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Capture, Transportation, and Pumping of Threadfin Shad, *Dorosoma petenense*

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ABSTRACT

Methods of capturing, transporting, and acclimating threadfin shad, *Dorosoma petenense*, for use as live bait in skipjack tuna, *Katsuwonus pelamis*, fishing are described. The shad were captured in a 122-ha (302-acre) reservoir on Oahu Island, Hawaii, using a seine net either 146 or 110 m long and 7 m deep which was deployed from a skiff 6 m in length. Captured shad slowly swam to the shoreline while enclosed in a pocket of netting alongside the skiff. After being bucketed into 2,347-liter (620-gal) portable tanks, the shad were trucked 37 km to holding facilities at the Honolulu waterfront where they were acclimated to 100% seawater over a 72-h period. Up to 22,500 (40 to 70 mm long) shad in individual portable tanks have been trucked the 37 km distance with mortalities that on occasion have been less than 1%. Five experiments were conducted to determine the feasibility of pumping the shad with a vacuum pump and a centrifugal pump. Shad pumped were from 19 to 95 mm long in groups ranging from 1,210 to 1,633 individuals. Mortalities ranged from less than 0.1% 264 h after pumping to 9.7% 25 h after pumping. Use of the centrifugal pump is recommended.

INTRODUCTION

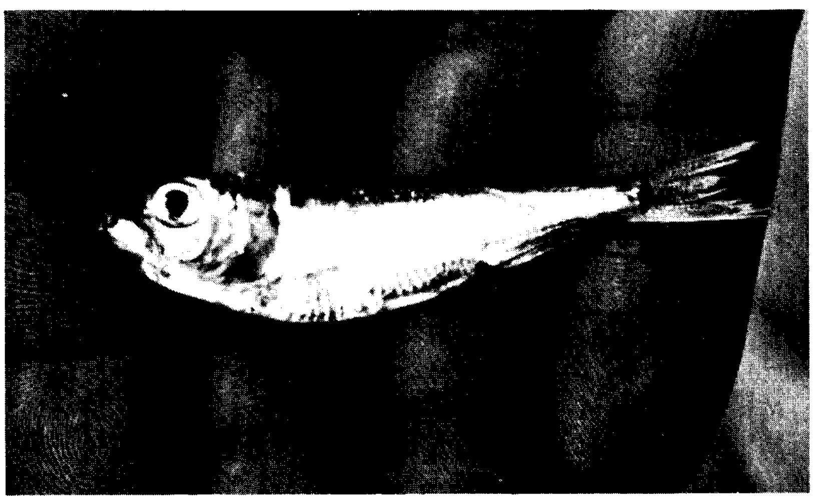
Development of an alternate live bait for Hawaii's pole-and-line fishery for skipjack tuna, *Katsuwonus pelamis*, by the Honolulu Laboratory, Southwest Fisheries Center, National Marine Fisheries Service, has since 1967 been based in part on the use of threadfin shad, *Dorosoma petenense* (Fig. 1).

In the process of capturing shad from a Hawaii reservoir, acclimating them to seawater, and conducting fishing trials, a considerable amount of experience has been acquired on handling and transportation of shad on a mass scale. The purpose of this report is to describe the techniques we have found successful in handling threadfin shad and also to present the results of several experiments which evaluated two different fish pumps for transferring shad.

SOURCE OF SHAD

Threadfin shad were first introduced into freshwater impoundments and streams in Hawaii in 1958, and by 1960 had become established in several reservoirs (Hida and Thomson 1962). Attributes of threadfin shad which

Figure 1.—Threadfin shad, *Dorosoma petenense*.



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led to their investigation as a new baitfish are: tolerance to both freshwater and seawater, hardiness, silvery color, size, and swimming behavior. In recent years shad in Wahiawa Reservoir, Oahu, have become sufficiently abundant to make large-scale capture and fishing tests possible.

