in the central Pacific

2. Otsu, T., and R. J. Hansen - Sexual maturity and spawning of the albacore in the central South Pacific Ocean

3. Legand, M. - Length, sex ratio, and sexual maturity of yellowfin tunas at New Caledonia (Part 1 of Rapport Scientifique No. 11 of the Centre d'Océanographie, Institut Français d'Océanie). (In French)

4. Legand, M., and R. Desrosières - Preliminary investigation of the stomach contents of yellowfin tuna of the coasts of New Caledonia (Part 2 of Rapport Scientifique No. 11 of the Centre d'Océanographie, Institut Français d'Océanie). (In French)

5. Suda, A. - Comparison of abundance between albacore and bigeye in the northwest Pacific

6. Yabe, H., and S. Ueyanagi - Contributions to the study of the early life history of the tunas

7. Yabuta, Y., and M. Yukinawa - Age and growth of yellowfin tuna

8. Kikawa, S. - Studies on the spawning activity of the Pacific tunas *Parathunnus mebachi* and *Neothunnus macropterus* by the gonad index examination

9. Matsumoto, W. M. - Identification of larvae of four species of tuna from the Indo-Pacific region. I.

10. Iversen, R. T. B. - Food of albacore tuna, *Thunnus germo* (Lacépède), in the central and northeastern Pacific

11. Uchida, R. N., and T. Otsu - Analysis of sizes of albacore occurring in various Pacific fisheries - a preliminary report

12. Bell, R. R. - The age composition of the California Pacific albacore catch

13. Watson, Margaret E., and F. J. Mather, III - Species identification of juvenile tunas (genus *Thunnus*) from the Straits of Messina, Northwestern Atlantic, and the Gulf of Mexico

14. Legand, M., and B. Wauthy - Presumed importance of *Alepisaurus* sp. in the biological cycle of longline caught tunas in the neighborhood of New Caledonia (In French)

15. Legand, M. - Stomach contents of albacores and yellowfins captured by longline by *Orsom III* (In French)

16. Legand, M. - Size, sex ratio, and seasonal cycle of maturation of albacore west of New Caledonia (In French)

These contributions were not discussed as a unit, but were drawn upon freely in the course of the six discussion groups.

of tuna into this layer. It is thought that yellowfin are especially sensitive to decreased oxygen pressure, and even under normal conditions are near the upper threshold of oxygen utilization. This latter hypothesis is based on a low recovery rate for yellowfin tagged and released in very warm waters. It has been hypothesized that larval tuna entering the thermocline layer suffer a high mortality due to low temperatures or lack of oxygen. Another explanation could be a reduced growth rate, with a subsequent increase in length of larval life and prolonged exposure to the hazards of larval life. Whether or not larval tuna have sufficient energy to overcome the marked change in density at the surface layer-thermocline interface should be considered as a factor limiting their vertical distribution. Considerable evidence from larval tuna collections indicates that most larvae are found above the thermocline.

One of the objects, but not the only one, of studies of oceanography as related to tuna is to be able to predict the amount of tuna available to commercial fishermen in a particular locality and at a particular time. While studies have not progressed to the extent that this objective can be fully realized, prediction techniques have been developed and are in use.

In studying the availability of albacore to the Oregon and Washington fishery (latitudes 40° to 50° N., and west from the coast to longitude 130° W.) it was found that above average catches were associated with above average August sea surface temperatures. Similarly, below average catches were made during years with below average temperatures for August. Further studies suggested that the August sea surface temperature, and thus the potential availability of albacore, could be predicted from a consideration of the temperature anomaly during May and June (the amount by which the monthly temperatures for the individual year differed from a 12-year monthly average). It is pertinent to note that in at least one instance when the August temperature-total catch relationship failed to develop, 1957, it is likely that the low catch was due, at least in part, to economic conditions rather than to a lack of fish.

It has been hypothesized that albacore available to the Japanese winter longline fishery make a vertical migration in the spring and become available to the Japanese summer live-bait fishery. Horizontal distribution of temperature of the surface waters during the winter appears to affect the migration of albacore from the longline fishery into the pole-and-line fishery. The variations and persistence of warm and cool water, winter to summer, together with the location of the winter longline fishery, appear to form a basis for predicting the location and abundance of albacore available to the summer live-bait fishery.

During some years in an area south of Japan (latitude 28° to 36° N., longitude 135° to 140° E.), cold inshore waters intruding from the north force the winter fishery to operate in the eastern and southern portions of the area. This cold water also forces the spring migration of albacore into an easterly and southerly direction, and as a result the fish are available to the fishery for only a short period of time, and catches tend to be below average. In other years, when warm water is adjacent to the coast, the winter fishery develops close to land, and the spring migration moves through the western and northern portions of the area. As a result albacore remain available to the pole-and-line fishery for an extended period of time. A third situation in which the relative persistence of winter conditions may be used to predict the success of the summer fishery involves a combination of the two situations described above.

In the area east of Japan (latitude 30° to 40° N., longitude 140° to 160° E.), a successful summer live-bait fishery depends upon the absence of cold water inshore and the formation of multiple pools of albacore in the winter longline fishery. When these fish migrate to form a single large aggregation in the western portion of the area, a good fishery is likely to develop. The catch from the live-bait fishery is likely to be small when cold water is present in inshore areas, when the winter aggregations of albacore are in the eastern portion of the area, and if the fish do not form a single aggregation in the spring.

From these descriptions it can be seen that in both the southern and eastern Japanese fisheries a knowledge of winter temperature patterns and winter fish distribution provides a predictive technique for evaluation of the degree of success which may be expected in the summer live-bait fishery.

The magnitude of the annual catch made by the Hawaiian live-bait skipjack fishery has been shown to be related to the time of the late winter reversal from cooling to warming of the surface waters in the area of the fishery. It was observed that when the time of first warming occurred during February or earlier a better than average skipjack catch in the Hawaiian fishery could be expected. When the warming occurred in March a poor catch could be expected.

The possibility of loss of pigment spots from exposure to ultraviolet rays or from the preservatives was mentioned, and care in handling and storage of samples was stressed.

One character which might be useful for larval tuna identification and, therefore, worthy of study was the position of the eye relative to the horizontal axis through the tip of the snout.

Identification of Juveniles

Results of preliminary trials with soft X-rays indicate that this technique is a promising tool for identifying juveniles and adults of certain tunas, particularly the smaller species such as T. atlanticus. For the yellowfin, bigeye, albacore, and bluefin, species determination was made by the position of the first ventrally directed parapophysis. The position of the first parapophysis in the juveniles, however, agreed with that of the adults only in the bluefin. In yellowfin this structure was on the seventh vertebra in the juvenile and on the ninth vertebra in the adult, as illustrated by Godsil and Byers (1944)[1/] and Kishinouye (1923).[2/] In albacore it was on the 9th vertebra in the juvenile and on the 10th in the adult (Godsil; Kishinouye). Since the total vertebral count of both species shown by the X-rays was identical with counts obtained from Kishinouye and Godsil, it was suggested that perhaps the difference in the position of the first parapophysis in these two species could be due to growth. It was therefore suggested that a wider range of sizes be X-rayed for each of these species.

Realizing that identifications obtained with the X-ray method would not be helpful to other larval tuna researchers unless they were interpreted in terms of external appearance of the fish, it was recommended that descriptions of external appearnace be supplied with X-ray data.

In view of the preliminary status of larval and juvenile studies and the fact that the results obtained are only tentative, it was agreed that it was premature to arrive at any conclusions concerning the positive identity of all the species. It was therefore recommended that the various investigators continue with their work until more definite results are obtained.

Hiroshi Nakamura presented figures and results of embryonic development of the bigeye, which personnel of the Nankai Laboratory had fertilized artificially aboard ship in the Indian Ocean. Unfortunately, all the larvae died soon after hatching. The failure to keep the larvae alive was attributed to inadequate preparation, as the opportunity to do this work was entirely unexpected. Because such opportunities appear unpredictably, it was suggested that adequate preparations to do this type of work be made on all future cruises. In order to ensure greater success in keeping the larvae alive after hatching, it was suggested that antibiotics be added to the water to keep bacterial counts at a low level.

Methods and Gear

While it was agreed that standardization of gear was desirable, there were contrasting opinions as to whether this should be done at the present time. Some felt that for the present the collecting of larvae in large numbers was still important and should be continued until positive species identifications were attained.

Gear modifications were suggested for sampling larvae. It was reported that attachment of a light to the 6-foot Isaacs-Kidd trawl and towing the net at slow speeds resulted in large catches of forage organisms. It was also reported that a plankton net attached to the float line of the last basket of longline gear resulted in large catches of larval fish. Finally, Nakamura suggested a possible method of collecting larvae and keeping them alive by attaching a piece of bamboo, which was open at one end and slit along the sides, to the cod-end of a plankton net, with the entire cod-end enclosed with netting. The larvae are less likely to be injured when taken in this device.

Recognizing that more effective gear for collecting juveniles is necessary, the Working Group recommends increased effort toward this end.

1/ Godsil, H. C. and R. D. Byers. 1944. A systematic study of the Pacific tunas. California Dept. of Fish and Game, Fish Bulletin No. 60, 131 p.

2/ Kishinouye, Kamakichi. 1923. Contributions to the comparative study of the so-called scombroid fishes. Journal of the College of Agriculture, Tokyo Imperial University, Vol. 8, No. 3, p. 293-475.

1. The Conference recognizes that there are problems in the taxonomy and nomenclature of the tunas and their allies (i.e., family Scombridae of Fraser-Brunner). The Conference recommends that a review of the family be made on the basis of existing knowledge and submitted to the FAO World Tuna Conference to be held in July 1962. Such a review would serve to identify areas of common agreement and areas requiring further study and material. The Conference requests that R. Gibbs, Jr. and B. Collette undertake such a preliminary review.

Realizing that additional specimens of certain kinds and from certain areas will be needed in any case, the Conference recommends that such collections be instituted as soon as possible (the details of kinds and areas to be specified by Gibbs and Collette). The Conference requests the Bureau of Commercial Fisheries Ichthyological Laboratory to explore sources of funds for the collection, shipment, and storage of specimens and other associated costs, including study of the material.

The Conference acknowledges with thanks and directs the attention of the Ichthyological Laboratory to the generous offer of H. Nakamura, Director, Nankai Regional Fisheries Research Laboratory, to provide specimens from the worldwide Japanese tuna fishery.

2. The Conference recommends that there be established a World Center to promote the exchange of tuna erythrocytes and reagents. The Conference notes that the Bureau of Commercial Fisheries Biological Laboratory at Honolulu volunteers to act in this capacity and requests that it do so.

Further, there is a need to standardize the terminology now in use for tuna blood groups. There is especial need to determine if identical blood groups have been independently discovered and given different names. The Conference recommends that the World Center perform this function and suggests that the consensus of workers in this field be determined regarding standard rules of nomenclature.

3. Realizing that identification of tuna larvae is in such an early stage of investigation and that the results are no more than tentative, the Conference recommends that both the Japanese and American researchers continue with their present work until a more definite basis for establishing correct identification of species is attained.

Results of the X-ray method and other internal characteristics would be most helpful to other workers if the species so identified are also described in terms of external characters. The Conference recommends that this be done.

Recognizing the difficulty in capturing the early juvenile stages, the Conference recommends that concerted effort be expended in night-light collecting by all research vessels on a worldwide basis.

4. The Conference recognizes that there remain many problems of population identification and migration and urges all research groups studying tunas to attack these problems through tagging experiments, studies of blood groups, or other appropriate methods. Examples of such studies, but by no means a complete list, include:

A. Tagging small southern bluefin off the south coast of Australia to determine if recoveries are made in the "Old" and "New" fishing grounds to the northwest and west of Australia.

B. Tagging small albacore (lessthan 50 cm., especially the 35-cm. modal group) off Japan, or wherever they may be found, to determine their subsequent movements into the commercial fisheries of the North Pacific.

C. Tagging small-medium albacore off the west coast of South America to determine if they are subsequently recovered in the longline fishery of the tropical South Pacific.

5. The Conference notes the recent advances in the problems of determining the age of albacore and recommends that those studying this problem work together in resolving uncertainties about the absolute ages to be associated with particular sizes.

6. The Conference points out the substantial advances made in identifying year classes in the North Pacific albacore fisheries and the desirability of studying the individual year-class strength and the individual year-class contribution to the entire fishery with a view to establishing a basis for the study of factors affecting year-class contribution to the entire North Pacific albacore fishery.

