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Success of the live-bait tuna fishery rides on the success of the fishery for bait.

Some Considerations of the Problems Associated with the Use of Live Bait for Catching Tunas in the Tropical Pacific Ocean

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ABSTRACT

This report provides a summary of tropical Pacific tuna live-bait fishing methods, identifies the major problems restricting the expansion of live-bait fisheries in the Pacific, and gives references and suggestions on methodology to investigators interested in working on baitfish problems.

INTRODUCTION

The use of live bait to catch tunas, called baitfishing in the eastern Pacific and pole-and-line fishing in the central and western Pacific, has been described by a number of authors (Godsil, 1931; June, 1951; Iwasaki, 1970; Isa, 1972; and Webb, 1972, 1973). The method probably was developed to its highest form in Japan from whence it spread, with modifications, across the Pacific and into the Atlantic during the first part of the 20th century.

The 1971 world tuna landings were 1,150,000 metric tons (FAO, 1971). Of this total catch, baitfishing accounted for about 244,000 metric tons (21%), purse seining took 228,000 metric tons (20%), and longlining took 427,000 metric tons (37%). The remaining 251,000 metric tons (22%) of tunas were taken by a variety of methods such as trolling, and traps and weirs, or were caught by the three principal methods but could not be so identified from the statistics.

For a description of tuna purse seining see McNeely (1961) and Green, Perrin, and Petrich (1971), and for tuna longlining, Shapiro (1950).

Live-bait fishing for tunas depends upon quantities of suitable baitfishes, which are used to attract schools of tuna to the boat and to excite them into a feeding mode so that they can be caught by lure and a pole and line. The principal tuna species taken with baitfishes are skipjack tuna, *Katsuwonus pelamis*; yellowfin tuna, *Thunnus albacares*; and albacore, *T. alalunga*. The live-bait albacore fisheries are in temperate waters. The discussion of live-bait tuna fishing in this paper will be limited to the tropical tunas—yellowfin and skipjack. Five elements of baitfishing for tunas will be reviewed and discussed: types of bait, catching the bait, holding and transporting the bait, fishing the tuna schools, and bait supply.

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TYPES AND CHARACTERISTICS OF A GOOD BAITFISH

In order to be a suitable live bait, the baitfish must be of a size and appearance acceptable to the tunas, its behavior must be such that the tunas are attracted to the boat and induced to bite, and the bait must be sufficiently hardy to remain alive during capture and transport. In this regard resistance to mechanical damage, i.e., loss of scales and bruising, is important, as is the bait's tolerance to temperature and temperature change so that the bait can be carried by the fishing boat from one fishing ground to another through waters of varying temperatures.

The preferred baitfishes for tuna fishing are clupeoids, principally the anchovies and their relatives. The clupeoids in general are good baits, being of the proper size (25-100 mm) and possessing the silvery appearance and the behavior that induces feeding behavior in the tuna. These fish are active swimmers that do not disperse when thrown into the water but maintain a semblance of schooling behavior and do not swim away or dive deep but stay close to the vessel.

When suitable supplies of clupeoids

Table 1.—Effectiveness of live bait.

Area and period	Bait species	Unit of measure	Quantity	Tuna catch (metric ton)	Effectiveness Kilogram bait/ metric ton tuna
Japan, 1968[1]	Anchovy, *Engraulis japonicus*	Bucket ≈ 5.5 kg	4.4×10^6 buckets	168×10^3	143.0
Japan, 1971[2]	do	Bucket ≈ 5.5 kg	250 buckets 1,375 kg	71.9	19.4
Hawaii, 1965-71[3]	Anchovy (nehu), *Stolephorus purpureus*	Bucket ≈ 3.5 kg	34×10^3 buckets 0.8×10^6 kg	4.5×10^3	28.50 $S^2 = 51$ (variance)
Eastern Pacific, 1948-59[4]	Anchoveta, *Cetengraulis mysticetus*	Scoop 4.1 kg	3.5×10^6 scoops 14.5×10^6 kg	114×10^3	128.1 $S^2 = 783$
Eastern Pacific, 1960-69[4]	do	Scoop 4.1 kg	0.41×10^6 scoops 1.7×10^6 kg	23×10^3	68.2 $S^2 = 158$
Palau Islands, 1966[5]	Anchovy (nehu), *Stolephorus heterolobus*	Bucket ≈ 3.5 kg	62.7×10^3 buckets 0.22×10^6 kg	2.9×10^3	87.4 $S^2 = 1008.8$
Ryukyu Islands, 1967[6]	Mixed—predominantly apogonids and lutjanids	Kilogram	0.27×10^6 kg	5.1×10^3	52.6
Hawaii, 1962[7]	Tilapia, *Tilapia mossambica*	Not available	Not available	Not available	≈ 60
Hawaii, 1968[8]	Shad, *Dorosoma petenense*	Bucket ≈ 3.5 kg	56 buckets 176 kg	4.8	37
Hawaii, 1971[9]	Shad, *Dorosoma petenense*	Bucket ≈ 3.5 kg	204 buckets 728 kg	12.5	58
Hawaii, 1973[10]	Northern anchovy, *Engraulis mordax*	Bucket ≈ 3.5 kg	3 buckets 10.5 kg	0.7	15
Hawaii, 1973[11]	Golden shiner, *Notemigonus crysoleucas*	Bucket ≈ 3.5 kg	Not available	Not available	118

[1] Based on total anchovy bait catch and total home and southern waters landings of yellowfin tuna, skipjack tuna, and albacore. (Source: [Japan.] Ministry of Agriculture and Forestry. Statistics and Survey Division, 1970.)

[2] Based on average bait capacity and average catch per trip of southern waters vessels (Anonymous, 1971).

[3] Source: Hawaii Division of Fish and Game and Bumble Bee Seafoods (1970).