Wahiawa Reservoir is located in central Oahu, 37 km from the Honolulu waterfront, where they were trucked prior to experimental use. The reservoir has a surface area of 122 ha (302 acres) at high water, a maximum depth of 26 m, and contains approximately 1.14×10^{10} liters (3 billion gal) of water. The annual range in surface temperature is approximately 21°-30°C, and the annual fluctuation in water level can be as much as 12 m. Banks of the reservoir are as steep as 45° in many places; this allows the use of relatively deep seines close to shore where the shad often aggregate. The magnitude of the shad population in Wahiawa Reservoir is unknown but probably contains 14,000-17,000 buckets of shad during the summer (William Devick, Hawaii Division of Fish and Game, pers. commun.). During 32 days of baiting in the reservoir between 18 February 1970 and 16 August 1971, we captured 2,076 buckets of shad, an average of 65 buckets/day. More could have been captured, for the amount removed was limited by the carrying capacity of our portable tanks and the holding facilities at docksite. The unit of bait measure in the Hawaiian skipjack tuna fishery is the "bucket," so-called because the fishermen use stainless steel buckets to transfer the bait. A bucket of bait-sized (40-70 mm) shad weighs approximately 3 kg, ±1.5 kg, and contains about 1,500 shad, depending on size.

BAIT SEINE AND SKIFF

The principal seines used measured either 146 or 110 m long by 7 m deep. Side measurement of the square mesh was 6.4 mm. The longer net was set from a skiff 6 m in length, while the shorter net could be set from a 4.8-m skiff. The larger skiff contained a live well that could be used to transport a few buckets of shad to the truck when distance to the capture site was greater than about 0.5 km. A minimum of seven men were needed to set and haul either net, including two scuba divers.

PORTABLE TRANSPORT TANKS

Elliptical fiber glass tanks (Fig. 2) with a capacity of 2,347 liters (620 gal) were used to transport the shad. Each tank is 2.4 m long, 1.8 m wide, and 60 cm deep. An elliptical opening 46 cm wide, 76 cm long, with a raised 30 cm coaming, is located in the center of the lid. The lid is secured to the tank with wing nuts and bolts and can be removed. A detailed description of the tank, base, and lifting A-frame is given by Nakamura (1966). These tanks were originally designed for the transfer of tuna and other pelagic fishes to shoreside tanks. A 7.5-cm-diameter drain pipe is located in the bottom of the tank. We later added a plastic cloth tube 30 cm in diameter by 1.1 m long to the other end of the tank. This allowed rapid transfer of the shad with less crowding in the tank as the water level dropped. The entire tank could be drained in 60 s through this tube. When not in use, the tube was rolled up and held tightly against the outside wall of the tank by a hinged aluminum cover (Fig. 3).

OXYGENATION SYSTEM

The oxygenation system consisted of a 6.8-m^3 cylinder of 100% oxygen, pressure regulator, a 10-gang valve, and hoses leading to two oxygenation stones in each tank (Fig. 4). The oxygenation stones were modified from grinding wheels (#800 grit) 15 cm in diameter. The upper and lower surfaces of the grinding wheels were coated with fiber glass resin and the oxygen bubbles escaped from the outer edges of the stones. Such oxygenation devices release bubbles about 0.25 mm in diameter and are much more efficient than round aquarium stones which release much larger bubbles. For a description of this type of an oxygenation device, see Baldwin 1970.

DOCKSITE HOLDING TANKS

Circular, plastic-lined swimming pools, 7 m in diameter and 1.2 m deep, containing 34,822 liters (9,200

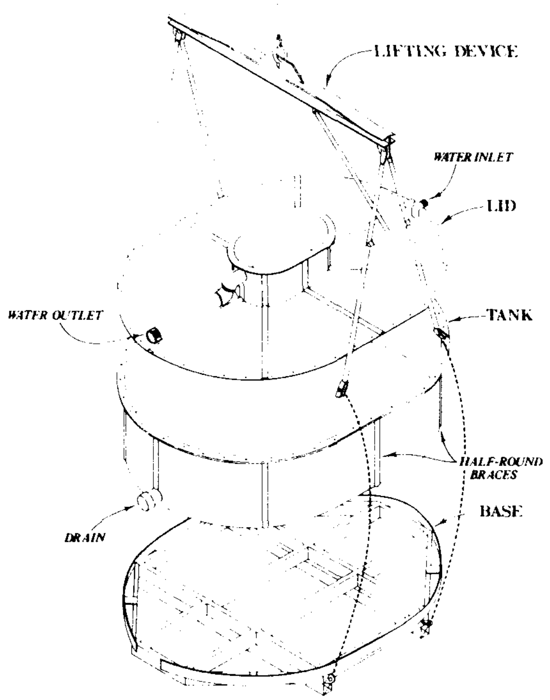

Figure 2.—A diagram of the portable transport tank, base, and lifting device. From Nakamura (1966).

