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A Summary of the Tuna Baitfish Workshop

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An invitational workshop on tuna baitfish problems, cosponsored by the National Marine Fisheries Service and the University of Hawaii Sea Grant College, was held at the Honolulu Laboratory, Southwest Fisheries Center, on 4-6 June 1974. The central issues addressed by the workshop dealt with the problem of securing adequate supplies of bait to support the development or expansion of skipjack tuna, *Katsuwonus pelamis*, fishing in the central and western tropical Pacific.

The 38 participants (see Appendix A for list of participants) from the mainland United States, Hawaii, Japan, and islands of the western Pacific reviewed and discussed a number of background papers prepared for the workshop. These background documents make up the bulk of the papers provided in this volume.

The workshop was organized around three sessions which focused attention on 1) natural stocks of baitfish, 2) culture of suitable baitfish species, and 3) transporting and holding bait and substitute baits. These sessions were preceded by a general review of baitfish problems and a discussion on the criteria for a good baitfish species. The workshop concluded with a general summary session. The following brief review of the workshop should provide the reader with a framework for relating the individual papers of this volume.

TUNA FISHING AND THE BAITFISH PROBLEM

Presently the only two economically viable methods of catching tuna in commercial quantities in tropical waters are purse seining and pole-and-line fishing with live bait. The expansion of tuna fishing in the central and western tropical Pacific is currently limited by certain technical problems associated with both methods of fishing. Purse seine trials conducted thus far in the central and western tropical Pacific using conventional seines have resulted in a success rate much lower than that enjoyed in the eastern tropical Pacific tuna fishery. It is generally believed that the clear waters and deep thermoclines of the central and western Pacific make it possible for tuna, especially skipjack tuna, to avoid capture by conventional purse seines. Thus, new net designs or new fishing techniques will have to be developed before purse seining can become a widespread, economically successful method of fishing in these waters.

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The major problem associated with development or expansion of existing pole-and-line tuna fisheries in the central and western tropical Pacific is the lack of adequate supplies of baitfish. In the most severe cases suitable baitfish species are lacking altogether. In many areas of the Pacific, e.g. American Samoa, the stocks of naturally occurring baitfish species are inadequate to support even a small domestic tuna fishery. In other areas, baitfish may occur only in small quantities, limiting catches of tuna to a point far below the probable level of optimum sustainable yield.

In Hawaii and the Western Carolines, the supply of baitfish has been sufficient for the operation of only small fleets of tuna vessels. The Hawaiian fishery is conducted by 12 to 15 boats, generally less than 90 ft in length, which annually land about 4,500 t of skipjack tuna. Based on skipjack tuna surveys and an analysis of the fishery conducted several years ago by the National Marine Fisheries Service, it is believed that the catch of the Hawaiian fishery could be increased in direct proportion to an increase in fishing effort. However, because successful purse seine fishing in these waters seems technologically unfeasible at this time, the increase in tuna fishing effort can only be achieved by an increase in pole-and-line fishing effort. While the problems faced by the Hawaiian tuna fishery are complex, a basic constraint has been the limited supply of suitable baitfish. A similar situation exists in the Western Carolines.

In developing their southern fishery for skipjack tuna, the Japanese have overcome the lack of locally available baitfish by transporting baitfish from the Japanese home ports. Despite the problems of transporting an anchovy species, *Engraulis japonicus*, which is native to colder waters of the higher latitudes into tropical waters, the Japanese southern fishery has expanded to a present annual catch exceeding 100,000 t/yr.

CRITERIA OF GOOD BAITFISH SPECIES

The workshop started with a discussion of the characteristics that are considered important in a good baitfish for tuna fishing. A consensus resulting from the discussion was that while some species could be categorized as "good" baitfish, none of the species examined to date could be considered a "perfect" baitfish. For example, some species may be good at initially attracting the tunas, but may not be too effective in holding the fish at the boat.

