The Production Of Threadfin Shad As Live Bait For Hawaii's Skipjack Tuna Fishery: An Economic Feasibility Study

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FOREWORD

The fishing industry seems to be "natural" for Hawaii. Yet, it accounts for a relatively small percentage of the State's income and employment, and over the last decade or so has failed to keep pace with other sectors of the economy.

The previous study, The Skipjack Tuna Industry in Hawaii: Some Economic Aspects by Dr. Yung Cheng Shang, analyzed the economic problems of the industry. It concluded that the inadequate profit levels were responsible for the current performance of the industry, and that the future of the industry will depend on its ability to increase productivity.

One possible way to accomplish this task is through the development of new bait, an important input to the industry. The current study, sponsored jointly by the Economic Research Center and the National Marine Fisheries Service Hawaii Area Fishery Research Center, evaluates the economic feasibility of producing threadfin shad as live bait for Hawaii's skipjack tuna fisheries. It concludes that such a production would be economically feasible if a yield of 3,660 buckets of shad per 10-acre pond unit can be achieved.

It is hoped that the results of this study will contribute to the solution of the industry's problems and will be useful in directing future research efforts.

Walter Miklius
Director

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Nonetheless, responsibility for the contents of the study remains with the authors.

Yung C. Shang
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I. Introduction

The fishery for skipjack tuna, Katsuwonus pelamis, is the most important commercial fishery in Hawaii, producing about 5,000 tons per year. The pole-and-line fishing method used to catch the skipjack requires the use of live bait. A small anchovy called nehu, Stolephorus purpureus, is the major species of bait and constitutes about 92 percent of all baitfish utilized. Nehu are caught by the crew of the tuna boat before leaving for the fishing grounds. The local fleet spends about 30-40 percent of fishing time fishing for bait.[1] This practice limits the number of fishing trips that can be made during the fishing season. In addition, the nehu is a very delicate fish which suffers a substantial mortality rate. The mortality rate averages about 25 percent a day after capture.[2] Fishermen usually fish inshore, generally within 90 miles from the coastline of the main islands, since they must use the bait before mortality becomes heavy.

Attempts have been made to establish a source of baitfish available to the fishermen to minimize the loss of tuna fishing time. The Marquesan sardine, Sardinella marquesensis, has been introduced into island waters; tilapia, Tilapia mossambica, has been cultivated; and artificial bait has also been tried. However, these attempts have not proved successful.

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[1]Rothschild, Brian J., and Richard N. Uchida. "The Tuna Resources of the Oceanic Regions of the Pacific Ocean," in De Witt Gilbert (ed.), The Future of the Fishing Industry of the United States, pp. 19-51. University of Washington, Publications in Fisheries, New Series, vol. 4, Seattle, Washington, 1968.

[2]Brock, Vernon E., and Richard N. Uchida. Some Operational Aspects of the Hawaiian Live-Bait Fishery for Skipjack Tuna (Katsuwonus pelamis), U.S. Fish and Wildlife Service, Special Scientific Report--Fisheries 574, Washington, D.C., 1968.

Research conducted during the past several years by the National Marine Fisheries Service Hawaii Area Fishery Research Center (NMFS, HAFRC) on the threadfin shad, Dorosoma petenense, has shown this fish to have considerable potential as a substitute live bait for pole-and-line fishing for skipjack tuna.[3] It is hardy, relatively easy to handle, and comparable to the nehu in its tuna-catching ability. In addition, it can be cultured in fresh water impoundments until bait size, and then acclimated to sea water prior to transfer to the fishing boats.

Although this research has established the technical feasibility of using shad as bait, and provides information on input requirements for shad production, the economic feasibility of this production has yet to be determined. In this study we present an evaluation of the economic feasibility of shad production. This evaluation requires a knowledge of the price of the substitute, nehu, in addition to the investment and output data for the shad production.

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[3]Iversen, Robert T. B. Use of Threadfin Shad, Dorosoma Petenense, as Live Bait during Experimental Pole-and-line Fishing for Skipjack Tuna, Katsuwonus pelamis, in Hawaii, U.S. National Marine Fisheries Service Special Scientific Report--Fisheries, No. 641, in press.

II. An Estimate of the Value of Bait

The purpose of this section is to estimate the value of nehu to fishermen, and then to approximate the value of shad by comparing the tuna-catching abilities and mortality rates of nehu and shad.

The Value of Nehu

Due to the vertically integrated nature of the fishing operation in the local skipjack tuna fishery, no market exists for bait. Therefore, an estimate of the value of nehu to fishermen must rely on an indirect approach.

Under certain circumstances, the value of nehu may be estimated by its productivity. This can be done by treating nehu as one of several input factors in the production function of skipjack tuna. The marginal value product of nehu would be its unit value. Due to the limited information available at present, however, a proper production function of skipjack tuna in Hawaii cannot be formulated.

In this study, the value of nehu as a baitfish to local skipjack fishermen is estimated by its opportunity cost approach. The opportunity cost is what fishermen could have earned had they gone fishing instead of baiting. The procedure consists of estimating the income foregone by fishing for bait. This in turn requires estimates of the cost of fishing, the cost of baiting, the demand for bait, and the break-even price for bait.

Opportunity cost. If the fishermen had gone fishing on the days spent baiting, they would have caught an additional quantity of skipjack tuna thereby producing additional income. This additional income would represent the opportunity cost of baiting time to fishermen.

However, the expenses of fishing and baiting are different. A fishing trip requires more fuel and oil than a baiting trip. This difference in expense should be deducted from the opportunity cost. The net opportunity cost should be calculated as follows:

$$C_o = (Q_a \cdot P_t) - (D_b \cdot C_d) \qquad (1)$$

$$= (D_b \cdot \frac{Q_t}{D_f} \cdot \frac{V}{Q_t}) - (D_b \cdot C_d) \qquad \text{assuming fishing rates to be constant}$$

$$= (\frac{D_b}{D_f}) V - (D_b \cdot C_d)$$

where

Q_a = additional poundage of skipjack which could have been caught fishing full time (baiting days eliminated)

P_t = average ex-vessel price of skipjack tuna per pound

D_b = average number of days of day baiting annually

C_d = difference in costs of fishing and baiting

Q_t = average amount of skipjack caught annually

D_f = average number of days of skipjack fishing annually

V = average ex-vessel value of skipjack caught annually

Total amount of bait required. If the fishermen spend full time fishing, they would have to buy the bait instead of catching the bait themselves. In order to catch the additional skipjack tuna, the bait requirements would also have to be increased. It is assumed that this increase in bait requirements would be in proportion to the additional time spent fishing. As mentioned earlier, the mortality rate of nehu is about 25 percent before being used at sea. If the fishermen were to buy the bait required, they would have to pay for the portion which dies. Therefore, the calculation of total bait requirement should be based on the amount of bait caught, or aboard the fishing vessels, rather than the actual amount used, as follows:

$$B_t = B_o + B_a \qquad (2)$$

or $$B_t = (B_d + B_a)\ (1 + 0.25) \qquad (2\text{-}1)$$

$$B_a = \frac{Q_a}{Q_b} = Q_a \cdot \left(\frac{B_o}{Q_t}\right) \qquad (2\text{-}2)$$

where

B_t = total amount of bait required (buckets, one bucket of nehu is approximately 7 lbs.)