7. The Conference recognizes that common attention to taxonomic problems by immunogeneticists, biochemists, and classical taxonomists would be fruitful and requests

A. Suzuki, R. Gibbs, Jr., G. Ridgway, and L. Sprague (Chairman) to identify problems in tuna taxonomy which could most profitably be so examined, to proceed with such examination insofar as possible, and to report their findings to the FAO World Tuna Conference.

8. The Conference recognizes the need for identification of tuna subpopulations, urges those studying blood groups to improve methods for transporting and storing blood samples, and suggests that the wide-ranging tuna fleets of the world be used to collect blood samples.

9. The Conference recognizes the importance of genetic identification of subpopulations and urges that additional emphasis be placed on the problem of how much mixing must take place between subpopulations before they are no longer "independent."

10. Studies which bring together research workers engaged in biological and oceanographic studies on the tunas and the seas inhabited by them should be encouraged by international cooperation. Such studies should include, for example, research on the interaction between sea and atmosphere, oceanic fronts, water masses, current systems, changing oceanic climates, year-class sizes, and interaction between fish and environment.

11. In view of the ever-increasing world need for protein and of the rapidly expanding tuna fisheries of the world, attention should be directed to estimates of the magnitude of the world tuna resource and the potential sustained yield of tuna.

12. The Conference agrees that abstracts of submitted papers, summaries of discussion sections, copies of resolutions, and a list of participants should be published, if possible, in the Special Scientific Report--Fisheries series of the Bureau of Commercial Fisheries and directs the Chairman to make arrangements for such publication.

Further, the Conference requests the Bureau of Commercial Fisheries Biological Laboratory at Honolulu to supply copies of the submitted papers upon request.

13. The Conference recognizes the advantages, especially in promoting the exchange of information and in stimulating the rate of progress in fishery studies, of contact between scientists from different laboratories and suggests that, in addition to scientific conferences, exchange of scientists between laboratories be facilitated.

14. The Conference recognizes the desirability of a report from this Conference to the FAO World Tuna Conference and directs the Chairman to furnish FAO with copies of all contributions, summary reports of discussions, resolutions, and a list of participants.

15. The Conference appreciates the meeting facilities made available by the University of Hawaii and directs the Chairman to prepare a letter of thanks to the University.

Alverson, Dayton L.

Ocean temperatures and their relationship to albacore tuna (Thunnus germo) distribution in waters off the coast of the States of Oregon and Washington, and the Province of British Columbia. [Conference Paper V - 2.] (See also Alverson, Dayton L. 1961. Ocean temperatures and their relationship to albacore tuna (Thunnus germo) distribution in waters off the coast of Oregon, Washington, and British Columbia. Journal of the Fisheries Research Board of Canada, vol. 18, no. 6, p. 1145-1152.)

Commercial albacore fishing offshore from Pacific Northwest States and the Province of British Columbia occurs during summer months when offshore surface water temperatures exceed 58° F. Fishermen have established 58° F. surface temperature as an indicator of "tuna water," and this rule-of-thumb relationship for surface water temperatures and albacore has generally been substantiated by past qualitative observations made during albacore investigations. Catch-per-hour data are also in accord with this general relationship. However, catch-per-unit-effort data do not indicate as marked a decline in availability at temperatures between 54° and 58° F. as might be interpreted from qualitative observations. With the exception of one albacore caught by gill net in 1956, all albacore have been taken in Bureau of Commercial Fisheries investigations where surface temperatures exceeded 54° F., and the highest catch rates have been obtained between 58° and 61° F. As the thermocline depth averages about 60 feet in the summer months offshore from the Pacific Northwest States and temperatures fall well below 50° F. at the bottom of the thermocline, albacore probably inhabit only the overlying (mixed layer) lens of warm oceanic water. Concentrations of albacore appear to occur along the interface of the warm oceanic waters and the cooler waters adjacent to the coast.

Austin, Thomas S., and Richard A. Barkley

Use of oceanographic monitoring stations in fishery research. [Conference Paper V - 9]

With the support of data from monitoring stations established by the Bureau of Commercial Fisheries Biological Laboratory, Honolulu, a plea is made for the establishment of similar monitoring station programs by other laboratories.

Oceanographic studies in support of fisheries investigations should normally begin with investigations of local midwinter and midsummer conditions, which establish extreme conditions at times of minimal rates of temporal change. These studies should be followed by similar broad-scale surveys, preferably synoptic, during periods of transition. Later, the results of these surveys lead to research on particular features of the ocean thought to be ecologically significant. At this point oceanographic studies should progress from the stage of exploratory surveys to the stage of research into mechanisms and rates of change in the ocean, and conventional surveys per se cease to be economical or practical means for gathering data. Logically, it is at this stage that monitoring stations become most useful, in that they provide time-series data at a series of points in space, making it possible to determine rates and study processes. The final choice of sampling locations for monitoring purposes will be determined by the results of surveys, but it is a worthwhile risk to establish monitoring stations in likely locations at the same time oceanographic surveys themselves are begun, knowing that some stations may have to be relocated or discontinued as knowledge accumulates, but that some will provide data of interest for periods between surveys and perhaps for indefinite periods thereafter.

Examples of the value of data from monitoring stations are given. A station established at Koko Head, on Oahu, Hawaii, has been in operation for over 7 years. Data from this station are now used to predict the year-to-year changes in the catch of the Hawaiian skipjack fishery, a prediction which has been successful for the past 4 years and has been applied to accurately hindcast the catches for 7 previous consecutive years. A station at Christmas Island was established in 1954, in time to detect precisely the time at which unusual cooling of the surface waters occurred, during 1955, and the details of a subsequent warming trend which reached a maximum in the early winter of 1957. More recently, a network of monitoring stations, including eight island stations and two weather ships, has yielded evidence of coherent changes in surface salinity over distances of many thousands of miles in the central North Pacific Ocean.

Bell, Robert R.

The age composition of the California Pacific albacore catch. [Conference Paper VII -12] (See also Bell, Robert R. 1962. Age determination of the Pacific albacore of the California coast. Calif. Fish and Game, vol. 48, no. 1, p. 39-48.)

Recent development of the scale method for aging albacore by marine scientists of the California State Fisheries Laboratory on Terminal Island has made it possible to determine the age composition of the catch and measure year-class strength and fluctuations with increased precision.

This paper reports on their preliminary effort to determine the age composition of the California commercial albacore catch.

The age composition of the California albacore catch for the last 3 months of the 1959 season was determined by sampling the catch and aging the fish by the scale method. Scales were selected from the area of the fifth dorsal finlet. The checks found on these were believed to be annual in nature largely because of the good correlation between them and the length frequency modes found in the commercial catch.

The smallest fish entering the California catch (mean length for 1959 of 573 mm.) had one check and therefore were hypothesized to be fish in their second year of life, most likely 16 to 18 months old. This hypothesis was also based on the absence of a smaller mode either in the catch or in survey collections.

The majority of the fish appearing in the second mode, the most important in the California fishery, had two checks on their scales. These fish, believed to be in their third year of life, had a mean length of 657 mm.

The sample produced a class with a mean length of 774 mm. for fish believed to be in the fourth year of life, and two other age groups, those in the fifth and sixth year of life having mean lengths of 837 and 878 mm., respectively.

The California tagging studies have since verified assumptions that the length frequency modes are 1 year apart in age. Tagging studies have also verified the growth determined by the scale aging method.

The California commercial albacore catch in the last 3 months of the 1959 season (September-November) amounted to 13,978,766 pounds. The catch in numbers was computed to be 934,297 fish. Fish of age group II were found to comprise 58 percent of the catch. Fifty-five percent of the catch was supported by fish from 63 to 68 cm. in fork length. This is the second mode in the commercial catch and composed of 86 percent age group II fish, 11 percent age group I fish, and 3 percent age group III fish.

Blackburn, Maurice

Distribution and abundance of Eastern Tropical Pacific tunas in relation to ocean properties and features. [Conference Paper V - 4]

The coastal waters from southern California to northern Chile were divided into 16 areas, 5 of which included offshore islands or island groups. In explaining the generally high abundance of skipjack and yellowfin in this region of complex oceanographic conditions, the following generalizations about the region are made:

1. Temperatures in surface waters are generally $\geq$ 21° C. (70° F.) in the fishing seasons.

2. Winds result in upwelling and enrichment in certain areas and a shoaling of the thermocline in the region as a whole.

3. Winds over very shoal thermoclines result in localized vertical mixing and enrichment.

4. Seasonal changes are minimal; thus favorable conditions for tuna aggregations may persist for several months.

The 16 areas may be grouped loosely in three general categories:

(1) The extremes of the region: areas north of 22° N. and south of 5° S. Seasonal variations in distribution of yellowfin and skipjack tuna are rather pronounced and correspond to the seasonal march of surface isotherms, particularly 21° C. in the northern areas. During years in which the warm waters are found in more northerly and southerly latitudes, tuna are also found in more northerly and southerly areas. Some areas are biologically productive because of upwelling.

(2) The center of the region: coastal areas from southern Mexico to Ecuador (22° N. to 5° S.). Surface temperatures are almost always $\geq$ 21° C. Thermoclines are shoal in most areas. Tuna (yellowfin and/or skipjack) occur in most areas at most seasons. Skipjack may be excluded from areas of surface temperatures above 28° C. (83° F.). Seasonal variations in tuna abundance and ocean properties are smaller

than in (1). Results from the area most extensively studied (Gulf of Tehuantepec), if extrapolated to the other areas, suggest association between depth of thermocline, biological productivity of the surface waters, and tuna abundance. In areas of shoal thermoclines, destratification by the winds leads to enrichment of the surface waters.

(3) Offshore islands. Tuna, yellowfin and/or skipjack, occur at each island or island group in greater abundance than in the immediately adjacent ocean waters. It is not clear why they do so, but little oceanographic work has been done except at Clarion Island. Seasonal variations in tuna abundance are comparable with those in (2).

Brown, Robert P., and Kenneth Sherman

Oceanographic observations and skipjack distribution in the North Central Pacific. [Conference Paper V - 11]

Recent investigations by the staff of the Bureau of Commercial Fisheries Biological Laboratory, Honolulu, have indicated that seasonal fluctuations in availability of the commercially important skipjack tuna, Katsuwonus pelamis (Linnaeus), in Hawaiian waters are related to seasonal movements of surface water types within the Hawaiian region. Five cruises were undertaken from January to October 1959 by the staff of the Laboratory within the general area of the North Pacific bounded by latitude 15° N. and 26° N., and longitude 150° W. and 170° W., with two primary objectives: (1) To delineate, by surface temperature and salinity values, the boundaries between the North Pacific Central, intermediate, and North Pacific Equatorial water types, and (2) to monitor the seasonal movements of these water types and their associated biota, particularly skipjack tuna.

Background material and sources of information concerning oceanographic conditions in the Hawaiian Islands region are given. The results of the five 1959 cruises were discussed, and it was shown that a reliable description of the seasonal movements of the surface water types within the survey region could be obtained by monitoring the surface salinity of these waters. Tonguelike features noted in the surface salinity distribution were discussed, and possible causal mechanisms were discussed. Salinity gradients associated with the boundary zones between the water types were found to move seasonally with the water types and to undergo a widening as the year progressed. The possible cause for this was discussed.

Available scouting data indicated that skipjack sightings during January-February and March-April prior to the summer appearance of large fish, which comprise the bulk of seasonal skipjack landings, were concentrated in the boundary between the intermediate and adjacent water types. However, additional observations of skipjack distribution and boundary conditions are needed before any definite conclusions regarding a relationship can be reached.

The greater frequency of occurrence of skipjack schools west of longitude 155° W. suggested movement of summer "season" skipjack to the island region from the west.

Survey results showed no evident relation between water type and seasonal distribution of zooplankton. It was suggested, however, that a relation may exist between the observed increase in zooplankton abundance and skipjack larvae during the summer months attributable to a spawning periodicity of adult skipjack.

Distribution of large predators caught during longline and trolling operations and aquatic mammal sightings did not appear related to water types. Bird flocks were usually associated with fish schools.

Clemens, Harold B.

The distribution of California bluefin tuna in the eastern North Pacific. [Conference Paper I - 4]

California bluefin are caught by purse seine from Cape San Lucas to Pt. Conception primarily from May to November. The species is taken mainly in coastal waters and favors water with temperature-salinity characteristics intermediate between the cold low-saline water in which albacore occur and the warm high-saline water in which yellowfin occur. In warm years, the bluefin ranges considerably farther north than normal. There has been a marked change in size of the fish landed during the past 50 years, and there also are large annual fluctuations in the catch.

