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National Marine Fisheries Service

A Review of the Literature on the Development of Skipjack Tuna Fisheries in the Central and Western Pacific Ocean

FRANK J. HESTER and TAMIO OTSU

SEATTLE, WA
January 1973

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ABSTRACT

There has been a rapid acceleration in efforts to develop skipjack tuna fisheries in the central and western Pacific. This is because the resources of the larger tunas (yellowfin, bigeye, bluefin, and albacore) are already being fished at or near the maximum sustainable level. The greatest potential for increased harvest appears to be the skipjack resource. To assist the skipjack development effort, pertinent information on the subject is summarized and a bibliography of selected references is included.

INTRODUCTION

The rapid acceleration of interest in skipjack tuna, *Katsuwonus pelamis*, fishery development in the central and western Pacific has prompted several exploratory fishing operations in the area beginning in 1971. To aid the development of skipjack tuna fisheries we thought that a review of the literature and a compilation of a bibliography on earlier developmental work would be useful. Most of these references are available in any reasonably large research library or in most fisheries libraries. All are available in the library of the Honolulu Laboratory of the Southwest Fisheries Center or in its archives and files. Many references dealing with the subject have been omitted, no doubt some through oversight but chiefly because they are incorporated in other documents in our bibliography.

The development of a fishery, from the discovery of the resource to the time that full production is reached, can be diagramed. Figure 1 is a convenient diagram for considering the development of a skipjack fishery in the central and western Pacific. The diagram is complicated by the fact that one of the methods widely used in capturing skipjack tuna requires live bait. Thus we have a fishing method dependent upon another fishery, and it is desirable to consider the development of a fishery for the bait species along with that for skipjack. Hence, a parallel flow chart for the baitfish fishery is included and pertinent references are incorporated.

There is less literature on the baitfishes used for skipjack fishing in the central and western Pacific than there is on the skipjack. Only in three areas is systematic collection of baitfish information under way, these being Palau, Hawaii, and American Samoa. In both Palau and Hawaii, where substantial skipjack fishing is carried out, baiting records are available for several years, and some research has been or is being conducted to provide a better understanding of the biology and management of the bait resources.