B_o = average amount of bait caught annually (buckets)

B_a = additional amount of bait required to catch additional skipjack (buckets)

B_d = average amount of bait used (buckets)

Q_a = additional skipjack which could have been caught fishing full time (day baiting eliminated)

Q_b = average amount of skipjack caught per bucket of bait

0.25 = mortality rate of nehu

Break-even (maximum) price of nehu. How much would the fishermen be willing to pay for their total bait requirement in order to fish full time? If they paid any amount less than the opportunity cost, they would realize an increase in their total receipts. If the cost of bait were greater than the opportunity cost, the total receipts would be reduced. The break-even price of nehu would be:

$$\frac{C_o}{B_t} \qquad (3)$$

The results of calculation. The intra- and inter-seasonal catch records of skipjack tuna and bait for 1965-1969 for the entire fleet are summarized in Table 1, and the estimated costs of fishing and baiting are shown in Table 2. The difference in costs between fishing and baiting is about $34.5 per trip. The data in Table 1 and 2 were used in equations (1) - (3). The results of the calculation are summarized in Table 3. It is interesting to note that local fishermen are paying about $14 per bucket for bait during the peak fishing months and about $11 during the other fishing months.

In 1953, Brock and Takata[4] used the same concept to approximate the value of nehu. Their finding was that nehu were worth at least $4.23 per pound or about $30 per bucket to the fishermen. When compared with the results of this study it is remarkably high. The 1953 study was based on information for only four boats over a period of one peak fishing month of a good (above average) catching year. In addition, it was based on the amount of bait actually used rather than the amount caught. The difference in costs of fishing and baiting was not considered.

Based on the results of this study, Hawaii's fishermen pay much more than those in Japan and California for their bait. The Japanese tuna fishermen pay about $4.17 per bucket for their live bait. In California live bait is sold for about $1 to $2 per scoop (about 10 lbs).

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[4] Brock, Vernon E., and Michio Takata. Contributions to the Problems of Bait Fish Capture and Mortality Together with Experiments in the Use of Tilapia as Live Bait, Division of Fish and Game, Board of Commissioners of Agriculture and Forestry, Territory of Hawaii, 1955.

TABLE 1

SUMMARY OF SKIPJACK TUNA AND BAIT CATCH RECORDS, ALL BOATS COMBINED, 1965-1969

	Year-round	Peak Fishing Months	Other Fishing Months
	Jan.-Dec.	May-Sept.	Jan.-Apr.; Oct.-Dec.
Total number of fishing trips	10,223	5,946	4,277
Total pounds of skipjack caught (1,000 lbs.)	48,421	35,395	13,026
Total value of skipjack caught ($1,000)	7,384	4,825	2,559
Total number of days of day baiting	4,295	2,428	1,867
Total buckets of bait caught (day and night)	163,844	98,757	65,087

Source: NMFS, HAFRC.

TABLE 2

COSTS OF FISHING AND BAITING PER TRIP

Item	Fishing	Baiting
Hours of operation[a]	14	3 hours day baiting 5 hours traveling
Fuel consumption per hour (gallons)	12.5	5 gallons during baiting 12.5 gallons during traveling
Price of fuel per gallon	\$ 0.20	\$ 0.20
Price of ice	\$15.	--
Total cost[b]	\$50.0[c]	\$15.5[d]

[a]Fishing: 10 hours scouting-fishing and 4 hours traveling time (both ways)

Baiting: 5 hours traveling--about 2 hours to Pearl Harbor, 8 hours to Kaneohe Bay, both ways.

[b]Baiting trip uses less time than fishing trip and allows for more leisure time. The value of leisure time of fishermen is not incorporated in the calculation.

[c]$(14 \times 12.5 \times \$.20) + \$15 = \$50.0$.

[d]$(3 \times 5 \times \$.20) + (5 \times 12.5 \times \$.20) = \$15.5$.

Source: NMFS, HAFRC.

TABLE 3

ESTIMATED BREAK-EVEN (MAXIMUM) PRICES OF NEHU BY SEASON

	Year-round	Peak Fishing Months	Other Fishing Months
Average annual opportunity cost	$588,734	$376,392	$212,342
Total amount (buckets) of nehu required annually	46,513	27,260	19,253
Break-even price of nehu per bucket	$12.7	$13.8	$11.0

Break-even (Maximum) Price of Shad

Once the break-even price of nehu has been determined, the break-even price of shad can be derived by comparing its mortality rate and tuna catching ability with that of nehu. The mortality rate of shad, based on results of preliminary tests, is in the range of 10-16 percent compared with a 25 percent mortality rate of nehu.[5] At sea, the catch rate of skipjack using shad is about equal to nehu, as mentioned earlier. However, due to the lower mortality of shad, the overall catch rate of skipjack per bucket of bait caught is presumed to be about 9-15 percent higher with shad than with nehu. The break-even price of shad is also assumed to be 9-15 percent higher than that of nehu and is calculated as follows:

$P_s = 1.15\ (P_n)$ if the mortality rate of shad is 10 percent (4)

$P_s = 1.09\ (P_n)$ if the mortality rate of shad is 16 percent (5)

where

P_s = estimated break-even (maximum) price of shad

P_n = estimated break-even (maximum) price of nehu

The results of the calculations are shown in Table 4. Shad is worth about $15-16 per bucket during the peak fishing months and about $12-13 during the other fishing months.

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[5]Iversen, Robert T. B., and Jay O. Puffinburger. "Capture, Transportation, and Pumping of Threadfin Shad (Dorosoma petenense)," NMFS, HAFRC (manuscript).

TABLE 4

ESTIMATED BREAK-EVEN (MAXIMUM) PRICE OF SHAD BY SEASON

Percent Mortality of Shad	($ per bucket)		
	Year Round	Peak Fishing Months	Other Fishing Months
10	14.6	15.9	12.6
16	13.8	15.0	12.0

III. Costs-Revenue Analysis of a Shad Enterprise

Several measures are available in appraising the economic worth of investments. The two most widely used are the pay-back and the simple rate of return methods. The weakness of both is that they fail to take into account the timing of expected earnings or of expected outlays. In most cases, a large amount of capital must be laid out at the beginning stage of investment, whereas the returns accrue to the investor over a period of time. A dollar in hand today is more valuable than a dollar to be received sometime in the future. Therefore, in this study, the profitability of investment in a shad enterprise is measured by the present value method. This method measures the present value of the associated stream of net receipts, discounted by the appropriate rate of interest, and subtracts the initial costs of the investment. This statement can be expressed mathematically as:

$$NPV = \sum_{i=1}^{n} \frac{(Q_s P_s + I_o)_i}{(1+r)^i} - \left\{ C_o + \sum_{i=1}^{n} \left[\frac{C_i}{(1+r)^i} \right] \right\} + \frac{S}{(1+r)^n} \qquad (6)$$

where

NPV = net present value

Q_s = expected quantity of shad to be produced

P_s = expected price of shad

I_o = other income

C_o = initial construction costs of ponds and bait-holding facilities

C_i = annual production costs

S = salvage value of the assets in year n

r = discount rate

i = 1...n (number of years)

If the calculated net present value is positive, investment in a shad interprise would be profitable because the present value of net cash inflow is greater than capital outlay. On the other hand, if the investment has a negative net present value, it would be undesirable from an economic viewpoint.