Clemens, Harold B.

The distribution of albacore in the North Pacific, [Conference Paper I - 5]

Pacific albacore are creatures of the open sea. They are most abundant in the temperate regions, where they make far-ranging seasonal migrations.

The most productive fishing grounds in the eastern North Pacific are located between central Baja California and the Columbia River.

During the last decade, heaviest catches have been made south of Oregon within the 5-month period June to October and predominate in small (< 40 pounds), immature fish.

Sea temperatures greatly influence the distribution of albacore on the eastern North Pacific fishing grounds. This influence is characterized by seasonal shifts of the entry route into the grounds, and subsequent variation in the patterns of northward movement within the grounds as the season progresses.

Size distribution also is related to sea temperatures. Small fish abound in temperatures of 60 to 65° F., while larger fish are caught where surface temperatures range from 66 to 70° F.

Small (13 to 20 pounds) albacore are the largest contributors to the eastern Pacific catch while medium to large fish (>20 pounds) are most abundant in the Japanese fisheries. Tremendous numbers of youngsters (>10 pounds) remain undiscovered in the mid-Pacific.

Clemens, Harold B.

Migration, age and growth, and spawning studies of the North Pacific albacore (Thunnus germo). [Conference Paper II - 2] (See also Clemens, Harold B. 1961. The migration, age, and growth of Pacific albacore (Thunnus germo), 1951-1958. Calif. Dept. of Fish and Game, Fish Bulletin no. 115, 128 p.

This paper presents a brief summary of part of the progress made from 1951 to 1958 by California Department of Fish and Game marine biologists in their study of North Pacific albacore stocks. Investigations were primarily on albacore interchange between the major North Pacific fishing grounds and changes in fish size, accomplished by making oceanographic and exploratory fishing cruises, studying fishing fleet activities, tagging albacore, and subsequently recovering marked fish from which migratory patterns and growth rates could be interpreted.

Data from exploratory cruises and fishermen's logbooks showed that sea-surface temperature is one of the important factors that influence albacore movements and distribution. The route used by albacore entering the West Coast fishing grounds each season was transient in nature, and its position was regulated primarily by sea-surface temperatures between 58° and 68° F. After entering the southern California-Baja California fishing grounds, the albacore swing northward upcoast. The route taken in this northward movement also is transient.

During 15 cruises, 4,585 albacore were tagged and released in the major fishing areas south of San Francisco. There were 73 recoveries, representing 1.6 percent of the total released. About 80 percent of the tags were recovered within the first calendar year of release. Omitting those, 7 percent of the remainder were recovered in the central Pacific, 21 percent off Japan, 62 percent in the West Coast fishery the second season, and 10 percent in the West Coast fishery the third season.

The tagging data confirmed a northward coastal migration as the season progresses. Ninety-five percent of the marked albacore recaptured during their first season at liberty had moved northward from the release point, at an average rate of 6 nautical miles per day (24 hours). Summarizing the data by distance from shore revealed that albacore traveling within 100 miles of the coast averaged about 4 nautical miles daily, while offshore migrants swam almost 4 times faster.

A hypothesis on the migratory pattern of albacore was presented. The hypothesis is that albacore from the American fishery (mostly small fish under 20 pounds) cross the ocean in late fall and early winter to enter the area of the Japanese longline fishery, and intermingle with medium-sized fish (20 to 40 pounds) that had moved into the area during the late summer and fall from the Japanese coastal fishery, and with fish of all sizes that had remained in the central Pacific. These fish then move south as the winter season progresses. In the spring, the large fish (over 40 pounds) continue south into the North Equatorial Current and Equatorial Countercurrent areas, while the small- and medium-sized fish reverse their course and begin moving north. At this time, some of the fish (medium-sized) travel up the Japanese coast, and some (all sizes) may remain in midocean and travel north and south seasonally. Others (small fish), however, return from the mid-Pacific winter grounds, enter the American fishing grounds, and again travel up the coast and back across the Pacific.

Albacore growth was estimated from tag recovery data. Data from 21 tagged albacore that had been at liberty from 9 to 15 months were used to calculate an annual growth curve. The line of best fit for these data is described by the equation $Y = 210.31 + 0.845 X$, and the asymptotic length attained by the species is calculated at 135.6 cm. The results showed that albacore averaging 52 cm. in June (start of the California albacore season) grow to 65 cm. in 1 year, to 76 cm. in 2 years, to 85 cm. in 3 years, to 93 cm. in 4 years, and to 100 cm. in 5 years. It was postulated that the 52-cm. size group would consist of 1-year-old fish (14 months), the 65 cm. size group 2-year-old fish, etc.

Regarding spawning of the albacore, it appears that first maturity may be reached by some of the larger fish in the 85-cm. size group (4-year-olds), since examination of fish caught near Guadalupe Island during July and August 1953 revealed that those in the 93- and 100-cm. size groups had recently spawned. Apparently these large albacore had spawned prior to their coastward migration from the mid-Pacific, which is in progress primarily from June to September for large fish and from May to August for smaller ones. This means that albacore spawning may occur in the west-central Pacific during the period preceding an annual coastward migration, for it seems unlikely that they would spawn en route. Based on the reported capture of small albacore, 23 cm. long, about 500 miles west of Midway Island from January to May 1937, 139 albacore from 30 to 37 cm. long in the Japanese coastal fishery in June 1951, and young albacore 18.8 and 12.4 cm. long caught in May 1949 and June 1952, it is believed that spawning probably takes place during the winter or spring. Most of the albacore comprising the California fishery originate between the longitude of Japan and the Hawaiian Islands (probably nearer the Islands) and migrate into the West Coast fishing grounds during the first season they become strong enough to school and endure a long migration.

Collette, Bruce B.

A preliminary review of the tunas of the Genus Thunnus. [Conference Paper VI - 1]

This is a first step in a proposed revision of the large tunas of the world. The artificiality of splitting the Scombridae into the families Thunnidae, Cybiidae, and Katsuwonidae and placing the Thunnidae and Katsuwonidae in a separate order, the Plecostei, has been shown by a number of workers. The differences between Thunnus South, Parathunnus and Neothunnus Kishinouye, Germo Jordan, and Kishinoella Jordan and Hubbs are specific, not generic. The species of Thunnus have been greatly split as a result of using even smaller differences as specific differences, since specific differences were used to separate genera.

Although further and more detailed study is necessary, present evidence indicates that there are only six species of great tunas in the world: albacore (T. alalunga), yellowfin (T. albacares), blackfin (T. atlanticus), bigeye (T. obesus), bluefin (T. thynnus), and longtail (T. tonggol).

Synonymies are presented as tentative allocations of the many names that have been applied to the tunas, both generic and specific. The generic names Thynnus Cuvier, Orcynus Cuvier, Orcynus Cooper, Albacora Jordan, Germo Jordan, Parathunnus Kishinouye, Neothunnus Kishinouye, Kishinoella Jordan and Hubbs, and Semathunnus Fowler are placed as synonyms of Thunnus South. The six species are designated as above with the recognition of two subspecies of bluefins, T. thynnus thynnus from the Atlantic and T. thynnus orientalis from the Pacific, on the basis of gill raker counts.

Fujii, Yutaka; Koichi Mimoto, and Shichiro Higasa

Biochemical studies on the races of tuna. Base composition of testis deoxyribonucleic acid (DNA). [Conference Paper III - 3.] (See also Fujii, Yutaka et al. Biochemical studies on the races of tuna. Report of Nankai Regional Fisheries Research Laboratory no. 9, p. 136-142 (1958); no. 11, p. 1-6 (1959); no. 12, p. 14-22, 23-32 (1960).)

Studies of the relative proportion of the bases adenine (a), thymine (t), guanine (g), cytosine (c), extracted from tuna testis deoxyribonucleic acid have shown that characteristic values of the ratio of $(a+t) / (g+c)$ may be obtained for bigeye, yellowfin, Indo-maguro, and Goshu-maguro tunas.

A study to relate these values to subpopulations within each species is being carried out. There is some evidence that the ratio of bases in the testis DNA is different for the same species collected from different areas.

Hiyama, Yoshio, and Kenji Kurogane

Morphometrical comparisons of tuna from areas in the Pacific and Indian Oceans. [Conference Paper III - 7]

Morphometric and meristic studies were made of albacore, yellowfin, and bigeye tunas. Five hundred ninety-six albacore were examined, including 288 from the northwest

Pacific, 141 from the equatorial Pacific between 160° W. and 150° E., 42 from east of Australia, and 125 from the Indian Ocean. Meristic characteristics showed no differences. Differences in morphometric characteristics lead to the conclusion that there exist distinct populations in the North Pacific, the southwest Pacific, and the Indian Ocean, although there exists the possibility of some mixing between the latter two areas.

One thousand fifty-seven yellowfin tuna were examined, including 353 from the northwest Pacific, 375 from the equatorial Pacific, 94 from the Coral Sea, 60 from the Banda Sea, and 175 from the Indian Ocean. Similarities and differences in morphometric characteristics lead to the conclusion that there are a number of independent or semi-independent populations within each major area, somewhat restricted in distribution, and probably intermingling with adjacent groups.

Six hundred ninety-seven bigeye tuna were examined, including 313 from the northwest Pacific, 284 from the equatorial Pacific between 130° W. and 120° E., and 100 from the Indian Ocean. Although some differences were observed, no definite conclusions were drawn owing to conflicting biological information and the need for more data. It is probable that bigeye population structure is intermediate between that of albacore and yellowfin.

Inoue, Motoo

Relation of sea condition and ecology of albacore in the northwest Pacific Ocean. [Conference Paper V - 3.] (See also Inoue, Motoo. Studies on movements of albacore fishing grounds in the Northwest Pacific Ocean-I, II, III. Bulletin of the Japanese Society of Scientific Fisheries, vol. 23, no. 11, p. 673-679 (1958); vol. 25, no. 6, p. 424-430 (1959); vol. 26, no. 12, p. 1152-1161 (1960).)

It has been hypothesized that albacore available to the Japanese winter longline fishery make a vertical migration in the spring and become available to the Japanese summer pole-and-line fishery. Horizontal distribution of temperatures of the surface waters during the winter appears to affect the migration of albacore from the longline fishery into the pole-and-line fishery. The variations and persistence of warm and cool water, winter to summer, are primary criteria for predicting the location and abundance of albacore available to the summer fishery.

To facilitate the prediction for the summer fishery, the patterns of temperature distribution for the periods January-June, 1951-58, were classified into three types. In the first, cool waters are found inshore, winter to summer. The warm Kuroshio waters do not reach the mainland. In the second, warm Kuroshio waters are inshore with the cooler waters offshore during the January-June period. In the third classification, cool waters are inshore from January to April or May and are then replaced by warmer waters.

In the first category, winter albacore are found east or south of the inshore cold water. As the spring and summer fishery begins, these fish, which tend to migrate northward, are barred from doing so by the cold water, and so move rapidly eastward through the 18°-20° C. water. These fish remain available to the pole-and-line fleet during April and May and then move out of the area of the fishery.

In the second category (cold inshore water lacking), winter albacore are found in more westerly and northerly areas than in the first category. Although the start of the summer season may be delayed, good fishing may continue well into late summer in areas close to land.

In the third category (cold inshore water is present until April, then disappears), the winter fishery develops to the south and east, although not to the extent observed in the first category. Albacore remain west of longitude 140° E. until May, and the pole-and-line fishery develops during May and June, relatively close to land.

Thus the knowledge of winter conditions and the degree of persistence of these conditions through the spring period provides a means for determining the potential location and success of the summer pole-and-line fishery.

The location of the principal summer fishing grounds, whether westerly and inshore or easterly and offshore, results not only from the oceanographic conditions in the area of the summer fishery but also from the fluctuations of oceanographic conditions of the previous winter and the associated variations in the migration of the albacore. The terms "environmental resistance" and "environmental induction" were proposed. Waters with temperatures below 16.3° C. impede or deflect the migration of albacore and thus are in the category of an environmental resistance; those between 16° and 22° C, delimit the areas of migration and are termed environmental inductance. Using 10-day surface temperature charts for the period December through May, it was possible to delimit areas of environmental resistance and induction. These areas were then considered for various years along with the records for winter and summer albacore catch records. The area was then classified by two basic patterns. In the first, the warmer waters are inshore; in the second, the cooler waters are inshore.

