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# COMMERCIAL PRODUCTION OF STURGEON: <br> THE ECONOMIC DIMENSIONS OF SIZE AND PRODUCT MIX 

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The fishery history of the white sturgeon (Acipenser transmontanus) and related sturgeon species dates back to the 19th century in the United States. Prior to the end of the century, the annual sturgeon harvest of the United States was 25 million pounds, but overfishing and the damming of rivers serving as spawning grounds led to a severe decline in sturgeon population. The current commercial catch (where still permitted) is extimated to be less than 5 million pounds annually (McGuire, 1979).

Since the late 1970s, University of California, Davis, researchers have investigated the physiology and growth of white sturgeon in an effort to mitigate this decline in population through enhancement programs and the development of sturgeon aquaculture. This study is part of that effort its goal is to assess the economic feasibility of the artificial propagation and intensive culture of white sturgeon based on current biological data and aquaculure techniques. While long-run planning by firms frequently centers around consideration of economies of size, the confined production of sturgeon offers a more complex situation; size is just one dimension which must be incorporated into the planning process. Because the sturgeon can be marketed at different stages of growthnewly hatched larvae, 1 -month-old fry, 3 -month-old fingerlings, or as larger adult fish - the commercial hatchery can become a multi-product firm. The strategy with which the sturgeon are marketed defines the multiproduct nature of the firm. Therefore, this study will consider the sturgeon hatchery in its multi-product format and evaluate the various measures of economic perfor.
mance-cost, profit and rate of return-for such a firm.
To achieve this objective, a quantitative systems model of sturgeon hatchery and growout facilities was developed relying on the major biological and physical input-output relationships reflected in the research by the UC Davis aquacutural facility. Engineering economics techniques were used to establish the systems model. ${ }^{1}$
In addition to data on the economic measures mentioned above, the systems model also provides information on requirements for capital investment and annual operating costs during the start-up and subsequent operation of a facility over a 10 -year period. Computer simulation techniques then are applied to the model in order to study the economic outcome of varying management decisions. Figure 1 presents an overview of the modeling process utilized in this study and the information derived therefrom.

This report is divided into three main sections. The first, the Nature of Commercial Sturgeon Production, discusses the techrical and economic aspects of intense production of sturgeon. The format of the systems model which will be used in the analysis is also described. The second section, Empirical Estimation of the Model, reports the quantification of the systems model for a base model facility from which the remainder of the analysis is developed. The third section deals with the simulations used to evaluate economically the scale and product mix dimensions of sturgeon production. Finally, the conclusions section considers further implications and possible additional research needs.

## THE NATURE OF COMMERCIAL STURGEON PRODUCTION

Sturgeon to date have not been bred successfully in captivity. Therefore, commercial production relies on obtaining broodstock from their natural habitat during the spawning season. Eggs are removed from the females and hand fertilized with the sperm taken from the males. After hatching, the fish are reared to various ages in progressively larger holding tanks.

The primary feature of sturgeon production which distinguishes it from many other livestock or aquacultural operations is its multi-product nature. Fish can be produced to several stages of growth and either marketed as final products at any of these stages or retained as inputs for further production. Thus, when the firm determines at which one or more of the several stages of growout it will market its output and in what amounts, it has defined
uniquely its mult-product dimension. We shall refer to this decision as the firm's "marketing strategy." The next step is to designate the size of operation. While other operational dimensions are important in evaluating plant economics (e.g., stocking density of fish per pond or tank), the focus of this study will be on size and marketing strategy.
Plant size may be measured in terms of either inpot or output capacity. In the case of the sturgeon facility, defining capacity in terms of final product is not as meaningful as a measure in terms of some input capacity because a given single output value might result from more than one marketing strategy. Thus, size of facility is specified as the total number of broodstock handled each spawning season.

[^1]

Figure 1. Overview of the modeling process. The biological functions, production input-output relations and operating conditions are the major components of the model. The model subsequenty derived provides information on input requirements, costs, production levels, and revenue.

The multi-product characteristic of sturgeon production also creates problems of joint costs and how they should be allocated to the individual products for purposes of cost analysis. Generators, water treatment equipment, and office equipment are examples of such inputs whose use is not particular to any given product. Allocation of such costs when necessary is, of course, arbitrary, but the method of the allocation may itself affect the relative costs and profitability of the various products.
In the analysis which follows, the cost estimates represent points of the long-run cost surface. The effects of short-tun variation of output are not considered. When the marketing strategy of the firm changes - even though plant capacity (broodstock numbers) is unchanged-the input requirements including building, holding tanks, and other investment items will also change-- hence the longrun nature of the cost points.

## The Systems Model

A system is simply a set of integrated elements which together perform some real world process or function. Our system, for example, encompasses the set of hatchery and
growout operations required to produce sturgeon of various ages, i.e., it transforms inputs into output.

Development of a systems model of sturgeon production in the context of size and market strategy dimensions utilizes three fundarnental components: (1) operating procedures and operating conditions, (2) biological functions regarding fish growth and mortality, and (3) inputoutput relationships.

The operating procedures specify the stepwise culture process in a technical sense and directly follow the hatchery and growout techniques developed at UC Davis and a private facility. These procedures define how the brood fish are collected, how the eges are obtained, fertilized and hatched, and how the newly hatched fish are raised to the various stages of growth. A detailed discussion of these aspects of the production process is presented in Appendix A.

Operating conditions characterize the technical and economic environment in which the firm operates. Economic factors include the pricing mechanisms for purchasing inputs and marketing final outputs and certain costs affected by location (e.g., property taxes, utilities,
etc.). Technical conditions include the physical inputouiput relations such as yield of hatchlings from a given spawn. In this sense, the size and marketing strategy dimensions along with the operating procedures and conditions form the specifications which characterize the firm.

The biological functions (see Figure 2) provide the driving mechanism for the systems model by quantifying the physical response of animals to the culture environment specified above. Different functions, based on data from the UC Davis aquaculture program, relate to growth, mortality, feed consumption and stocking densities for different ages of fish. Growth, feed requirements, and mortality are each determined by the interactions of many factors but in this study are expressed as a function of age in months. This approach provides a useful means of tracking these biological components of the model over time. These functions are described in detail in Appendix B.

Whether the operating procedures and the biological functions incorporated in the model represent optimal culture conditions is not known. They do reflect the general efforts at the UC Davis aquaculture facility to
maintain fish in an overall healthy state, and are, therefore, specific to the particular culture system employed.

The biological functions provide the means for calculating the physical input-output requirements from which the costs are developed. Given the assumption of ad libitum feeding practices, measuring growth of the fish as a function of age is appropriate. Feed requirements then are estimated on the basis of maximum growth for the particular operating procedures applied. Mortality also is a function of age. Growth and maturity coupled with a stocking density relationship for different weights of fish provide the basis for specifying the number of various sizes of holding tanks which in turn sets the stage for developing other input requirements (water, mechanical feeders, utilities, etc.).

The systems model is designed to evaluate various size and product mix combinations in terms of costs and revenues. Cost per fish is calculated for each of the production stages to permit analysis of the effects of changing the plant specifications on relative costs of the individual outputs. From the output of the systems model, the rate of return on investment can be determined.

## EMPIRICAL ESTIMATION OF THE MODEL

As indicated earlier, the objective of the study is to analyze the nature of costs, profits and rates of return on investment for sturgeon facilities with differing dimensions of size and marketing strategy. To accomplish this end, the general operating conditions confronting the facility, regardless of size and marketing strategy must be stipulated. Then, a base model for a particular production operation is developed which is subsequently expanded to include the differing dimensions of size and marketing strategy.

## Operating Conditions

For any plant size (capacity) specification, the broodstock are assumed to be maintained in the ratio of 60 percent female and 40 percent male. The average female body weight is specified to be 36 kilograms with an average spawn of 9,075 eggs per kilogram of body weight. A fertilization rate of 75 percent and a hatch rate of 55 percent result in a yield of about 135,000 hatchlings per brood female fish.

From these specifications, the mortality function permits calculation of the number of surviving fish at subsequent stages of growoul.

As discussed earlier, management decisions in the planning process focus on size, marketing strategy and stocking density. These items all constrain the production process and hence the requirements of inputs. In this analysis, such decisions remain constant from year to year during the 10 -year horizon over which operations are modelled.

The model stipulates that the production from a given cohort of fish may be sold at four age categories: Stage I, newly hatched (nonfeeding) larva; Stage II, 1 -month-old fry; Stage III, 3-month-old fingerling; and Stage IV, 3 years of age. However, all fish of a given cohort must be sold by the end of the third year of growout. ${ }^{2}$ The marketing strategy determines the proportion of surviving product to be sold at each of these selling stages. For the first three selling stages (nonfeeding larva, fry, and fingerling), the proportion of surviving animals sold (P) may range from 0 to $I$. In the case of 3 -year-old fish, $P$ always equals 1 since all retained fish are sold at the end of three years of growout.

At the end of the first year of operation, the facility will have 1-year-old fish only (provided some newly hatched larvae are retained for growout). At the end of the second year of operation, the facility will have 2 -year-old fish

[^2]

Figure 2, The biological functions describing mortality, growth, stocking density, and daily feed per fish. See Appendix B for the equations.
(provided some fry and fingerlings are retained) and 1 -year-old fish resulting from the current year's spawn. By the end of the third year of operation, the facility will have 3 -year-old fish ready for sale, 2 -year-old fish (from the second year's spawn), and the newest cohort of 1-year-old fish. Since the size of the facility and marketing strategy remain constant, operations in year 3 are replicated during years 4 through 10 .

The location of a facility affects the cost of items such as property taxes and utilities. The model incorporates cost conditions appropriate to Davis, California, and uses a state property tax rate of 1 percent and a utility rate comprised of a demand charge of $\$ 1.82$ per KW per month and $\$ .064$ per KWH. Thus, the costs of production for other geographic locations would have to be altered when such cost items differ from those specified here.

The initial start-up and operating costs of the facility may be supported by debt, equity, or some combination of debt and equity financing. Interest payments on debt are tax deductible and hence affect after tax earnings and measures of investment value. The model assumes 100 percent equity financing.

## Base Model Facility

Operating conditions were initially defined for a base model facility, whose production costs subsequently serve as a point of reference. The base model facility obtains 10 broodstock (six females, four males) per season for spawning purposes.