In discussing size of baitfish, it was noted that the visual acuity of skipjack tuna and the clear waters of the

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tropics make it unnecessary for the maximum size of the baitfish to exceed 8 cm. Under most circumstances in tropical waters a baitfish 8-cm long can be detected at 50 m, the usual distance of a fish school from the fishing vessel when chumming is initiated.

A summary of the relative merits of several baitfish species currently used in the Pacific is given in Table 1. The use of a species in an area is generally related to its availability. The effectiveness of the various baitfish species (catch of tuna per unit of baitfish) has not been determined because, while some data are available, there are still too many unknown variables to allow comparisons. In Hawaii, the skipjack tuna catch per pound of baitfish, nehu—*Stolephorus purpureus*, would rank very high due to judicious use of this scarce commodity. In the eastern Pacific where the availability of baitfish is generally not a critical problem, the skipjack tuna catch per pound of northern anchovy, *Engraulis mordax*, or anchoveta, *Cetengraulis mysticetus*, would be considerably lower than the catch rate for Hawaii because of the liberal use of baitfish by the eastern Pacific fishermen.

NATURAL STOCKS

The objectives of the Natural Stocks Session were 1) to evaluate the principal natural baitfish resources of the Pacific with respect to their capacity for supporting local skipjack tuna fisheries and as sources of baitfish for distant-water transport systems, and 2) to recommend specific actions for improving the understanding, development, and management of natural baitfish resources.

Resource Evaluation

Based on available baitfish resource information in the Pacific, areas were described as having 1) known large stocks of baitfish species, 2) limited supplies of baitfish and capable of supporting only localized fisheries, and 3) very little baitfish. In the third category were also areas where information on baitfish is altogether lacking.

In the first group are areas in the Pacific where stocks of anchovies of various species (*Engraulis* spp.) are sufficiently large to support large tuna pole-and-line fisheries. In the eastern Pacific the anchovy and anchoveta found from southern California to Peru have formed the basis for the successful tuna fishery in that region. The annual landings of skipjack tuna in the eastern Pacific fishery ranged from 15,690 to 61,235 t during the period from 1950 to 1960 (before the purse seiners dominated the fishery). In the western Pacific the stocks of *Engraulis japonicus* from coastal waters of Japan currently support Japan's coastal skipjack tuna fishery as well as the recently successful distant southern water tuna fishing operation. The annual Japanese catch of skipjack tuna ranged from 70,428 to 212,985 t from 1960 to 1970. The baitfish stocks in other areas of the western Pacific including Korea, Taiwan, the Philippines, and Australia were believed to be adequate to support any currently existing or projected local skipjack tuna fishery.

A number of the island areas of the central and western Pacific fall into the second category. The principal baitfish species available in these areas belong to the genus *Stolephorus*. Skipjack tuna fisheries in Hawaii, Palau, Papua New Guinea, and the Solomons are examples of localized fisheries.

In Hawaii, the principal baitfish species is the nehu, *Stolephorus purpureus*. The skipjack tuna fishery there is relatively small with total annual landings of less than 5,000 t. The availability of nehu is inadequate for any substantial expansion of the skipjack tuna fishery in Hawaii; thus, increases in the baitfish supply must come from other sources, e.g., cultured species or transport of baitfish from other areas.

The anchovy, *S. heterolobus*, supports a modest skipjack tuna fishery in Palau; the average annual catch was around 4,650 t from 1966 to 1971. A recent study of the baitfish resource indicates that the current harvest of *S. heterolobus* may be approaching the maximum sustainable yield of the stock. Further expansion of the fishery is possible primarily through improved bait handling and usage.

In 1971 the catch of skipjack tuna in the Papua New Guinea fishery amounted to 16,864 t. There appears to be sufficient reason to believe that the *Stolephorus* resources of the area are large enough to support and expand the tuna fishery with current fishing practices. In

Table 1.—Characteristics of various bait species used in the Pacific.