Figure 3.—(a) Plastic cloth tube attached to portable transport tank for rapid unloading of baitfish. (b) Hinged aluminum cover holding rolled up tube against outside of tank (arrow).

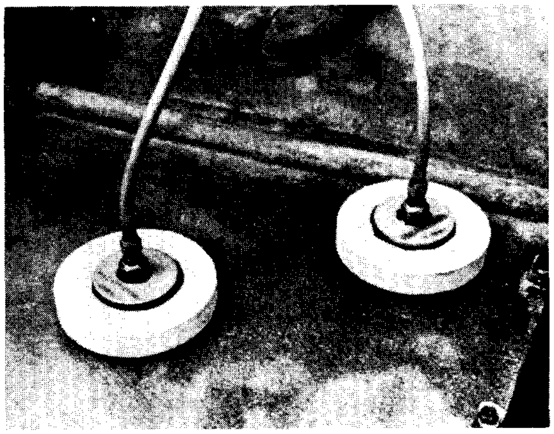

Figure 4.—Oxygenation stones used during transportation of shad. They are modified from 15-cm-diameter grinding wheels.

gal) of water, were used to hold the shad during acclimation to seawater (Magnuson 1965).

FISH PUMPS

Two pumps were tested. One, the Morton[3] batch pump developed by the Oregon State Game Commission (Morton 1963), utilized a vacuum principle to move the shad. The other was a standard centrifugal pump used extensively in the food processing industry.

Morton Batch Pump

This device (Fig. 5) is operated on a vacuum principle with a 76.2-mm (3-in) Homelite 1,135 liters/min (300 gal/min) water pump. A 5.2-m snorkel tube, 12.7 cm in diameter, is attached to the top of a fiber glass vacuum tank holding approximately 946 liters (250 gal) of water. The other end of the snorkel tube is submerged in the holding tank. The system is pumped full of water and all air purged from the system by a valve on the top of the vacuum tank. The water flow is then reversed instantaneously by closing two three-way valves. As the water is drawn from the vacuum tank through the bottom, the fish are gently drawn into the tank via the snorkel tube in the holding tank. After the fish enter the vacuum tank, the vacuum is broken by the air-purge valve and the water flow reversed. The end of the snorkel tube is then raised to the receiving tank and the water flow increased. A round brass screen crowder in the bottom of the vacuum tank is slowly raised to the top of the tank, gently forcing the fish into the snorkel tube for delivery to the receiving tank. The screen crowder is then lowered to the bottom of the vacuum tank before the next "batch" of fish enters the tank.

Centrifugal Pump

This system (Fig. 6) consisted of a Pacific Pumping Company 10.2 cm (4 in) BM type standard frame mounted food pump, and a Reliance 3 hp variable speed

[3]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

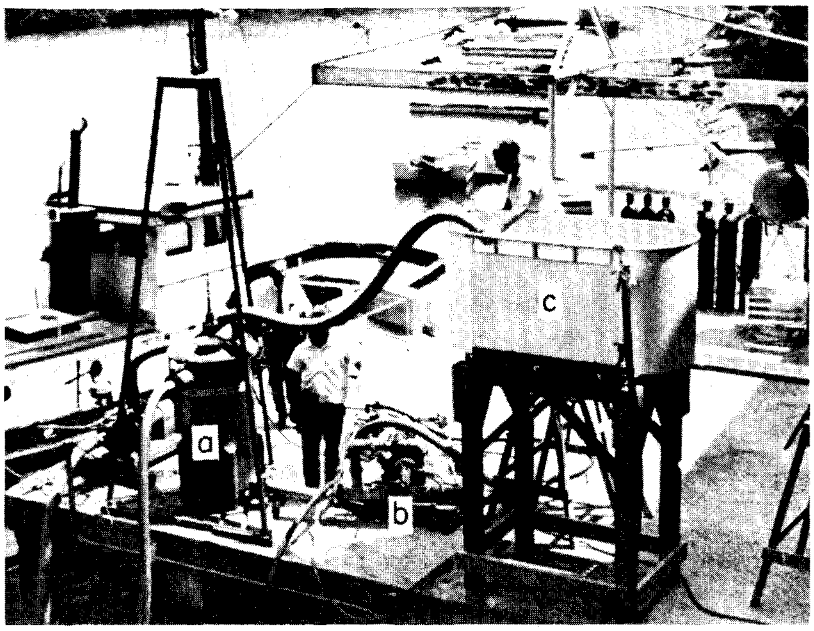

Figure 5.—Morton batch pump system.
(a) Fiber glass vacuum tank.
(b) Pump and motor.
(c) Elevated receiving tank.
(Hawaii Institute of Marine Biology photo.)