From the data presented, it is concluded that if the winter fish are concentrated in two or three pools from which they move southerly to form a single congregation during the summer close to Japan, good catches of summer albacore may be expected. Concentrations of winter albacore in the eastern portion of the area, or lack of definite concentrations, result in a poor summer catch of albacore.

Iversen, Robert T. B.

Food of albacore tuna, Thunnus germo (Lacépède), in the central and northeastern Pacific. [Conference Paper VII - 10]

The stomach contents of 544 albacore tuna, Thunnus germo (Lacépède), captured in the central and eastern North Pacific during the years 1950-57 were analyzed to: (1) identify the organisms eaten; (2) determine if the abundance and distribution of albacore is related to the abundance and distribution of their food; and (3) relate feeding to size, method of capture, geographic location, season, distance from land, time of day, and water clarity. The albacore were captured by longline, gill net, and troll.

Stomachs of the larger albacore contained more food than smaller albacore, but the larger albacore contained less per pound of body weight. Stomach contents consisted mainly of a variety of fish, squid, and crustaceans, the percent volume of each differing according to the method of capture.

The latitudinal abundance of albacore in the equatorial Pacific, determined from catch statistics, was not related to the amount of food eaten by albacore captured in this area. During the summer in the temperate North Pacific, fish with high volumes of stomach contents were found south of successive peak volumes of organisms captured by midwater trawls and zooplankton nets. This suggests successive trophic levels associated with an advancing oceanographic and biological "frontier" in the Transition Zone. In the equatorial Pacific, fish with highest volumes of stomach contents were found to the west, while in the temperate North Pacific, stomach content volumes were highest to the east. There was little seasonal difference in food volumes. Reef-associated organisms appeared most frequently in the diet of albacore caught near land.

Troll-caught albacore in the North Pacific fed, prior to capture, throughout the day, but evidence for distinct feeding periods was not clear. Evidence is presented that albacore also feed at night. The higher stomach content volumes of troll-caught albacore occurred in waters of mid-clarity. Some competition for food may exist among albacore, yellowfin, and bigeye tuna in the equatorial Pacific.

Checklists of the organisms identified in stomach contents show the number of such organisms, their frequency of occurrence, and aggregate total volume.

Johnson, James H.

Sea temperatures and the availability of albacore (Thunnus germo) off the coasts of Oregon and Washington. [Conference Paper V - 6]

Wide variations exist in landings of albacore in Oregon and Washington. In 1944, Oregon and Washington landings reached 34 million pounds but dropped to 0.6 million pounds a decade later. Variations in landings may be a result of fluctuations in availability. Investigators have shown that distribution of albacore along the North American coast is influenced by sea temperatures. Although weather conditions and economic factors are reflected in Oregon-Washington landing statistics, it may be that annual variations in sea temperatures are affecting the success of the fishery by varying availability to the fishermen.

Relations between sea surface temperatures and landings were investigated for the years 1947-60. In years of above normal temperatures, landings were, in general, significantly greater than in years of below normal temperatures. Whereas warm water did not insure a good fishery, widespread cold water was detrimental to the success of the fishery. The data suggest that in June, if the sea temperature anomaly is large enough, it is possible to predict whether or not sea temperatures will be favorable for albacore at normal time of commencement of the fishery in mid-July.

Kamimura, Tadao, and Misao Honma

Distribution of yellowfin in the longline fishing ground in the Pacific Ocean, especially on the regional variation of the density in each size group. [Conference Paper I - 2]

Yellowfin catch data for the years 1954-59 were classified by area, season, and fish size category. In general, fish smaller than 120 cm. were located in east longitudes, whereas those larger than 140 cm. were in west longitudes. Artificial causes of this pattern (effect of fishing, gear selectivity, and land mass effect) were discounted, and the distribution instead hypothesized as caused by a west-to-east migration of fish.

Kikawa, Shoji

Studies on the spawning activity of the Pacific tunas Parathunnus mebachi and Neothunnus macropterus by the gonad index examination. [Conference Paper VII - 8]

This paper gives a general review of the spawning of bigeye and yellowfin in the Pacific Ocean. The "gonad index" is used to represent degree of sexual maturity, and is defined as follows:

G.I. = $W_o/L^3 \times 10^4$, where W_o is the weight of a pair of ovaries in grams, and L^3 is the cube of the fork length of the fish in cm. Frequency distributions of gonad indices were used to evaluate group maturity of fish in different areas.

The frequency distribution of bigeye gonad indices in a spawning area enables the separation of spawning from nonspawning fish; the former may be distinguished by having a mode around 3.5 to 5.5 and a very wide range. The nonspawning group has a mode centering between 0.6 and 1.5. The gonad index of 3.1 was selected to separate the two groups. In the case of the yellowfin, the two groups were not as clearly distinguishable. An arbitrary index of 2.1 was chosen to separate spawning from nonspawning groups.

In order to delineate spawning localities of deep-swimming bigeye and yellowfin, the monthly mean gonad index in unit areas was calculated. It was assumed that spawning occurs in the vicinity of areas showing high gonad indices.

In bigeye tuna, the basin of the Equatorial Countercurrent is a principal center of spawning in the western Pacific. It is also a good bigeye fishing ground. There are indications of prolonged spawning throughout this area, with a probable peak during the summer. In the eastern equatorial Pacific (110° W. to 150° W.), spawning is likely to occur between January and June in the area just south of the Equator. There are indications of spawning in the South Pacific near the Tuamotu Islands between 10° S. and 20° S., but very few indications elsewhere in the Pacific.

For yellowfin, it has been reported that spawning occurs nearly throughout the year in the equatorial Pacific (8° S. to 10° N., 120° W. to 180°), with peak activity between March and July. The present study indicates that throughout the areas between the Equator and 12° N., peak spawning probably occurs between July and September. In the eastern area (100° W. to 150° W.) spawning occurs largely between April and June in the area between the Equator and 10° S. Spawning in Hawaiian waters has been reported to extend from about mid-May to the end of October. Another spawning area in the North Pacific is found in waters from Luzon Island to southern Japan, where the season is between April and June. In the South Pacific it is highly probable that spawning occurs in the Coral Sea and its adjacent waters and in the vicinity of the Tuamotu Islands (10° S. to 25° S., 130° W. to 150° W.) between October and March. It has been reported that spawning of yellowfin along the coasts of New Caledonia is likely to be between October and March, with a probable maximum during the summer.

In general, it appears that yellowfin spawning occurs over a broad area, but is centered in the area of the South Equatorial Current. The spawning season of yellowfin seems to vary with latitude. It is extended in equatorial waters, but confined to the early summer in waters off southern Japan, and to the summer months in the Coral Sea and the Tuamotu Islands area. The spawning seasons in these latitudes coincide with the periods of best fishing.

Near-spawning bigeye (over 100 cm. in length) comprise under 40 percent of the total catch throughout the year in the western equatorial Pacific. The percentage composition increases from west to east, reaching as high as 90 percent during the peak spawning season in the eastern area. This marked increase of mature fish from west to east indicates that the spawning potential of bigeye is highest in the eastern Pacific.

In yellowfin, the percentage composition of near-spawning fish (over 110 cm., the size at which most yellowfin reach first maturity) is no more than 40 percent throughout the year in the entire equatorial Pacific. There appears to be no tendency for the proportion of mature fish to increase toward the east, as there is in the case of the bigeye. Previously it was thought that the main yellowfin spawning season changed gradually from east to west, but presently it is considered that this change can be attributed to latitudinal variations.

King, Joseph E., and Robert T. B. Iversen

Midwater trawling for forage organisms in the central Pacific. [Conference Paper VII - 1.] (In press as a U. S. Fish and Wildlife Service Fishery Bulletin, number unknown.)

Collections from 274 midwater trawl hauls made in the central Pacific Ocean by the Bureau of Commercial Fisheries in 1951-56 were quantitatively analyzed to obtain estimates of the abundance and distribution of forage organisms. Their occurrence in the trawl catches was compared with the occurrence of similar organisms in the stomachs of yellowfin, bigeye, skipjack, and albacore tunas. Four trawls were utilized (6-foot beam trawl, 1-meter ring trawl, and 6-foot and 10-foot Isaacs-Kidd trawls) in double oblique hauls between the surface and 400 meters.

The largest catches by the Isaacs-Kidd trawls were made in the Aleutian Current and in the region of upwelling at the Equator, with the poorest catches south of latitude 5° S. in the North Equatorial Current between latitude 10° N. and 18° N., and in Hawaiian waters. The greatest variety of organisms occurred in catches made in the South Equatorial Current and in the Countercurrent.

There was a poor correspondence between the composition of trawl catches and the contents of tuna stomachs; this was not unexpected since most hauls were made at night and tuna fishing occurred in the daytime. There was marked diurnal variation in the trawl catches. Night hauls produced catches larger in volumes, numbers, and sizes of organisms. Diurnal differences in the composition of the trawl catches were striking.

The larger trawls generally produced the largest catches, but in catch per unit of mouth area the trawls were about equally efficient in each geographic area. The largest catches and greatest variety of organisms were obtained in the catches of the largest and most frequently used trawls. All four trawls sampled about the same phyla, classes, and orders; the major differences occurred in the families and genera of fishes. Only six juvenile tunas, from 18 to 60 mm. in length, were captured, although juvenile tunas were known to be present in the area at the time of the trawling.

Trawl catch volumes were correlated with various environmental factors and found to be more closely related to zooplankton than to inorganic phosphate or to the uptake of C^{14} by phytoplankton.

Checklists of the organisms captured show the percent occurrence and average numbers per haul of members of a large number of taxonomic categories according to six latitudinal zones. A table of references useful in identifying organisms captured by midwater trawling was presented.

Legand, M.

Données biométriques sur les thons à nageoires jaunes en Nouvelle-Calédonie. [Conference Paper III - 1.] (In Legand, M. and R. Desrosières. 1960. Premières données sur le thon à nageoires jaunes en Nouvelle-Calédonie. Office de la Recherche Scientifique et Technique Outre-Mer, Institut Français d'Océanie, Rapport Scientifique No. 11, p. 33-54.)

Data (16 morphometric and 2 meristic characteristics) were collected on 504 yellowfin tuna caught in the vicinity of New Caledonia. The relationship of total length (L) to standard length (L_s) was found to be $L = 1.085 L_s$. In regression analysis of morphometric data, regression equations of the form $y = a+bx$ and $y = ax^b$ were used, rather than polynomial equations. Nevertheless, for each character it was necessary to calculate two equations for the data; one for fish above about 80 cm. total length and one for fish below that size. The average number of gill rakers was 28.96 + 0.075. This is one of the smallest values observed in the Pacific and is in accord with the west (small) to east (large) cline reported by Royce for yellowfin from the equatorial Pacific. There is an indication of sexual dimorphism in pectoral fin length. For the larger fishes, the relative growth of fins and middle and posterior parts of the body and relative increase in weight tend to be faster than for smaller fishes (less than 80 cm.). For the anterior parts, the reverse is true. Thus, yellowfin tuna from New Caledonia tend to have smaller heads and longer dorsal and anal fins than fish from further east.

Legand, M.

Quelques données biométriques sur les albacores de la région ouest de la Nouvelle-Calédonie. [Conference Paper III - 11.] (In Legand, M. and B. Wauthy. In Press. Premières données sur l'albacore et les poissons de longue-ligne. Centre d'Océanographie, Institut Français d'Océanie, Nouméa, Nouvelle-Calédonie, Rapport Scientifique No. 24.)

Data (8 morphometric and 1 meristic characteristics) were collected on 143 albacore tuna caught to the west of New Caledonia. There is a suggestion of sexual dimorphism in pectoral fin length, but not in other characters studied. In general, results were similar to those of Kurogane and Hiyama for the Northern Coral Sea, but different from their results in the Northwest Pacific. The average number of gill rakers was 28.7 ± 1.2.

Legand, M.

Longueur, répartition des sexes et maturation sexuelle des thons à nageoires jaunes de Nouvelle-Calédonie. [Conference Paper VII - 3.] (In Legand, M. and R. Desrosieres. 1960. Premières données sur le thon à nageoires jaunes en Nouvelle-Calédonie. Office de la Recherche Scientifique et Technique Outre-Mer, Institut Français d'Océanie, Rapport Scientifique No. 11, p. 7-20.)