The base model facility marketing strategy stipulates that 50 percent of all newly hatched larvae is sold immediately. One month later, 50 percent of the surviving fry is sold. An additional two months later, 50 percent of the surviving fingerlings is sold. At the end of three years growout, all remaining fish of a particular cohort are sold. Although actual prices for the different ages of fish typically are variable, the following price schedule was employed here: $\$ .15$ per newly hatched larva, $\$ .45$ per 1-month-old fry, $\$ 1.25$ per 3 -month-old fingerling, and $\$ 4.00$ per pound for (whole) 3 -year-old fish. This schedule reflects average 1984 prices received at commercial facilities and information available from wholesale distributors. A federal income tax rate of 46 percent and a labor wage rate of $\$ 6.00$ per hour are used. ${ }^{3}$

## Input-Output Relationships

Based on a given number of broodstock, and the hatch and fertilization rates, the growth and mortality functions determine the individual weight and surviving number of fish at various ages. Operating procedures (such as stocking density) and operating conditions built into the
model link these biological functions to associated requirements for physical inputs (e.g., tanks, feed, etc.). In the short run, some inputs are available only in fixed supply. Typically, equipment, buildings, and land are fixed inputs. The use of other inputs varies with the production level. In this study, the major variable inputs include feed, labor, and utilities.
The four production stages defined above serve as subsets of the production process for purposes of analyzing input requirements. Thus, for example, production Stage I, hatchery operations, encompasses all activities culminating in the production of hatchlings: fishing for broodstock, spawning of broodstock (i.e., collection of eggs and sperm, and in vitro fertilization), and incubation of the fertilized eggs. The other stages include those activities required for production required for production of 1-month fry, 3month fingerlings, or 3-year fish, respectively.
Equipment requirements specific to each stage of production are determined for a 10 -year period of operation. Broodstock fishing operations use a 16 -foot, flat bottom boat. Three gill nets are used for fishing for broodstock and are assumed replaced every 'season. Broodstock are transported back to the facility in a partitioned rectangular, fiberglass fish hauler ( 304 -gallon capacity) which can accommodate two fish. The incubation system has a capacity of 700,000 eggs per incubation; or, 5.6 million eggs per 8 -week spawning season (assuming the incubation system operates at capacity each incubation run, and each incubation period is equal to one week). At the beginning of production stage II (hatch to 1 -month growout) larval tanks are initially stocked at a constant level of 25,000 larvae per tank.
The semi-moist diet (fed during the first $11 / 2$ weeks of feeding) requires storage at $4^{\circ} \mathrm{C}$ to prevent spoilage. Freezer requirements, sufficient to store enough feed for one spawning season, are calculated assuming each freezer has a capacity of 23 cubic feet, and 50 pounds of feed requires three cubic feet of storage space. During production stages III (I- to 3 -month growout) and IV (3month to 3 -year growout), the stocking density function determines the number of fish stocked per tank and hence the required number of tanks. Beginning with production stage III food is dispensed from automatic feeders (2 feeders per tank). The various types of tanks used in the production process have different aeration requirements as determined by the water depth and total water volume per tank (Appendix 1). The aeration systems associated with the different types of tanks are described in Appendix 2.
Buildings consist of prefabricated, corrugated sheet metal pole barns; the roofing for outdoor tanks is similarly constructed, but without walls. Building space requirements reflect the square footage needs of the incubation system(s)

[^3]and the larval and indoor 12 -foot diameter tanks. An additional 2,400 square feet of building space is designated for office, laboratory, and living quarters. Roofing requirements for outdoor tanks are based on the number and areas of outdoor 30 -foot diameter tanks to be sheltered (Appendix 4). The land needed by the facility is a conservative estimate and incorporates only the acreage required for buildings and roofing for outdoor tanks.

Joint equipment items are not specific to a particular phase of operations; but rather contribute to all production slages. The emergency generator system must be capable of supporting the entire aeration system in case of power failure; hence its capacity is based on the combined KW requirements of the aeration systems (Appendix 2). The number of wells required is a function of the maximum water requirements of the facility at any given time and the production capacity per well (see Appendix 6 a for calculation of well requirements for the base model facility).

The quantities of the variable imputs of tabor, utilities, and feed required are also determined for each production stage. Labor requirements for each production stage (as estimated from discussions with operators of private facilities and the UC Davis aquaculture facility) are listed in- Appendix 5. Fuel consumed during the fishing expedition is computed on the basis of distance of the facility from the fishing site and hours spent fishing. Truck fuel mileage is assumed to be 15 miles per gallon; one hour of boat operation uses six gallons of fuel.

Electric utility service is used to pump water and to operate the aeration systems and automatic feeders. Total water requirements for a given stage of production are determined on the basis of flow rates per tank, the number of tanks used, and the number of days tanks are occupied. Water requirements for the base model facility are shown in Appendix 3. Given engineering specifications as to well head (total feet water is lifted) and overall efficiency of the well pump, the KWH required to pump the water can be determined (see Appendix 6b). KW requirements for operation of aeration systems are based on manufacturer's specifications (see Appendix 2). Automatic feeders are assumed to operate a total of one hour per 24 -hour period and draw 0.88 KW . Feed requirements are determined by the feed function and the number of fish retained at each production stage.

The input requirements and their respective prices define the total expenditures for capital (ixed) investments (i.e., equipment, building, and land) and operating expenses (labor, feed, and utilities). Total annual labor costs are based on a specified hourly wage rate of $\$ 6.00$ plus an overhead expense (employee benefits and workman's compensation) of 30 percent of wages.
Capital investments give rise to the annual costs of
maintenance, insurance, taxes, and depreciation. Annual maintenance costs are set at 0.5 percent of the original cost of equipment. Annual insurance costs for buildings and equipment are estimated acoording to the schedule in Appendix 7. Property taxes are assessed at 1 percent of the original cost of equipment and buildings. The accelerated cost recovery system (ACRS) of depreciation is used to allocate the costs of equipment and buildings on an annual basis over the 10 -year period of operations. Depreciable property may be classified as having a life of $3,5,10$ or 15 years (see Appendix 8a). Based on the life of an asset, the ACRS determines the recovery percentage for each year of the asset's lifetime (see Appendix 8b). For a given class of asset, the ACRS depreciation schedule may not be constant from one year to the next; consequently, the annual depreciation cost of an asset as determined by the ACRS may not be constant.

Expenditures for capital investments (excluding joint equipment) and operating expenses have been separately specified for each of the four production stages. Because joint equipment items contribute to all phases of production, their cost is apportioned equally among the four production stages. ${ }^{4}$

## Model Validation

The purpose of model validation is to determine whether inferences made about the production transformation process incorporated in the model are representative of the actual real world process. Naylor and Finger (1967) consider model specification and validation a multi-stage process which begins with: (1) specification of model components and functional relationships, followed by (2) attempts to validate these components and functional relationships built into the model, and (3) comparisons of "input-output transformations generated by the model to those generated by the real world" (Van Hom, 1971).

There is little empirical data regarding sturgeon production at the present stage of industry development. Thus, statistical comparisons between model and real world input-output data cannot be made. As input-output data from commercial facilities become available, such comparisons can be made and validation can proceed further. Until such time, validity of the present systems model is based on the credibility of the model as determined by the reasonableness of the components (i.e., operating procedures and biological functions) which drive the model internally.

The operating procedures and biological functions built into this model were based on information from researchers and operators of private facilities. Hence, these model components are "reasonable" in that they reflect current culture practices and the associated biological responses of animals.

[^4]
## Model Output and Measures of Performance

The total cost associated with a given stage of production is determined annually for years 1 through 10 of operations and consists of the annual cost of: (1) depreciation of equipment and buildings, (2) property taxes on land, equipment, and buildings, (3) insurance for buildings and equipment, (4) utilities for pumping water and operation of the aeration systems and automatic feeders, (5) feed, (6) labor, and (7) maintenance. Items 1 through 3 are fixed costs, 4 through 7 are variable costs. Maintenance has both fixed and variable components; some maintenance is required even if buildings and equipment are unused. However, usage of these items adds significantly to the required upkeep. Therefore, in this study maintenance has been treated as a variable cost item. In addition to the preceding items, total cost for production stage I also includes the cost of fuel for travel to and from the fishing site and operation of the boat, and the cost of pituitary extract required for induction of gonadal maturation.

The average total cost per unit of output (ATC) for the production of hatchlings, fry, fingerlings, or 3-year-old fish is also determined annually for years 1 through 10 of operations. ATC for a particular production stage in year i is calculated by dividing the total annual cost in year i for that production stage by the number of animals retained by the facility which survive to the end of that stage. The average variable cost (AVC) is similarly calculated for each stage produced, but incorporates only the vanable input costs of feed, labor, utilities, and maintenance.

In the growout process, outputs from earlier stages of production serve as inputs for later stages. In calculating average costs per unit for each stage, the production costs of those outputs serving as inputs must be incorporated into the production costs of subsequent outputs. If the proportion of product sold at a particular production stage (as specified by the marketing strategy) is $\mathbf{P}$, then the proportion of that stage's total production costs to be passed along to the next stage of production is 1-P.

Production costs, per se, do not determine the economic feasibility of the sturgeon culture system. Information on revenue or product demand in the form of prices obtainable for hatchlings, fry, fingerlings, and 3 -year-old fish is also needed. Given a price schedule and marketing strategy, the revenue generated from each production stage can be calculated and total annual revenue for the facility obtained. For a facility, net income (or loss) before taxes in year $i$ is:

Net $^{\text {income }}{ }_{i}=$ Revenue $_{i}$-Equipment depreciation ${ }_{j}$ Building depreciation ${ }_{i}$-Property taxes ${ }_{i}-$ Maintenance $_{j}$ - Insurance ${ }_{i}$-Operating costs ${ }_{i}$
where revenue and all cost figures are the annual totals for the facility derived from all four production stages. Operating cost is the total variable cost in year i for labor, fuel, pituitary extract, feed, utilities (for pumping water and operating the aeration systems and automatic feeders), and maintenance.

Federal income taxes are assessed on net income earned by the facility; in the case of a negative net income, or net operating loss (NOL) there is no income tax liability. A NOL also can be used to reduce taxable income in other tax years. It may be carried back to an earlier tax year (up to three years before the NOL year) or carried forward up to 15 years after the NOL year. Property which is depreciated under the ACRS is eligible for an investment tax credit of 10 precent of the investment. The total annual credit allowable is assumed to be limited to the income tax liability of that year. As with a NOL, investment tax credits may also be carried backward (up to three, years) or forward (up to 15 years) to reduce the tax liability in other years. Thus, federal income tax is assessed on net income after adjustments for any NOL. The resultant income tax liability is then reduced by any investment tax credits (up to the amount of the tax liability itself) in order to determine the federal income tax liability for that year.

In order to evaluate further the economic performance of a sturgeon culture system, the cost and revenue information is used to measure the potential internal rate of return of the investment.

The rate of retum, the measure used in this study, is the discount (interest) rate that equates the present value of cash inflows with the present value of cash outlows (Bierman and Smidt, 1975; Osteryoung, 1979; Clark, Hindelang, and Pritchard, 1979). The rate of retum of an investment is determined iteratively when the annual flows of cash outlay and income are not uniform. The model assumes cash inflows occur at the end of each annual period, while cash outflows occur at the beginning. $A$ different timing of inflows and/or outlows will alter the rate of return values.

In this study, expenditures for capital investments represent cash outflows; cash inflow is represented by annual net income after tax, but with annual charges for equipment and building depreciation added back. There are 10 annual time periods.

To reflect the dynamic nature of the sturgeon production, the systems model evaluates the operation every 10 days for fish up to six months of age and every 20 days thereafter. The biological functions are evaluated for the midpoint of the time intervals and these values form the basis for extrapolating feed requirements, etc., for the rest of the time period.