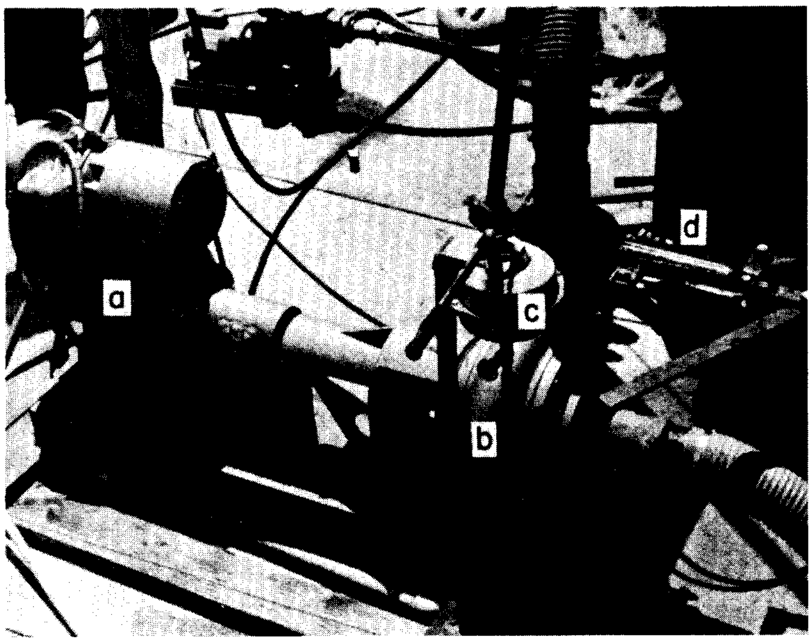

Figure 6.—Centrifugal pump.
(a) Motor. (c) Printing unit.
(b) Pump. (d) Fabri valve.
(Hawaii Institute of Marine Biology photo.)

drive electric motor (600-1,200 rpm). Other components were a 10.2-cm (4-in) Fabri valve and a 12.7-mm (½-in) hand-operated diaphragm priming unit. Smooth bore plastic hose, 10.2-cm diamter, was used on the suction and discharge sides of the pump. This pump has a hollow impeller and the fish pass through the impeller as they move through the pump.

CAPTURE AND HANDLING

Seining

Upon locating a school of shad, the seine was set in a large circle around the school. Some sets were "blind" sets, i.e., sets made with no surface signs of shad. After completion of a set, the ends of the float line were draped over the bow and stern of the skiff, and the ends of the lead line were brought together amidships. One swimmer was positioned at the water's surface next to the skiff to keep the two lead lines close together, and as far as possible, in a vertical position. Two other swimmers using scuba gear were positioned 4.6 to 6.1 m (15-20 ft) below the surface swimmer in order to keep the lead lines together and prevent an opening under the boat through which the shad might escape. In case of snags on bottom debris, one scuba diver could patrol the lead line until the obstruction was cleared. The scuba divers also assisted in pulling the net while underwater.

One end of the net was then hauled until the entire lead line was aboard, and a small pocket of netting was formed alongside the skiff. Bamboo poles and oars were used to keep the pocket from collapsing, and the shad in the pocket were slowly brought to the shoreline with the outboard motor at slow speed (Fig. 7). As much as 128 buckets of shad per set have been captured and delivered to the shoreline in this manner. Times en route after the shad were in the pocket have been as much as 30 min. Upon reaching the shoreline, the floaters of the net were placed over the edge of a floating dock which had one arm extending from each end in order to keep the skiff about 1 m (Fig. 8) from the dock. This prevented the pocket in the net from collapsing. The net was then gradually gathered up and the concentrated shad were bucketed (Fig. 9) to the portable transport tanks on the trailer (Fig. 10). Other species were often captured with the shad, especially *Tilapia* sp., and catches of 25 to 50 kg of tilapia per set were not uncommon. Some tilapia escaped by jumping over the float line (Fig. 7) while others were removed by using a large mesh (5-7 cm) dip net to separate them from the shad. The distance over which the shad were carried in the buckets was not less than about 10 m and occasionally was as much as 40 m.