Category	Dussumieridae	*Stolephorus* sp.	Anchovy	Caesiodidae	Apogonidae	Atherinidae	Clupeidae
Survival	Weak	Weak	Medium	Strong	Strong	Strong	Medium
Abundance							
Eastern Pacific	?	Low	High	None	None	High	High
Central Pacific	Low	Moderate	Low	None	Low	Low	Low
Western Pacific	High	High	High	Low	Low	Low	High
Behavior	Good	Good	Good	Good	Good	Poor	Fair
Size (cm)[1]	5	4-6	8-14	4-8	4-5	4-8	8-14
Body form	Elongate	Elongate	Elongate	Elongate	Deep bodied	Elongate	Elongate
Color	Shiny	Shiny	Shiny	Dull	Shiny	Shiny	Shiny
Color pattern	Silvery	Silvery	Silvery	Nonsilvery	Nonsilvery	Silvery	Silvery

[1]Size used as bait.

addition, more effective use of the baitfish resources can be achieved with improved handling and carrying techniques.

In the British Solomons, the stocks of *Stolephorus* presently support a skipjack tuna harvest of 6,000 t. Prospects for expansion are unknown.

The third category includes all other areas where baitfish stocks are known to be very small (e.g., American Samoa), or areas where the available information is too scanty to permit an accurate assessment for skipjack tuna development. Included in this category is Fiji, where a skipjack tuna fishery is in the early stages of development.

Recommendations

In summarizing the discussion on natural stocks of baitfishes, the Session participants developed a set of recommendations for the National Marine Fisheries Service and other organizations interested in baitfish research. The recommendations included:

1. Develop better bait handling and holding techniques to permit fullest utilization of natural baitfish stocks for tuna fishing.
2. Clarify the taxonomic status and nomenclature of the stolephorids and establish a reference collection of specimens.
3. Encourage the exchange of information on research and natural baitfish stocks including unpublished data and trip reports.
4. Adopt the recommendations of the South Pacific Commission's Expert Committee on Tropical Skipjack regarding the collection of standardized baitfish catch statistics, including a measure of nominal baiting effort.

CULTURED BAITFISH SPECIES

From a review of the workshop documents and a discussion based on individual participants' expertise, it was apparent that there is no single baitfish species to solve the problems of all the areas of the Pacific. Nor is there a simple solution to the use of cultured baitfish. Problems faced in culturing baitfish differ markedly from place to place, especially as to the availability of land and fresh water necessary for developing the culture facilities.

In discussing pond culture of baitfishes, a set of general requirements for potential culture species was developed. These included: 1) high reproductive potential, 2) ability to spawn readily in ponds, 3) ability to obtain food low in the food chain, 4) readily handleable and transportable, 5) euryhaline, and 6) lacking spines. Although hardiness is an important factor in the baitfish used in tuna fishing, experience in freshwater baitfish culture work suggests that this characteristic can be developed through proper selective breeding.

Table 2 summarizes the principal characteristics of species that have either been cultured or show culture potential. Highlights of the discussion of these species follow.

Threadfin Shad

This is a euryhaline species which is probably a suitable candidate for polyculture. Threadfin shad, *Dorosoma petenense*, are reported to spawn several times per year, subsist on material low on the food chain, and be fairly economical to raise. Being a euryhaline species, threadfin shad is ideally suited for areas where fresh water is abundant. Unfortunately, for many areas of the Pacific where natural stocks of baitfish are lacking, e.g., most of the tropical islands, fresh water is also a scarce commodity. It was noted that in Hawaii where threadfin shad have been introduced into an agricultural water impoundment system the standing crop of bait-sized threadfin shad during the 1969-70 season was estimated to be 45,454-68,181 kg (100,000-150,000 lb). The reservoir has a surface area of 122 ha at high water and contains approximately 1.14×10^{10} liters of water. The estimated standing crop is equal to approximately 17% to 25% of the baitfish caught in the Hawaiian fishery in 1971.