The biological output of the base model facility resulting from one year's spawning activity is summarized in Table 1. Each female yields 326,700 eges, of which 245,025 (75 percent) are successfully fertilized in vitro; of these, 134,763 ( 55 percent) successfully hatch. Thus, six females produce 808,582 hatchlings, 50 percent of which are sold immediately. The 404,291 hatchlings retained weigh a total of 6.46 kg . The mortality function determines the cumulative proportion of the oniginal
number of hatchlings (in this case the 404,291 hatchlings retained) which have died at a given age. For example, cumulative mortality at 1 month of age is approximately 37 peroent hence 254,0071 -month-old fry survive from the original retained hatchlings population of 404,291 . At the age of 1 month, the base model sells 50 percent of the 254,007 surviving fry (i.e, 127,004 ) and is left with a total of 24.13 kg production ( $0.19 \mathrm{gram} / \mathrm{fryx} 127,004$ fry xl $\mathrm{kg} / 1000$ grams). The following equation is used to determine the proportion of the population at time $t$ which dies during the interval from t to $\mathrm{t}+\mathrm{N}$ (where N is some positive number of months):

Proportion of population at time $t$ dying duning the time interval from $=\frac{\mathrm{CM}_{t+N}-\mathrm{CM}_{1}}{1-\mathrm{CM}_{\mathrm{t}}}$ $t$ to $\mathrm{t}+\mathrm{N}$

Table 1
Base Model Facility Productiona (Per Cohort of Fish)

Total Number of Broodstock: 10
Marketing Strategy: 50 percent

| Age | Body Welght | Number Produced | Number Sold | Production ${ }^{\text {(grams } / \mathrm{fish})}$ |
| :--- | :---: | :---: | :---: | :---: |
| Hatchling | 0.016 c | 808,582 | 404,291 | $(\mathrm{~kg})$ |
| l month | 0.19 | 254,007 | 127,004 | 6.46 |
| 3 months | 19.08 | 95,021 | 47,511 | 24.13 |
| 6 months | 102.60 | 47,502 | 0 | 906.49 |
| 12 months | 537.32 | 47,502 | 0 | $25,873.59$ |
| 18 months | $1,415.41$ | 47,502 | 0 | $67,234.97$ |
| 24 months | $2,814.08$ | 47,502 | 0 | $133,674.59$ |
| 30 months | $4,795.52$ | 47,502 | 0 | $227,796.73$ |
| 36 months | $7,412.82$ | 47,502 | 47,502 | $352,124.02$ |

[^5]where CM is the cumulative mortality as determined by the mortality function. The numerator represents the proportion of the original population which dies during the time interval from $t$ to $t+N$. The denominator is the proportion of the original population alive at time t .
During the growout period from one to three months of age, approximately 74.82 percent of the retained 1-monthold fry (based on the preceding equation) survive to the age of three months, resulting in 95,021 fingerlings. After selling 50 percent of the fingerlings, 47,510 are retained for continued growout to three years of age, at which time all are sold. Mortality is small between the ages of three and six months (about 0.02 percent), and becomes insignificant from six months to three years of age. The 906.49 kg of fingerlings retained will yield $352,124.02 \mathrm{~kg}$ of 3 -year-old fish.

## Capital Investments and Operating Cost

The type, amount required, and total cost of equipment specific to each production stage over the 10 -year period are presented in Table 2. Table 3 lists similar information for the joint equipment items which are not specific to any one production stage. Land and building requirements for each production stage are found in Table 4 (see Appendix 4). Fish are raised indoors up to the age of 6 months. At 6 months of age, fish are transferred to the outdoor tanks which are sheltered by roofing. Essentially all capital investment in equipment, buildings, and land is made during the first three years of operation (as shown in Table 5). The $\$ 1,500$ expenditure for fishing equipment in years 2-10 represents the annual replacement cost of fishing nets. The total investment cost of equipment (including fishing nets) and buildings is converted into annual cost figures for years 1 through 10 of operations by the ACRS method of depreciation. The annual depreciation costs for equipment and buildings are listed in Tables 6 and 7.

Operating costs of the variable inputs are shown for each production stage in Table 8. In the present systems model, the production of a facility is constrained by size (capacity) and marketing strategy. During the 10 -year period over which operations are modelled, these two characteristics of the facility are assumed to remain constant. Hence production from each year's spawning activities is identical to that described in Table 1. As a result, annual operating costs are constant after the hatchery reaches full operation in the third year.

## Production Costs

The annual average total costs (ATC) per fish for the production stages of hatch, fry, fingerling, and 3 -year-old fish are summarized in Table 9a. Over the 10-year horizon,
annual ATC decreases as equipment and buildings become fully depreciated. In contrast, the average variable costs (AVC) per unit for the four production stages remain constant through year 10 at the values shown in Table 9b. In Table 10 the variable costs of labor, utilities, and feed per fish for each production stage are separately identified. For 3 -year-old fish (weighing about 7.25 kg ) these costs can be represented in dollars per kg (of whole fish): (1) labor cost $=\$ .040$ per kg , (2) utilities cost $=\$ 1.78$ per kg , and (3) feed cost $=\$ 1.91$ per kg . The sum of the variable costs of labor, utilities, and feed is slightly less than the AVC values listed in Table 9 b because the latter also include the costs of hormone injections and fuel used by the truck and boat in broodstock fishing and maintenance.
Total annual production costs for the base model facility are listed in Table 11. The total variable cost increases over years 1 through 3 because the facility does not operate at full capacity until the third year. In the first year, the total variable cost of $\$ 120,509$ represents the cost of variable inputs required to cultivate only one cohort of fish to one year of age. In the second year of operation, total variable cost increases to $\$ 483,893$, and includes the variable cost of raising a second cohort of fish to one year of age (i.e., production from the current year's spawn) plus the variable costs of growout from one to two years of age (for fish resulting from the previous year's spawn). The total variable cost of $\$ 1,360,910$ in the third year of operations includes the variable costs of culture for three cohorts of fish, each at a different phase of growout. At the end of the third year, facility operations reach a steady state.

## Revenue, Income and Investment Analysis

Table 12 presents the revenue associated with each stage of production under the base facility marketing strategy. Total annual revenue over a 10 -year horizon is shown in Table 13. Annual revenue of $\$ 177,184$ occurs in the first and second year of operations and results from the sale of hatch, fry, and fingerlings only in both years. At the end of the third year of operations 3 -year-old fish are sold for the first time. Thus annual revenue increases to $\$ 3,282,353$ in the third year and remains at this level for subsequent years. Annual cost deductions from revenue result in net losses for the first two years of operation and positive net income (before taxes) thereafter. As indicated in Table 13, no income tax is paid by the base model facility until the sixth year of operation.

Table 14 summarizes the cash inflows and outflows of the base model facility over 10 years of operation. A rate of return of 1.26 percent is associated with the base model facility. While the rate of return for the base model plant is small, the base model facility is an arbitrarily selected point of reference and is not necessarily an optimal point of operation as will be seen later.

Equipment Requirements

Total Number of Broodstock: 10
Marketing Strategy: 50 percent

| Equipment | Number Required for Years 1-10 | Total Cost |
| :---: | :---: | :---: |
|  |  | (dollars) |
| Production Stage I |  |  |
| Boat | 1 | 16,000 |
| Fishing nets | 30 | 15,000 |
| Fish hauler | 1 | 1,100 |
| Brood tanks | 4 | 6,380 |
| Incubation system | 1 | 3,600 |
| Aeration system | 1 | 1,972 |
| Total |  | 44,052 |
| Production Stage II |  |  |
| Larval tanks | 9 | 4,050 |
| Freezer | 1 | 600 |
| - Aeration system | 1 | 1,622 |
| Tot al |  | 6,272 |
| Production Stage III |  |  |
| 12-foot diameter tanks | 135 | 131,625 |
| Automatic feeders | 270 | 93,150 |
| Aeration system | 17 | 35,003 |
| Total |  | 259,778 |
| Production Stage IV |  |  |
| 12-foot diameter tanks | 134 | 130,650 |
| 30-foot diameter tanks | 451 | 2,255,000 |
| Automatic feeders | 1,170 | 403,650 |
| Aeration system (12-foot tanks) | 17 | 35,003 |
| Aeration system ( 30 -foot tanks) | 113 | 265,889 |
| Total |  | 3,090,192 |

## Table 3

## Joint Equipment Requirements

```
Total Number of Broodstock: 10
Marketing Strategy: 50 percent
```

| Joint Equipment | Number Required <br> for Years $1-10$ | Total cost |
| :--- | :---: | ---: |
| Emergency generator | 1 | $($ dollars |
| Wells | 10 | 72,180 |
| Stripping towers | 10 | 646,120 |
| Office and laboratory equipment |  | 40,000 |
| Small tools | 2 | 10,000 |
| Trucks | 2,000 |  |
| Total | 22,500 |  |

Table 4

Total Number of Broodstock: 10
Marketing Strategy: 50 percent

| Production Period | Land |  |  | Building and Roofing |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Acres Required | Total Cost | Annual Tax | Square Feet Required | Total Cost | Annual Tax |
|  |  |  |  |  |  |  |
| Hatch production | 0.02 | 69.02 | 1 | 1,002 | 25,050 | 251 |
| Hatch to 1 month growout | 0.02 | 61.99 | 1 | 900 | 22,500 | 225 |
| 1 to 3 month growout | 0.77 | 2,324.70 | 23 | 33,750 | 843,750 | 8,438 |
| 3 month to 1 year growout | 5.24 | 15,714.97 | 157 | 163,350 | 1,497,987 | 14,980 |
| 1 to 2 year growout | 5.84 | 17,523.07 | 175 | 169,600 | 856,162 | 8,562 |
| 2 to 3 year growout | 14.55 | 43,642.37 | 436 | 422,400 | 2,132,328 | 21,323 |
| Office and lab building | 0.07 | 206.64 | 2 | 2,400 | 139,872 | 1,399 |
| Total | 26.51 | 79,546.12 ${ }^{\text {a }}$ | 795 | 793,402 | 5,517,649 | 55,178 |

${ }^{\text {a }}$ Sum of column may not equal total because of rounding.