Transportation[4]

Ten to fifteen buckets of shad were usually placed in each portable tank for the 37-km trip to the docksite, but on two occasions 21 to 27 buckets per tank were carried with mortalities of only 1% or 2%. We carried five por-

[4]This report does not cover experiments in transporting shad during 1975 utilizing a 18,925-liter (5,000-gal) tanker-trailer. A total of 1,241 buckets of shad were captured during 25 days of baiting from 23 June to 18 September 1975. Mortalities during the transport phase were low, less than 10%, but became heavy during the acclimation phase, probably due to excessive handling as the fish were removed from the tanker-trailer.

Figure 7.—Delivering threadfin shad to shore via net. Note the tilapia (arrow) escaping by jumping over the oar and float line.

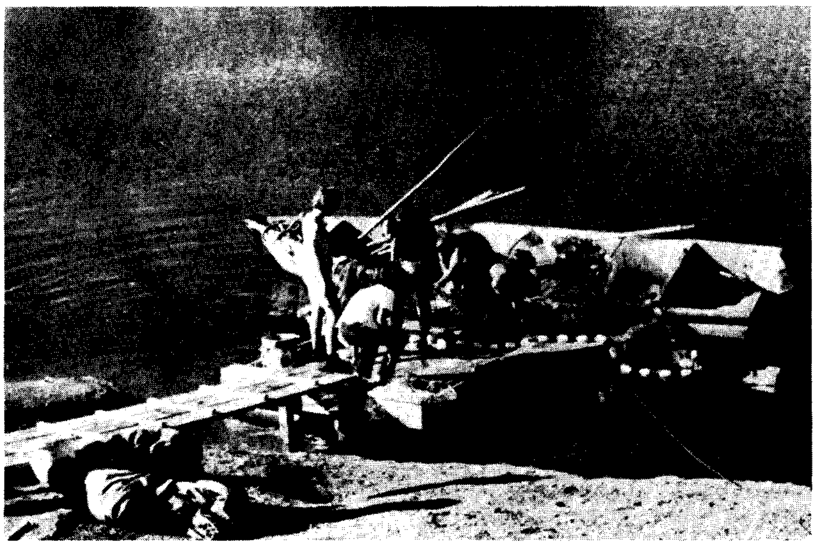

Figure 8.—Floating dock used in removing shad from the bait seine.

table tanks on a 12.2-m-long (40-ft) flatbed trailer (Fig. 10). Water in the tanks was a mixture of 75% freshwater and 25% seawater, and was not recirculated. Seawater was added to make the transport water more closely isotonic with the shad's internal environment, thus lessening osmotic stress caused by loss of scales during capture and bucketing. Tranquilizing chemicals were not added to the water.

An oxygen level of at least 10 ppm was maintained in the portable tanks, and levels that occasionally reached as high as 17 ppm for a short time did not have any adverse effect on the shad. Oxygen levels were checked about every 30 min with a portable electronic oxygen meter. Under these conditions it was not unusual to find less than 100 dead shad out of 15 buckets (ca. 22,500 individuals) in a portable tank upon arrival at docksite.

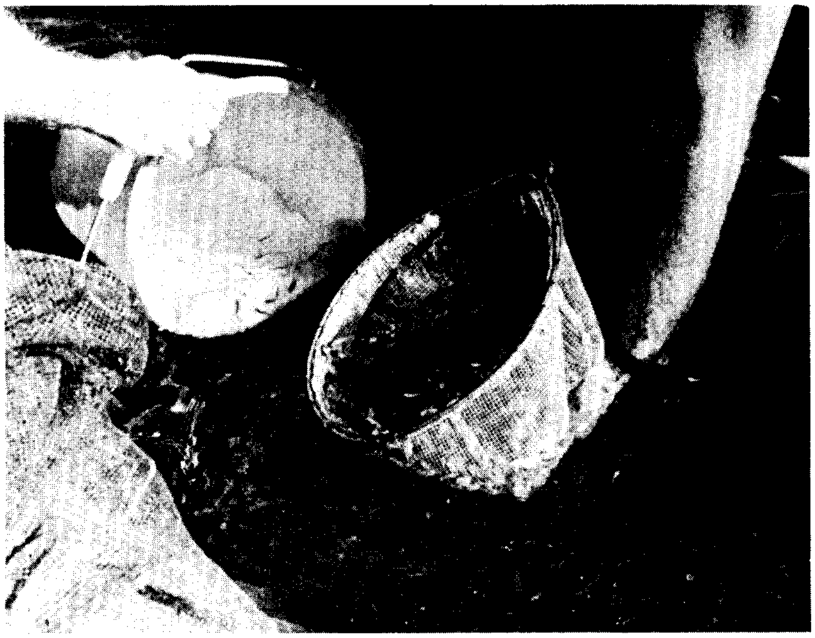

Figure 9.—Bucketing shad from the bait seine. Note adequate supply of water in the bucket.