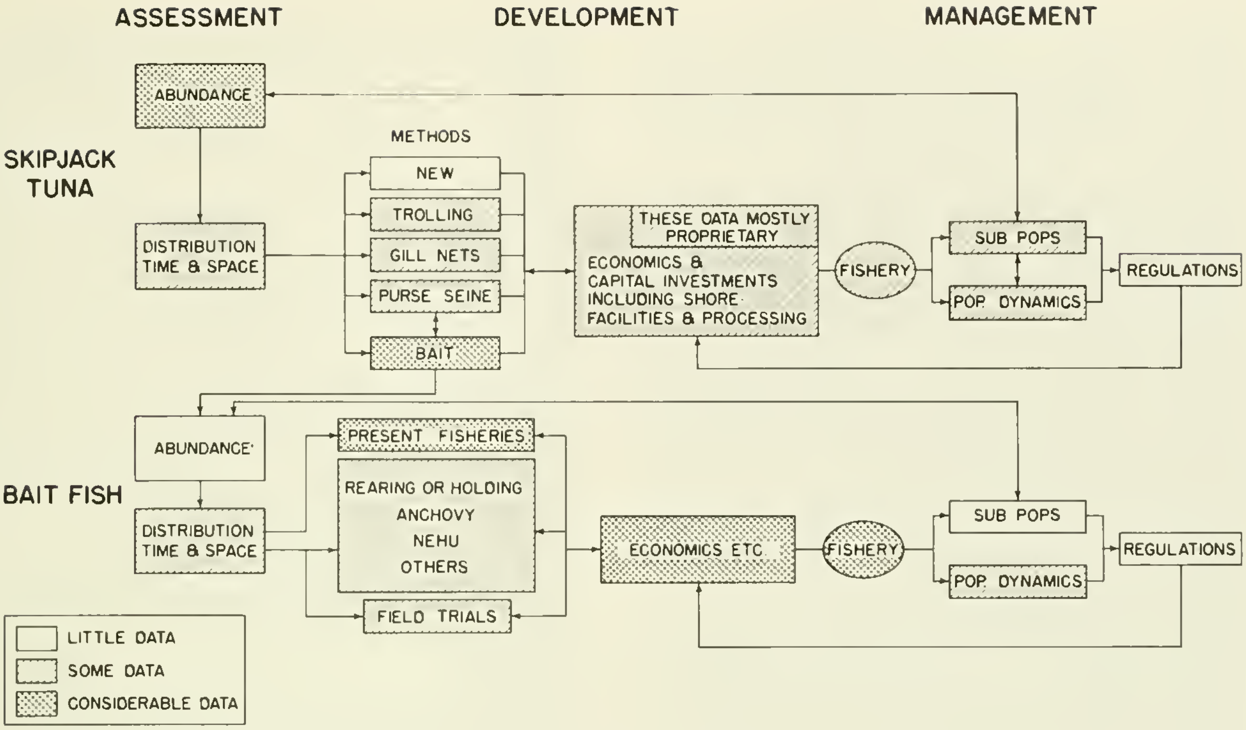

Figure 1. — Flow diagram for the development of skipjack fisheries in the central and western Pacific.

SKIPJACK FISHERY ASSESSMENT

Abundance

We will consider those references that attempt to quantify the potential yield of skipjack from the central and western Pacific. These fall generally into three categories: (1) papers and reports coming from Japanese workers, who have concentrated primarily on fisheries near Japan and in the southwestern (south of lat 24° N, west of long 160° E) Pacific, (2) papers originating with the Honolulu Laboratory, and (3) papers from the west coast of the United States, chiefly from the Inter-American Tropical Tuna Commission (IATTC).

The Japanese workers have estimated the potential yield of skipjack in the Pacific in a number of ways based upon current and prewar production and distributional records from their fishing fleet. Estimates for the western Pacific made several years ago include 30,000 metric tons for the Caroline Islands, 15,000 metric tons for Palau (Uchida, 1970), and 150,000-200,000 metric tons for the Japanese home island and Ryukyu Islands fishery (based on peak landings). No estimates were found for the potential of the New Guinea and Coral Sea grounds, but recently Japanese estimates as high as 1.5-2.0 million tons for the entire Pacific have been made ([U.S.] Bureau of Commercial Fisheries, 1970a; U.S. National Marine Fisheries Service, 1971).

In the eastern Pacific the IATTC workers (Shimada and Schaefer, 1956; Calkins, 1961; Broadhead and Barrett, 1964; Joseph and Calkins, 1969) have suggested that (1) a considerable tonnage of skipjack are either unexploited or never enter the eastern Pacific fishery, and are located somewhere west of long 120° W, and (2) present landings (ca. 50,000 metric tons) could safely be increased and perhaps doubled.

Workers at the Honolulu Laboratory, particularly Rothschild (1966), Silliman (1966), and Rothschild and Uchida (1968), also concluded that there is a large potential yield of skipjack tuna in the central Pacific, their estimates ranging from some 40,000 to over 200,000 metric tons on a maximum sustainable yield basis.

Although all the conclusions are highly

speculative, it is reasonable to assume that the potential yield of skipjack in the central and western Pacific has not been reached and that the resource is large enough for a sizable expansion of the fishery.

Distribution in Time and Space

Our knowledge of skipjack distribution comes primarily from the established fisheries in the eastern Pacific, Hawaii, French Polynesia. and the western Pacific, as reported by a number of workers including Imamura (1949), Shimada (1958), Shippen (1961), Calkins and Chatwin (1967), Brun and Klawe (1968), Isa (in press), and Tohoku Regional Fisheries Research Laboratory (n.d.). Supplementing this information are incidental catches of skipjack taken from tuna longline records (Kasahara, 1968; Miyake, 1968). Records are also available from research and exploratory vessels scouting for skipjack (Smith, 1947; Smith and Schaefer, 1949; Royce and Otsu, 1955; Yoshida, 1960; McKenzie, 1961; Waldron, 1964; York, 1969; Hida, 1970a, b). Currently an FAO development project has been initiated in Fiji, and new fisheries established in the Solomons and New Guinea area are beginning to provide information from the southwestern Pacific.

Tag recoveries are beginning to contribute to the understanding of the migration and seasonal occurrence of skipjack (Rothschild, 1965; Fink and Bayliff, 1970; Kasahara et al., 1971). From such observations several summaries on their occurrence have been published. These include [U.S.] Bureau of Commercial Fisheries (1963), Kawasaki (1965), Kasahara (1968), Rothschild and Uchida (1968), and Kasahara et al. (1971). These summaries led to hypotheses on the origin and migration of skipjack in the Pacific, including those by Rothschild (1965), Naganuma (in Kasahara, 1968), and Matsumoto[1].