[4] Source: Inter-American Tropical Tuna Commission (1956, 1960, 1966, 1970). Note: From 1960 on most of the large bait boats converted to purse seiners and left the bait boat fleet.

[5] Source: Congress of Micronesia (1972).

[6] Source: Isa (1972).

[7] Source: Shomura (1964). Quantity and weight of bait not given. Results are based on average catch rate comparison with nehu, nehu being considered to have an effectiveness of 30.

[8] Source: Iversen (1971).

[9] Source: Iversen, R. T. B. 1973. Commercial fishing for skipjack tuna with threadfin shad as bait. Unpublished report, 4 p. Southwest Fisheries Center, National Marine Fisheries Service, NOAA, Honolulu, HI 96812.

[10] Source: Uchida, R. N., Southwest Fisheries Center, National Marine Fisheries Service, NOAA, Honolulu, HI 96812, pers. comm.

[11] Source: Kato, K., Fishfarms Hawaii, P.O. Box 898, Kihei, HI 96753, pers. comm.

are not available, bait boats, especially those operating in island areas, resort to the use of any proper-sized fishes that can be obtained in reasonable quantity including a wide variety of tropical reef fishes such as juvenile mullets, Mugilidae; goatfishes, Mullidae; cardinalfishes, Apogonidae; damselfishes, Pomacentridae; silverside, Atherinidae; snapper, Lutjanidae; mosquitofish, Poeciliidae; rabbitfish, Siganidae; etc.

Baitfish acceptability is determined by three factors: supply, which is discussed in a separate section of this report, mortality, and effectiveness. Live bait is subject to continuous loss from the time it is obtained to the time that it is used for fishing. Strong bait, that is bait that survives capture and holding well, is in great demand. Studies of factors affecting mortality have been made by Baldwin, Struhsaker, and Akiyama (1971), and Anonymous (1971). Bait mortality is a complex problem and needs much additional work, particularly in connection with long distance transport and holding of large quantities of bait.

Effectiveness, that is the production of tuna per quantity of bait, is difficult to quantify owing to lack of good statistics on bait usage. From Table 1 it is apparent that there is a wide range of effectiveness expressed in kilogram bait per metric ton of tuna produced. The smaller the ratio the more effective the bait. These measures of effectiveness are subject to several biasing errors that result in an overestimate of the bait needed. The largest error is due to the use of total bait caught rather than bait used in fishing. Thus mortality is included in these estimates.

Also included is bait dumped when fishing is completed.

Sources of error that affect the variance of the estimates are the size of the tuna fished, more bait being required to take a ton of small tuna, the reporting of bait catches by the bucket or scoop, the constancy of which is questionable, and the complex relation between bait mortality and time spent looking for fish. The latter may account in part for the increase in effectiveness in the eastern Pacific fishery after 1960 when the bigger boats dropped out of the fishery leaving as the principal users of bait the smaller boats that perhaps did not spend as much time scouting for tuna.

BAIT CATCHING METHODS

Baitfishes are caught by several types of gear, the most common being the bait seine. The details of this type of gear and operation vary from locality to locality. In Hawaii the so-called day net, a round-haul net for shallow water that lacks wings, bag, or purse line, is used. The dimensions for a typical day net are 175 by 4 m constructed of 4.8 mm stretched mesh webbing (Figure 1). The main bait species taken is the nehu, an anchovy, *Stolephorus purpureus*, which is quite small and requires a small-meshed net. Another common bait net, used chiefly in the eastern Pacific, is the lampara, which has wings and a bag section, is deeper, and can be used in waters where the leadline does not necessarily maintain contact with the bottom. Details of the operation using this gear are given by Scofield (1951) and Du Plessis (1959).

For baiting in deep water, the purse seine is effective, being superior to the lampara but requiring more manpower. For shallow water areas where the bottom is too rough to drag or walk the leadline of the net, the drive net is used (Figure 2).

"The 'drive-in-net' fishing method is said to have been developed in the Ryukyu Islands (Shapiro, 1949) to catch shoaling fishes in coral reef areas. Divers, sometimes carrying fish-chasing devices, drive the fish school into a net set strategically to block the path of the fish. As soon as the fish are driven into the net, the net is lifted to the surface. This method has long been used for catching mainly the Apogonidae and Caesionidae. The size and design of the net differ according to the fish to be captured. The net usually consists of a bunt and two wings when catching larger and faster swimming fishes such as adult *Caesio*, flyingfish, and garfish. Only the bunt of the net or a blanket net is used for catching apogonids or other slower swimming fishes or juvenile fishes. The drive-in net is used to capture apogonids early in the morning by taking advantage of their nocturnal habit. The bait fishermen cover a reef with the net before sunset. The fish are found hiding in crevices. The net is allowed to remain overnight. The opening over the crevice in which the fish are hiding is kept open in order to enable the fish to move out at night. The fishermen catch the baitfish early in the morning by driving the fish into the net before the fish can return to their hiding places.

"The fishermen also catch the apogonids during the day by inserting tree leaves into crevices and scaring them out. Some apogonids are observed during the day with other baitfish and are caught along with them. The red scads (*Caesio*) and 'blue bait' are caught during the day." Isa (1972).

A second type of baiting operation is night baiting, commonly used in coral-island areas. In this operation a strong underwater light, 750-1,500 w, is submerged to as deep as 20 m below the surface and allowed to remain until a quantity of bait has been attracted. The light then is slowly drawn up toward the surface near a net suspended vertically in the water. The net typically is of 6.4 mm mesh and nearly square, being about 25 m on a side. Once the light and bait are at the surface, the net is raised under the bait (Figure 3). For details of this method see June (1951).