## Annual Investment

Total Number of Broodstock: 10
Marketing Strategy: 50 percent

| Item | Year of Operation |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Fishing equipment | 18,600 | 1,500 | 1,500 | 1,500 | 1,500 | 1,500 | 1,500 | 1,500 | 1,500 | 1,500 |
| Incubation system | 3,600 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Brood tanks | 6,380 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Larval tanks | 4,050 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12-foot tanks | 262,275 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30-foot tanks | 405,000 | 530,000 | 1,320,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Automatic feeders | 241,500 | 73,140 | 182,160 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Aeration systems | 123,013 | 61,178 | 155,298 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Emergency generator | 72,180 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Freezer | 600 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Wells | 646,120 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Stripping towers | 40,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Office and lab equipment | 10,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Tools | 2,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Trucks (2) | 22,500 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Land | 79,546 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Buildings | 2,529,159 | 856,162 | 2,132,328 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total Investment | 4,466,523 | 1,521,980 | 3,791,286 | 1,500 | 1,500 | 1,500 | 1,500 | 1,500 | 1,500 | 1,500 |

Totc avaber of Broodstock: 10
Marketing Stritegy: 50 percent

| Equipment | Year of Operation |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Production Stage I |  |  |  |  |  |  |  |  |  |  |
| Boat | 2,280 | 3,344 | 3,192 | 3,192 | 3,192 | 0 | 0 | 0 | 0 | 0 |
| Fishing nets | 375 | 570 | 555 | 375 | 570 | 555 | 375 | 570 | 555 | 375 |
| Fish hauler | 157 | 230 | 219 | 219 | 219 | 0 | 0 | 0 | 0 | 0 |
| Brood tanks | 909 | 1,333 | 1,273 | 1,273 | 1,273 | 0 | 0 | 0 | 0 | 0 |
| Incubation system | 513 | 752 | 718 | 718 | 718 | 0 | 0 | 0 | 0 | 0 |
| Aeration system | 296 | 434 | 414 | 414 | 414 | 0 | 0 | 0 | 0 | 0 |
| Building | 2,505 | 2,756 | 2,255 | 2,004 | 1,754 | 1,503 | 1,503 | 1,503 | 1,503 | 1,253 |
| Production Stage II |  |  |  |  |  |  |  |  |  |  |
| Larval tanks | 576 | 845 | 807 | 807 | 807 | 0 | 0 | 0 | 0 | 0 |
| Freezer | 86 | 125 | 120 | 120 | 120 | 0 | 0 | 0 | 0 | 0 |
| Aeration system | 243 | 357 | 341 | 341 | 341 | 0 | 0 | 0 | 0 | 0 |
| Building | 2,250 | 2,475 | 2,025 | 1,800 | 1,575 | 1,350 | 1,350 | 1,350 | 1,350 | 1,125 |
| Production Stage III |  |  |  |  |  |  |  |  |  |  |
| Tanks | 18,752 | 27,502 | 26,252 | 26,252 | 26,252 | 0 | 0 | 0 | 0 | 0 |
| Automatic feeders | 13,284 | 19,483 | 18,598 | 18,598 | 18,598 | 0 | 0 | 0 | 0 | 0 |
| Aeration system | 5,250 | 7,701 | 7,351 | 7,351 | 7,351 | 0 | 0 | 0 | 0 | 0 |
| Building | 84,375 | 92,813 | 75,938 | 67,500 | 59,063 | 50,625 | 50,625 | 50,625 | 50,625 | 42,188 |
| Production Stage IV |  |  |  |  |  |  |  |  |  |  |
| Tanks | 76,325 | 187,468 | 405,725 | 488,470 | 475,930 | 369,075 | 263,340 | 0 | 0 | 0 |
| Automatic feeders | 21,156 | 41,459 | 70,894 | 82,321 | 80,590 | 50,971 | 36,369 | 0 | 0 | 0 |
| Aeration system | 12,662 | 27,748 | 54,481 | 64,740 | 63,187 | 45,460 | 32,613 | 0 | 0 | 0 |
| Building | 150,050 | 166,520 | 140,012 | 126,349 | 111,242 | 95,099 | 93,497 | 89,505 | 89,505 | 74,588 |
| Total | 392,044 | 583,915 | 811,170 | 892,844 | 853,196 | 614,638 | 479,672 | 143,553 | 143,538 | 119,529 |

Total Number of Broodstock: 10
Marketing Strategy: 50 percent

| Joint Equipment | Year of Operation |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|  |  |  | - | -- | ol | rs | --- | - | ----- | ----- |
| Emergency generator | 10,286 | 15,086 | 14,400 | 14,400 | 14,400 | 0 | 0 | 0 | 0 | 0 |
| Wells | 61,381 | 67,520 | 55,243 | 49,105 | 42,967 | 36,829 | 36,829 | 36,829 | 36,829 | 30,691 |
| Stripping towers | 3,800 | 4,180 | 3,420 | 3,040 | 2,660 | 2,280 | 2,280 | 2,280 | 2,280 | 1,900 |
| Office and lab building | 13,987 | 15,386 | 12,588 | 11,190 | 9,791 | 8,392 | 8,392 | 8,392 | 8,392 | 6,994 |
| Office and lab equipment | 1,425 | 2,090 | 1,995 | 1,995 | 1,995 | 0 | 0 | 0 | 0 | 0 |
| Small tools | 285 | 418 | 399 | 399 | 399 | 0 | 0 | 0 | 0 | 0 |
| Trucks (2) | 5,625 | 8,550 | 8,325 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 96,789 | 113,230 | 96,370 | 80,129 | 72,212 | 47,501 | 47,501 | 47,501 | 47,501 | 39,585 |

Tabie 8
Annual Operating Costs

Tot al Number of Broodstock: 10
Marketing Strategy: 50 percent

Growout Period
Annual Operating cost (dollars)

Hatch production
Fishing labor ${ }^{\text {a }} \quad 864$
Spawning labor ${ }^{\text {a }} \quad 324$
Fishing fuel 269
Pituitary extract 370
Water pumping 159
Water aeration 275
Maintenance 220
Total 2,481
$\frac{\text { Hatch to } 1 \text { month growout }}{\text { Larval labora }} \quad 7,392$
$\begin{array}{lr}\text { Larval feed } & 259\end{array}$
Water pumping 182
Water aeration $\quad 1,566$
Maintenance 31
Total 9,430

| 1 to 3 month growout |  |
| :--- | ---: |
| Fry labora | 2,430 |
| Fry feed | 1,120 |
| Water pumping | 2,359 |
| Water aeration | 1,856 |
| Autofeeder operation | 393 |
| Malntenance | 1,299 |
|  |  |
| Total | 9,457 |


| 3 month to l year growout |  |
| :--- | ---: |
| Finger labora | 3,870 |
| Finger feed | 29,095 |
| Water pumping | 26,493 |
| Water aeration | 28,173 |
| Autofeeder operation | 3,205 |
| Maintenance | 3,842 |
|  |  |
| Total | 94,678 |

$\frac{1 \text { to } 2 \text { year growout }}{\text { Labora }^{\text {a }}} \quad 1,908$
Feed 183,553

Water pumping 84,020
Water aeration 84,569
Autofeeder operation $\quad 5,440$
Maintenance 3,322
Total 362,812

| 2 to 3 year growout | 4,752 |
| :--- | ---: |
| Laborá | 462,609 |
| Feed | 193,789 |
| Water pumping | 193,607 |
| Water aeration | 12,548 |
| Autofeeder operation | 8,287 |
| Maintenance |  |
|  | 875,592 |

[^6]Total Number of Broodstock: 10
Marketing Strategy: 50 percent

| Production Stage | Year of Operation |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |


|  | Average Total Cost Per Fish |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Haschling | 0.047 | 0.055 | 0.049 | 0.043 | 0.041 | 0.026 | 0.025 | 0.026 | 0.026 | 0.023 |
| Fry | 0.234 | 0.266 | 0.237 | 0.211 | 0.199 | 0.144 | 0.144 | 0.144 | 0.144 | 0.131 |
| Fingerling | 2.266 | 2.624 | 2.338 | 2.172 | 2.04 .5 | 1.269 | 1.269 | 1.269 | 1.269 | 1.142 |
| 3 year old fish |  |  | 46.435 | 51.239 | 49.596 | 49.120 | 48.669 | 33.892 | 33.892 | 33.878 |

## Table 10

Table 9b
Variable Cost Per Fish
Average Variable Cost of Production Per Fish

Total Number of Broodstock: 10
Marketing Strategy: 50 percent

| Stage | Average Variable Cost Per Fish |
| :--- | :---: |
|  | (dollars) |
|  |  |
| Hatchling | 0.003 |
| Fry | 0.042 |
| Fingerling | 0.156 |
| 3 year old fish | 28.02 |

Total Number of Broodstock: 10
Marketing Strategy; 50 percent

| Production Stage | Labor | Utilities | Feed |
| :--- | :---: | :---: | :---: |
| Hatching | 0.001 | \$/Unit of Production | 0.001 |
| Fry | 0.031 | 0.008 | - |
| Fingerling | 0.067 | 0.055 | 0.001 |
| 3 year old fish | 0.289 | 13.24 | 0.013 |

Total Number of Broodstock: 10
Marketing Strategy; 50 percent

|  | Year of Operation |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| FIXED COSTS |  |  |  |  |  |  |  |  |  |  |
| Equipment depr. | 268,138 | 455,644 | 683,428 | 762,577 | 741,982 | 459,710 | 339,193 | 39,679 | 39,664 | 32,966 |
| Building depr. | 253,167 | 279,949 | 232,818 | 208,843 | 183,424 | 156,970 | 155,367 | 151,375 | 151,375 | 126,146 |
| Taxes | 44,800 | 60,004 | 97,902 | 97,902 | 97,902 | 97,902 | 97,902 | 97,902 | 97,902 | 97,902 |
| Insurance | 26,723 | 35,760 | 58,269 | 58,269 | 58,269 | 58,269 | 58,269 | 58,269 | 58,269 | 58,269 |
| Total fixed cost | 592,828 | $8.31,357$ | 1,072,417 | 1,127,591 | 1,081,577 | 772,851 | 650,731 | 347,225 | 347,210 | 315,283 |
| VARIABLE COSTS |  |  |  |  |  |  |  |  |  |  |
| Maintenance | 5,793 | 8,714 | 17,001 | 17,001 | 17,001 | 17,001 | 17,001 | 17,001 | 17,001 | 17,001 |
| Labor and overhead | 19,344 | 21, 824 | 28,002 | 28,002 | 28.002 | 28,002 | 28,002 | 28,002 | 28,002 | 28,002 |
| Fiahing fuel | 269 | 269 | 269 | 269 | 269 | 269 | 269 | 269 | 269 | 269 |
| Pituitary extrac* | 370 | 370 | 370 | 370 | 370 | 370 | 370 | 370 | 370 | 370 |
| Feed | 30.474 | 214,027 | 676,635 | 676,635 | 676,635 | 676,635 | 676,635 | 676,635 | 676.635 | 676.635 |
| Utilxties |  |  |  |  |  |  |  |  |  |  |
| Water pumping | 29.192 | 113,212 | 307,001 | 307,001 | 307,001 | 307,001 | 307,001 | 307,001 | 307,001 | 307,001 |
| Water aeration | 31,870 | 116,439 | 310,046 | 310,046 | 310,046 | 310,046 | 310,046 | 310,046 | 310,046 | 310,046 |
| Automatic feeders | 3.597 | 9,038 | 21,586 | 21,586 | 21,586 | 21,586 | 21,586 | 21,586 | 21,586 | 21,586 |
| Total variable cost | 120,509 | 483,893 | 1,360,910 | 1,360,910 | 1,360,910 | 1,360,910 | 1,360,910 | 1,360,910 | 1,360,910 | 1,360,910 |
| Total annual cost | 713,337 | 1,315,250 | 2,433,327 | 2,488,501 | 2,442,487 | 2,133,761 | 2,011,641 | 1,708,135 | $1.708,120$ | 1,676,193 |

Table 12
Annual Production, Sales and Revenues at Maturity

| Total Number of Broo Marketing Strategy: | ds tock: 10 <br> percent hatch sold $=$ <br> percent fry sold $=$ <br> percent fingerlings <br> percent 3 year old f | $\begin{aligned} & \$ .15 \text { each } \\ & 45 \text { each } \\ & 50 \text { at } \$ 1.25 \text { e } \\ & 1=100 \text { at } \$ 4 \end{aligned}$ | pound |
| :---: | :---: | :---: | :---: |
| Production Stage | Number Produced | Number Sold | Revenue |
|  |  |  | (dollars) |
| Hatchling | 808,582 | 404,291 | 60,644 |
| Fry | 254,007 | 12, 004 | 57,152 |
| Fingerling | 95,021 | 47,511 | 59,389 |
| 3 year old fish | 47,502 | 47,502 | 3,105,168 |

## SIMULATION EXPERIMENTS

The base model analysis provides a starting point for study of the effect on measures of economic performance of changes in the planning variables specified for the base model. Simulation experiments permit the alteration of the decision variables of the base model facility in order to draw inferences about the relationships between the altered variable(s) and the system's performance.