To date only limited field trials have been conducted using threadfin shad as baitfish for skipjack tuna fishing. Definitive results describing the fishing power of threadfin shad relative to the natural baitfish used in Hawaii are still lacking.

Tilapia

The most extensive field trials using tilapia, *Tilapia mossambica*, as baitfish for tuna fishing have taken place in Hawaii. The results to date have been inconclusive. While the evidence suggests that tilapia may be a suitable substitute baitfish species, in Hawaii it has been generally rejected as such by commercial fishermen. This nonacceptance by fishermen has been attributed to the general conservative nature of fishermen.

Tilapia has the attribute of hardiness and ease in culture. It is conceivable that improvement in fishing success could be achieved by changes in fishing technique.

Mollies

Although cost figures for the culture of various baitfish species are not readily available, the mass-rearing of mollies appears to be the most attractive in terms of economics. An estimate of $2.60/bucket (investigators used 2.7 kg (6 lb)/bucket) was provided as the cost for mollies under a 30,000-bucket annual production system. Favorable characteristics of the mollies include being euryhaline, having the ability to withstand extreme crowding conditions in the baitwells, and having the ability to withstand low oxygen levels. To date the effectiveness of mollies in skipjack tuna fishing has not been demonstrated. While evidence exists that mollies have been used in the past by commercial fishermen in Hawaii

Table 2.—Principal factors of tuna baitfish culture.

Item	Threadfin shad	Tilapia	Mollies	Golden shiner	*Apogon*
Fecundity	14,000-16,000 eggs per female per year. Multiple spawnings	200-800 eggs per female per year (six times per year). 700-1,000 fry survival per female per year	1,600 per female per year	Unknown	Unknown
Hardiness	Satisfactory	Satisfactory	Satisfactory	Satisfactory	Satisfactory
Density tolerance	1,000 lb per acre per year (estimated possible)	Present: 8,000-13,000 lb per acre per year. Estimated: 25,000 lb per acre per year	18,000 lb per acre per year	800-1,600 lb per acre per year (one or two crops)	Unknown
Appearance re traditional bait	Same	Different	Different	Same	Different
Behavior:					
Culture	Satisfactory	Satisfactory	Satisfactory	Satisfactory	Unknown
Used at sea	Satisfactory, but more tests needed	Satisfactory	Inconclusive	Inconclusive	Satisfactory
Ease of culture:					
Intensive	Not established	Good	Good	Not established	Unknown
Extensive	Good	Good	Good	Good	Unknown
Economics	$14 per bucket and 3,660 buckets per acre	$19.58 per bucket with profit; $1.06-1.65 reduced	$2.69 per bucket or $0.45 per pound (@ 30,000 buckets)	$4.00 per pound (air-shipped to Hawaii)	Unknown
Polyculture	Unknown	Unknown	Unknown	Unknown	Unknown
State of the art re mass culture	Not much known	Known	Known	Known	Unknown
Field experiments to date	Inconclusive	Inconclusive	Inconclusive	Inconclusive	Satisfactory
What needs to be done?	1. Project costs, etc. Wahiawa Reservoir 2. Field test	1. Project proposal 2. Field test	1. Hawaii project proposal 2. Hawaii test 3. American Samoa	1. Project costs, etc. 2. Hawaii test	1. Life history research (fecundity)

to catch skipjack tuna, evidence is still lacking that the fishing power of mollies is comparable to that of natural baitfish species, e.g., nehu, in the Hawaiian Islands.

Golden Shiner

Although golden shiner, *Notemigonus crysoleucas*, is strictly a freshwater species and cannot live in seawater, some views were expressed that freshwater species should not be discounted in the search for a suitable baitfish for skipjack tuna fishing. The underlying assumption is that circulation systems can be developed to economically carry freshwater species in baitwells for varying periods of time. The advantages of golden shiner are that the mass culture of this species is well known, they have some of the physical attributes of a good baitfish species, e.g., light coloration, and this species is relatively hardy and withstands mass transport.