Catching bait for tuna fishing is dependent primarily on the availability of quantities of bait and not on the lack of a suitable method of taking them; i.e., the methodology

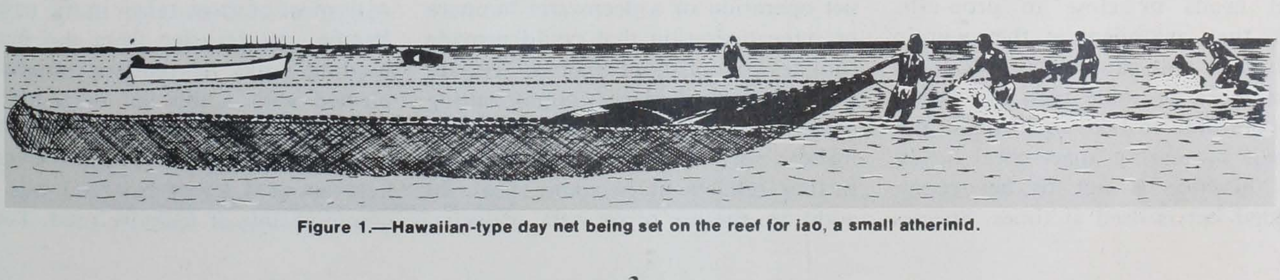


Figure 1.—Hawaiian-type day net being set on the reef for iao, a small atherinid.

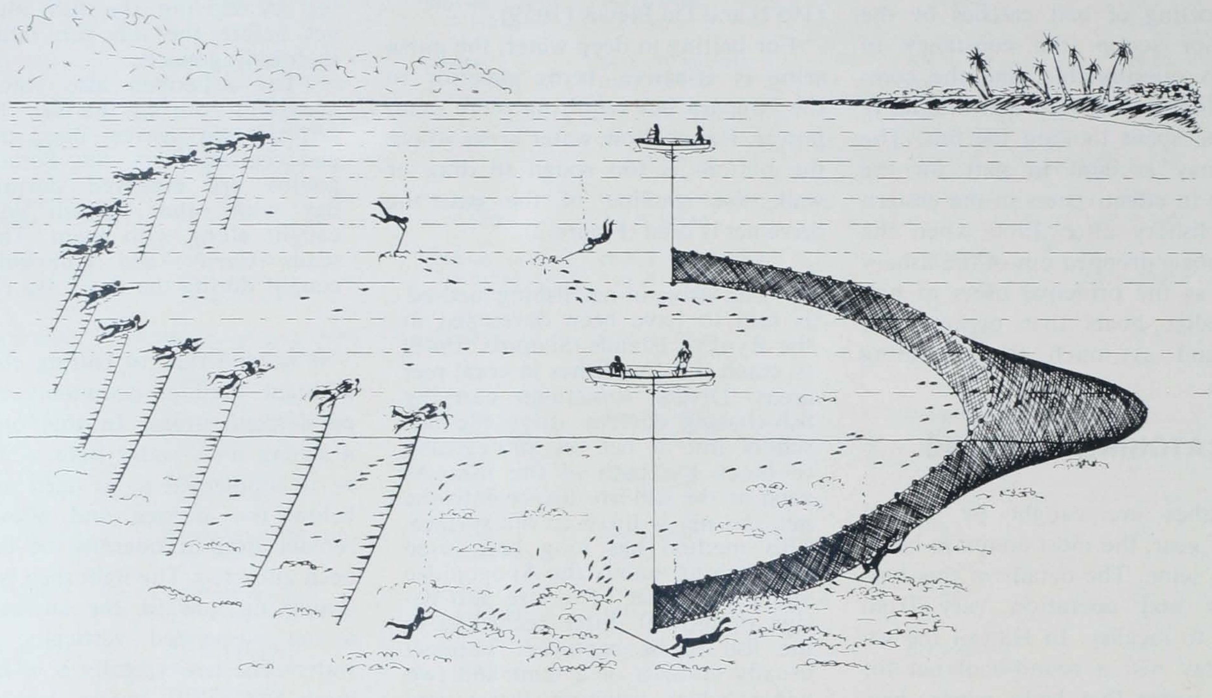


Figure 2.—Catching bait with a "drive-in" net.

has been well worked out and usually presents a minor problem to a bait boat. However, there are some exceptions. These include the introduction of, or the learning of, methods suited for certain areas by fishermen from other areas. For example, the Okinawan live-bait fishermen are generally believed to be the best or most knowledgeable for operating in coral island areas where they manage to find and take bait when fishermen from Japan or the United States would fail. In part their success lies in the use of wall nets (Isa, 1972) suspended near coral heads or close to drop-offs. Also, they are adept at the swim-in method of bait catching (*ibid.*). Even when more desirable baits are absent they are able to take small quantities of bait by tearing apart coral heads. This practice is not to be recommended but is used at times. Species taken in this manner include small damselfish and cardinalfish.

A source of bait that might be used if the catching techniques could be developed occurs offshore where schools of clupeoids and carangids exist in considerable abundance and sometimes come to a light. Also it is frequently observed that floating objects attract quantities of small fish, and it may be that natural or artificial floating "logs" together with a lampara or purse seine might be used to obtain bait. It may be possible to develop a night-light, lift-net operation or a deepwater lampara or seine operation that could provide supplies of offshore bait at certain times in certain places. Night baiting using deeply submerged lights either inshore or offshore is undergoing further refinement in some areas. In addition, the use of set nets, or weirs, may hold promise in areas where the bait species are migratory either along the shore or inshore-offshore.

HOLDING AND TRANSPORT OF THE BAIT

Once the bait is in the net, it must be transferred to holding tanks or wells (eastern Pacific and Japan, Figure 4) or "boxes" (central-western Pacific) aboard the vessel or into receivers if it is not to be loaded on the vessel immediately. When the baitfishes are hardy, as is the case with most of those taken in the eastern Pacific, the transfer from the net to holding tanks or receiver is accomplished with a dip net or scoop. In the 1950's at the height of the bait boat era in the eastern Pacific a scoop held about 4 kg of bait and was the common unit of measure used. Today with the trend towards smaller bait boats the scoops are smaller and hold 1-2 kg. Elsewhere, where the bait species are more delicate and subject to high mortality by abrasion and bruising (the tropical clupeiods with their highly deciduous scales are particularly susceptible), the transfer is made by the use of buckets. These are generally of seamless stainless steel with a capacity of about 15 liters. The bucket keeps the fish mixed with sufficient water to reduce scale loss and bruising. In areas such as Hawaii and Japan, the bucket is the common unit of measure for baitfishes. The bucket holds on the average 3.5 kg of bait in Hawaii and 5.5 kg of bait in Japan although, as with the scoop, the actual amount is quite variable.