Various types of simulation experiments are possible; however, the ones presented here focus on the effects of changes in plant capacity and marketing strategies. There is little doubt that the management decision on stocking density has an important effect on costs of production. However, biological data on the interactions between stocking density and growth and mortality rates are not available; therefore, this experiment was omitted.

In addition to the plant capacity of 10 broodstock used in the base model, the process was also simulated using size levels of 5,15 and 20 broodstock. These changes were also considered in the context of different marketing strategies or product mixes. The base model facility sells 50 percent of remaining production from a given cohort of
fish at each of the three initial stages of growout and all remaining fish at the end of three years. Four altemative marketing strategies were examined for each of the four plant sizes: marketing 10 percent, 25 percent, 75 percent and 90 percent of remaining production at each selling stage (with all remaining fish sold at the end of three years' growout).
Results of simulations varying only the plant capacity (holding marketing strategy constant) will be reported first, followed by the results of the experiments varying only marketing strategy while holding size at the base model level. Finally, the results of varying both diliensions will be discussed.

For the first two discussions, the ATC per unit of production of the base model facility serves as the performance measure against which the outputs from simulation experiments are compared. ${ }^{5}$ Rather than replicate the individual 10 -year format of costs shown for the base model in Table 9a for each simulation experiment, we have presented in Table 15 the 10-year simple averages of the ATC for the various experiments.

[^7]Total Number of Broodstock; 10 Marketing Strategy: 50 percent

|  | Year of Operation |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Revenue | 177,184 | 177.184 | 3,282,353 | 3,282,353 | 3,282,353 | 3,282,353 | 3,282,353 | 3,282,353 | 3,292,353 | 3,282,353 |
| Total annual cost | 713,335 | 1,315,250 | 2,433,327 | 2,488,501 | 2,442,487 | 2,133,761 | 2,011,641 | 1,708,135 | 1,708,120 | 1,676,193 |
| Nef loss or income | $-536.151$ | $-1,138,066$ | 849,026 | 793,852 | 839,866 | 1,148,592 | 1,270,712 | 1,574,218 | 1,574,233 | 1,606,160 |
| Income tax | 0 | 0 | 0 | 0 | 0 | 482,829 | 584,438 | 724,050 | $724,0.77$ | 73,874 |
| Net income after tax | -536, 151 | $-1,138,066$ | 849,026 | 793,852 | 839,866 | 665,763 | 686,275 | 850,168 | 850,176 | 867,416 |

Table 14
Cash Inflow and Outflow for the Base Nodel Facllity

```
Number of Broodstock: }1
Marketing strategy: 50 percent
```

| Item | Year of Operation |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 6 | 9 | 10 |
| Net Income after tax | $(536,151)$ | $(1,138,066)$ | 849,026 | 793,852 | 839.866 | 665,763 | 686,275 | 850,168 | 850,176 | 867.416 |
| Equipment deprectasion | 268,138 | 459,644 | 683,428 | 762,577 | 741,982 | 459,710 | 339,193 | 39,674 | 39,664 | 32,966 |
| Butlding deprectation | 253,167 | 279,949 | 232,818 | 208,843 | 183,424 | 156,970 | 155,367 | 151,375 | 151,375 | 126,146 |
| Cash inflow | $(14,840)$ | (402,473) | 1,765,272 | 1,765,272 | 1,765,272 | 1,282,443 | 1,180,835 | 1,041,222 | 1,041,215 | 1,026,528 |
| Cash outflow | 4,466,523 | 1,521,980 | 3,791,286 | 1,500 | 1,500 | 1,500 | 1,500 | 1,500 | 1,500 | 1,500 |

asee Table 5 for detailed presentation of investment costs.

## Economies of Size

Given the 50 percent marketing strategy of the base model, changes in facility capacity result in equally proportionate changes in production and revenue. (See Appendix 9a-c for production levels of the various sizes of facilities.)

The effect of changes in capacity (i.e., the number of broodstock handled each spawn season) on ATC is shown in the first section of Table 15. As illustrated in Figures 3 and 4 , the production costs of hatch, fry, fingerling and 3 -year-old fish exhibit economies of size. The long-run average cost curves in Figures 3 and 4 were constructed from the average ATC values in Table 15. For the stages of hatch, fry and fingerling, the ATC per unit of production decreases as facility capacity increases from 5 to 20 broodstock. The ATC per 3-year-old fish decreases over a narrower range from 5 to 15 broodstock capacity. After a capacity of 15 broodstock, there is no apparent reduction in ATC.

The proportionate reduction in ATC, in response to increases in capacity of the facility, is greatest for the production of hatchlings, followed by fry, fingerlings, and 3 -year-old fish. When the smallest facility ( 5 broodstock capacity) is compared with the largest ( 20 broodstock capacity), there is on average a 37.5 percent difference in the ATC per hatchling, a 26.8 percent difference in the ATC per fry, and differences of 8 percent and 0.3 percent in the ATC per fingerling and 3-year-old fish respectively. ${ }^{6}$

## Cost per Hatchling

The production of hatchlings (i.e., broodstock fishing, spawning activities, and incubation) exhibits the greatest economies of size mainly because increased production requires little additional equipment (Appendix 9d-f). The number of broodstock holding tanks increases proportionately, but no new aeration systems, fishing equipment or incubation systems are required as capacity increases from 5 to 20 broodstock. Additional broodstock tanks result in increased building square footage requirements; however, since increased production does not require further square footage for additional incubation systems, there is a less-than-proportionate increase in building cost (and, therefore, property taxes, insurance, and maintenance) for hatchery operations when production is increased (Appendix 9g-i).

Expenditures for some joint equipment items such as office and laboratory equipment, small tools and trucks remain constant regardless of production level; however, the costs of the emergency generator, wells, and nitrogen stripping towers are influenced by production levels. Changes in the cost of joint equipment which accompany
changes in production level (Appendix 9j-1) reflect the combined changes in requirements for all four stages of production. Since the total cost of joint equipment is equally apportioned among the four production stages, the economies in joint equipment costs are shared equally among the four stages. Hence one-quarter of these cost savings are attributed to hatchery operations. ${ }^{7}$

## Cost per Fry

As was the case with hatchery operations, economies of size in the production of fry (i.e., hatch to 1 -month growout) are largely the result of more intensive and better utilization of the capacity of existing equipment. This is apparent from comparison of the equipment requirements (for hatch to 1 -month growout) listed in Table 2 with those listed in Appendix 9d-f. The model assumes spawning activities can be carried out any time during an 8 -week period (i.e., the months of March and April). Hatchlings are maintained in larval tanks for a 1-month period, at the end of which they are transferred to a 12 foot diameter tank. Thus a larval tank can be used more than once during an 8 -week spawning period. This is why (despite a constant stocking level of 25,000 hatchlings per larval tank) the number of larval tanks required increases less than proportionately as production expands. Similarly, the additional building square footage required to accommodate these larger number of larval tanks is a source of economies since it too increases less than proportionately with increased production (Appendix 9 g -i). Only one freezer and one aeration system are required by the four different size facilities.

## Cost per Fingerling

Economies of size associated with the production of 3-month-old fingerlings is greatly diminished compared to the economies realized in hatchery operations and growout to one month of age. This results primarily rocause the requirements for 12 -foot diameter tanks and automatic feeders increase more than proportionately as production expands (Appendix 9d-f). Because equipment is purchased in discrete units with a given capacity per unit of input, increases in production levels can be associated with greater-than-proportionate increases in input requirements. The 12-foot diameter tanks are housed indoors; thus there are also more-than-proportionate increases in building requirements as production increases. A capacity expansion from 5 to 10 broodstock is associated with a proportionate increase in aeration system requirements for 12 -foot diameter tanks; some cost savings (in aeration systems) occur when capacity expands from 10 to 15 and from 15 to 20 broodstock.

[^8]
# Average Total Costs Per Fish of Producing <br> Sturgeon to Varlous Stagee of Growout ${ }^{\text {a }}$ 

| Item | Average Total Cost for Production Stage: |  |  |  |
| :---: | :---: | :---: | :---: | :---: |
|  | $\frac{\mathrm{I}}{\text { Hatchling }}$ | $\begin{aligned} & \text { II } \\ & \text { Fry } \end{aligned}$ | $\begin{gathered} \text { III } \\ \text { Fingerling } \end{gathered}$ | $\begin{gathered} \text { IV } \\ \text { 3-year-old fish } \end{gathered}$ |
| 1. Size or broodstock capacity |  |  |  |  |
| 5 | . 048 | . 228 | 1.87 | 43.42 |
| 10 (Base Mode1) | . 036 | . 185 | 1.77 | 43.34 |
| 15 | . 032 | .172 | 1.73 | 43.31 |
| 20 | . 030 | . 167 | 1.72 | 43.31 |
| 2. Marketing Strategy (percent sold) |  |  |  |  |
| Sell 10 | .131 | . 467 | 2.31 | 43.78 |
| 25 | . 083 | . 332 | 2.06 | 43.56 |
| 50 (Base Mode1) | .036 | . 185 | 1.77 | 43.34 |
| 75 | . 019 | .135 | 1.75 | 43.24 |
| 90 | . 016 | .178 | 2.65 | 39.52 |

a These figures are averages of 10 years of hatchery operations.


Figure 3. Long-run average cost curves for the production of hatchlings and 1-month fry (50 percent marketing strategy).


Size (capacity) of facility in number of broodstock

Figure 4. Long-run average cost curves of the production of fingerlings and 3-year-old fish ( 50 percent marketing strategy).

When annual operating costs for 1 - to 3 -month growout are compared for the different size facilities (Appendix $9 \mathrm{~m}-\mathrm{o}$ ) there are no cost savings. In fact, as facility capacity expands, the per-unit costs of labor, water pumping, and aeration increase slightly. The overall lack of savings in equipment, building, and operating costs seemingly contradicts the data of Table 15 which indicate that ATC per fingerling is reduced with increasing production. However, recall that a portion of the total costs associated with earlier production stages serving as inputs is incorporated in the successive production stages which utilize them. The same is true for any cost savings. Thus the reductions in ATC per fingerling which accompany increased production reflect a portion of the cost savings associated with the production of 1-month-old fry. (Similarly, ATC per fry includes a portion of the cost savings derived by hatchery operations as production increases; and ATC per 3-year-old fish incorporates some of the cost savings associated with fingerling production.)

## Cost per 3-Year-Old Fish

As facility capacity is increased, the production of 3-year-old fish requires a more-than-proportionate increase in the number of 12 - and 30 -foot diameter tanks; however, there are less-than-proportionate increases in aeration system requirements (Appendix 9d-f). As facility capacity expands, additional aeration systems are required only if the increased number of tanks exceeds the unused capacity of the existing aeration system. Table 4 and Appendix 9 g -i break down building square footage requirements for the production of 3 -year-old fish into separate requirements for growout period from: (1) 3 months to 1 year of age, (2) 1 to 2 years of age, and (3) 2 to 3 years of age. The sum of these separate building requirements increases more than proportionately when production increases. As with the other three production stages, one quarter of the cost savings associated with joint equipment is assigned to the production of 3 -year-old fish.