Enumeration of Costs and Revenues

Initial costs. Initial costs here refer to construction costs of ponds, wells, and bait-holding facilities, as shown in Table 5. The full amount of these costs is treated as initial costs as of time 0. There is no allowance for annual depreciation and no charge for interest.

The construction costs of ponds are estimated on two sizes: (1) one 10-acre pond as one unit and (2) ten 1-acre ponds as one unit. The latter costs more to construct and requires more land area than the former (Appendix Tables A-1 and A-2). Therefore, the second case is not used in the calculations.

The construction costs of bait-holding facilities are estimated on two capacities: 2,000 buckets and 5,000 buckets. For each case, fresh water can be purchased or supplied from a well. The construction cost would be higher for the latter case, while the operation costs would be lower.

The ideal site for fishponds has a ready source of fresh water and is not too far from the harbor. The site for bait-holding facilities

TABLE 5

CONSTRUCTION COSTS OF PONDS AND BAIT-HOLDING FACILITIES

1. Construction Costs of Pond

One 10-acre Pond	10 One-acre Ponds
$63,457	$87,463

2. Construction Costs of Holding Facility

2,000 Buckets Holding Facility		5,000 Buckets Holding Facility	
Water from Well	Water Purchased	Water from Well	Water Purchased
$12,997	$2,456	$14,969	$4,401

Source: Appendix Tables A-1 - A-6.

should be adjacent to the harbor or landing facility where the fishing boats tie up. Land on Oahu is quite expensive to purchase for these purposes. In this study, it is assumed that the land required is leased.

Production costs. Production costs include the costs of operating fishponds and bait-holding facilities, lease rental, as well as the costs of equipment. It varies by the size of fishponds, the capacity of bait-holding facilities and the source of fresh water (Appendix Tables A-1 - A-6). Total cost of equipment varies every year depending upon the physical life of the equipment (Appendix Table A-7).

Salvage value. The normal physical life of ponds and wells is estimated to be about 40 years. However, the loss of value of these facilities due to changes in fishing technology is far less predictable than their physical life. In this study we considered only the physical depreciation. However, shorter physical life periods (20 and 30 years) are used to allow for risk and uncertainty. It is assumed that there is no salvage value after the end of the physical life.

Discount rate. The choice of a proper discount rate is subject to considerable debate. The appropriate rate of discount is the rate of return that might reasonably be expected in an alternate investment. If explicit allowance for risk and uncertainty is made in the estimates of costs and revenue, the rate of return in a riskless investment can be used for discounting. This rate is estimated to be in the 5-7 percent range. If specific allowances for risk and uncertainty are not made in the cost and revenue estimates, an average allowance can be incorporated in the base discount rate. This rate is estimated in the 8-10 percent range. The risk and uncertainty of investment in a bait fishery is assumed to be higher than in other industries because (1) the purse seining technique could be successful for local skipjack tuna fishing in the near future. If this is the case, no live bait may be required; and (2) the population of skipjack tuna may decline in the future after intensive exploitation. Therefore, a 6-14 percent range is used in this study to test the sensitivity of the calculation.

Production and Revenue. Production levels of shad are based on an assumed rate of 200 buckets per 1-acre pond (1 bucket = ca. 5 - 7 lbs.). In a preliminary experiment with no feeding, but with some fertilization, 50 buckets of shad were produced in 1969 in a pond at Makaha, Oahu, Hawaii. The pond had a surface area of 1.4 acres (6,328,000 gal.) when initially stocked and 1.2 acres (3,500,000 gal.) when seined 6 months later. The pond also yielded 420 pounds of tilapia, Tilapia mossambica. With advanced fish culture techniques and a lack of competitors and predators, it may be possible to produce 200 buckets of shad in a 1-acre pond with a depth of 10 feet and containing 2,432,000 gallons of water.[6]

At the present time, it is less likely that 300 buckets of shad can be produced in a 1-acre pond, but with advanced fish culture techniques, it may be possible in the future. Therefore, this high level of production

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[6] This experiment and the levels of threadfin shad production reported by Swingle indicate that further research is necessary to determine if production of 200 buckets per 1-acre pond is attainable. Swingle obtained an average net production of threadfin shad of 122 lbs. per acre over a five-month period in Alabama using two 0.25-acre ponds and two 1-acre ponds. His ponds also produced large amounts of unwanted species, averaging 234 lbs. per acre. (Swingle, Hugh A. Ms., "Production and Growth of the Threadfin Shad, Dorosoma petenense (Gunther), Alone and in Combination with Piscivorous Species," Thesis, Auburn University, Auburn, Alabama, 1967).

is also included in the calculation.

The above assumed production levels would result in 2,000 and 3,000 buckets of shad per unit of ten 1-acre ponds. Production levels of 2,440 and 3,660 buckets per one 10-acre pond were extrapolated on the basis of increased volume of water in one 10-acre pond compared to ten 1-acre ponds due to proportinally smaller requirements for levees in the 10-acre pond.

Annual revenue is estimated by multiplying the total amount sold by the price of shad, and adding income from other sources, as shown in Table 6. "Other income" refers to the rental of the tractor-trailer and mobile crane during the months they are not used to haul bait. Total revenue is estimated at two levels of production: 2,440 and 3,660 buckets per unit of 10-acre pond; and by two rates of mortality: 10 and 16 percent.

Shad spawn in the winter and spring in Hawaii and bait-sized fish are available in quantity from May or June through September. Revenues are based on a 4-month period, June through September. There would be no revenues the rest of the year, except those resulting from truck rental. However, it is possible that the fishponds could be used to raise fresh-water shrimp, *Macrobrachium rosenbergii*, to increase income without affecting the production of shad. Further research is needed, however, before definite statements can be made about this possibility.

The Results of Calculation

The present value calculation of shad operation was done in two ways: (1) on a per unit basis, and (2) the entire operation as one enterprise. Results of the calculation are summarized as follows:

TABLE 6

ESTIMATED ANNUAL REVENUES OF SHAD OPERATION BY SOURCES, LEVELS OF PRODUCTION, AND MORTALITY RATES

A. Value of Shad Production

Levels of Production	Mortality Rate	Break-even Price	Value of Production
2,440 buckets	10%	$15.9	$34,916
	16%	$15.0	$30,744
3,660 buckets	10%	$15.9	$52,375
	16%	$15.0	$46,116

B. Other Income (Rental of tractor-trailer and mobile crane during off season)

$11,480

On a per unit basis: One 10-acre pond with one 2,000-bucket bait holding facility.

The net present values are all negative with the production of 2,440 buckets (Table 7) and are all positive with the production of 3,660 buckets, except when the mortality rate of shad is 16 percent and the discount rate is 14 percent (Table 8).

On the entire operation as one enterprise: Thirteen or nine units of 10-acre ponds and six units of 5,000-bucket holding facilities.

The units required to produce enough bait for the entire fleet during the fishing season are calculated by dividing the total bait requirement by the amount of bait produced per unit, which is one 10-acre pond. To meet the total bait requirement at the peak fishing season (as estimated in Table 3), thirteen or nine 10-acre ponds are required with a unit production of 2,440 or 3,660 buckets, respectively. The number of bait-holding facilities required is derived by dividing the total amount of bait produced by the capacity of a 5,000-bucket holding facility. This is about six units.