Injury and shock during transfer of the bait into the holding tanks or receivers account for most of the mortalities. Losses can be very high if the bait has been handled carelessly. Bucketing appears to reduce mortality as does increasing the amount of oxygen in the holding tanks, reducing the temperature, lowering salinity, and avoiding crowding and undue excitement of the bait until it has had a chance to acclimate to its new environment. For discussion of ways of reducing the rate of mortality associated with the Hawaiian live-bait fish nehu, *S. purpureus*, see Baldwin et al. (1971). In addition, methods of avoiding brailing or bucketing bait from the net to the wells could stand closer examination. For example, the swim-aboard technique used by the west coast bait haulers might be adapted to commercial baitfishing operations. This is a method where the fish enter the well through a gate at the waterline of the vessel thereby avoiding the brailing operation.

Some work has been done in transferring bait by means of pumps (Baldwin, 1969). Whether or not this

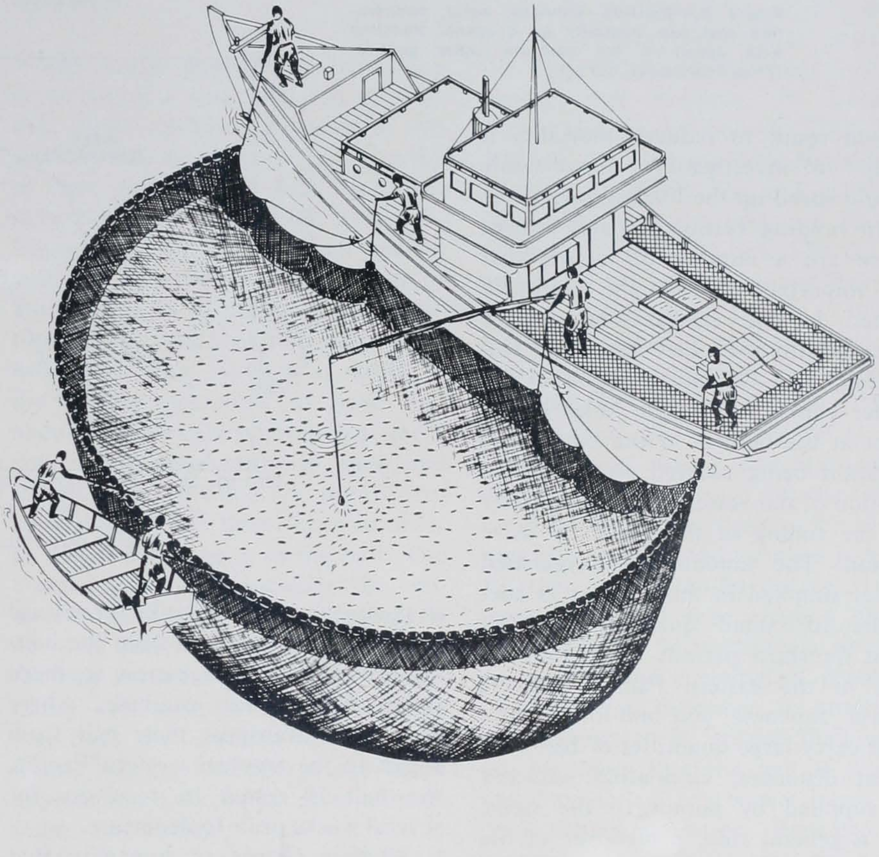


Figure 3.—Night baiting with a Hawaiian-type lift net.

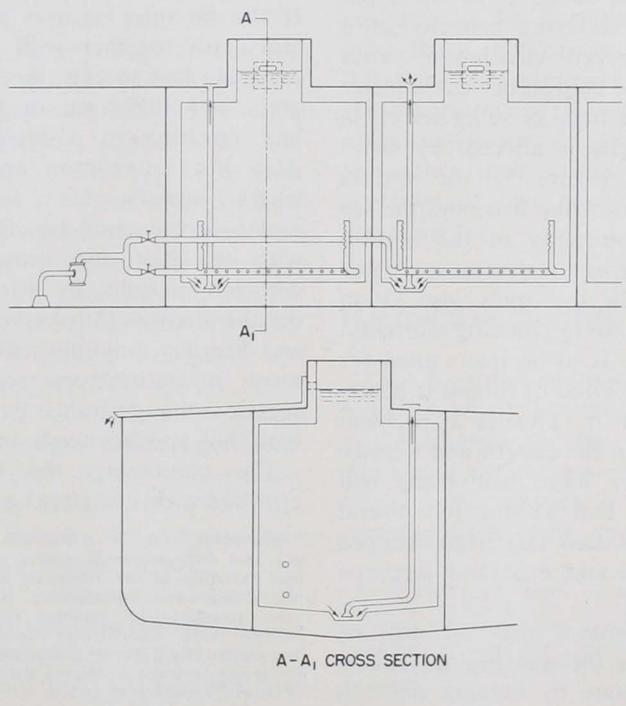
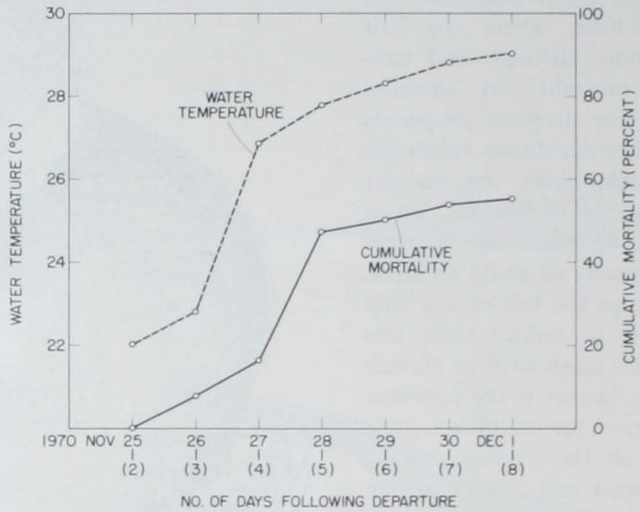