Annual operating costs have also been separately identified for the growout periods from 3 months to 1 year of age, 1 to 2 years of age, and 2 to 3 years of age. Increasing production leads to aeration cost savings, resulting from better utilization of the capacity of the aeration systems.

## Alternative Marketing Strategies

In this series of simulations, all facilities begin operations with the same number of broodstock as the base model facility (10). Thus broodstock fishing, spawning and incubation activities under different marketing strategies duplicate those of the base model facility. The production of fry, fingerlings, and 3-year-old fish (and associated costs of production) will differ according to marketing strategy. Appendix 10a-d describes the production resulting from
the alternative marketing strategies examined. Appendix 10 e lists the average value (over 10 years of operation) for fixed, variable, and total costs of production associated with each production stage. As the marketing strategy increases the proportion of production sold, input requirements are reduced as the numbers of fry, fingerlings, and 3 -year-old fish produced decrease. Thus ATC will decrease only if reductions in the amount of fry, fingerlings, or 3-year-old fish produced are accompanied by more-thanproportionate reductions in total cost. The percent reduction in output and associated costs when marketing strategy is increased from 10 percent to 25 percent, 25 percent to 50 percent, 50 percent to 75 percent and from 75 percent to 90 percent are presented in Appendix 10f. For example, 457,213 fry are produced when a facility follows a 10 percent marketing strategy; 381,011 fry are produced under a 25 percent marketing strategy. Thus, as indicated in Appendix 10f, when the percent production sold increases from 10 percent to 25 percent, fry production is reduced by 16.67 percent ( $1-(381,011 / 457,213)$ ). Percent reductions in fixed cost, variable cost, and total cost are similarly calculated from cost information in Appendix 10 e. In general, percent reductions in output are accompanied by even greater percent reductions in the total cost of production.

The ATC per unit of production changes (see Table 15) as the marketing strategy of a facility increases the percentage of production sold at the stages of hatch, fry, and fingerling. ATC per hatchling consistently decreases as the percent production sold increases from 10 percent to 90 percent. At the 10 percent marketing strategy, the average ATC per hatchling over 10 years of operation is 3.6 times that of the base model ATC. At the 25 percent marketing strategy, the ATC per hatchling is on average 2.3 times that of the base model. At the 75 percent and 90 percent marketing strategies, ATC per hatchling is less than the base model value by an average of 47.2 percent and 55.6 percent, respectively.

Over the 10 percent to 75 percent marketing strategy range, ATC per fry decreases; but at the 90 percent marketing strategy it reverses this trend and increases (see Table 15). At the 10 percent and 25 percent marketing strategies, ATC per fry is an average (for the 10 -year period of operations) of 2.50 and 1.78 times greater than the base model ATC. At the 75 percent marketing strategy ATC per fry is reduced by an average of 27.6 percent (as compared to base model ATC per fry); at the 90 percent marketing strategy it is reduced by an average of 4.9 percent.

As the percent production sold increases up to (and including) 75 percent, ATC per fingerling decreases. At the 10 percent and 25 percent marketing strategies, ATC per fingerling is an average of 30.5 percent and 16.4 percent higher than the base model ATC (see Table 15). There is not a great difference in ATC per fingerling when the base
model facility (i.e., the 50 percent marketing strategy) is compared with a facility following a 75 percent market strategy, but at the 90 percent marketing strategy ATC per fingerling reaches its highest level (for all the marketing strategies examined) and is an average of 51.4 percent greater than the base model ATC per fingerling. This discrepancy will be discussed below.

The ATC per 3 -year-old fish shows a slight reduction as the marketing strategy increases the proportion sold for a given stage of production from 10 percent to 90 percent; however, the average reductions in ATC are relatively small as indicated in Table 15.

## Cost per Hatchling

The production of hatchlings is identical to that of the base model facility regardless of the marketing strategy followed by a facility (Appendix 10a-d). Base model equipment requirements and operating costs for production of hatchlings listed in Tables 2 and 8 are repeated at the various marketing strategies as indicated in Appendices $10 \mathrm{e}-\mathrm{h}$ and $10 \mathrm{k}-\mathrm{n}$. ATC and AVC per hatchling are based on the total number of hatchlings produced (which is constant at 808,582 hatchlings per year) not the number retained. Since annual operating costs remain constant at the various marketing strategies, so does AVC per hatchling. While marketing strategy does not influence the amount of hatchlings produced or equipment requirements specific to hatchery operations (compare equipment requirements for hatchery operations in Table 2 with those in Appendix $10 \mathrm{e}-\mathrm{h}$ ), it does directly determine the proportion of hatchlings, fry, and fingerlings sold versus retained for continued growout, and hence affects equipment and operating costs for the subsequent growout of hatchlings not sold. However, the economies in joint equipment requirements produce a reduction in ATC per hatchling as the marketing strategy increases the proportion of a production sold despite the fact that operating costs and equipment requirements specific to hatchery operations remain constant.

## Cost per Fry

As the proportion of production sold is increased from 10 percent to 25 percent, 25 percent to 50 percent and from 50 percent to 75 percent, the percent reduction in total cost of fry production exceeds the percent reduction in fry produced. Thus ATC per fry decreases as shown in Table 15. The percentage reductions in fixed costs are large, due principally to reduced requirements for emergency generator capacity, wells, and nitrogen stripping towers (Appendix 10i-1). Percent reductions in the cost of joint equipment exceed percent reductions in fry production. For example, when marketing strategy changes the percent
sold from 10 percent to 25 percent, production of fry is reduced by 16.67 percent and the cost of joint equipment falls by 41.3 percent.

Previously, increases in the percent production sold resulted in greater than proportionate reductions in the cost of joint equipment; however, when changing from a 75 percent to 90 percent marketing strategy, the number of larval tanks required decreases, but freezer and aeration system requirements remain unchanged (Appendix $10 \mathrm{e}-\mathrm{h}$ and Table 2). Thus, these equipment costs are reduced less than proportionately as compared to reductions in fry production (and the disparity increases as the percent output sold increases). When this occurs ATC will increase.

## Cost per Fingering

As the proportion of production sold increases from 10 percent to 75 percent, percent reductions in the number of fingerlings produced are associated with even greater percent reductions in the total cost of fingerling production. Thus the ATC per fingerling falls as marketing strategy changes from 10 percent to 75 percent (as indicated in Table 15). Reductions in fixed coxts, largely the result of reduced joint equipment requirements (described previously), account for the savings in total costs (Appendix 10i-1 and Table 3).

When 90 percent of output is sold instead of 75 percent, the resultant percent reduction in the number of fingerlings produced exceeds percent reduction in fixed costs, variable costs, and thus total costs. Hence ATC and AVC per lingerling both increase (Table 15). Although joint equipment requirements are reduced, they are not a source of relative cost savings in this case. In fact, the annual cost of joint equipment allocated to fingerling production is largely responsible for the increase in ATC per fingerling observed when marketing strategy changes from 75 percent to 90 percent. The cost of joint equipment associated with the 75 percent and 90 percent strategies is converted into annual depreciation costs in Appendices 10 q and 10 r . The annual cost of joint equipment for fingerling production in year is calculated as: 25 (Annual joint equipment cost in year i)/(Number of fingerlings produced in year i). Depending upon the year of operation, this cost ranges from $\$ .13$ to $\$ .45$ under the 75 percent marketing strategy, and from $\$ .54$ to $\$ 1.99$ under the 90 percent marketing strategy. Requirements for 12 -foot diameter tanks and automatic feeders are reduced proportionately in comparison to fingerling output, but aeration system requirements are not (Appendix 10i and 10 j . This occurs because the model specifies aeration systems can only be purchased in discrete units. As a result, the 69.16 percent reduction in the cost of water aeration is also less than the 75 percent reduction in fingerling output. ${ }^{8}$

[^9]
## Cost per 3-Year-Old Fish

Over the range of alternative marketing strategies examined, each incremental increase in percent output sold, produces reductions in ATC. The percent reductions in total and variable costs just slightly exceed the percent reductions in output of 3 -year-old fish and thus result in only small decreases in ATC (see Table 15).
When the proportion of output sold increases, accompanying reductions in equipment requirements produce savings in fixed costs (Appendix 10e-h). Recall fish are cultured in 12 -foot diameter tanks from the ages of 1 to 3 months. Three-month-old fingerlings not sold continue growout in 12 -foot diameter tanks until the age of six months when they are then transferred to 30 -foot diameter tanks. In some cases, additional 12 -foot diameter tanks (in excess of those required for growout from one to three months of age) may be necessary to accommodate growout of fingerlings to 6 months of age at the desired stocking density. When the marketing strategy changes from 10 percent to 25 percent and from 25 percent to 50 percent, reductions in the required number of 12 -foot diameter tanks (for the continued growout of retained fingerlings) produces cost savings. Furthermore, at the 75 percent and 90 percent marketing strategies, the number of 12-foot diameter tanks required for growout from one to three months of age is sufficient for the continued growout of retained fingerlings. Hence no additional 12 -foot diameter tanks need be purchased. The number of 30 -foot diameter tanks required changes in proportion to changes in output. One aeration system has capacity for four $30-$ foot diameter tanks. Thus, situations of excess aeration capacity are more likely to be avoided since a reduction of only four 30 -foot diameter tanks eliminates one aeration system.

## Economies of Size and Product Mix

In this part of the analysis, both size and product mix were altered. Given the four size categories and the five marketing strategies, 20 combinations were evaluated. The results can be considered as points on a multi-dimensional cost (revenue or rate of return) surface encompassing these dimensions. From such a surface, management can then analyze the outcomes of different planning options and select that option which best meets its objective function (e.g., highest profit, best rate of retum, etc.).

The isolated effects of size and marketing strategies considered ATC. Here, however, we shall view total cost, total revenue and rate of retum. Because costs vary from year to year, one year (year 5) was selected as representative for cost and revenue evaluation purposes.
The results of the 20 model formats are given in Tables 16 through 21. For analytical exposition, functional relationships for these "surfaces" were estimated and will be reported below. Based on the tables of results, the
general premise was that cost, revenue and rate of return were related to management decisions regarding size, marketing strategy. A variety of functional forms and transformations of variables was considered. An interaction (cross product) term for size and marketing strategy was utilized as was a squared term for marketing strategy where appropriate. The functional forms included regular linear relationships, nonlinear relations using a squared term, logarithmic relationships, and transcendental functions. Selection of the functional results presented here relied for the most part of comparisons of the coefficients of determination ( $\mathrm{R}^{2}$ values) and the mean absolute deviation of predicted from actual values.

Reliance on coefficients of determination in engineering economics studies, however, can be erroneous. Relatively high $\mathbf{R}^{2}$ values are to be expected since the performance measures from the systems model generally follow directly from the model builder's specifications of the internal operations of the system. Therefore, evaluation is needed with respect to the predictive ability of the resulting functions as well as whether the predictions yield "reasonable" results (e.g., nonnegative forecasts).

## Joint Output

As a possible single measure of production, a firm's biomass output was defined as simply the kilograms of fish produced, regardless of product mix. Of course, this is an imperfect measure if one considers all combinations of plant size and marketing strategies because different combinations of marketing strategies and size could yield the same biomass for different cost levels. However, for the divergent set of marketing strategies used here, the problem did not occur.