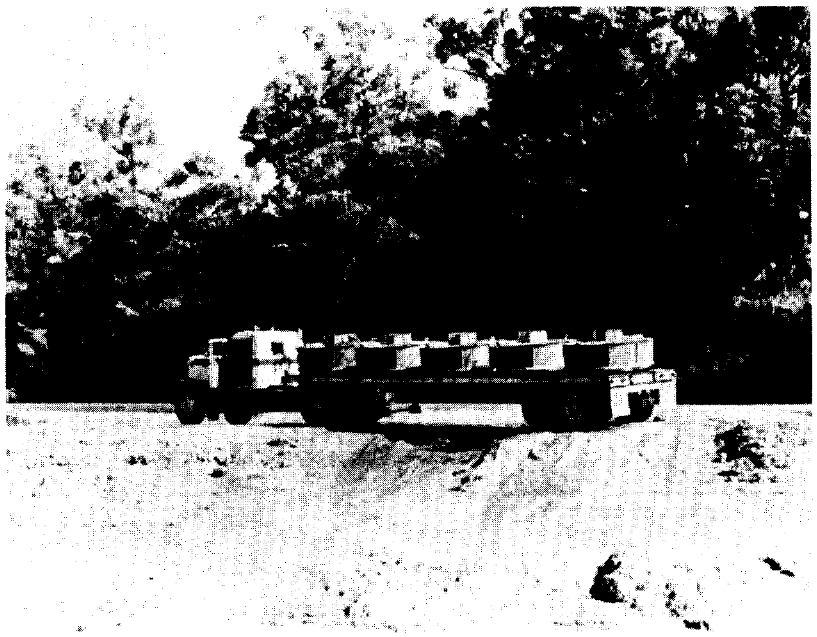

Figure 10.—Portable tanks and trailer used for transporting shad.

On a few occasions we had no mortalities. If the oxygen level went as low as 3 ppm, even momentarily, mortalities as high as 50% sometimes resulted. High oxygen levels are apparently required to offset an oxygen deficit incurred during capture and bucketing.

Upon arrival at docksite, the shad were transferred to the large holding tanks either by immersing the portable tank, minus the lid, and then overturning it (Fig. 11) or through the plastic cloth tube (Fig. 12). Immersing the portable tank resulted in fewer mortalities.

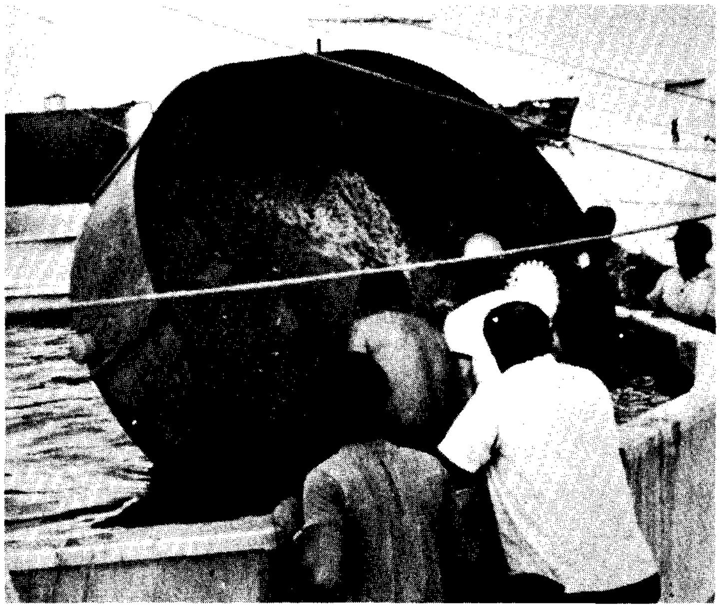

Figure 11.—Overturning a portable transport tank *to transfer threadfin shad to the 34,822-liter* (9,200-gal) holding tank for acclimation to seawater.