Figure 4.—Japanese bait boat wells showing the perforated inflow pipe, overflow, and "bilge"-pipe for continuous removal of dead bait. (From Miho Shipbuilding Co., 1966.)

Figure 5.—Relation between water temperature and bait mortality on a vessel traveling from Japan to the southern water gounds. (From Anonymous, 1971.)



would result in reduced mortality is open to investigation. It certainly would speed up the loading operation.

In holding baitfish aboard vessels, there are a number of factors that are important. First is the supply of water. In the central and western Pacific with the older Japanese, Hawaiian, and Okinawan style vessels, water comes in through holes in the boat at the bottom of the boxes, circulation being assured either by the motion of the vessel through the water or the rolling of the vessel by wave action. The amount of oxygenated water supplied in this manner is adequate for small quantities of bait held for short periods. With the vessels of the eastern Pacific and the newer Japanese pole-and-line vessels that carry large quantities of bait over great distances, circulating seawater is supplied by pumps to the wells. As a general rule, a turnover of the water in the wells 5 to 10 times an hour is desirable. Typically, a 10-m^3 well would have a water exchange at the rate of about 1,500 liters per minute. The carrying capacity of a well with forced circulation varies from 10 kg of baitfish per cubic meter of water to as high as 50 kg per cubic meter. Capacity is affected by water temperature (Figure 5), the species and condition of the bait, and the sea state, high mortality of the baitfish occurring during rough weather. Proper lighting in the wells also is an important factor in reducing mortality.

If the bait is to be maintained for an extended period of time it is necessary to feed it. This is a problem particularly in the eastern and western Pacific where large bait boats will try to keep bait aboard for several weeks. Foods used vary from chopped fish to bread and meal and prepared fish chows.

It is important that the bait be rested before the trip begins. This is frequently done by holding the bait in receivers or in the tanks for several days prior to departure from the baiting grounds. In the Japanese southern water fishery, for example, where the vessels transport their bait from Japan to the tropical western Pacific, the bait is rested in receivers for several weeks prior to departure.

Another source of mortality that can present a problem in the central and western Pacific occurs when the bait comprises a mixture of species. If the mixture involves larger predatory fish together with the smaller desirable bait species, the larger predators will either eat or frighten the bait resulting in a high mortality. Also not uncommon are instances where juvenile lae, *Scomberoides sancti-petri*, a small carangid, is taken with the bait and causes high or complete mortality by biting the scales off the baitfish (Struhsaker, Baldwin, and Murphy, unpublished[1]). Development of satisfactory separators to separate the desirable from the undesirable species needs investigation.

For chumming, the baitfish are crowded with a small net or "crowder" so that they can be easily brailed out. With some species this causes an extreme fright reaction and high and rapid mortality. The sprats, *Spratelloides* sp., called piha in Hawaii, are plentiful and ubiquitous throughout the central and western Pacific. However, these are very delicate baitfish that die within a few hours of loading into the well. In part the mortality occurs during crowding for chumming and if this mortality could be alleviated, these plentiful fishes would represent a major increase in bait supply throughout the island areas.

A so far neglected area for investigation is the use of drugs to lessen the fright reaction and metabolic requirements of baitfishes. For example, the use of anesthetics and tranquilizers in the transport of trout, salmon, and other freshwater fish is more or less routine, whereas this is not the case in the transport and holding of marine baitfishes.

FISHING OPERATIONS—CHUMMING

Baitfishing for tunas depends upon locating surface tuna schools. Once the school is located, a portion of the bait in the well is crowded with

[1] Struhsaker, J. W., W. J. Baldwin, and G. I. Murphy. n.d. Environmental factors affecting stress and mortality of the Hawaiian anchovy *(Stolephorus pupureus)* in captivity. n.p. Completion report prepared for National Marine Fisheries Service under Commercial Fisheries Research and Development Act (P.L. 88-309), Project H-10-R. Hawaii Institute of Marine Biology, University of Hawaii, Kaneohe, HI 96744.

a net into a reduced area where it can be dipped out with a dip net. Small amounts of bait are tossed into the water in such a way as to bring the tuna to the boat. Chumming techniques vary somewhat with area and with the type and quantity of bait available. Various tricks are used to alter the behavior of the bait to make it attractive to the tunas. A good chummer has techniques that produce tuna at a rate that an inexperienced chummer cannot match.

The handling of the boat varies with area, too. In the eastern Pacific and in Hawaii the vessel moves slowly ahead and fishing is conducted from the stern. In the Japanese- and Okinawan-type fishing the vessel is stopped dead in the water and fishing is conducted along one entire side from the stern to the end of the extended bowsprit. The crewmen aboard Japanese- and Okinawan-style boats generally number 3 to 5 times the men aboard a Hawaiian- or west coast-style bait boat. Production figures per day's fishing between the two methods are generally comparable, however. It is believed that the use of bait by the eastern Pacific boats is more profligate than by the Hawaiian or oriental boats and indeed there appears to be some truth to this belief (Table 1). However, the number of baitfishes thrown per school is probably near equal owing to the different size of the fish used. Good data are not available for the Japanese southern water fishing vessels.