Most yellowfin tuna taken near New Caledonia are 55 - 85 cm. standard length; much smaller numbers of larger fish occurred. The ratio of males to females is 1:1.3. This ratio has been observed in similar size yellowfin in other parts of the Pacific, whereas for extremely large fish it is 1:0.6. The proportion of females is much higher at the beginning of the spawning season and very low at the end. Sexual maturity is achieved at a larger size in males than in females. Minimum gonad development is observed between April and August, but even at other seasons the individuals observed were far from complete ripeness. Spawning may occur between October and March, with a peak during summer; similar observations, with respect to the Northern Hemisphere in summer, have been reported for yellowfin near Hawaii. The average stage of maturation seems to be more advanced on the east coast of New Caledonia than on the west coast.

Legand, M., and R. Desrosières

Enquête préliminaire sur les contenus stomacaux des thons à nageoires jaunes des côtes de Nouvelle-Calédonie. [Conference Paper VII - 4.] (In Legand, M. and R. Desrosières. 1960. Premières données sur le thon à nageoires jaunes en Nouvelle-Calédonie. Office de la Recherche Scientifique et Technique Outre-Mer, Institut Français d'Océanie, Rapport Scientifique No. 11, p. 22-31.)

The stomach contents of 148 yellowfin tuna taken by trolling along the south coast of New Caledonia in December 1958 and April 1959 were examined. In 1958, average fish weight was 7.1 kg., and average content volume 11.2 ml. Of identified organisms, 51.9 percent were fish, 22.5 percent cephalopods, and 25.6 percent crustaceans. In 1959, average fish weight was 8.3 kg., and average content volume 26.1 ml. Stomachs contained 71.7 percent fish, 4.3 percent cephalopods, and 24.0 percent crustaceans. Content composition varies diurnally. A minimum of fish and a maximum of crustaceans are found in the morning. The percentage of almost completely digested material is practically nil in the morning and increases during the day. Balistoidea, Ostraciidae, Tetraodontidae, Diodontidae, Acanthuridae larvae, *Dactylopterus*, and stomatopods were the main food items.

Legand, M., and B. Wauthy

Importance présumée d'Alepisaurus sp. dans le cycle biologique des thons de longue-ligne au large de la Nouvelle-Calédonie. [Conference Paper VII - 14.] (In Legand, M. and B. Wauthy. In Press. Premières données sur l'albacore et les poissons de longue-ligne. Centre d'Océanographie, Institut Français d'Océanie, Nouméa, Nouvelle-Calédonie, Rapport Scientifique No. 24.)

In experimental longline fishing for albacore off New Caledonia, 76 *Alepisaurus* sp. (probably *A. ferox*) were caught, making this the second most numerous species in the catch, after albacore. The vertical distribution of Alepisaurus catches, as evidenced by longline hook numbers, closely paralleled that of albacore catches. The abundance of the two species in the longline catches, however, appeared to be inversely correlated. Indications of a similar inverse correlation were found in published American data on experimental longline fishing in the northern and equatorial central Pacific.

Legand has previously reported that Alepisaurus sp. is an important component of albacore stomach contents in New Caledonian waters. Numerical and volumetric data on Alepisaurus stomach content composition presented in this paper show that Alepisaurus is an excellent collector of a wide variety of plankters and bathypelagic fishes. Squid and fish predominate in volume; crustaceans are present in important numbers but in small volume. Some of the leading constituents of Alepisaurus stomach contents, such as Alepisaurus and Sternoptyx diaphana, have also been prominent in the stomachs of albacore from New Caledonian waters.

The authors suggest that the apparent inverse correlation of albacore and Alepisaurus catches may result from an exclusion due in part to predation by the former on the latter and in part to competition for prey between the two species.

Legand. M.

Contenus stomacaux des albacores et yellowfins capturés à la longue-ligne par l'Orsom III. [Conference Paper VII - 15.] (In Legand, M. and B. Wauthy. In Press. Premières données sur l'albacore et les poissons de longue-ligne en Nouvelle-Calédonie. Centre de Océanographie, Institut Français d'Océanie [Nouméa], Rapport Scientifique No. 24.)

The stomachs examined were those of 117 albacore and 43 yellowfin from the longline catches dealt with in the author's paper "Taille, répartition sexuelle, cycle annuel de l'albacore dans l'ouest de la Nouvelle-Calédonie." The average weights of these tuna were 21 kg. for the albacore and 45 kg. for the yellowfin.

The average total volume of stomach contents for the albacore was 14.7 cc., the composition by volume being 45.4 percent fish, 44.6 percent squid, and 10.0 percent crustaceans. The yellowfin stomachs contained on the average 80.6 cc., of which 78.2 percent was fish, 16.4 percent squid, and 5.4 percent crustaceans.

No important seasonal difference in either total volume or composition was seen in either species. Yellowfin differed from albacore in the considerably greater proportion of fish in their diet and in the greater relative as well as absolute volume of their stomach contents (1.68 cc. per kg. of body weight as compared with 0.73 cc. for albacore). The average amount of squid consumed by albacore appeared to increase offshore but the opposite trend was shown by yellowfin.

Alepisaurus sp. was the fish that occurred most frequently in the stomachs of both albacore (60 percent) and yellowfin (40 percent), and the bramid-pteraclid group of fishes was important in the diet of both species. Ostracion sp., which is also prominent in the diet of troll-caught yellowfin from the New Caledonia coast, was found in 45 percent of the yellowfin stomachs but in only 20 percent of the albacore.

The crustaceans eaten by both species of tuna were primarily decapods.

Legand, M.

Taille, répartition sexuelle, cycle annuel de l'albacore dans l'ouest de la Nouvelle-Calédonie. [Conference Paper VII - 16.] (In Legand, M. and B. Wauthy. In Press. Premières données sur l'albacore et les poissons de longue-ligne. Centre d'Océanographie, Institut Français d'Océanie, Nouméa, Nouvelle-Calédonie, Rapport Scientifique No. 24.)

From 1959 to July 1961 experimental tuna longline fishing from the ORSOM III at 24 stations took 140 albacore within 200 miles of the southwest coast of New Caledonia, between 21°30' S. and 24° S., using 7-hook units 500 m. long. Numbers of albacore per 100 hooks fished were 1.5 to 5.0, exceptionally 10.0.

The lengths ranged from 825 to 1075 mm. There was a significant difference in size between the sexes; the males averaged 966 mm. and 20.6 kg., the females 930 mm. and 18.8 kg. The average size of the albacore captured was significantly greater in summer than winter, although there was no important seasonal departure from the overall average sex ratio, which gave 27.5 percent females. One example of hermaphroditism was found.

The seasonal trend of the ovary volume to body length relationship indicated summer (December-January) spawning. Five ovary samples over 200 cc. in volume and over 300 cc. were thought to indicate that the spawning area was not far distant from the area of collection.

The distribution in depth of captures, judged from the presumed relative depth of the seven hooks on each unit of longline, indicated that the albacore were concentrated about 50 m. deeper in summer than in winter. This difference corresponds roughly to the seasonal range of vertical movement of the 19° C. and 21° C. isotherms in the area.

Marr, John C., and Lucian M. Sprague

The use of blood group characteristics in studying subpopulations of fishes. [Conference Paper III - 4.] (In press in papers of the International Commission for North Atlantic Fisheries Tagging Symposium, Woods Hole, 1960.)

The necessity for studying population units of fishes, the desirability of using genetic characteristics in such studies, and the nature of blood group systems are briefly reviewed.

Examples are drawn from the M-N and A-B-O blood groups in man. Examples are given of blood group systems recently found in several bony fishes, including western Atlantic herring, northeastern Pacific sardine, sockeye salmon, albacore tuna, and one elasmobranch, the spiny dogfish.

Illustrations are given of how data on blood group systems are useful in attacking the kinds of problems encountered by fishery biologists. Such problems include (1) determination of whether one or more than one subpopulation is contributing to a fishery in a particular area, (2) determination of whether fish from two fishing areas belong to the same or different subpopulations, and (3) determination of the contributions of two known subpopulations to a single fishing area.

It is suggested that blood group data will also contribute to the solution of broader problems.

Matsumoto, Walter M.

Identification of larvae of four species of tuna from the Indo-Pacific region. I. [Conference Paper VII - 9.] (Published in 1962 by the Carlsberg Foundation as Dana Report No. 55, 14 p.)

Examination of larval thunnids collected from Indo-Pacific waters by the "Dana" during the 1928 - 30 round-the-world oceanographical expedition resulted in the tentative identification of larvae of four species of thunnids, Parathunnus sibi (Temminck and Schlegel), Thunnus germo (Lacépède), T. orientalis (Temminck and Schlegel), and Kishinoella tonggol (Bleeker), which have hitherto been unidentified. Neothunnus macropterus (Temminck and Schlegel) has been identified and described by numerous authors, so it was not included in this discussion. To avoid digressions concerning the nomenclature of the tunas found in different parts of the world, the earliest generic and specific names given to tunas from this region were used.

Species identification was done by segregating the larvae from three localized areas into various "types" on the basis of number and position of chromatophores on the body, particularly the chromatophores along the dorsal edge of the trunk. The number of larval types in each area was then compared with the species composition of adult tunas caught on longline fishing gear, including a species (K. tonggol) which is known to be present in the areas, but which is not commonly taken on this gear.

All specimens examined had 40 myomeres and had no pigmentation over the forebrain. Larvae with no pigmentation along the dorsal edge of the trunk, exclusive of the caudal fin, but with one to five chromatophores along the ventral margin were designated as P. sibi. Larvae similar to P. sibi but having one chromatophore along the dorsal margin of the trunk, at the base of either the second dorsal fin or one of the dorsal finlets, were diagnosed as T. germo. Larvae similar to P. sibi but having two or three chromatophores along the dorsal edge of the body, the initial chromatophore being at the base of either the second dorsal fin or one of the dorsal finlets, were identified as T. orientalis. On all these three species, the origin of the second dorsal fin was located on the 16th myomere. Larvae similar to T. orientalis but having the initial dorsal chromatophore anterior to the 15th myomere or the origin of the second dorsal fin were designated K. tonggol.

Mimura, Koya

Studies on Indo-maguro. [Conference Paper I - 3]

Indo-maguro, or bluefin tuna, are caught by the Japanese in two places off Australia, the Old and the New Fishing Grounds. These grounds lie to the northwest and west of Australia; no bluefin occur in peripheral areas and few on the grounds outside of the September-April season. The catches differ in that there are two catch peaks on the Old Ground and one on the New, and the Old Ground fish are large through the season whereas the New Ground fish are small at the season's peak. The fish on both grounds are thought to be spawning groups.

Nakamura, Eugene L.

The establishment and behavior of skipjack tuna (Katsuwonus pelamis) in captivity. [Conference Paper IV - 2]

Skipjack tuna (2-6 pounds) were successfully maintained in an outdoor pool for 5-1/2 months at the Kewalo Basin dockside laboratory of the Bureau of Commercial Fisheries Biological Laboratory at Honolulu. The circular pool, 4 feet deep and 23 feet in diameter, was supplied with 50 gallons of oxygenated salt water per minute. Successful establishment was achieved by transferring the fish from the place of capture to the shore pool in a portable tank. The portable tank contained 620 gallons of water and, while on the vessel, was supplied with 100 gallons of new water per minute. Skipjack were caught by pole-and-line, lowered into the portable tank and allowed to shake out the barbless hook. On shore the portable tank was lowered into the pool, and the skipjack were allowed to swim out. The fish fed in captivity, and recovered from minor wounds received at capture. After 4 months one fish had sunken eyes, but could still feed.

Skipjack swim with their mouths agape, and erect their first dorsal and pectoral fins when turning. All fins are erected to maximum extension when the fish decelerate suddenly. They demonstrate no rheotaxis. They school in captivity, but schooling is disrupted when food is presented. While the tuna are feeding or when they are presented with a food stimulus, vertical bands appear on their dorsal lateral surface. When the fish were trained to associate a slap on the water surface with food, the appearance of vertical bars could also be elicted by the slap alone. After the tuna had fed to satiation these responses did not occur. When not in a feeding state, the tuna is marked with horizontal bars on the latero-ventral surfaces. Other noticeable colorations are the silvery tongue and the leading white spine in the first dorsal fin.

When fed to satiation once a day they ate 1.6 ounces of squid and shrimp per pound of skipjack per day, but when fed 13 times per day this increased to 3.2 ounces per pound per day. Greatest food consumption occurred at the first feedings early in the day, and smaller amounts were eaten through the remainder of the day. Shrimp exoskeletons begin to occur in the feces about 1.5 hours after a meal at 74° F. They ate little or nothing after dark and would not take food particles from the bottom of the pool. The size of food particles they would eat decreased as they became satiated.