Given the biological functions, biomass would be expected to increase with the size of the plant. On the other hand, as the marketing strategy calls for higher percentages to be sold at each stage, biomass would be expected to decrease. As evident from Table 16, production behaves as expected, reaching a peak for the largest scale of operation with the lowest marketing percentage and dropping rapidly as larger percentages of fish are sold at younger ages.

The general functional relationship considered initially was

> Biomass $=\mathrm{f}$ (size, strategy, strategy squared, interaction)
where biomass $=$ kilograms of fish produced each year at full production
size = number of broodstock
strategy = percent of fish marketed at initial three selling stages (e.g., 10,25 , etc.)
interaction $=($ size $) \times($ strategy $)$

## Table 16

## Aggregate Production (kilograms) of all Fish by Plant Capacity and Product Mix

| Marketing Strategya | Plant Capacity (No. of Broodstock) |  |  |  |
| :---: | :---: | :---: | :---: | :---: |
|  | 5 | 10 | 15 | 20 |
| 10 | 1,027,100 | 2,054,300 | 3,081,400 | 4,108,500 |
| 25 | 594,740 | 1,189,500 | 1,784,300 | 2,379,000 |
| 50 | 176,530 | 353,060 | 529,610 | 706,140 |
| 75 | 22,180 | 44,378 | 66,570 | 88,763 |
| 90 | 1,444 | 2,895 | 4,346 | 5,798 |

an Tables $16-23$, marketing strategy means the percent sold in each size category through the fingerling stage, All remaining fish are sold at three years of age.

Table 17
Total Production Costs by Plant Capacity and Product Mix (year 5)

| Marketing Strategy | Plant Capacity (No. of Broodstock) |  |  |  |
| :---: | :---: | :---: | :---: | :---: |
|  | 5 | 10 | 15 | 20 |
| 10 | 6,834,772 | 13,647,095 | 20,464,917 | 27,277,584 |
| 25 | 3,999,572 | 7,976,890 | 11,954,669 | 15,931,013 |
| 50 | 1,234,813 | 2,442,487 | 3,651,578 | 4,862,587 |
| 75 | 193,333 | 358,780 | 523,617 | 688,042 |
| 90 | 40,521 | 57,313 | 73,347 | 91,532 |

## Total Revenue by Plant Capacity and Product Mix (year 5)

| Marketing Strategy | Plant Capacity (No. of Broodstock) |  |  |  |
| :---: | :---: | :---: | :---: | :---: |
|  | 5 | 10 | 15 | 20 |
| 10 | 9,090,472 | 18,181,140 | 27,271,872 | 36,362,540 |
| 25 | 5,310,061 | 10,620,316 | 15,930,509 | 21,240,700 |
| 50 | 1,641,176 | 3,282,353 | 4,923,660 | 6,564,901 |
| 75 | 272,065 | 544,196 | 816,328 | 1,088,460 |
| 90 | 79,359 | 158,783 | 238,209 | 317,633 |

Table 19
Average Total Cost Per Kilogram

| Marketing Strategy | Plant Capacity (No. of Broodstock) |  |  |  |
| :---: | :---: | :---: | :---: | :---: |
|  | 5 | 10 | 15 | 20 |
| 10 | 6.65 | 6.64 | 6.64 | 6.64 |
| 25 | 6.72 | 6.70 | 6.70 | 6.70 |
| 50 | 6.99 | 6.92 | 6.89 | 6.89 |
| 75 | 8.72 | 8.08 | 7.86 | 7.75 |
| 90 | 28.06 | 19.80 | 16.88 | 15.79 |

Table 20
Profit by Plant Capacity and Product Mix (Year 5) for Base Model Pricesa

|  | Plant Capacity (No. of Broodstock) |  |  |  |
| :---: | ---: | :---: | :---: | ---: |
| Marketing Strategy | 5 | 10 | 15 | 20 |
|  | - |  |  |  |
| 10 | $2,255,700$ | $4,534,043$ | $6,806,954$ | $9,084,956$ |
| 25 | $1,310,489$ | $2,643,426$ | $3,975,838$ | $5,309,685$ |
| 50 | 406,363 | 839,866 | $1,272,082$ | $1,702,314$ |
| 75 | 78,732 | 185,416 | 292,711 | 400,417 |
| 90 | 38,838 | 101,470 | 164,862 | 226,101 |

[^10]Table 21
Investment Requirements for First Three Years of Operation

| Plant Size | Year of Operation |  |  |
| :---: | :---: | :---: | :---: |
| Marketing Strategy | 1 | 2 | 3 |
| Size $=5$ |  |  |  |
| 10 | 10,310,885 | 4,450,451 | 11,056,219 |
| 25 | 6,394,722 | 2,585,445 | 6,388,998 |
| 50 | 2,336,221 | 764,093 | 1,896,393 |
| 75 | 635,891 | 86,455 | 244,951 |
| 90 | 284,709 | 1,500 | 17,620 |
| Size $=10$ |  |  |  |
| 10 | 20,424,202 | 8,901,755 | 22,108,586 |
| 25 | 12,588,098 | 5,155,623 | 12,792,616 |
| 50 | 4,466,524 | 1,521,980 | 3,791,286 |
| 75 | 1,016,027 | 187,530 | 474,635 |
| 90 | 344,079 | 17,620 | 15,267 |
| Size $=15$ |  |  |  |
| 10 | 30,544,480 | 13,350,706 | 33,163,304 |
| 25 | 18,748,372 | 7,723,448 | 19,193,882 |
| 50 | 6,594,134 | 2,284,573 | 5,686,179 |
| 75 | 1,383,424 | 288,605 | 704,319 |
| 90 | 403,936 | 31,387 | 29,034 |
| Size $=20$ |  |  |  |
| 10 | 40,622,384 | 17,802,010 | 44,229,440 |
| 25 | 24,927,856 | 10,307,393 | 25,583,732 |
| 50 | 8,733,713 | 3,044,813 | 7,581,072 |
| 75 | 1,777,964 | 375,913 | 947,770 |
| 90 | 468,344 | 29,034 | 45,154 |

Functions were estimated by ordinary least squares regression. While $\mathbf{R}^{2}$ values above .90 were obtained in many cases, the precise relationship estimated frequently did not predict well over the entire range of data. For example, negative values were forecast for some sizestrategy combinations. The equation yielding the best performance both in terms of $\mathrm{R}^{2}$ and prediction characteristics was transcendental with the following parameters:

$$
\begin{array}{r}
\ln (\text { biomass })=13.22454+\underset{(.01132)}{.09134 \text { Size }+} \quad .0221 \text { Strategy }- \\
(.01038)
\end{array}
$$

$$
.001 \text { Strategy² }
$$

$$
(.00001)
$$

$$
\mathrm{R}^{2}=.9894
$$

The figures in parentheses are standard errors.
This function behaves as expected. When size remains constant, biomass decreases with increased percentage marketed at the smaller weights.

Thus, even though various combinations of percentages and size could produce the same biomass, a strong relation is evident among these variables, a relationship which is useful in studying costs and revenues.

## Costs and Revenues

The simulation results for total costs and revenues are summarized in Tables 17 and 18. Both follow similar patterns, increasing with respect to size and decreasing with higher percentages of fish marketed at small sizes.

The economies of size reported for individual sizes of fish under the base model marketing strategy also persist over different strategies when considered on a perkilogram basis, as shown in Table 19. Given the nature of some of the equipment and joint cost items which may not vary much with marketing strategy, the per-unit costs go up as more fish are sold at smaller weights. The scale economies are much more pronounced, however, at the higher sales strategies.

Cost could be viewed as a function of the same variables used in the biomass relation, or, it could be analyzed as a function of biomass instead. Relations of both types were evaluated using the several functional forms described earlier. Again high $\mathrm{R}^{2}$ values were obtained; however, a linear form relating cost to biomass gave the best results in terms of both $\mathrm{R}^{2}$ and predictive performance.

Total cost $=75555.73917+6.62951$ Biomass
(.00917)

$$
\mathbf{R}^{2}=1.000
$$

where total cost = total annual cost excluding income tax for year 5 .

Fitting a function relating total revenue to biomass is not appropriate in this case because the nature (form) of
the functional relationship depends in a large measure on the price relations among the four sizes of sturgeon being sold. This aspect of the analysis will be discussed later under the sensitivity of the model's results to prices.
Profits for the currently specified set of prices, however, are shown in Table 20 for the various plant sizes and marketing strategies.
The implications of these functional relations for managerial decisions will be discussed following the results for the rate of return.

## Rate of Return

The rate of retum is one measure of the relative worth of an investment alternative. In this analysis, the rate of return was computed for the 10 -year planning horizon. A different time span would, of course, yield different results.
The annual cash flow used in calculating the rate of return was the net profit (loss) after income taxes with the depreciation charges then added back in.
The cash outflow is the annual investment requirement for land, buildings, and equipment. The initial investment in land, buildings and equipment is spread over the first three years of operations as the plant reaches maturity. After that point, a fixed charge for replacement of nets of $\$ 1,500$ per year is assessed for all plants.
Table 21 shows the investment requirements for the initial 3 -year period for the various plants considered. Investment is assumed to be made at beginning of the year cited.
The rate of return (see Table 22) shows a definite increase with the higher percentages of fish sold at small sizes and with larger scales of plants. In fact, the peak rate of return is associated with the limiting scale ( 20 broodstock) and marketing strategy ( 90 percent) used in this study. As seen in Table 21, the investment requirements for handling the smaller fish reflect a major reduction over the needs for similar plants which carry most of their output to adult size.
In relating the management decisions to the rate of return, a transcendental function showed the best predictive power with the following estimates:

$$
\begin{aligned}
& \ln (\text { rate })=.70553-.06117 \text { Strategy }+.0008 \text { Interaction }+ \\
& \text { (.00661) } \\
& \text { (.00001) } \\
& .00084 \text { Strategy }^{2} \\
& \text { (.00001) }
\end{aligned}
$$

$$
\mathrm{R}^{2}=.9812
$$

This equation illustrates that as size of plant is held fixed, the rate of retum increases (after a small initial decline) as larger percentages of fish are sold at the initial stages of growout. Similarly, as the product mix remains unchanged, the rate of retum increases slightly with size of facility through the interaction term.

# Rate of Return on Investment by Capacity and Product Mix 

| Marketing | Plant Capacity (No. of Broodstock) |  |  |  |
| :--- | :---: | :---: | :---: | :---: |
| Strategy | 5 | 10 | 15 | 20 |
|  | -1.15 | 1.21 | 1.22 | 1.24 |
| 25 | 1.01 | 1.12 | 1.16 | 1.18 |
| 50 | 0.92 | 1.26 | 1.39 | 1.43 |
| 75 | 2.22 | 4.72 | 5.77 | 6.21 |
| 90 | 9.01 | 19.76 | 25.72 | 30.10 |

## Implications

Evaluation of the above functions provides valuable information for long-run planning by management. The results demonstrate clearly that management at the outset of planning must define its objective function (or company goal) because the decisions from the above set of functions differ with the goals of management.

The linear cost and revenue functions indicate that the most profii is obtained with plant size at its largest level and marketing strategy at its lowest percentage-or, where biomass is the largest. This relation indicates that raising fish to larger weights is preferable in terms of profit before taxes.