It is interesting to note that the use of a water spray system (Yuen, 1969) throughout the central and western Pacific is absent or very uncommon in the eastern Pacific. Whether or not the vessels would be more productive in the eastern Pacific if water sprays were used is not known, but comparison between fishing with and without the water spray shows that it indeed does affect the catch rate in Hawaiian waters (*ibid*.).

SUPPLY

The major problem in baitfishing is obtaining a sufficient and dependable supply of bait. Discussed in this section will be natural bait, rearing of bait, transport of bait, and artificial bait. The introduction and establishment of nonendemic bait species will not be considered. Pertinent to any discussion of supply is the question of the value of the bait to the fishermen. How much is it worth to the fishing operation to have bait aboard? Obviously without bait there can be no production of tuna and therefore no income. A number of studies have been undertaken in order to assign some value to the bait. The methodology used includes the empirical approach, the examination of what fishermen are willing to pay for bait available for sale; the opportunity cost approach, what catching bait costs the vessel in terms of lost fishing time; and the marginal product approach, a method that gives a maximum value for bait.

Live bait is sold to commercial fishing operations in Japan and to a lesser degree on the west coast of the United States. In the case of the former, the vessels pay about $10 per bucket ($2 per kg) at the bait seller's receiver. The bait then has to be transported to the fishing grounds and may undergo considerable mortality, typically 20% to 30% but at times much higher. On the west coast of the United States the selling price of bait may be as low a $2 per scoop ($0.50 per kg), the amount of bait in the scoop being less than the Japanese bucket. Again, the buyer has to accept the mortality during transport from the bait seller to the fishing grounds. During a recent experiment where northern anchovy, *Engraulis mordax*, was brought in from California to Hawaii, the vessels were willing to pay $20 per bucket.

With the exception of Japan it appears to be more traditional for each vessel to carry its own bait net and bait skiff and to catch its own bait. Under these circumstances it is possible to estimate the cost of catching the bait based on the time lost to fishing. For example, in Hawaii, studies suggest that between 25% and 30% of the time available for fishing is spent searching for and catching bait. This puts the cost per bucket of bait between $12 and $30 ($3.50 and $8.50 per kg) (Brock and Takata, 1955; Shang and Iversen, 1971). Similarly studies in Hawaii based on the production function method suggest that the value of a bucket of bait is as high as $80 ($23 per kg) to the vessel (Elliott, Keala, and Matsuzaki, unpublished[2]). Because of the wide range among these figures, for planning purposes a good estimate is $10-$20 per bucket ($3-$6 per kg). It is questionable whether refining these cost estimates is worthwhile at this point since the sociological problem of convincing fishermen to purchase bait appears to be greater than convincing them that the bait is worth so many dollars per bucket based on their fishing operation. Past experiments for example whereby the State of Hawaii raised tilapia, *Tilapia mossambica*, for bait (Brock and Takata, 1955; Shomura, 1964) and made it available to the vessels at a nominal price failed, not because the price of the bait was too high but because the fishermen felt that the bait they could catch was superior and free. Since then their attitude towards the purchase of bait has changed to a great degree.

Natural Bait Supplies

The location of abundant natural baits (Table 2 and Figure 6) is of prime concern for the expansion of bait fisheries in the central and western Pacific. The location of bait usually depends upon bait surveys, which

[2] Elliott, D. P., B. A. Keala, and C. Matsuzaki. n.d. Estimation of demand for live bait to be used in the skipjack fishing industry. 21 p. [Technical report submitted to Southwest Fisheries Center, National Marine Fisheries Service, NOAA, Honolulu, HI 96812.]

Table 2.—Availability of bait for live-bait fishing in the Pacific and Indian Oceans.

Area[1]	Kinds of baitfish	Commercial landings	Used for live bait	Potential
1 Indian Ocean	Anchovy, sardine, herring	>100,000 metric tons	?	Very good
Minicoy, Laccadive Is.	Reef fishes—apogons, damsels, etc.	Limited amount	Yes	Limited, small fishery
2 Southeast Asia	Anchovy, sardine, herring	>40,000 metric tons	?	Very good
3 Japan: Northeast	Anchovy, *Engraulis japonicus*	7,299 tons	1,970 tons	Excellent
Central	do	73,541 tons	10,857 tons	Excellent
Southwest	do	144,508 tons	11,200 tons	Excellent
4 Formosa[2]	Anchovy	?	?	?
5 South Korea[3]	Anchovy	?	?	?
6 Philippine Is.	Anchovy	20,000 metric tons	?	Very good
7 Marianas	Rabbitfish, etc.	?	?	Very poor (highly seasonal)
8 Western Carolines	Anchovy, sardine, silverside, round herring, etc.	?	Est. >100,000 buckets	Good
9 Eastern Carolines	do	?	?	Poor, OK for small scale operation
10 New Guinea[4]	Anchovy, sardine	?	?	?
11 Fiji	Anchovy, sardine, silverside, mackerel, etc.	?	Experimental	Good
12 Solomon Is.[5]	Sardine	?	Yes	?
13 Gilbert Is.[6]	Sardine	?	?	?
14 Phoenix Is.	Goatfish, mullet, etc.	?	?	Poor
15 Marshall Is.	Sardine, silverside, round herring, etc.	?	Experimental	Good
16 Samoa	Sardine, anchovy, mackerel, etc.	?	Experimental	Poor
17 Society Is.	Mackerels, round herring, etc.	?	Experimental	Poor
18 Tuamotu Archipelago	Goatfish, mullet, round herring	?	Experimental	Poor
19 Marquesas Is.	Sardine	?	Experimental	Good (seasonal)
20 Line Islands	Goatfish, mullet, etc.	?	Experimental	Poor
21 Hawaii	Anchovy, silverside, round herring, etc.	?	ca. 35,000 buckets (130 metric tons)	Good
Leeward Is.	Silverside, mullet, goatfish, etc.	?	Experimental	Poor
22 Eastern Pacific: California to Panama	Anchovy, anchoveta, sardine	>200,000 metric tons	4,000,000 scoops (14,500 metric tons)	Excellent
23 Southeastern Pacific: Panama to Chile	Anchoveta	Est. 10,000,000 metric tons	600,000 scoops (2,200 metric tons)	Very good