Following the formulation of distributional and migration hypotheses, some attempts have been made to generalize the distribution of the skipjack and to relate them to their environment. In the eastern Pacific, their north-south distribution is believed to be limited between surface isotherms of 20° and 29°C (Williams, 1969). In the central Pacific various attempts have been made to describe the relation of skipjack distribution to the various current systems (Seckel and Waldron, 1960; Seckel, 1963) and in the western Pacific to seasonal changes in water temperature and current systems (Inanami, 1941; Kawasaki, 1965). For the central and western Pacific, the general pattern is one of a northward expansion from near equatorial waters as the summer season progresses and a contraction to the lower latitudes with the onset of fall and winter. The seasonal shift can best be seen in reports by Kasahara (1968) and the Tohoku Regional Fisheries Research Laboratory (n.d.).

[1]Matsumoto, W.M. Distribution, relative abundance and movement of skipjack tuna (*Katsuwonus pelamis*) in the Pacific Ocean based on Japanese tuna longline catches, 1964-67. Unpublished manuscript filed at National Marine Fisheries Service, Southwest Fisheries Center, Honolulu Laboratory, Honolulu, Hawaii 96812.

SKIPJACK FISHERY DEVELOPMENT

Methods

Until recently pole-and-line fishing with live bait accounted for most of the skipjack landings. Recently purse seining has begun to produce an increasingly significant fraction of the catch. These two methods have greatly exceeded the small amounts taken by trolling and with gill nets. Trolling is generally limited to nearshore, small-boat subsistence fisheries and by research vessels. In French Polynesia, however, this method has been developed into a fairly productive fishery (Van Campen, 1953; Van Pel and Devambez, 1957; Brun and Klawe, 1968). Some estimates of potential production by trolling can be obtained from survey reports such as Smith (1947), Smith and Schaefer (1949), Bates (1950), Welsh (1950), Murphy and Ikehara (1955), and Iversen and Yoshida (1957).

As with trolling, gillnetting until recently has been limited to scientific surveys as an indicator of the distributions of tunas (Matsumoto, 1952; Shomura, 1963). In the last decade gillnetting for tunas has been developed commercially in Australia and New Zealand (Temple, 1963; York, 1969; Avery, 1970).

Purse seining is the preferred method for taking tunas in the eastern Pacific, where in 1971 approximately 100,000 metric tons of skipjack were taken. A review of this method is given by McNeely (1961) and Green and Perrin (1970). In the central Pacific purse seining has been tried on a few occasions in Hawaiian waters (Murphy and Niska, 1953). The method has shown some promise ([U.S.] Bureau of Commerical Fisheries, 1969a) and recently another attempt (Hawaii. Fish and Game and Bumble Bee Seafoods, 1970) has taken place with partial success. In the western Pacific the Japanese have been increasing their experimental and exploratory purse seine work, which is summarized by Watakabe (1970). Like the Hawaiian experiments, these efforts have not been an unqualified success. American west coast purse seiners have also made some excursions into the western Pacific with mixed success ([U.S.] Bureau of Commercial Fisheries, 1970b). Numerous reasons have been cited for the difficulties encountered in applying this method of fishing in the central and western Pacific, chief among these being the greater depth of the thermocline and the clearer waters in the tropics. This method may yet become increasingly important following development work involving gear modifications and specialized techniques.

Pole-and-line fishing with live bait is still the preferred method in the central and western Pacific. There are many references to live-bait fishing in these areas from prewar years (Ikebe and Matsumoto, 1937; Matsumoto, 1937; South Seas Government-General, 1937a, b, c; Watanabe, 1940; Ikebe, 1941) and numerous reports from after the war including June (1951b), Inoue (1966), Hida (1970b), and Uchida (1970).

Little has been published on new methods (Alverson and Wilimovsky, 1964; Kristjonsson, 1968). Some work has been done on improved purse seining (Green, Jurkovich, and Petrich, 1970) and purse seining in combination with live bait (Hawaii. Fish and Game and Bumble Bee Seafoods, 1970).

Attracting and concentrating fish under floating objects (Gooding and Magnuson, 1967; Hunter and Mitchell, 1968) and electro-fishing (Tester, 1959) are other methods that have been tried or suggested. Recently the Japanese have developed an automatic skipjack fishing device which shows considerable promise (Suzuki Tekkojo Kabushiki Kaisha, 1970) and the Tahitian troll-pole method (Van Campen, 1953), though not new, is a method that may well prove applicable to other areas.