Nakamura, Hiroshi

An outline of the tuna longline grounds in the Pacific. [Conference Paper I - 1]

The Pacific Ocean is characterized by a series of current systems extending in an east-west direction. These systems are distinct environments and have distinctive fisheries, for example, the North Pacific Current north of 28° is noted for its albacore, while part of the South Equatorial Current is conspicuous for yellowfin. In addition to stratification by current systems, the fisheries show east-west gradients in length composition, as well as variations in amount of catch per unit of fishing effort. There is an overall tendency for tuna and marlin catches to be heavier in the Southern Hemisphere than in the Northern Hemisphere.

Otsu, Tamio, and Richard J. Hansen

Sexual maturity and spawning of albacore in the central South Pacific Ocean. [Conference Paper VII - 2.] (In press as U. S. Fish and Wildlife Service, Fishery Bulletin 204, vol. 62.)

Developmental stages of gonads of the albacore, Thunnus germo (Lacépède), taken in the central South Pacific Ocean by Japanese and South Korean longline vessels based in American Samoa were studied. The samples comprised 782 pairs of ovaries and 990 pairs of testes collected from 256 landings between August 1957 and September 1958.

Occurrence of ova in late stages of development indicates that the South Pacific albacore spawn during the southern summer, between September and March, as opposed to the northern summer spawning of the North Pacific albacore. This difference in spawning periods is believed to constitute evidence that the stocks of albacore in the South Pacific and the North Pacific are independent of each other. The data suggest that the bulk of the spawning activity is confined to the area between the Equator and latitude 20° S.

No east-west differences in occurrence of developing ovaries were discernible.

Otsu, Tamio, and Richard N. Uchida

A model of the migration of albacore in the North Pacific Ocean. [Conference Paper II - 1]

On the basis of tag recovery data, age and growth information, and distribution and size frequency data from the various fisheries, a model of the migration of albacore in the North Pacific Ocean has been developed. This model is consistent with the hypothesis that there is a single population of albacore in the North Pacific Ocean.

The migration of albacore within the areas of the three major fisheries is in general reflected by the seasonal shifting of the respective fishing grounds. The migration between fisheries may be summarized briefly as follows: A varying portion of the 2-, 3-, and 4-year-old fish and nearly all of the older fish in the American fishery migrate westward each fall into the Japanese longline fishery, and during the following spring, into the Japanese live-bait fishery. The remainder of the fish from the area of the American fishery move westward to the mid-ocean waters of the North Pacific, some as far west as to the eastern fringe of the Japanese longline fishing grounds. These fish, largely young individuals, tend to return to the American fishery the following summer. Thus, some albacore may be available to the American fishery for as many as four or five successive seasons.

Of the more common sizes taken in the Japanese live-bait fishery, only the 4- and 5-year-old groups provide some fish that enter the American fishery the following summer, but these are few since 5- and 6-year-old fish comprise only a very small proportion in the American catch. This would explain why none of the albacore tagged in the Japanese live-bait fishery has thus far been retaken in the American fishery.

Albacore enter the winter longline fishery from both the American fishery and the Japanese live-bait fishery. A large part of these fish migrate southwestward in the winter longline fishery and subsequently enter the live-bait fishery in the spring, whereas a few separate and migrate into the American fishery by summer.

A portion of the large adults occurring in the Japanese winter longline fishery (6-year-olds and older) move southward during the spring into subtropical waters, where they make up the reproductive unit of the North Pacific population.

It is hypothesized that spawning occurs in subtropical waters during the summer and that the larval and early juvenile stages are spent in these waters. When about 1 year old, the fish migrate into temperate waters, but they do not immediately join the exploited stock. The albacore are generally not available to the commercial fisheries until they reach the age of 2 or 3.

It appears that most of the recruitment into the exploited stock takes place in the eastern rather than the western North Pacific. There is a greater volume of migration of the commercial sizes of albacore in the westerly direction from the American fishery into the Japanese fisheries than vice versa.

Ridgway, George J.

Distinction of tuna species by immunochemical methods. [Conference Paper III - 5]

Through the application of the Ouchterlony method of diffusion precipitin analysis, with rabbit immune sera, the presence of species specific differences in serum antigens of adult tuna was demonstrated. The existence of these differences was confirmed by absorption methods.

In studies on soluble antigens of the muscle tissue of tuna, evidence was obtained for the distinction of skipjack from albacore, yellowfin, and bigeye tuna.

No characteristic differences in their soluble tissue antigens, allowing the mutual distinction of the latter three species, were found. Technical problems in the study of soluble tissue antigens, involving extraction media, stability of extracts, and production of potent antisera were encountered, and preliminary methods for their solution developed.

The course was discussed which further developments in these and allied fields might take resulting in possible distinction of larval forms.

Roedel, Phil M., and John E. Fitch

Taxonomy and nomenclature of the Pacific tunas. [Conference Paper VI - 2]

The basic problems of taxonomy and nomenclature of tunas still remain unresolved. Even among American tuna research laboratories now studying eastern Pacific tunas, there exist some differences in the usage of names. Some uses stand on reasonably firm scientific ground; others are based on custom and generally follow Kishinouye's lead.

In the category of true tunas are included the bluefins, albacores, yellowfins, bigeyes, and members of genera Kishinoella and Allothunnus. Among the bluefins, the authors feel that (1) T. maccoyi is a distinct species, (2) T. saliens is at least subspecifically distinct from the Atlantic form, (3) the relationship of T. saliens to T. orientalis is unknown, and (4) until necessary research is done, the best course is to call the California bluefin T. saliens and the Japanese T. orientalis.

There is but one species of albacore in the North Pacific, but no one knows whether it is in any way distinguishable from that in the Atlantic. The Pacific albacore has been listed as T. germo, G. germo, T. alalunga, and G. alalunga. The question of specific names cannot be properly resolved until a direct comparison of Atlantic and Pacific material is made.

The problem with yellowfins is whether the various forms from the oceans of the world are identical or whether they are specifically and subspecifically distinct. This problem will be resolved only by a global attack; pending that, continued use of macropterus for the Pacific forms is recommended.

For the bigeye, Pacific workers have generally used sibi, and it seems wise to continue this practice for the present.

Serventy (1942)3/ has documented the case for the Australian northern bluefin, Kishinoella tonggol; the New Zealand fish, Allothunnus fallai, rounds out the Pacific tunas.

In the category of the skipjacks are included the skipjack, the black skipjacks, and the frigate mackerels. The skipjack appears almost universally in the literature as Katsuwonus pelamis. Such usage tacitly recognizes the existence of a species worldwide in distribution. K. vagans is used by some authors who regard the Pacific form as separable from the Atlantic form. There are no factual data to support either view, and there is need for a direct comparison of specimens.

The black skipjacks are now universally consigned to genus Euthynnus. The number and definition of species are matters of debate, but it is reasonably certain that alletteratus, lineatus, and affinis are valid names for valid species. It is suggested that the name E. yaito be retained for the western Pacific species until such time as its confusion (it may be synonymous) with affinis has been clarified.

As for higher classification, the authors believe that Germo should be submerged in favor of Thunnus and that Neothunnus would have to be submerged in favor of Parathunnus, on page priority, if their separation from Thunnus seems advisable. Despite these opinions, no changes are recommended at present, except for Germo. Katsuwonus should be retained as a separate genus because of the many characters by which it differs from the three black skipjacks.

These suggestions are offered for action: (1) Determine the relationships of these fishes at the specific or subspecific level and above all on a worldwide basis as soon as sponsorship and funding can be arranged; (2) establish a committee which would submit a detailed proposal for action to the FAO World Tuna Conference; and (3) those concerned with the Pacific tuna resource should implement the program through tuna research agencies active in the Pacific basin, if worldwide sponsorship cannot be obtained.

Rosa, H., Jr., and T. Laevastu

World distribution of tunas and tuna fisheries in relation to environment. [Conference Paper V - 1]

Bluefin and albacore occur in the temperate subtropical and tropical waters of the oceans of the world, are often associated with frontal zones, and have a narrow optimal temperature range. Bigeye and yellowfin are mainly pelagic and are found in the equatorial current systems of the Pacific, Atlantic, and Indian Oceans. Skipjack are found in the warmer temperate subtropical and tropical waters of the world. Bonitos and little tunas are found in the coastal areas of the temperate subtropical and tropical oceans.

Aggregations of tuna are to be found in regions of shallow thermocline, cold and warm eddies and intrusions, in areas of upwelling

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3/ Serventy, D. L. 1942. The tuna Kishinoella tonggol Bleeker in Australia. Journal of the Council for Scientific and Industrial Research, vol. 15, no. 12, p. 101-112.

along current boundaries, and in certain areas near islands, sea mounts, and along continental slopes. Each of these features may contribute to enrichment of the surface waters. Although temperature is a good indicator of each of these features, it may not be the main factor directing the behavior and distribution of tuna. Changes in the environmental factors in the sea are the result of interaction between the sea and atmosphere, and thus a correlation between meteorological factors and behavior of the tunas can be found. A discussion of tuna fishing grounds and methods is included.

Royce, William F.

A morphometric study of yellowfin tuna Thunnus albacares (Bonnaterre). [Conference Paper III - 6] (In press as U. S. Fish and Wildlife Service Fishery Bulletin, number unknown)

Morphometric measurements are compared from 4,180 yellowfin tuna from 29 locations in the Pacific Ocean, from the Atlantic Ocean off Angola, Africa, and from the Indian Ocean off Somaliland, Africa. The measurements used are head length, pectoral fin length, second dorsal fin height, anal fin height, snout to insertion of first dorsal fin, snout to insertion of second dorsal fin, snout to insertion of anal fin, snout to insertion of ventral fin, insertion of ventral to anterior edge of vent, and greatest body depth. Each measurement is related to fork length by regression analysis, and each relationship is called a character. Curvilinear regression due to allometric growth is controlled by transforming some data to logarithms and by separating all samples into small, medium, and large size groups (< 80, 80-120, and > 120 cm. fork length, respectively). Mean character sizes are determined for each sample at lengths of 65 cm., 100 cm., and 140 cm.

A comparison of mean character sizes from samples taken along the Pacific Equator reveals a cline in most characters between the vicinity of Costa Rica and the Caroline Islands. The yellowfin from the eastern Pacific have larger heads and greater distances from the snout to the insertion of first dorsal, second dorsal, ventral, and anal fins, a greater distance from insertion of ventral to insertion of anal fin, and a greater body depth. On the other hand they have shorter pectoral fins and much shorter anal and second dorsal fins. The samples from the more temperate parts of the Pacific and from off the coasts of Africa differ little from some part of this cline.

A multiple character comparison of overlap among samples from near the Pacific Equator shows less than 50 percent overlap between samples separated by 1,500 miles, less than 25 percent overlap between samples separated by 3,000 miles and less than 6 percent overlap between samples separated by 6,000 miles. The possibility of long intermigrations among the equatorial stocks seems remote.

The full variation in length of pectoral and heights of second dorsal and anal fins, which most authors have used to separate the species of yellowfin, occurs within the cline along the Pacific Equator. This occurrence plus the continuous circumtropical high seas distribution of the yellowfin indicates a single worldwide species. The appropriate name is Thunnus albacares (Bonnaterre) 1788.

Seckel, Gunter R., and Thomas S. Austin

The association between Hawaiian skipjack landings and the oceanographic climate. [Conference Paper V - 10]

In an effort to relate the seasonal and annual availability of Hawaiian skipjack to factors in their environment, it was found that the season catch could be correlated with the percentage occurrence of northeast trades during February through April for a number of years. This correlation later failed. In the Hawaiian Islands, low summer salinities (less than 35 ‰) were also associated, although not without exceptions, with better than average annual landings. Plotting the monthly rate of change of surface temperature obtained at Koko Head, Oahu, against time, one obtains a heating curve with a shape characteristic of the locality. Occurrence of initial heating during February was followed by an average or better than average fishing season and initial heating during March by a poorer than average season. This correlation, which has held for the 10 years for which data are available, is of predictive value.

In terms of environmental processes, initial warming of the heating curve signifies the beginning of the northward movement of the boundary between the high salinity North Pacific Central water and the lower salinity California Current Extension water. Later, the boundary, which during autumn and winter months lies just south of the islands, moves into the island area and accounts for the lower summer salinities. Early northward movement of the boundary as reflected by initial warming at Koko Head signifies a well-developed circulation.