The net present values are positive only with a discount rate of 6 percent and with 30 years of operation when the production is 2,440 buckets (Table 9). With the production of shad 3,660 buckets, the net present values are all positive (Table 10).

As expected, the choice of varying discount rates and the mortality rates of shad make a significant difference in calculating the net present value. The higher the rate of discount used, the lower the net present will be; and the lower the mortality rate used, the higher the net present

TABLE 7

NET PRESENT VALUE OF INVESTMENT IN ONE 10-ACRE POND
WITH AN ANNUAL PRODUCTION OF 2,440 BUCKETS OF SHAD AND ONE
2,000-BUCKET BAIT-HOLDING FACILITY

Discount rate	Years of operation	Mortality rate of shad = 10 percent		Mortality rate of shad = 16 percent	
		Well water	Water purchased	Well water	Water purchased
Percent		($1,000)	($1,000)	($1,000)	($1,000)
6	20	-54	-52	-105	-103
	30	-47	-46	-105	-104
8	20	-63	-60	-104	-101
	30	-61	-59	-108	-106
10	20	-71	-69	-107	-105
	30	-71	-68	-110	-107
12	20	-77	-72	-109	-104
	30	-71	-67	-105	-101
14	20	-82	-76	-109	-103
	30	-81	-76	-110	-105

TABLE 8

NET PRESENT VALUE OF INVESTMENT IN ONE 10-ACRE POND
WITH AN ANNUAL PRODUCTION OF 3,660 BUCKETS OF SHAD AND ONE
2,000-BUCKET BAIT-HOLDING FACILITY [a]

Discount rate	Years operation	Mortality rate of shad = 10 percent		Mortality rate of shad = 16 percent	
		Well water	Water purchased	Well water	Water purchased
Percent		($1,000)	($1,000)	($1,000)	($1,000)
6	20	146	148	75	77
	30	194	195	107	108
8	20	111	114	46	49
	30	136	138	65	67
10	20	78	80	24	26
	30	94	97	35	38
12	20	56	61	6	11
	30	69	73	19	23
14	20	34	40	-8	-2
	30	41	46	-3	2

[a] A 2,000 bucket capacity bait facility would have to be expanded somewhat to process 3,660 buckets of shad but the additional costs are a minor portion of the overall costs.

TABLE 9

NET PRESENT VALUE OF INVESTMENT IN THIRTEEN 10-ACRE POND UNITS WITH AN ANNUAL PRODUCTION OF 2,440 BUCKETS OF SHAD PER UNIT AND SIX 5,000-BUCKET BAIT-HOLDING FACILITIES

Discount rate	Years of operation	Mortality rate of shad = 10 percent		Mortality rate of shad = 16 percent	
		Well water	Water purchased	Well water	Water purchased
Percent		($1,000)	($1,000)	($1,000)	($1,000)
6	20	-19	-85	-641	-707
	30	186	92	-560	-654
8	20	-198	-246	-731	-779
	30	-76	-142	-686	-752
10	20	-338	-371	-800	-833
	30	-265	-309	-776	-820
12	20	-450	-471	-855	-876
	30	-405	-433	-842	-870
14	20	-539	-550	-898	-909
	30	-511	-527	-891	-907

TABLE 10

NET PRESENT VALUE OF INVESTMENT IN NINE 10-ACRE POND UNITS
WITH AN ANNUAL PRODUCTION OF 3,660 BUCKETS OF SHAD PER UNIT AND
SIX 5,000-BUCKET BAIT-HOLDING FACILITIES

Discount rate	Years of operation	Mortality rate of shad = 10 percent		Mortality rate of shad = 16 percent	
		Well water	Water purchased	Well water	Water purchased
Percent		($1,000)	($1,000)	($1,000)	($1,000)
6	20	1,453	1,383	807	737
	30	1,916	1,818	1,140	1,042
8	20	1,100	1,050	547	497
	30	1,374	1,306	740	672
10	20	826	791	347	312
	30	996	950	465	419
12	20	615	584	187	164
	30	714	684	260	230
14	20	431	418	58	45
	30	498	481	104	87

value (Figure 1). A 30-year operation results in a higher net present value than a 20-year operation. However, this difference is narrowed down when a higher discount rate is used (Figure 2). Fresh water supplied from a well also results in a higher net present value than when water is purchased. But the difference is relatively small (Figure 3). To operate the bait station on a large scale (as one enterprise) is more profitable than on a small scale. The large scale operation needs fewer but larger bait-holding facilities. The construction and operating costs of one large bait-holding facility are less than that of a number of smaller ones.

The Break-even (Minimum) Price of Shad Operation

The break-even price estimated in Table 4 was derived by the opportunity cost approach and it is the maximum price fishermen would be willing to pay for shad. That price was used in the net present value calculation in the previous section.

Now, given the construction costs (ponds and bait-holding facilities), the production costs, the level of production and the discount rate, it is possible to calculate another set of break-even price of shad, which is the minimum price resulting in a zero net present value of shad operation.

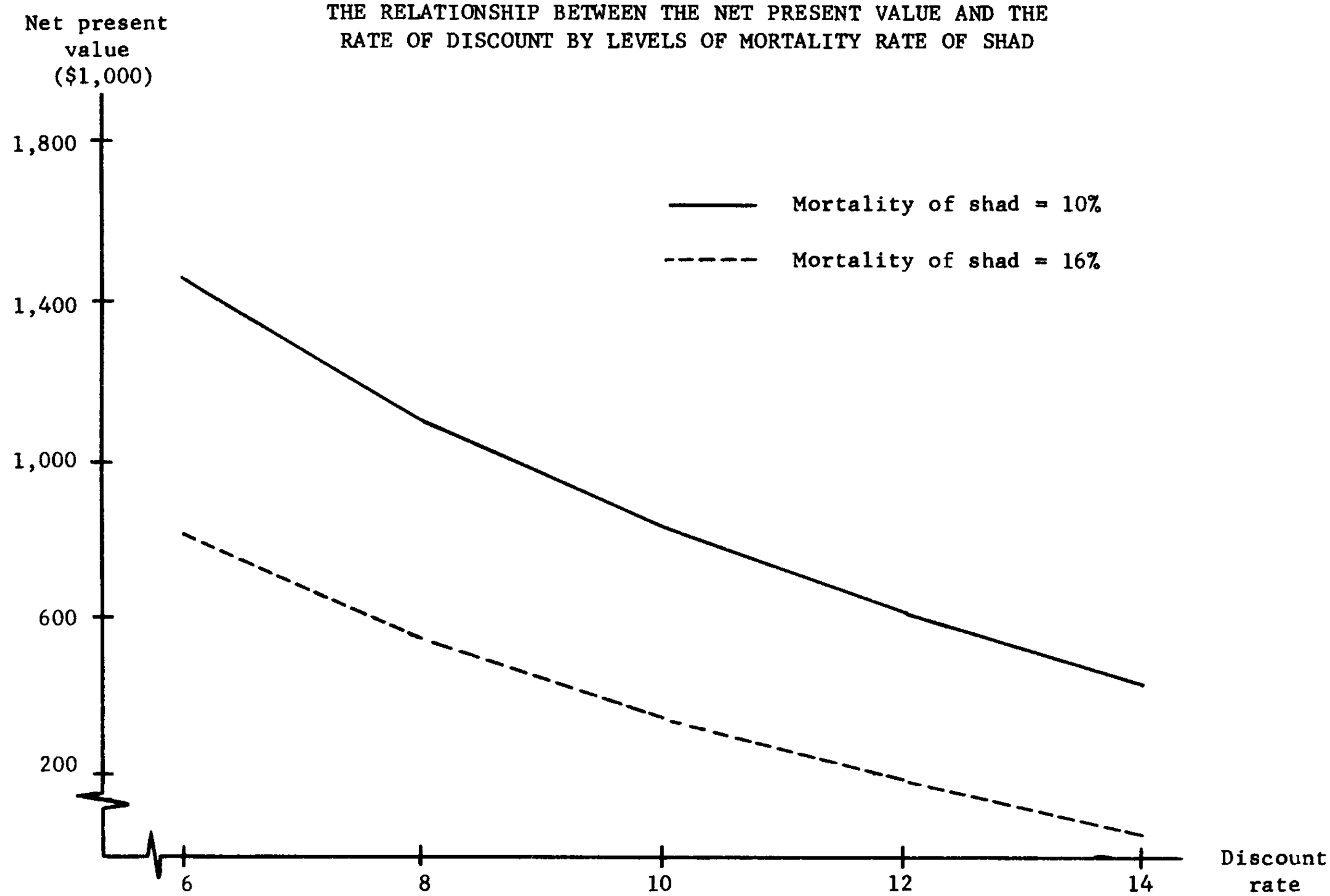
By assuming NPV = 0, then equation (6) can be rewritten as:

$$\sum_{i=1}^{n} \frac{[Q_s \cdot P_s + I_o]_i}{(1 + r)^i} = C_o + \sum_{i=1}^{n} \frac{C_i}{(1 + r)^i} - \frac{S}{(1 + r)^n} \qquad (7)$$

Since the average level of product (Q_s) and other income (I_o) are assumed constant over time, equation (7) can be rewritten as:

FIGURE 1

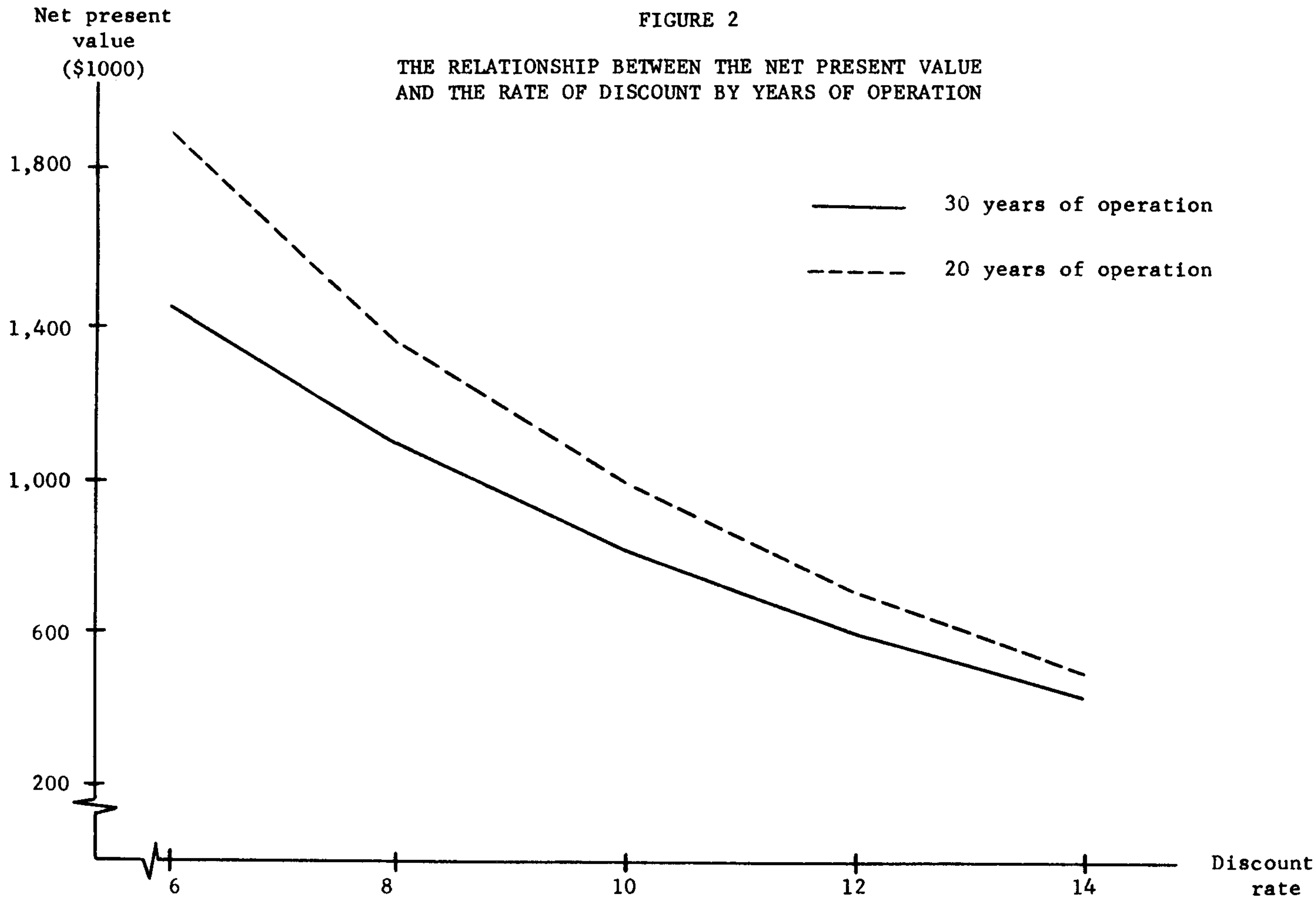
THE RELATIONSHIP BETWEEN THE NET PRESENT VALUE AND THE RATE OF DISCOUNT BY LEVELS OF MORTALITY RATE OF SHAD



Source: Table 10.