To date the golden shiner has not been field tested adequately. The short single test conducted in the Hawaiian Islands was inconclusive.

Apogon

In discussing the suitability of culturing apogons as a baitfish species, the general consensus was that not enough was known about this group to form any definite conclusions.

Since apogons have not been cultured and reared in laboratories to date, the general consensus was that the lack of biological information precludes even a rough estimate of the economics of large-scale culturing systems for these species.

Recommendations

The Session participants recommended the following:

1. Critically analyze future field tests to provide conclusive information on the effectiveness of different baitfish species.
2. Determine the fishing power of the various baitfish species under consideration, using existing data with particular reference to nehu and other *Stolephorus* species as models.
3. Conduct additional field tests with species that have previously shown promise as successful baitfish species, e.g., threadfin shad and golden shiner.
4. Reevaluate the economics of bait production at intervals, using updated cost figures.
5. Recognizing the lack of a "perfect" baitfish species,

continue the search for suitable candidates for cultured baitfish species.

6. Defer work on culture of *Apogon* until studies on critical parameters of this baitfish have been completed, e.g., estimates of fecundity and growth rates.

7. Conduct baitfish extension activities concurrently with the testing of the species in order to overcome problems in fishermen's acceptance of new baitfish species.

TRANSPORTING, HOLDING, AND SUBSTITUTE BAITS

In areas where the supply of natural baitfish stock is lacking or is in very short supply, the several alternatives available to solving the problems include:

1) culturing selected species of baitfish;
2) developing an artificial (substitute) bait; and
3) moving large quantities of baitfish from areas of abundance to areas of scarcity.

Participants of this Session reviewed activities on artificial bait and the transport of baitfish.

A very brief review was made during the Session of previous attempts to attract and hold skipjack tuna schools close to the fishing vessels by using nonliving material. It was noted that some work had been done in Hawaii on the use of dead baitfish, animal extracts, shiny metals, and calcium carbide. While some extracts appeared to create a feeding response by skipjack tuna, none of these responses was of sufficient strength or duration to be promising for commercial fishing application. There has been no work conducted in this field in recent years.

The expansion of the Japanese skipjack tuna fishery to southern waters of the central and western Pacific has been possible because the vessels are able to carry a full load of baitfish from Japan to the fishing grounds. Reports indicate that "aged" anchovy, *Engraulis japonicus*, are carried successfully for 4 wk or more without much mortality.

The attempt by the Honolulu Laboratory (National Marine Fisheries Service) to develop a method of transporting large quantities of northern anchovy from California to Hawaii on commercial freighters was discussed at length. Although the northern anchovy can be carried on baitfishing vessels, it was noted that the commercial roll-on/roll-off freighters represented a possible cost-effective method of transporting baitfish on a continuing basis. The experiment is still in progress and its success could not be predicted at the time.

Special emphasis was placed on the fact that the hardiness of baitfish could be increased substantially by holding the baitfish in pens prior to transporting them. Hardiness appeared to be a key factor in transportation over long distances. If a method of successfully transporting baitfish from one area to another can be developed, the opportunities for an expanded fishery become obvious. The availability of an increased supply of hardy baitfish would mean extending the range of a fishery, providing opportunities for an expansion of fleet size, and increasing the efficiency of tuna fishing by eliminating a major nonfishing activity, i.e., catching of bait.

SUMMARY SESSION

At the Summary Session each chairman reviewed briefly the major findings of his group. The participants then held a general discussion on priorities of future research. Table 3 provides a summary of this discussion.

Table 3.—Three action priorities/alternatives.

	1	2	3
Hawaii	Anchovy transport (Sea Grant, NMFS)	Improve bait handling and utilization (nehu)	Shiners and shad
American Samoa	Mollies (Government of American Samoa)	Economic evaluation of bait transport	—
Trust Territory	*Apogon*	—	—
Other areas	Develop use of natural stocks (availability and accessibility)	Culture suitable species	—

APPENDIX A

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