Economics and Capital Investment

Most of the information on cost and investment economics is from industry, and the data are proprietary and can only be obtained by special arrangement with the appropriate companies. Some information on the importance of skipjack fishery development for the western Pacific is included in the Nathan Report (Nathan Associates, 1966), in [U.S.] Bureau of Commercial Fisheries (1969a), and in Pacific Islands Development Commission (1971). Shang (1969) discusses the economic aspects of the Hawaiian skipjack fishery. Production figures are generally available from a number of sources including IATTC, the National Marine Fisheries Service, the State of Hawaii, and the Japan Fisheries Agency.

FAO summarizes these statistics annually in its Yearbook of Fishery Statistics (Food and Agriculture Organization of the United Nations, 1970). These are generally several years late and do not reflect the rapid changes that are occurring. Because of the proprietary nature of the data, the production figures often are pooled for a large geographical area so it is impossible to tell how many fish are landed from any one location.

SKIPJACK FISHERY MANAGEMENT

With the rapid expansion of the skipjack fishery, conservation and management of the resource should be of concern to all interests. At present there is no convention to manage and protect the tunas of the central and western Pacific.

Management requires certain broad items of information. The first is whether or not a fishery exploits a single stock or several more or less independent stocks or subpopulations. Generally the skipjack population is believed to be separated into a western Pacific stock that ranges from the Philippine Sea to the home islands of Japan and from the Ryukyus south to New Guinea and into the Coral Sea, and a central Pacific stock that probably extends from the Carolines and the eastern side of the Marianas all the way to the Americas. This theory is supported by genetic evidence summarized by Fujino (1967, 1970a, b, in press) by morphometrics (Kawasaki, 1955a, b, 1964), and by tagging (Otsu, 1970; Kasahara et al., 1971).

The second factor in the management of the skipjack is the dynamics of the exploited population. Sources of data on the population dynamics of skipjack are listed in the bibliography (Tauchi, 1943; Shimada and Schaefer, 1956; Kawasaki, 1964, 1965; Fink, 1965; Rothschild, 1965, 1966; Silliman, 1966; Joseph and Calkins, 1969; Joseph, 1970). Because the fisheries we are concerned with are in the developmental stage, there has been no concerted effort toward the development of a management plan for these fisheries. None of these references deals specifically with management.

BAIT FISHERY ASSESSMENT

Abundance

There is little published data on the quantitative abundance of baitfishes in the central and western Pacific. The majority of the available work has been done on the Hawaiian anchovy, or nehu, *Stolephorus purpureus* (Tester, 1951, 1955; Bachman, 1963; Au, 1965). Investigations are currently underway on the abundance and population dynamics of the Palauan anchovy, *Stolephorus heterolobus*, by Garth Murphy and his group at the University of Hawaii. In addition, there are some notes on the biology of the Marquesan sardine, *Sardinella marquesensis*, (Nakamura and Wilson, 1970) which may have some bearing on a similar species that occurs in the Eastern Carolines, Marshall Islands, Fiji, and elsewhere. This study suggests that the Marquesan sardine cannot withstand extensive fishing pressure. Ikebe and Matsumoto (1938) made some estimates of bait resources near Saipan. Few species and small populations were reported and special fishing techniques were required to take them.

Distribution in Time and Space

Apart from estimates of abundance based on quantitative analysis, a great deal of work has been done to locate suitable bait species by search and sampling in areas where these fishes are needed to support tuna fisheries. Reports of bait surveys include translations from Japanese investigations ranging from prewar investigations in the waters of Ponape and Palau (South Seas Government—General, 1937a, c), Loliai, Lamotrek, and Puluwat (Matsumoto, 1937) to the recent (Kikawa, 1971) report on baitfish surveys in the New Guinea area.

There are reports in English from several areas. For Hawaii and the Leeward Islands there are June (1951a), Tester (1951), Hida and Morris (1963), Au (1965), and Nakamura (1970). For the Micronesian area and the central Pacific, there are Ikehara (1953) and June and Reintjes (1953) on the baitfishes of the central Pacific and Wilson (1971) on the baitfishes in Truk. Still being prepared is a paper by Wilson[2] covering live bait in the Palaus. In addition is the report by Hida (1971) on the current National Marine Fisheries Service investigations in the Trust Territory. There is some unpublished material on baitfishes in Samoa (Swerdloff[3]); a paper by Royce (1954) covering the Marquesas and Tuamotus; and finally papers by Hida and Thomson (1962) covering the introduction of threadfin shad, *Dorosoma petenense*, and Hida and Morris (1963) reporting on the introduction of the Marquesan sardine into Hawaii.