FIGURE 2

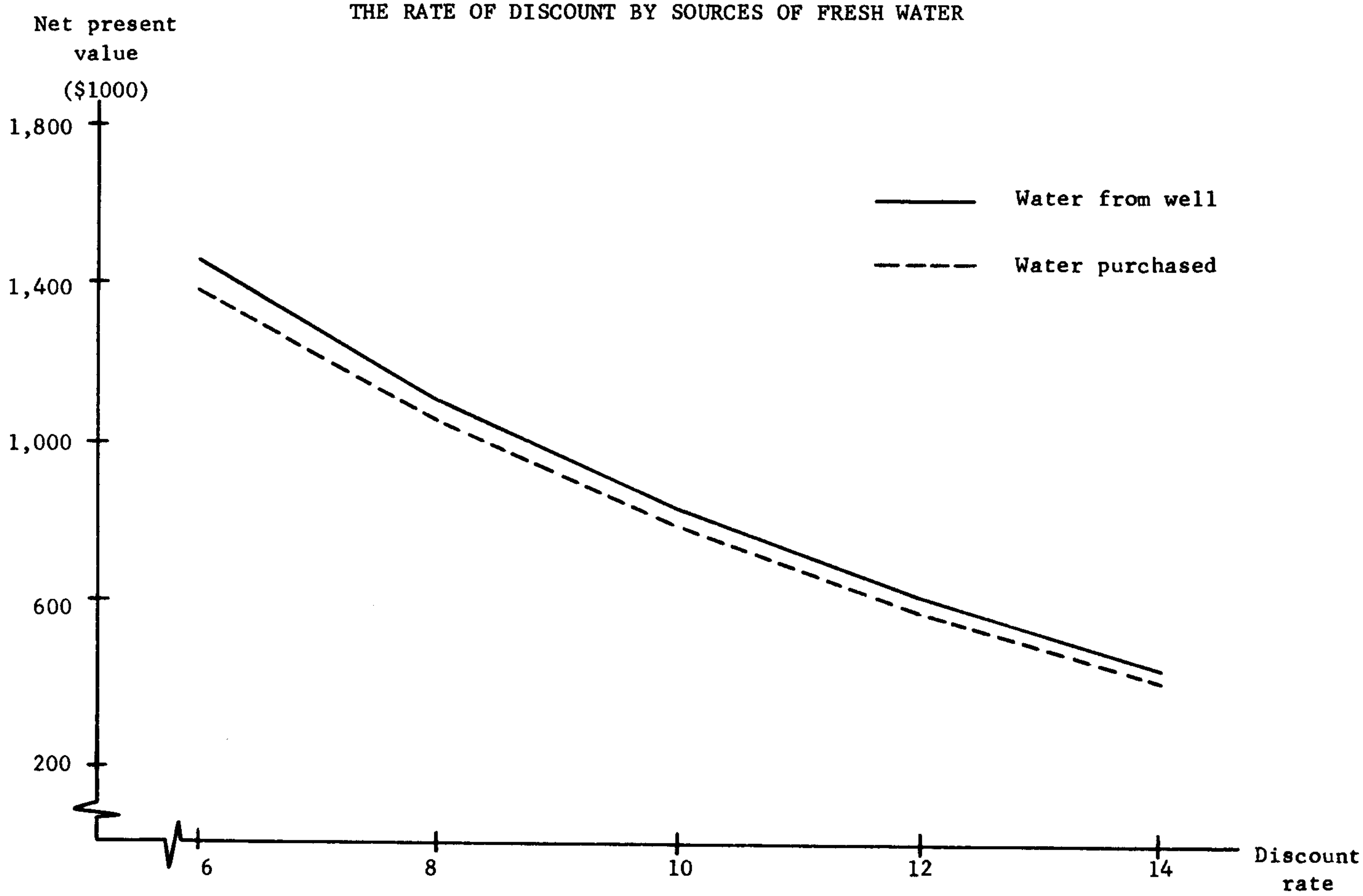
THE RELATIONSHIP BETWEEN THE NET PRESENT VALUE
AND THE RATE OF DISCOUNT BY YEARS OF OPERATION



Source: Table 10.

FIGURE 3

THE RELATIONSHIP BETWEEN THE NET PRESENT VALUE AND THE RATE OF DISCOUNT BY SOURCES OF FRESH WATER



Source: Table 10.

$$[(Q_s \cdot P_s) + I_o] \cdot \left[\frac{1 - (1 + r)^{n}}{r}\right] = C_o + \sum_{i=1}^{n} \frac{C_i}{(1 + r)^{i}} - \frac{S}{(1 + r)^{n}}$$

$$Q_s \cdot P_s = \frac{\left[C_o + \sum_{i=1}^{n} \frac{C_i}{(1 + r)^{i}} - \frac{S}{(1 + r)^{n}}\right]}{\frac{1 - (1 + r)^{n}}{r}} - I_o$$

$$P_s = \left[\frac{C_o + \sum_{i=1}^{n} \frac{C_i}{(1 + r)^{i}} - \frac{S}{(1 + r)^{n}}}{\frac{1 - (1 + r)^{n}}{r}} - I_o\right] \frac{1}{Q_s} \qquad (8)$$

The minimum break-even price calculation of shad operation will not be made for those estimates with negative net present values in the previous section. When the net present value is negative, the break-even price of shad operation would be higher than the maximum price the fishermen are willing to pay. This is not feasible from an economic viewpoint. The minimum break-even price is calculated only for those estimates with a positive net present value in the previous section. The results of the calculation are summarized in Tables 11 and 12. The estimated minimum break-even price of shad ranges from about \$11 to \$15 per bucket.

TABLE 11

ESTIMATED BREAK-EVEN (MINIMUM) PRICE OF SHAD OPERATION FOR ONE 10-ACRE POND WITH AN ANNUAL PRODUCTION OF 3,660 BUCKETS OF SHAD, AND ONE 2,000-BUCKET BAIT-HOLDING FACILITY

Discount rate	Years of operation	Mortality rate of shad = 10 percent		Mortality rate of shad = 16 percent	
		Well water	Water purchased	Well water	Water purchased
(%)	(years)	($ per bucket)		($ per bucket)	
6	20	12.0	12.3	12.8	12.8
	30	11.6	11.6	12.5	12.5
8	20	12.6	12.5	13.5	13.4
	30	12.2	12.2	13.1	13.1
10	20	13.1	13.1	14.1	14.0
	30	12.8	12.7	13.7	13.6
12	20	13.7	13.5	14.7	14.5
	30	13.7	13.5	14.6	14.5
14	20	14.3	14.1	15.4	15.1
	30	14.1	13.9	15.1	14.9

TABLE 12

ESTIMATED BREAK-EVEN(MINIMUM) PRICE OF AN ENTIRE SHAD OPERATION (INCLUDING NINE UNITS OF 10-ACRE PONDS AND SIX UNITS OF 5,000 BUCKET BAIT-HOLDING FACILITIES) WITH AN ANNUAL PRODUCTION OF 3,660 BUCKETS OF SHAD PER POND UNIT

Discount rate	Years of operation	Mortality rate of shad = 10 percent		Mortality rate of shad = 16 percent	
		Well water	Water purchased	Well water	Water purchased
(%)	(years)	($ per bucket)		($ per bucket)	
6	20	11.6	11.8	12.5	12.7
	30	11.2	11.4	12.0	12.3
8	20	12.1	12.3	13.0	13.2
	30	11.7	11.9	12.6	12.8
10	20	12.6	12.7	13.5	13.7
	30	12.3	12.5	13.2	13.4
12	20	13.1	13.2	14.1	14.2
	30	12.9	13.0	13.8	14.0
14	20	13.7	13.7	14.7	14.8
	30	13.5	13.5	14.5	14.6

IV. Harvesting Shad from the Existing Reservoir

The Wahiawa Reservoir is in an agricultural region in the interior of Oahu. This reservoir has an area of 302 acres (3 billion gal.) and is used for irrigation and sport fishing. Shad is well established and the reservoir probably contains at least 5,000 buckets of shad in the summer. These shad could be used as a bait supplement assuming there is no conflict with sport fishing in the reservoir.

The economic worth of investment in harvesting shad from the reservoir is evaluated by the same methodology developed in the previous sections. The costs of harvesting shad are summarized in Appendix Table A-8 and the costs of a bait facility (5,000 buckets) are the same as shown in Appendix Tables A-5 and A-6. Since most of the important equipment have to be replaced every 5 or 10 years, the present value calculation is based on a 10-year span.

The results of present value calculations are shown in Table 13. It is noted that all the present values are positive. However, it should be mentioned that the social costs of this operation due to possible conflict with sport fishing are not included in the calculation.