Figure 12.—Plastic cloth tube extending from portable transport tank. The tube is used to flume shad from the portable tank into a larger shad holding tank. The portable tank is partially immersed in the large holding tank.

Acclimating Shad to Seawater

We have found it possible to acclimate shad from freshwater to seawater in 8 h, using shad held in captivity for 2 mo. However, we ordinarily took from 36 to 72 h, preferably 72 h, to acclimate them if the acclimation period occurred just after capture. For a 72-h acclimation period the shad were held in 75% freshwater and 25% seawater for the first 24 h; 50% freshwater and 50% seawater for the next 24 h; 25% freshwater and 75% seawater for the next 24 h. Following this time the freshwater was turned off over a period of several hours. Through trial and error, we have found it impractical to acclimate more than about 50 buckets of shad in a 7-m diameter tank with 34,822 liters (9,200 gal) of water. The flow of water into such a tank should not be less than 284 liters (75 gal)/min, and preferably 378 liters (100 gal)/min. Once the shad are in large holding tanks, the oxygen level should not be less than 5 to 6 ppm. We did not recirculate the water supplying the large holding tanks. When possible, shad were held for several days in 100% seawater prior to placing them aboard vessels for fishing. The best sign of shad in good enough condition to withstand the rigors of a second transfer to a fishing vessel's baitwell is a tank of actively feeding fish. We used a mixture of 50% fish meal and 50% trout chow to feed the shad.

Transfer of Shad to Vessels

Shad were transferred to the fishing vessel either by bucketing or by the portable tank used to transport the shad from the reservoir. A small crowder was used to concentrate the shad for bucketing or for herding into the submerged portable tanks. Bait was drained from the portable tank into the vessel's baitwells by two methods. One method employed a smooth bore plastic hose 10 cm in diameter placed over the 7.5-cm drain pipe. The tank was then lifted by crane, and the bait flowed through the hose into the baitwell. One man was deployed on top of the tank with a seawater hose to flush out the last of the shad and to provide enough weight to tilt the tank slightly. Using this technique, for example, 113 buckets of shad were transferred by hose into three baitwells of the RV *Charles H. Gilbert* during cruise 116 with a mortality of only 2% the following day.

The other draining method employed the large diameter plastic cloth tube and long stainless steel chutes (Fig. 3) to place bait aboard the purse seiner *Jeanne Lynn*. Mortalities aboard the *Jeanne Lynn* averaged 10% for six transfers. Until 1971, over a wide variety of transfer conditions to different vessels, the average mortality of 1,033 buckets of shad the following day was 16%. In some cases, it was necessary to bucket the shad under adverse conditions, or to place shad aboard that had not been completely "rested" following acclimation to seawater. Assuming optimum conditions for transfer, we believe mortalities of 10% or less can be consistently achieved. This is suggested by the fact that placing 204 buckets of shad aboard the fishing vessel *Marlin* during July and August 1971 for commercial fishing trials resulted in a mortality of only 7%. Once shad have adjusted to the baitwell environment, long distance transportation at sea is feasible. The 113 buckets aboard the *Gilbert* during cruise 116 were carried for 14 days to an area 4,300 km southeast of Hawaii for use as live bait in skipjack tuna fishing. Mortalities of these shad en route were negligible.

We placed up to 36 buckets of shad aboard the *Gilbert* in a baitwell containing 10,704 liters (2,828 gal) of water, for a maximum ratio of one bucket of shad per 295 liters (78 gal) of water. Water flow through the baitwell was 378 liters (100 gal)/min. This is less than the ratio of one bucket of shad per 696 liters (184 gal) of water for 50 buckets of shad in 34,822 liters (9,200 gal) of water in the holding tank. When 36 buckets of shad were placed in the baitwell, the mortality was 7% for the first 24 h. On a few occasions when shad were placed aboard commercial skipjack tuna vessels, the maximum crowding ratio was one bucket per 322 liters (85 gal) of water.