[1] See Figure 6.
[2] The Japanese mention Formosa as a possible baitfish source.
[3] The Japanese mention Pusan as having a good supply of strong bait.
[4] The Japanese operate several boats in this area.
[5] The Japanese have 6 boats in this area; will increase to 11.
[6] The Japanese have been operating in the area.

may give misleading results unless they extend over a long time span. Survey methods include full-scale catching operations, diver surveys, interviews with inhabitants, aircraft, beachwalking, etc. Examples of recent bait surveys are [Japan.] Fisheries Agency (1969), Hida (1971), Wilson (1971), and Kearney, Lewis, and Smith (1972). Problems with surveys include the seasonal or cyclic changes in abundance of species whereby certain areas that may have plentiful quantities of bait one day, may have none the next. Too, the amount of bait may vary from year to year or over a many-year period. Even when baitfishes are located in quantity, the question still arises as to the amount of bait that can be taken. Few if any population dynamics studies have been done on tropical bait species. Perhaps the most intensive involved the anchoveta in Central America (Bayliff, 1966), and a study of the tropical anchovies in Palau by Garth I. Murphy (University of Hawaii, Honolulu, HI 96822) is still in progress. Most of these fisheries appear to be capable of tol-

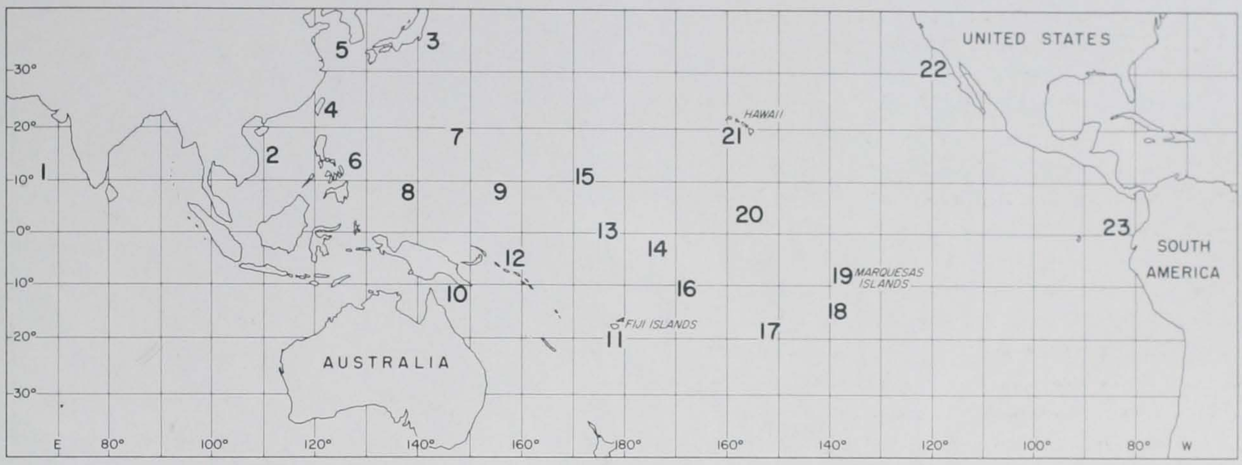


Figure 6.—Areas of baitfish availability. Numbers refer to Table 2.

erating high fishing mortality; however, better information is needed before it will be possible to manage these resources. For much of the Pacific, however, supplies of natural baits are less than required for maximum tuna production.

Aquaculture

Aquaculture is a possibility for supplying baitfishes in areas where natural baits are limited or lacking. The problems here are threefold, namely rearing a baitfish that is an acceptable bait for tuna, producing it at a competitive cost and producing it in sufficient quantity to support a number of tuna boats. The provisional bait price developed above, about $15 per Hawaiian bucket ($4.50 per kg), is sufficiently high that aquaculture should be an economically acceptable solution.

Mass rearing probably presents minimal difficulties because of a fairly extensive background in the production of fish through aquaculture.

Acceptability as discussed previously covers both mortality and effectiveness. With the Hawaiian nehu, mortality typically runs 25% per day in the baitwell, suggesting that a hardier bait produced by aquaculture that suffered only a 5% mortality rate could be 20% less effective in the production of tuna and yet be acceptable. Similarly, a less effective bait that could be produced at lower cost than nehu might, from the standpoint of economics, be an acceptable substitute bait.

In selecting a species for aquaculture, consideration has to be given to those factors affecting its acceptability, that is, hardiness and effectiveness, and those factors affecting its production, for example, can spawning be controlled? Are there difficulties in production of the young? Does it grow to an unacceptable size, etc.? Work has been done with several species—tilapia (King and Wilson, 1957), threadfin shad (Iversen, 1971), commercial sharpnosed molly (Herrick, unpublished[3]). Other species considered or tested include carp, fingerling catfish, juvenile mullet and goatfish, and golden shiner. The difficulties lie in finding species that can be raised in quantity and in devising a quantitative measure of their acceptability. For screening, a method that appears practical at present, since the characteristics of a good baitfish are poorly defined, is a series of field tests whereby sufficient quantities of bait are used in sea trials to determine its relative acceptability, that is, its mortality and effectiveness.

[3] Herrick, S. F., Jr. 1972. Economic analysis of commercial molly *(Poecilia sphenops)* baitfish aquaculture. 11 p. and attachments. Hawaii Institute of Marine Biology, University of Hawaii, Kaneohe, HI 96744.