The break-even prices of shad operation from an existing reservoir calculated by using equation (8) are summarized in Table 14. All of them are much less than the maximum price the fishermen are willing to pay.

TABLE 13

NET PRESENT VALUE OF INVESTMENT IN HARVESTING SHAD FROM AN EXISTING RESERVOIR WITH ONE 5,000 BUCKET BAIT-HOLDING FACILITY

Discount rate	Mortality rate of shad = 10 percent		Mortality rate of shad = 16 percent	
	Well water	Water purchased	Well water	Water purchased
Percent	($1,000)	($1,000)	($1,000)	($1,000)
6	108	105	45	42
8	93	92	35	34
10	79	78	27	25
12	68	67	19	18
14	57	57	13	13

TABLE 14

ESTIMATED BREAK-EVEN (MINIMUM) PRICE OF SHAD OPERATION FROM AN EXISTING RESERVOIR

Discount rate	Mortality rate of shad = 10 percent		Mortality rate of shad = 16 percent	
	Well water	Water purchased	Well water	Water purchased
(%)	($ per bucket)		($ per bucket)	
6	10.1	10.2	10.8	10.9
8	10.3	10.3	11.0	11.1
10	10.5	10.5	11.2	11.3
12	10.7	10.7	11.5	11.5
14	10.9	10.9	11.7	11.7

V. Summary and Conclusions

Since no market exists for bait used by the commercial skipjack fishery, the value of bait (nehu) is calculated indirectly by the opportunity cost method. The value of shad is, in turn, derived by comparing the tuna-catching abilities and the mortality rates of nehu and shad.

The economic worth of investment in the shad culture operation is measured by the present value method. The criterion is that if the calculated net present value is positive, investment in a shad enterprise would be profitable. On the other hand, if the investment has a negative net present value, it would be undesirable from an economic viewpoint.

The calculations were made at two levels of production, 2,440 and 3,660 buckets of shad per 10-acre pond unit; two levels of mortality rate of shad, 10 and 16 percent; five levels of discount rate, 6, 8, 10, 12, and 14 percent; two sources of fresh water, from well and to be purchased; two terms of operation, 20 and 30 years; and two ways of operation, on a per unit basis and on the entire operation as one enterprise.

The results of the calculations indicate that the shad operation is feasible with an annual production of 3,660 buckets of shad per 10-acre pond unit and with the selected range of discount rates (6-14 percent). However, it is not feasible with an annual production of 2,440 buckets. The rates of discount and mortality of shad and terms of operation have a significant effect on the profitability of the operation, while the sources of fresh water make no significant difference in profitability of the operation. It can be supplied from a well or purchased. To operate the bait station on a large scale (as one enterprise) is more profitable than on a small scale. The large scale operation needs fewer but larger bait-holding facilities. The construction and operating costs of a large bait-holding facility are less than those of a few smaller ones.

The results of present value calculations also indicate that the investment in harvesting shad from an existing reservoir is profitable if there is no conflict with sport fishing.

Since most of the data used in this study are based on preliminary estimates, future research should be directed in the following areas: (1) study the possibility of raising fresh water shrimp or other species in the ponds to increase income; (2) test the actual mortality rate of shad on commercial fishing boats; (3) determine the maximum production of shad in various sized ponds; and (4) study the feasibility (both technical and economic) of constructing larger size ponds and higher capacity bait facilities to reduce costs.

APPENDIX

Table A-1. Costs--One 10-acre Pond (Depth: 10 feet)

	Cost (dollars)	
COSTS OF CONSTRUCTION:		
Engineering design[a]	8,959	
Excavation and levee construction	41,698	
Well (12" diameter, 150' deep)	10,800	
Access road (500' long, gravel topped)	2,000	
		63,457
COSTS OF EQUIPMENT:[b]		
Pump (800 gpm) and motor (10 hp)	1,442	
Pipes, valves, etc. (8" cast iron, 6" pvc)	839	
Installation of pipes, pump, etc.	448	
Fence (0.67 miles, 4-strand barb wire)	1,000	
Surfacing of levee (grass)	500	
Boat and motor	631	
Harvest equipment		
Fish pump, portable, on trailer	3,600	
Seine	1,770	
Fish transfer hoses	180	
Net handling system (tow-bar)	365	
Pickup truck	2,800	
Water analysis kit	250	
Workshed-storage house	1,000	
Miscellaneous	500	
		15,325
		78,782
ANNUAL OPERATION COSTS:		
Cost of pumping (electricity)	586	
Fish food	2,928	
Fertilizer	244	
Labor	11,550	
Pickup truck, 5,000 miles at .10/mile	500	
Land lease rental (13.5 acres)[c]	2,700	
Maintenance (pond and equipment)	766	
		19,274

[a]15 percent of cost of construction and selected equipment.

[b]Total costs of equipment varies every year depending upon the physical life of equipment (Table A-7).

[c]The value of agricultural land ranged from $4,000 to $30,000 an acre. In this study a $10,000 per acre value is used. Land lease rental as a percentage of land value ranged from 2 percent to 6 percent on Oahu. A 2 percent rate is used in this study.

Source: NMFS, HAFRC.

Table A-2. Costs--Ten 1-acre Ponds (Depth: 10 feet)

	Cost (dollars)	
COSTS OF CONSTRUCTION:		
Engineering design[a]	13,053	
Excavation and levee construction	61,610	
Well (12" diameter, 150' deep)	10,800	
Access road (500' long, gravel topped)	2,000	
		87,463
COSTS OF EQUIPMENT:[b]		
Pump (800 gpm) and motor (10 hp)	1,442	
Pipes, valves, etc. (8" cast iron, 6" pvc)	6,552	
Installation of pipes, pump, etc.)	2,016	
Fence (0.7-mi., 4-strand barb wire)	1,100	
Surfacing of levees (grass)	500	
Boat and motor	631	
Harvest equipment		
Fish pump, portable, on trailer	3,600	
Seine	600	
Fish transfer hoses	180	
Net handling system (tow-bar)	365	
Pickup truck	2,800	
Water analysis kit	250	
Workshed-storage house	1,000	
Miscellaneous	500	
		21,536
		108,999
ANNUAL OPERATION COSTS:		
Cost of pumping (electricity)	548	
Fish food	2,400	
Fertilizer	200	
Labor	11,550	
Pickup truck, 5,000 miles at .10/mile	500	
Land lease rental (14.6 acres)[c]	2,920	
Maintenance (ponds and equipment)	783	
		18,901

[a]See footnote a of Table A-1.

[b]See footnote b of Table A-1.

[c]See footnote c of Table A-1.

Source: NMFS, HAFRC.