BAIT FISHERY DEVELOPMENT

Present Fisheries

With regard to present fisheries for bait, there is no current report available on any of the important bait species, except Bachman (1963). However, catch and effort statistics are maintained both in Hawaii and Palau and reports of the current status of these fisheries can be obtained from the appropriate Fish and Game and Marine Resources Departments.

Rearing or Holding

From time to time attempts have been made to improve the availability of bait by supplementing the natural supply with bait held in pens or reared in ponds.

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[2]Wilson, P. T. Observations of various tuna bait species and their habitat in the Palau Islands. Division Headquarters, Trust Territory of the Pacific Islands, Koror, Palau, Western Caroline Islands 96940.

[3]Stanley N. Swerdloff, Director, Office of Marine Resources, Government of American Samoa, Pago Pago, American Samoa 96920.

Anchovy.—The success of the Japanese southern waters fishery depends upon the transportation of live bait from the home islands of Japan to as far south as the equator (Iwasaki, 1970; Anonymous, 1971). Similar efforts have been made in Hawaiian waters with the transportation of west coast anchovy in 1932 (Brock, 1960). In 1971, an additional attempt was made to bring anchovies from California to Hawaii. More than 100 buckets (1 bucket $\approx$ 8 lb.) of the northern anchovy, *Engraulis mordax*, were brought from San Diego, Calif., to Honolulu aboard a bait boat with better than 80% survival after 15 days. The problems of mortality do not appear to be great and the cost of transportation for large quantities of bait may be economically feasible.

Nehu.—A number of attempts have been made to improve the keeping of nehu aboard vessels (Hiatt, 1951; Pritchard, 1953; Burdick, 1969; Baldwin, 1970; Baldwin, Struhsaker, and Akiyama, 1971). The handling of nehu for better survival is summarized by Baldwin (1969) and Baldwin et al. (1971). There is also a report on development of a separate baitfish holding facility for nehu ([U.S.] Bureau of Commercial Fisheries, 1969b).

Others.—Studies also have been made on rearing introduced species as substitutes for native baitfishes. These species include the threadfin shad (Iversen and Puffinburger)[4] and tilapia, *Tilapia mossambica* (Brock and Takata, 1955; King and Wilson, 1957; Hida, Harada, and King, 1962; Uchida and King, 1962). Marquesan sardine were introduced into Hawaii in 1961 and are established but not in sufficient quantity for bait fishing (Hida and Morris, 1963).

Field Trials

There have been several experiments designed to improve the effectiveness of natural live bait, as well as tests of new live bait species. Tests of the natural baits are reported in Welsh (1949) and Yuen (1959, 1969). Tests conducted using tilapia as an alternate bait for skipjack in Hawaii are reported by Shomura (1964). A report of recent trials using threadfin shad as live bait in Hawaiian waters is given by Iversen (1971).

Economics and Capital Investment

Studies were conducted to determine the value of live bait to the tuna fishermen in order to explore the economics of supplying live bait to tuna vessels. Some estimates of the value of nehu to fishermen and a breakdown on the probable production costs for threadfin shad as a live bait are reported by Shang and Iversen (1971). Brock and Takata (1955) also provided an estimate of the value of nehu to Hawaiian fishermen.

BAIT FISHERY MANAGEMENT

Some work on the problem of defining subpopulations of live bait species has been done in Hawaii. Matsui (1963) reports on populations of nehu in the vicinity of Maui, Strasburg (1960) reports on the discovery of an offshore species of nehu, and Tester and Hiatt (1952) report on variations in meristic characters in the nehu.

Management of baitfishes in the central and western Pacific has not been implemented. There is, however, some information on the population dynamics of these fishes. Bachman's (1963) thesis considers fluctuations and trends in the abundance of nehu for Hawaii. The present study by Murphy, University of Hawaii, in Palau is the only current investigation in the population dynamics of a baitfish. However, the National Marine Fisheries Service is beginning to study the biology of the sardine in the Marshall Islands. The Fisheries Departments of the Government of American Samoa and the Trust Territory of the Pacific Islands are collecting or will collect fishery and biological data from their baiting grounds for future management investigations.

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