PUMPING EXPERIMENTS

During the summer of 1970, the purse seiner *Jeanne Lynn* was chartered by Bumble Bee Seafoods, in a joint venture with the State of Hawaii, to conduct experimental purse seining for skipjack tuna in Hawaiian waters ([Hawaii.] Division of Fish and Game and Bumble Bee Seafoods [1970]. In anticipation of the need to use live bait in conjunction with purse seining, several experiments were conducted during August 1969, to test the feasibility of pumping shad from a portable transport tank to a 1,260-liter (333-gal) receiving tank elevated 3 m above the portable transport tank. The tests simulated pumping bait from the *Jeanne Lynn*'s baitwell to a bait skiff on the deck above.

Following capture, the threadfin shad used in the experiment were acclimated to seawater in the portable transfer tanks instead of the large holding tanks. Water flow through the portable transport tanks was 19 liters (5 gal)/min. An oxygen level greater than 5.0 ppm was maintained by bubbling compressed air through three airstones. Water flow through the elevated receiving tank was 8 liters (2 gal)/min and oxygen was provided in the same manner as the portable transport tanks. The shad were acclimated to seawater over a 48-h period. The shad used for the tests ranged from 13 to 95 mm total length. Mortalities were computed by weight as well as by number.

About 3 to 5 buckets of shad remained in the tanks upon completion of acclimation, but only one to two buckets were pumped during any one experiment. Water temperature in the portable tanks and elevated receiving tank was 24° to 26°C.

After pumping, the dead bait were removed every hour or several hours for the first 4 to 8 h, counted, and weighed. The remainder were left unattended overnight. The following day the dead fish were removed, counted, and weighed. The tank was then drained and the remaining fish were counted and weighed. A screen on the drainpipe prevented the loss of shad between measurement intervals.

Mortalities in the hours following pumping for the five tests are given in Table 1. Mortalities for shad pumped with the centrifugal pump ranged from less than 0.1% by number and weight after 11 days to a high of 5.0% by weight and 9.7% after 25 h. Mortalities of the shad pumped through the batch pump were intermediate. The low mortalities observed during centrifugal pump tests 2 and 3 are apparently due to larger average size of the shad used for these tests. However, the mortalities observed with the smaller shad are still much less than those occurring during the first 24 h with the nehu, *Stolephorus purpureus*, used as skipjack tuna bait by Hawaiian fishermen. The average mortality of nehu for the first day after capture is about 25% (Brock and Uchida 1968).

No significant difference is apparent in mortalities between the two pumps. However, since the batch pump is more difficult to operate, and pumping times are twice as long, the centrifugal pump is recommended for pumping threadfin shad. Care should be taken, however, that all internal surfaces of the pump and impeller are smooth and free of holes. Two preliminary tests when the centrifugal pump had a hole in the impeller resulted in mortalities of 75% to 90% within 5 min after pumping. After the impeller was repaired, rust removed, and the inside of the pump painted, the results cited above were obtained.

ACKNOWLEDGMENTS

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Table 1.—Mortalities of threadfin shad after pumping.

Test No.	Date 1969	Total length: Range (mm)	Total length: Mean (mm)	Quantity pumped (no.)	Quantity pumped (g)	Pumping time (min)	Mortalities: Elapsed time (h)	Mortalities: Cumulative percent (g)	Mortalities: Cumulative percent (no.)
Morton batch pump									
1	8/13	19-51	38	1,348	2,035.2	10	1	0.5	0.7
							2	1.0	1.4
							4	1.9	2.4
							5	2.9	3.7
							7	3.6	4.8
							23	4.6	6.2
2	8/14	51-64	—	1,210	2,960.4	11	1	1.6	1.3
							5	1.9	1.8
							22	2.1	2.0
Centrifugal pump									
1	8/22	13-38	—	1,257	1,699.1	3	1	1.2	2.6
							2	2.3	4.2
							3	2.9	6.0
							5	3.6	7.2
							25	5.0	9.7
2	8/28	19-95	64	1,633	2,629.1	4	1	0.0	0.0
							2	0.0	0.0
							4	0.0	0.0
							8	0.0	0.0
							23	0.1	<0.1
3	8/29	19-95	64	1,511	2,908.1	5	1	0.0	0.0
							2	0.0	0.0
							4	0.0	0.0
							8	0.0	0.0
							24	0.0	0.0
							264	<0.1	<0.1

the manuscript and for technical advice. We also thank the many crewmen, technicians, and biologists of the Honolulu Laboratory, NMFS, for their efforts in catching and transporting the shad. The pumps were provided through the courtesy of Bumble Bee Seafoods and the Oregon State Game Commission.

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