Table A-3. Costs--2,000-bucket Threadfin Shad-holding Facility, Fresh Water from a Well

	Cost (dollars)	
COSTS OF CONSTRUCTION:[a]		
Engineering design	2,997	
Site preparation	1,000	
Well (10" diameter, 150' deep)	9,000	
		12,997
COSTS OF EQUIPMENT:[b]		
Pump (200 gpm) and motor (5 hp) for fresh water	1,270	
Pump (300 gpm) and motor (3 hp) for salt water	1,057	
Pipes, valves, etc.	1,831	
Holding tanks (3)	825	
Installation of tanks and water system	1,552	
Fence (chain link)	945	
Salt water filter	1,500	
Bait transfer hose	120	
Pickup truck	2,800	
Mobile crane	12,000	
Tractor-trailer combination (to haul bait)	27,800	
Portable fish tanks (including metal bases)	5,500	
A-frame to lift tanks	200	
Oxygen system	1,050	
Workshed-storage house	1,000	
Miscellaneous	500	
		59,950
		72,947
ANNUAL OPERATION COSTS:		
Labor	9,487	
Cost of pumping (electricity)	289	
Fish food	200	
Oxygen	300	
Vehicles		
Pickup truck 5,000 miles at .10/mile	500	
Tractor-trailer (summer only) 2,000 miles at .30/mile	600	
Mobile crane (summer only)	100	
Land lease rental (7,500 square feet)[c]	1,500	
Maintenance	609	
		13,585

[a]See footnote a of Table A-1.

[b]See footnote b of Table A-1.

[c]Land value in harbor area is estimated about $10 per square foot. Lease rental is estimated about 2 percent of the land value.

Source: NMFS, HAFRC.

Table A-4. Costs--2,000-bucket Threadfin Shad-holding Facility, Fresh Water Purchased

	Cost (dollars)	
COSTS OF CONSTRUCTION:		
Engineering services [a]	1,456	
Site preparation	1,000	
		2,456
COSTS OF EQUIPMENT: [b]		
Pump (300 gpm) and motor (3 hp) for salt water	1,057	
Pipes, valves, etc.	1,831	
Holding tanks (3)	825	
Installation of tanks and water system	1,552	
Fence (chain link)	945	
Salt water filter	1,500	
Bait transfer hose	120	
Pickup truck	2,800	
Tractor-trailer combination (to haul bait)	27,800	
Mobile crane	12,000	
Portable fish tanks, including metal bases	5,500	
A-frame to lift tanks	200	
Oxygen system	1,050	
Workshed-storage house	1,000	
Miscellaneous	500	
		58,680
		61,136
ANNUAL OPERATION COSTS:		
Fresh water (8.64 million gallons)	1,250	
Labor	9,487	
Cost of pumping (electricity)	155	
Fish food	200	
Oxygen	300	
Vehicles		
Pickup truck, 5,000 miles at .10/mile	500	
Tractor-trailer (summer only) 2,000 miles at .30/mi.	600	
Mobile crane (summer only)	100	
Land lease rental (7,500 square feet) [c]	1,500	
Maintenance	302	
		14,394

[a]See footnote a of Table A-1.

[b]See footnote b of Table A-1.

[c]See footnote c of Table A-3.

Source: NMFS, HAFRC.

Table A-5. Costs--5,000-bucket Threadfin Shad-holding Facility, Fresh Water from a Well

	Cost (dollars)	
COSTS OF CONSTRUCTION:[a]		
Engineering costs	3,969	
Site preparation	2,000	
Well (10" diameter, 150' deep)	9,000	
		14,969
COSTS OF EQUIPMENT:[b]		
Pump (300 gpm) and motor (10 hp) for fresh water	1,454	
Pump (700 gpm) and motor (10 hp) for salt water	1,369	
Pipes, valves, etc.	3,501	
Holding tanks (7)	1,925	
Installation of tanks and water system	2,768	
Fence (chain link)	1,445	
Salt water filter	2,000	
Bait transfer hose	120	
Pickup truck	2,800	
Mobile crane	12,000	
Tractor-trailer combination (to haul bait)	27,800	
Portable fish tanks (includes bases)	5,500	
A-frame to lift tanks	200	
Oxygen system	1,050	
Workshed-storage	1,000	
Miscellaneous	500	
		65,432
		80,401
ANNUAL OPERATION COSTS:		
Labor	9,487	
Cost of pumping (electricity)	792	
Fish food	450	
Oxygen	750	
Vehicles		
Pickup truck, 6,000 miles at .10/mile	600	
Tractor-trailer (summer only) 4,000 miles at .30/mi.	1,200	
Mobile crane (summer only)	100	
Land lease rental (11,550 square feet)[c]	2,310	
Maintenance	716	
		16,405

[a]See footnote a of Table A-1.

[b]See footnote b of Table A-1.

[c]See footnote c of Table A-3.

Source: NMFS, HAFRC.

Table A-6. Costs--5,000-bucket Threadfin Shad-holding Facility, Fresh Water Purchased

	Cost (dollars)	
COSTS OF CONSTRUCTION:		
Engineering costs [a]	2,401	
Site preparation	2,000	
		4,401
COSTS OF EQUIPMENT: [b]		
Pump (700 gpm) and motor (10 hp) for salt water	1,369	
Pipes, valves, etc.	3,501	
Holding tanks (7)	1,925	
Installation of tanks and water system	2,768	
Fence (chain link)	1,445	
Salt water filter	2,000	
Bait transfer hose	120	
Pickup truck	2,800	
Mobile crane	12,000	
Tractor-trailer	27,800	
Portable fish tanks (includes bases)	5,500	
A-frame to lift tanks	200	
Oxygen system	1,050	
Workshed-storage house	1,000	
Miscellaneous	500	
		63,978
		68,379
ANNUAL OPERATION COSTS:		
Labor	9,487	
Cost of pumping (electricity)	478	
Fresh water (21.6 million gallons)	2,731	
Fish food	450	
Oxygen	750	
Vehicles		
Pickup truck, 6,000 miles at .10/mile	600	
Tractor-trailer (summer only) 4,000 miles at .30/mile	1,200	
Mobile crane (summer only)	100	
Land lease rental (11,550 square feet) [c]	2,310	
Maintenance	349	
		18,455

[a]See footnote a of Table A-1.

[b]See footnote b of Table A-1.

[c]See footnote c of Table A-3.

Source: NMFS, HAFRC.

Table A-7. Estimates of the Useful Life of Equipment Associated with Bait-holding Facilities and with Raising Shad in Ponds

Item	Useful life
	Years
Pickup truck	5
Mobile crane	10
Tractor-trailer truck	10
Well	25
Pumps	18
Pipes, valves	30
Earthen ponds	40
Fence (barbwire, around ponds)	5
Fence (chain link, around bait facility)	10
Boat	5
Outboard motor	5
Portable fish pump	10
Seine	3
Transfer hoses	5
Tow-bar system	5
Water analysis kit	5
Workshop-storage house	15
Trailer for skiff	10
Diving gear	5
Bait barge	5
Holding tanks	3
Salt water filter	5
Portable fish tanks	7
A-frame	7
Oxygen system	5
Miscellaneous items	2

Table A-8. Costs of Seining Threadfin Shad from Existing Reservoirs

	Cost (dollars)	
COSTS OF EQUIPMENT:[a]		
Seine skiff	2,000	
Trailer for skiff	1,000	
Bait seine	1,170	
Outboard motor	750	
Fish pump, portable, on trailer	3,600	
Pickup truck	2,800	
Diving equipment	950	
Bait transfer hoses	180	
Miscellaneous (nets, buckets, etc.)	300	
Water analysis kit	250	
Bait barge	1,500	
		14,500
ANNUAL OPERATION COSTS:		
Labor	24,750	
Vehicle, pickup, 4,000 miles at .10/mile	400	
Compressed air for diving	500	
Commercial fishing license	10	
Maintenance	337	
		25,997

[a]Total costs of equipment vary every year depending upon the physical life of equipment.

Source: NMFS, HAFRC.