For work in Hawaii and using nehu as a reference bait from Table 1, it would appear that 30 kg of nehu will produce a metric ton of tuna. Screening experiments should include alternate uses of nehu and the subject bait over an extended period of time. The variance of catch rates for tuna boats is high and screening tests of the proper sensitivity cannot be conducted with small amounts of bait. In order to give an indication of effectiveness 200 buckets or enough for approximately 5 days of fishing is suggested. This will provide an initial indication as to the desirability of continuing with the species or abandoning it. The difficulty in making such a judgment is pointed out in our experience with threadfin shad whereby the results obtained during 1 year with shad aboard RV *Charles H. Gilbert* and during another trial using a commercial vessel gave different answers.

The desirability of using a saltwater versus a freshwater or a euryhaline species needs consideration since production in fresh water may present fewer problems than in salt water, the methods being better developed, and there are many freshwater species that appear to possess the characteristics desirable and necessary to be good tuna bait. However,

(Opposite) Kawakawa and baitfish in tank. Tank is used for studies of behavior of fishes, including tunas.

in many island areas, sufficient fresh water for mass rearing is lacking and culture would have to be conducted in salt or brackish water. Also, there would be difficulty in maintaining fresh water in the baitwells aboard the vessel.

Transport

Another approach to bait supply is the transport of quantities of bait from an area where it is plentiful into the area of the fishery. In effect this is done in both the eastern and western Pacific by larger bait boats that bait in coastal areas and then carry the bait to the fishing grounds. The next step in this process is to transport the bait aboard a bait carrier to an area in the fishing grounds where it can be sold to the fishing vessels. This approach has not been examined in detail but it appears that using a $4.50 per kg bait price this may be feasible. This figure is based on data from the Hawaii fishery where bait usage is low owing to the large, 7 kg and up, skipjack tuna constituting the bulk of the "season fish." In areas where the average weight of the skipjack tuna is less the "value" of the bait may be expected to drop. Therefore, the profitability depends upon the amount of bait that can be carried in a given volume of water, the anticipated mortality during transport and holding at the final destination, and the value of the bait determined by its effectiveness. To evaluate such operations it is necessary to look both at the economics of shipping and the fishery, and at mortality during capture, loading, transport, unloading, and holding. Experiments conducted by the Honolulu Laboratory in transporting northern anchovy from California to Hawaii suggest that mortality in shipment may be acceptable. These shipments were made using commercial fishing vessels, which took approximately 10 days to make the crossing. Commercial shipping lines can make the crossing in about 4 days. The advent of roll-on, roll-off service between the mainland and Hawaii, for example, suggests that transport of anchovy might be practical aboard these vessels. Similarly the advent of LASH (lighter aboard ship) service to French Polynesia and American Samoa suggests that it might be feasible to ship bait from California, Latin America, or Australia to these areas. See Figure 7 for a diagrammatic summary of the preceding discussion.

Artificial Bait

The use of dead or inanimate substances and new live baits to replace conventional bait for surface tuna fishing should be considered. Early attempts such as those conducted at the Honolulu Laboratory in the 1950's (Tester, Yuen, and Takata, 1954) were unsuccessful, but these studies cannot be regarded as exhaustive and further experimentation should be supported. It is possible that dead baitfish or objects resembling baitfish could be made to sink and rise or move in the water so as to resemble a live baitfish. Incorporation of a scent into the objects or the use of dead bait for this purpose might serve to supplement live bait or even to replace it.

New Baits

The use of animals other than fish for bait has been suggested. Shrimp or large brine shrimp might prove to be an acceptable bait. Similarly crustacea that can be held in suspended animation or in the egg for extended periods of time might prove to be a valuable adjunct to live-bait fishing for tuna. The advantage here is that these types of animals can be produced almost upon demand and in large quantities from a small initial volume. Studies along these lines appear worthy of support although the probability of success is less likely than with aquaculture or transport.

SUMMARY

The use of live bait to catch tunas accounts for over 20% of the world tuna production. This method is especially suited for areas where tuna schools cannot be caught effectively using more efficient, that is, capital intensive, gear such as the purse seine.

Dependable supplies of acceptable

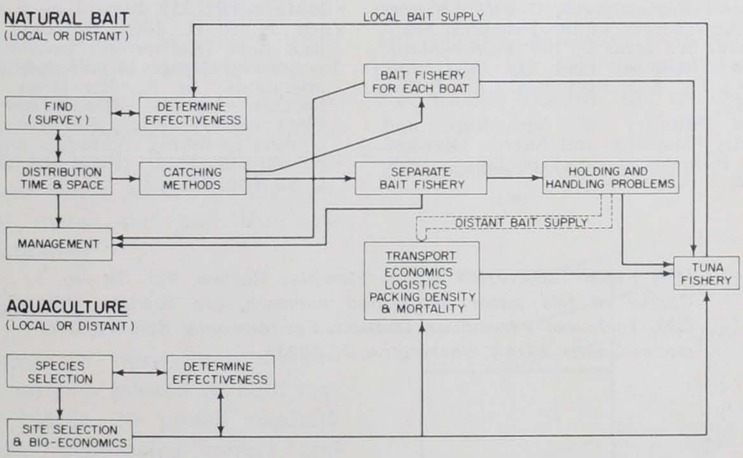


Figure 7.—Diagrammatic representation of alternative bait supply considerations.

live bait are the key to successful baitfishing. Acceptable bait species are those that can be held and transported with low mortality and are effective in catching tunas, that is, the ratio of bait used to tuna caught is minimal.

Dependable supplies of natural bait do not occur in the newest tuna fishing grounds in the tropical Pacific. Ways of providing a supply include aquaculture, importation of bait from other areas, and development of artificial baits. All of these alternatives are subject to the economic constraint of an estimated $4.50 per kg value of baitfish delivered to the fishing vessel, and require varying amounts of research before they can be considered feasible. Also needed are better reporting statistics from presently used baiting grounds and the continued search for new supplies of natural bait.

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