The 10-year Koko Head heating curve and monthly skipjack landings show that catches coincide with the summer cold advection period and that the duration of the peak fishing is related to the length of the summer cold advection period.

The excellent relations between environmental factors and the availability of skipjack indicate that changes in the magnitude of Hawaiian stocks due to changing magnitudes of year class or fishing pressure may not be of major importance. They indicate that, in addition to a favorable type of water, favorable dynamic conditions are necessary for a good fishing season. Since fishing success seems to be associated with the dynamics of the system, it is not surprising that an index reflecting environmental processes (initial heating at Koko Head) has proved to be of predictive value.

Sprague, Lucian M., and Leslie I. Nakashima

A comparative study of the erythrocyte antigens of certain tuna species. [Conference Paper III - 8]

The C-system of the skipjack (Katsuwonus pelamis) was recognized by the action of bovine normal serum containing natural anti-C fractions on the cells of C-positive skipjack (Cushing, 1956).[4/]

C-like blood factors also occur on the erythrocytes of albacore (Germo alalunga), bigeye (Parathunnus sibi), and yellowfin (Neothunnus macropterus). To date, absorption results have not revealed C-system antibodies which will differentiate subtyping relations between the species, although such relations probably exist. The relative frequency of occurrence of C-positive individuals is quite different among the members of the species tested. Albacore (120) were 94 percent, bigeye (113) were 77 percent, and yellowfin (37) were 98 percent positive with standard C reagents.

The A-system of the skipjack is recognized by specific agglutinates formed in extracts of the seeds of Glycine max (soy). A-positive bloods are also commonly found in the bigeye and albacore tunas, but to date they have not been recognized in the few yellowfin tested. Several other interspecific serological relationships are also under investigation.

Suzuki (1961)[5/] has reported his findings with regard to the serological cross reactions of these species. At the present time it is not known whether or not the relationships described here fall within those described by Suzuki.

Sprague, Lucian M., and Leslie I. Nakashima

Studies on the erythrocyte antigens of the skipjack tuna (Katsuwonus pelamis). [Conference Paper III - 9.] (See also abstracts of Symposium Papers, Tenth Pacific Science Congress. Symposium on immunogenetic concepts in marine population research, p. 186.)

At least five blood factors, which form four systems of blood groups, have been identified on the red blood cells of the skipjack tuna.

One, the C antigen, has been described by Cushing (1956).[6/] C-positive individuals are recognized by the action of natural bovine and ovine heteroagglutinins.

Four additional blood factors are now recognized by the use of saline extracts of legume seeds. Extracts of Glycine max detect A-positive bloods, extracts of Phaseolus vulgaris detect D-positive bloods, and extracts of Virgilia divaricata and Caragana arborescens detect two blood factors in the B system, Be and Bf. The relationships of Be and Bf are not well understood except that they are mutually exclusive properties, Be-positive animals being Bf-negative and vice versa. About 20 - 30 percent of the skipjack tested are Be-Bf-negative.

Of these reagents, those recognizing D-positive individuals and those recognizing Bf-positive individuals are not sufficiently definitive for use in population studies.

Reagents detecting C-positive, A-positive, and Be-positive animals, however, may be used to explicitly categorize skipjack erythrocytes. These reagents have been used in tests of 688 skipjack from the island or island systems of Hawaii, Johnston, Christmas, Marquesas, and Rangiroa (Tuamotu).

4/ Cushing, John E. 1956. Observations on serology of tuna. U. S. Fish and Wildlife Service Special Scientific Report: Fisheries No. 183, 14 p.

5/ Suzuki, Akimi. 1961. Serological studies of the races of tuna - V. The blood groups of yellowfin tuna. Report of Nankai Regional Fisheries Research Laboratory No. 13, p. 53-67.

6/ See footnote 4.

When the frequencies of the occurrence of Be individuals from these areas were compared, the relative proportion of Be individuals sampled near Rangiroa was clearly distinct from the frequencies of Be from all other areas sampled ($P < .001$; z- test).

The sample from the Marquesas Islands is different from all other areas with respect to the frequency of the occurrence of C-positive individuals ($.05 < P < .01$; z- test).

On the contrary, samples taken from Hawaii, Christmas, and Johnston Islands exhibit marked homogeneity in the frequencies of the characters A, C, and Be. These data indicate the occurrence of at least two reproductively isolated stocks of skipjack in the areas sampled.

Further studies are in progress which will attempt to delineate the range and character of these stocks in greater detail.

Sprague, Lucian M.

Blood group studies of albacore (Germo alalunga) tuna from the Pacific Ocean. [Conference Paper III - 10]

Reagents designated as anti-C by virtue of their reactions with the erythrocytes of the skipjack tuna (Katsuwonus pelamis) also recognize closely related antigens in the albacore.

The relative proportions of C-positive individuals of albacore taken in the fisheries of North America and Samoa are highly significantly different. Of 325 fish taken from North America, 97.5 percent were C-positive, and of 74 fish taken from Samoa 85.1 percent were C-positive. These data are interpreted as evidence for reproductive isolation between the North Pacific and South Pacific albacore.

Data were presented on a blood-group system designated G, in which at least two G blood factors, G_1 and G_2, are recognized. To date the relative proportions of G_1, G_2 and "___" (the three phenotypes of the G system) are similar for the two areas sampled.

Strasburg, Donald W.

An aerating device for salt well water. [Conference Paper IV - 1]

Salt-water wells drilled through hard packed coral and sand are used to supply water for the experimental facilities at the Kewalo Basin docksite laboratory of the Bureau of Commercial Fisheries Biological Laboratory at Honolulu. Such salt ground water is similar to oceanic water but contains only 0.15 - 0.69 ml./l. dissolved oxygen. A device was designed to increase the amount of oxygen to 95 - 100 percent saturation at rates of flow up to 100 gallons per minute. The aerator was composed of three stacks of 16 trays (each tray 2 feet x 7 feet), spaced at 2-inch intervals and perforated at half-inch intervals by one-eighth inch holes. Well water was directed onto the top tray and percolated down into a collecting basin below. Specifications of the aerator, such as number of trays and distance between trays, were based upon the operation of a test aerator in which these dimensions could be altered.

Suda, Akira

Comparison of abundance between albacore and bigeye in the northwest Pacific. [Conference Paper VII - 5.] (In press in Nankai Regional Research Laboratory, Report No. 14.)

The possibility of a correlation between albacore and bigeye abundance is discussed using recently accumulated data. Catch and size data of albacore and bigeye taken in the North Pacific Current area during winter longlining operations were used in this study. The data examined were for the years from 1949 to 1959.

The author used index-S to represent relative abundance of fish, and calculated S as follows: $S = \frac{1}{n} \sum_i \sum_j x_{ij}$, where x_{ij} is the hooked rate (catch/100 hooks) in the i-th month and in the j-th area, and n is 15 for albacore and 12 for bigeye.

For albacore, there is a strong tendency for index-S to fluctuate with large amplitude either at a high or a low level, which continues for a period of about 3 years and then changes to the opposite level for an approximately equal period. In comparison, the index-S for bigeye appears to be rather stable. However, the annual changes in index-S for both species are somewhat similar when smoothed by a moving average of 3 years.

The index-S' (length frequencies weighted by hooked rate) was used to represent relative abundance of each size group, S' being calculated as follows: $S' = \sum_i \sum_j (rx)_{ij}$, where r is the ratio of the size group and x is the hooked rate in the ij-th stratum. Index-S' shows that the abundance of both species is strongly influenced by the existence of a dominant size group. With the occurrence of one dominant size group, good catches can be expected for the following 2 or 3 years.

Index-P (formula explained in author's previous report), used as a measure of the population size of each year class, showed similar annual change in both species.

As both index-S and index-P in both species show similar changes, it is suggested that the changes in year class size of albacore and bigeye are caused by intraspecific and interspecific factors. Since the patterns of distribution and population structures of the two species are rather similar, some changes in environmental conditions may cause similar changes in the two populations.

Suzuki, Akimi

Blood types in tuna. [Conference Paper III - 2.] (See also Suzuki, Akimi et al. Serological studies of the races of tuna, I, II, III, IV and V. Report of Nankai Regional Fisheries Research Laboratory no. 8, p. 104-116 (1958); no. 11, p. 17-23, 165-172 (1959); no. 12, p. 1-13 (1960); no. 13, p. 53-67 (1961).)

Investigation of the erythrocyte antigens of albacore, bigeye, and yellowfin tunas by means of normal and immune sera has shown a variety of antigenic differences.

In the albacore, the Tgl and Tg2 antigens are recognized by rabbit immune sera. These two antigens form a blood group system with four phenotypes Tgl; Tg2; Tgl Tg2; and O (the absence of Tgl or Tg2). In the bigeye, three antigens are recognized, two of them very similar to Tgl and Tg2 of albacore. The antigen bigeye-3 also occurs in albacore taken from the North Atlantic. Yellowfin appear to have antigen y similar to Tg2 of albacore and bigeye.

An investigation of the agglutinins in tuna sera revealed that there are a variety of "serum types" reactive with human A and/or B erythrocytes.

Uchida, Richard N., and Tamio Otsu

Analysis of sizes of albacore occurring in various Pacific Fisheries - A preliminary report. [Conference Paper VII - 11]

Published and unpublished albacore length frequency data from foreign and domestic sources were analyzed to determine the general age structure of the species and the contributions of the several age classes to the major albacore fisheries in the Pacific Ocean.

Of the three major albacore fisheries in the North Pacific, the U. S. West Coast fishery, the Japanese winter longline fishery, and the Japanese spring live-bait fishery, the last normally accounts for the largest percentage of the total catch.

The 3-year-olds compose roughly 70 percent of the American albacore landings, while the 4- and 5-year-olds constitute a large part of the Japanese landings.

Australia and Chile have albacore fisheries, but they catch only a small portion of the albacore landed in the South Pacific. The smallest albacore are taken in waters around Australia and New Zealand, and these are estimated to be about 2- and 3-year-olds. In the small coastal fishery of Chile, the 3-year-olds predominate, making up roughly 71 percent of the catch.

The only major fishery for albacore in the South Pacific is the Japanese tropical longline fishery. Fishing is concentrated in an area between the Equator and latitude 30° S., and the predominant age group taken is the 6-year-olds, which compose 42 percent of the total landings.

Tagging results have shown that the albacore of the temperate North Pacific belong to a single population, but the relationship between the North and South Pacific albacore has not been determined. Evidence indicates, however, that the stocks in the North and South Pacific are independent of each other.

Comparison of North and South Pacific albacore landings indicates that 93 percent of the fish taken in the North Pacific fisheries are immature fish under 5 years old, while only 35 percent of the South Pacific fish were estimated to be under 5 years old.

A commercial longline fishery comparable to that found in the tropical South Pacific is nonexistent in the tropical North Pacific. It is hypothesized that one of the causes for this absence of a longline fishery in tropical waters of the Northern Hemisphere is the fishing effort expended on the immature stock (3- to 5-year-olds) during its migration in temperate North Pacific waters, with consequent reduction in the number of fish reaching 6 years of age, the predominant age group in the South Pacific longline fishery. This condition is reversed in the South Pacific, which may be the reason why the 6-year-old and older age groups are abundant enough to sustain a commercial fishery.

Uda, Michitaka

Cyclical fluctuation of the Pacific tuna fisheries in response to cold and warm water intrusions. [Conference Paper V - 7.] (In press (1962) in Journal of Tokyo University of Fisheries.)

Peak landings of skipjack from Japanese waters have occurred at irregular intervals since 1912. A study of oceanographic conditions showed that good catches were made during years with warm water temperatures, whereas poor catches were made during years with cooler water temperatures. These differences in temperatures were primarily related to the relative strengths of the warm Kuroshio and the cool Oyashio.

It was postulated that recruitment of skipjack is favored by the enriched zones associated with upwelling in the Equatorial Countercurrent and near the Equator. From these tropical waters there is a migration of skipjack (composed mainly of medium-sized fish) into Japanese waters. When the warm Kuroshio water spreads over a broad area, more skipjack become available to the Japanese fishery.

Conversely a strong Oyashio current (cold water) hinders the migration, and catches are low. However, good catches may also be made when both the Oyashio and Kuroshio are strong. Under the latter conditions skipjack are concentrated along the boundary between the warm and cold water (Polar Front). It is postulated that the yield of skipjack from Japanese waters varies inversely with that from American waters.

Albacore catch records also show peak landings at irregular intervals for both the Japanese and the U. S. fisheries. It is postulated that the variations between these two areas occur in a reciprocal manner, as was the case with skipjack. It is further postulated that the temperatures in the eastern and western Pacific vary in a reciprocal manner, with pulsations traveling west to east in the region of the dominant westerlies, returning in the lower latitudes dominated by the northeasterly trades. Intrusions of cold and warm waters into the coastal areas may be related to fluctuations in the atmospheric pressure systems. During 1955-59, an increase in pressure difference among the Siberian and North Pacific Highs and the Aleutian Low corresponded with a period of cooler temperatures in the western Pacific, warmer in the eastern Pacific.

Geographical variations in the location of the North Pacific High in winter and spring also affect the temperatures. Movement to the northwest results in warm intrusions in the western Pacific and good albacore catches, reciprocal in eastern Pacific. Movement of the high to the southeast corresponds to cool water in the west and poor catches, warm water in the east and good catches.

Bluefin catches off the coasts of Japan have also shown periodic fluctuations, with a decline in catch associated with periods of cold water intrusion, an increase in catch with periods of warming. The cause of these fluctuations may be related to dominant brood strength during periods of rising temperatures. When cool waters intrude southward into the spawning grounds, one or more year classes are seriously affected. However, these cooler waters are comparatively rich in nutrients and, with a reversal in temperature toward warming, succeeding year classes find more plentiful food and favorable temperature conditions for their migration northward into Japanese waters. Thus we have a cyclical situation—a reduction of year-class strength and the fishery during periods of cool surface waters, followed by an increase in brood strength during the subsequent period of warming and a more favorable ecological situation resulting from the enrichment of the surface waters during the cool period.

Uda, Michitaka

Localized concentration of tunas in the eddies along oceanic fronts. [Conference Paper V - 8.] (In press (1962) in Journal of Tokyo University of Fisheries.)

Aggregations of tuna are to be found along fronts, localized in eddies, cool or warm, and in zones of upwelling. Variations in concentration and location of the tuna are associated with growth, decay, and change in position of the eddies. Such eddies are to be found associated with the Polar Front and the subtropical convergence and near the Equator.

Albacore catch records for the period 1951-60 and surface temperature data were considered for the area between 140° E. and 154° E.

The albacore were in the cooler cyclonic eddies; the skipjack in the warmer anticyclonic eddies along the front and the bluefin in the cooler coastal waters.

In exploratory longline fishing (35°-45° N., 160° E. - 160° W., May-October), albacore were found between 15° - 21° C. with the peak catches centered around 175° W. The north-south and east-west distribution of albacore in the region north of the subtropical convergence (30° - 38° N.) was also investigated. In an east-west direction the peak catches were centered between 170° E. and 180°, decreasing sharply to the east and less sharply to the west. The peak catches were recorded during midwinter. As to the north-south distribution, the peak catches in the fall and winter centered about 38° N., moving to about 30° N. in March. The secondary peak in latitudes 30° - 20° N., west of 140° W. suggests to the author migration along the subtropical convergence.

In the western half of the Pacific, yellowfin tuna are caught along the Equatorial Countercurrent and are associated with areas of high productivity, which are in turn related to a series of eddies, i.e. eddies localized at about 135° - 145° E., 155° - 165° E., 175° E. - 175° W., and 155° - 157° W.

In the eastern equatorial Pacific, the rich yellowfin areas are associated with the regions of shallow thermoclines. The equatorial convergence at latitudes 1° to 3° N. may also concentrate yellowfin either through the concentration of food or through a barrier effect.

It is proposed that secular changes in oceanographic and fishery conditions are related to climatological changes and the relationships should be more fully studied.

Watson, Margaret E., and Frank J. Mather III

Species identification of juvenile tunas (genus Thunnus) from the Straits of Messina, northwestern Atlantic, and the Gulf of Mexico. [Conference Paper VII - 13]

Two vertebral characteristics visible in soft X-rays of juvenile fish as well as in hard X-rays of adult fish provide the first positive identification of juvenile bluefin tuna (T. thynnus), yellowfin tuna (T. albacares), blackfin tuna (T. atlanticus), and albacore (T. alalunga). Blackfin tuna are separable from the other species by having 19 precaudal and 20 caudal vertebrae, a count which contradicts the work of de Sylva (1955).[7] The other species having identical vertebral counts, 18 + 21, are separable one from each other on the basis of the position of the first ventrally directed parapophyses. For the yellowfin, this structure appears on the seventh precaudal, for the albacore on the ninth, for the bigeye and bluefin tuna on the eighth. A juvenile bigeye (T. obesus) has as yet not been X-rayed. It is presumed that the possible key characters for separating a juvenile bluefin from a juvenile bigeye would involve those also applicable to the adults, the measurement of the orbit diameter and depth, as well as comparing the contour of the lateral line characteristic of each species.

Yabe, Hiroshi, and Shoji Ueyanagi

Contributions to the study of the early life history of the tunas. [Conference Paper VII - 6]

Larval net tows, dip netting, and survey of stomach contents of adult fishes since 1949 by the Nankai Regional Fisheries Research Laboratory have resulted in collection of approximately 2,000 tuna larvae, 1,000 istiophorid larvae, and considerable numbers of juveniles of these fishes. The areas covered include a great portion of the Indian and Pacific Oceans. Larvae were taken in 1.4 or 2.0 m. nets hauled horizontally, either at the surface or at three levels, the deepest at 40-50 m.

Larvae of Katsuwonus pelamis, Auxis tapeinosoma, Neothunnus macropterus, and Thunnus orientalis are described. In addition, two types, A and B, suspected to belong to albacore and bigeye, respectively, are recognized through their geographical and seasonal occurrence. These types are thought to be quite similar to Neothunnus larvae with respect to the absence of pigmentation on the trunk and late appearance of chromatophores over the forebrain. Type A is characterized by the presence of pigment on the tip of the upper jaw in specimens about 8 mm. in fork length and the absence, or only very faint presence, of pigment on the tip of the lower jaw. Type B is mainly characterized by pigment on the tip of the upper jaw at 5.3 mm. and on the tip of the lower jaw at 7.0 mm. in fork length.

7/ de Sylva, Donald P. 1955. The osteology and phylogenetic relationships of the blackfin tuna, Thunnus atlanticus (Lesson). Bulletin of Marine Science for the Gulf and Caribbean, Vol. 5, No. 1, p. 1-41.

Horizontal distribution of tuna larvae is discussed with some mention of juveniles; however, these distributions are treated only qualitatively. In low latitudes between 10° N. and 10° S., larvae seem to occur all year round, but in higher latitudes they tend to occur in spring and summer. Larvae of frigate mackerel (A. tapeinosoma) also have a wide distribution, however, their abundance is assumed to be high in waters close to islands. Larvae of T. orientalis are taken in waters in the vicinity of Luzon Island, Okinawa, and in the area to the north of the Bonin Islands during May and June. They are assumed to be abundant also in the area of the Kuroshio Current. Most of the yellowfin (N. macropterus) larvae are taken in tropical (equatorial) areas, and some are found in subtropical areas which are under the influence of warm currents. Larvae representing types A, taken in July, and B, taken in December, are present in the area between latitudes 10° N. and 25° N. in the western Pacific.

Larvae of all five istiophorid species distributed in the Indo-Pacific areas are identified. Shortnosed spearfish (Tetrapturus angustirostris Tanaka), sailfish (Istiophorus orientalis T. and S.), and striped marlin (Makaira mitsukurii J. and S.) are characterized by a long snout, and black marlin (Eumakaira nigra Nakamura) and white marlin (Marlina marlina J. and H.) are characterized by a short snout. The former three species are distinguished from one another by the profile of the head and the number of dorsal fin rays, while the latter two species are distinguished from each other by the shape of the pectoral and dorsal fins.

Results of larval net hauls indicate that both tuna and istiophorid larvae undergo vertical, diurnal migration in the upper 50 meters of water.

Yabuta, Yoichi, and Mori Yukinawa

Age and growth of yellowfin tuna. [Conference Paper VII - 7.] (See also Yabuta, Yoichi et al. Age and growth of yellowfin tuna. Rept. Nankai Reg. Fish. Res. Lab. no. 5, p. 127 – 133 (1957); no. 11, p. 77 - 87 (1959); no. 12, p. 63-74 (1960).)

Length frequency distributions of yellowfin tuna taken by pole and line and by longline in waters adjacent to Japan were analyzed, and a growth curve was obtained. The scale method of age determination was also used to derive a growth curve. Tag recovery data substantiated the results obtained by the other two methods.

In the length frequency method, the monthly modal mean lengths for each age class were plotted for the years between 1953 and 1956, and the progression in size was noted. Of scale samples from 2,087 fish examined in scale studies, those from 1,204 (57.7 percent) were unreadable. Unreadable scales, however, occurred more frequently in larger fish. There were 24 percent unreadable samples from fish under 100 cm. in length, 68 percent from fish between 101 cm. and 131 cm., and 95 percent from fish larger than 131 cm. Scale studies also indicated that two rings are formed each year, one in March and April and the other in September and October.

In general, the growth rates estimated by the length frequency method and the scale method and from tagging data were in good agreement with one another. The results showed that the yellowfin is a relatively rapid-growing tuna and that growth during the early stage of life is particularly rapid. The first major group of fish entering the commercial fishery (at about 50 cm.) was estimated to be 1-year-old as determined by the scale method.

Yamanaka, Hajime, and Noboru Anraku

Relation between the distribution of tunas and water masses of the North and South Pacific Oceans west of 160° W. [Conference Paper V - 5]

A detailed examination of temperature and chlorinity in the Pacific west of 160° W., and in particular of temperature-chlorinity relationships in the upper 200 meters, suggests that the surface water layers can be divided into a series of types having characteristic ranges of temperature and chlorinity. The observations are grouped into (Northern Hemisphere) winter and summer classes, and the water types given preliminary designations based upon the current system which dominates the area in which each occurs. Thus, for example, there is a type O surface water, in the region of the Oyashio, which is associated with the underlying Sub-Arctic water mass, there are types K and N, representing the Kuroshio and North Equatorial Current surface water types which overlie the Western North Pacific Central water mass, and there are water types associated with the Countercurrent, equatorial waters, the South Equatorial Current, the Coral Sea, the Central and southwest Tasman Sea areas, and the Sub-Antarctic.

In general, the water types are relatively uniform from east to west. There is evidence of seasonal movement toward and away from the Equator, and the area covered by each water type varies seasonally. These movements are interpreted as reflecting seasonal changes in the location and intensity of the current system.

An approximate relation is shown between the occurrence of tunas and the location of various surface water types. The albacore in their feeding stage appear in the western K (Kuroshio) type, while albacore in the spawning stage are found in the southern N (North Equatorial Current) surface water type. Similarly, bigeye, yellowfin, and striped marlin appear to be associated with specific surface water types, often appearing in water of two different types without being abundant in an intermediate third type which geographically separates the two regions of abundance.

Yuen, Heeny S. H.

Experiments on the feeding behavior of skipjack at sea. [Conference Paper IV - 3]

These experiments were conducted at sea from the Charles H. Gilbert, research vessel of the Bureau of Commercial Fisheries Biological Laboratory, Honolulu, on skipjack schools which had been attracted to the ship by chumming with live bait and were being hooked by pole and line. The influence of water sprays, dead bait, various species of live bait, and glitter (a material obtained from artist's supply shops) on the feeding response of skipjack was investigated. Response was measured by catch rate (number caught per hook per minute) and by feeding attack rate (number of attacks on bait or hooks per fish per second). The latter statistic was obtained from 16 mm. color film shot with a cine-camera during the experiments from the underwater viewing port at the stern of the Charles H. Gilbert. Water sprays seemed to increase the responses when anchovy (Stolephorous purpureus), mountain bass (Kuhlia sandvicensis), tilapia (Tilapia mossambica), and goatfish (Mulloidichthys samoensis) were used as bait, to decrease the catch rate when mullet (Mugil longimanus) was used, and to have no effect when silversides (Pranesus insularum) were used. The sprays may change the bait's behavior rather than stimulate skipjack directly. When different bait species were used, caranx (Caranx mate) and anchovy elicited greater responses than silversides, and equal responses resulted from alternating anchovy and topminnow (Limia vittata), tilapia and mullet, and tilapia and mountain bass. Live bait was more effective than dead bait, and glitter seemed to raise the attack rate slightly but not the catch rate. Skipjack move toward shiny objects, but the movement of the food seems to provide the stimulus necessary to result in a grasping of the food.

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