However, operations with the greatest profits do not provide the highest rate of return on the investment. In this case, the rate of return increases as the size of plant goes up and as percentage sold rises. The latter condition is associated with a small biomass while the highest profit is related to a large biomass.

The above functions also permit management to consider trade-offs between profits and rate of returns. Thus, a firm with a lexicographic ordering of goals could seek the highest profit after a satisfactory rate of return had been achieved or vice versa. In this case, management could determine which combinations of size and product mix afforded satisfactory achievement of the restricting goal and then optimize their decision with respect to the second objective.

## Sensituity to Price Changes

The above discussion is conditioned on the specified set of prices received for the four sizes of sturgeon. If the relative or absolute levels of these prices change, the appropriate management decisions regarding marketing strategy and scale of plant may also change.

Several sets of prices were postulated to test the sensitivity of plant size and marketing strategy to these factors. Given the outcome of the base model with its initial set of prices, any reduction in the prices of hatchlings and/or fry would still leave the optimum strategy unchanged, although profits and rate of return would be reduced. The plants with the largest biomass ( 20 broodstock and a 10 percent marketing strategy) maintained the largest profit level.

However, when the price of 3 -year-old fish is reduced to $\$ 3$ per pound from the original $\$ 4$ per pound and all other prices remain unchanged, the most profitable marketing strategy becomes that of selling fish at smaller sizes (i.e., the 90 percent marketing strategy). The profit levels of the various combinations of sizes of plants and marketing strategies are given in Table 23. The table illustrates that scale of operation is still an important influence on protit but that, for each scale, marketing fish at smaller sizes provides the greatest profit-a decision strategy opposite from that reflected by the base price results in Table 20.

Thus, in its long run planning for capacity and marketing, management should carefully evaluate the projected prices at which the products can be sold.

Profit by Plant Capacity and Product Mix (Year 5) for Alternative Pricesa

| Marketing | Plant Capacity (No. of Broodstock) |  |  |  |
| :---: | ---: | :---: | :---: | :---: |
| Strategy | 5 | 10 | 15 | 20 |
| 10 | $-8,019$ | 6,556 | 15,682 | 29,916 |
| 25 | 473 | 23,347 | 45,710 | 69,509 |
| 50 | 18,217 | 63,574 | 107,611 | 149,681 |
| 75 | 30,228 | 88,392 | 147,167 | 206,352 |
| 90 | 35,749 | 95,276 | 155,563 | 213,697 |

[^11]
## CONCLUSIONS

The results from the simulations demonstrate that sturgeon production costs and rates of return are sensitive to both size of facility and product mix. Economies of size were exhibited over the range of capacities examined, while the rate of return was more sensitive to changes in marketing strategies. In addition, management marketing strategies based on profits were sensitive to prices of larger fish.

Given the price schedule and underlying functions utilized by the present systems model, the production of fingerlings (growout from one to three months of age) and fish (growout from three months to three years of age) should be evaluated carefully. This conclusion is supported by the relative increases in ATC for fingerlings as larger proportions of remaining fish are sold at each stage. And, as reflected by analysis of the multi-dimensional rate of return surface, marketing strategies which sell the majonty of production at the stages of hatch and fry give greater return than those which retain a majority of production for growout to three years of age, assuming the price relations used in the initial model.

This study examined simulation experiments relating to size and marketing strategies; however, numerous other situations involving changes in biological, economic, and/or operating conditions may be simulated. One can
hypothesize about the outcome of interactive effects by specifying change in more than one biological, economic, and/or operating condition of the systems model during a simulation experiment. For example, raising the stocking density level may simultaneously result in an increase in mortality and a decrease in growth rate. The net effect on the production and profitability of a facility is determined by the nature of these changes and their interactions with one another.
In this sense, the systems model in this study is a firstround version, based largely on experimental data. Due to the lack of information regarding the biological response of sturgeon to alternative intensive culture environments, operating conditions specified in the model are not necessarily the most economically efficient means of providing a suitable culture environment. Aquacultureoriented experiments are needed to better characterize oxygen and feed consumption, rexultant metabolite production and ensuing growth and suvival rates of sturgeon under intensive culture conditions. The impact of temperature changes on factors such as disease and mortality rates also needs study. A better understanding of oxygen consumption and metabolite praduction leading to improved delineation of stocking density levels and water flow rates also should be research prionities. Any possible
reductions in equipment (tanks, aeration systems) and joint equipment (wells, nitrogen stripping towers, emergency generator capacity) requirements which may result would be important moderators of production costs. This is particularly important in the production of fingerlings and 3 -year-old fish since the cost of utilities (for pumping and aerating water) and joint equipment are major components of ATC per unit for these two stages of production.

In the present systems model, input requirements are determined once the size and marketing strategy of the facility have been specified. Future economic research could examine situations where there is a discrepancy between the planned and actual number of broodstock obtained and/or marketing strategy implemented. What is the economic outcome if less broodstock are obtained than anticipated? What are the short-run costs (if any) of unused capacity should a facility increase its marketing strategy, selling a greater percentage of a given production stage(s) than originally planned?

Another item of prime economic importance in future
sturgeon research is the capability of producing sturgeon roe (used as the base for caviar) by growing female fish to larger sizes. Data in this study apply to fish 3 years of age or younger; to date (1986) female sturgeon rased at the U.C. Davis Aquaculture Facility have not reached sexual maturity. Given the luxury demand for caviar, the economic implications of adding roe as a joint product with adult female fish are sizable and should be studied in future research.

The value of simulation data at this early developmental stage of the systems model of sturgeon aquaculture lies in the nature of change predicted by the model rather than the precise quantitative aspects of change. The model is flexible and can readily incorporate new, additional information. Hence it serves as a starting point for revision, improvement, and elaboration. As the model building process contimues, resultant simulation experiments will more accurately assess the economic feasilibity of the production process.

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## APPENDICES

## Appendix A: Operating Procedures

Artificial propagation and culture of white sturgeon begins with broodstock collection during April and May when the animals migrate up river to their spawning grounds. Following capture, fish are transported back to the facility in a portable tank supplied with aerated water. Surgical techniques (Doroshov et al, (1983)) are used to determine the sex of the animal and stage of gonadal maturation. While in captivity, broodstock do not feed and are individually maintained in separate halves of a 1,795-gallon rectangular tank supplied with flowing water. ${ }^{9}$

Ovulation is hormonally induced in female broodstock with carp (Cyprinus carpio) pituitary extracts. If not already naturally occurring, a spermiation in male broodstock can also be hormonally induced. Two intramuscular injections are given at 12 and 24 hour intervals. Females receive a total dosage of 5 mg per kg of body weight; males, a total dosage of 1 mg per kg of body weight. Ova are collected from the female through a midventral incision. Sperm are collected by manual stripping and catheterization.

In vitro fertilization and incubation techniques for white sturgeon have been previously described by Doroshov $e t$ aL, (1983). Eggs are placed in bowls, then mixed with diluted sperm (1 part serninal plasma: 200 parts water). Following repeated washing with water, fertilized eggs are mixed with a suspension of silt. Silt particles adhere to the external jelly coat of eggs, thus preventing them from sticking to one another and forming clumps which would promote fungal growth and result in suffocation of the eggs.

The incubation system is comprised of 10 domedbottom plexiglass jars ( 3.4 -gallon), each with a capacity of holding approximately 70,000 eggs. The annual capacity of the incubation will exceed 700,000 eggs because more than one incubation run can be conducted during a spawning season. Each incubation jar receives sterilized flow-through water from an elevated head tank (Monaco and Doroshov, 1983). The flow of water through the incubation jar (see Appendix 1) rotates the eggs, promoting oxygenation and inhibiting fungal growth. Eggs hatch over
a 20 - to 35 -hour period after seven days of incubation at an average water temperature of $14.5^{\circ} \mathrm{C}$. Larvae swim vertically, exit the incubation jar through a spout, and are carried by a drain gutter to a holding trough.
From the holding trough of the incubation system, larvae are transferred to a 489 -gallon, square tanks with rounded comers at a density of 25,000 per tank where they remain for the first month posthatch. Newly hatched larvae obtain nutrition from a yolk sac and do not commence external feeding until approximately day 10 posthatch. Larvae are offered a semi-moist artificial feed ad libitum eight times daily for the first week of feeding. During the second week of feeding, larvae are gradually weaned form the semi-rnoist to a dry artificial feed. Not all larvae will accept an artificial feed; and of those that do, not all will be successfully weaned. Hence mortality is highest during this period. Larval tanks are cleaned twice daily to remove excess feed.
From the age of one to six months, animals are maintained indoors in 12 -foot diameter tanks; thereafter, they are reared outdoors in 30 -foot diameter tanks shaded by roofing (see Appendix 1 for water depth and flow rates). Feed is dispensed from automatic feeders for the 12 -foot and 30 -foot tanks. Animals are initially stocked at one-half the amount specified by a stocking density function. When growth and mortality result in a total biomass equal to that specified by a stocking density function, animals are transferred to a larger number of tanks, again at one-half the level dictated by the same stocking density function. The process is repeated until the animals are marketed.
Establishing the stocking density is an operating procedure which greatly influences the culture environment. In trout it was shown to be inversely related to growth rate and directly related to the feed conversion rate (Refstie, 1977). Increases in stocking density produce stress in channel catfish as measured by certain hematological parameters (Klinger, Delventhal, and Hilge, 1983).
The stocking density function reflects, in part, the metabolic processes of the fish. Typically, the metabolic rate per unit weight (measured in terms of oxygen consumption) decreases as size increases (Fry, 1971).

[^12]Smaller size fish have a greater metabolic rate than larger size fish and hence require a greater water volume per unit weight in order to obtain enough oxygen. In this context, the stocking density function expressed in grams of biomass (total body weight) per cubic foot of water (based on preliminary data from UC Davis) increases at a decreasing rate with the weight of the individual fish. The data used in estimating the relationship were observed densities used at the UC Davis aquaculture facility for sturgeon production. Data were not available on interactions of stocking density and mortality or feed consumption.
(1) Grams biomass per $\mathrm{ft}^{3}$ water $=48.9843$ (Weight) $)^{3072}$

$$
\begin{equation*}
\left(\mathrm{R}^{2}=.9971\right) \tag{.060}
\end{equation*}
$$

The weight variable is expressed in grams per fish. Figures in parentheses are the standard deviations for the coefficients.

The stocking density function is not applicable to incubation operations nor to production stage II. Larval tanks are stocked at a constant 25,000 hatchlings per tank.

Production is based on flow-through water derived from wells on site; no water is recirculated through any part of the facility. Sturgeon grow well in a relatively wide range of water temperatures; bence water is not heated and ranges in temperature from 13 to $20^{\circ} \mathrm{C}$. Flow rates vary with the stage of growout.
The level of nitrogen in the water can adversely affect the health of fish. Water is considered saturated with nitrogen gas when it contains all the dissolved gas it can hold at a given temperature and pressure (Gordon and Ford, 1972); however, under conditions of increased pressure (as may occur during pumping) groundwater may absorb even greater quantities of dissolved gas, becoming "supersaturated" with nitrogen. Fish cultured in water containing high levels of nitrogen gas may incur stress, increased susceptibility to secondary infections and gas bubble disease (Rucker, 1972; Bouck, 1980); therefore, all well water is first passed through a packed column aeration system (or "nitrogen stripping tower") prior to entering the hatchery and growout facility to reduce the dissolved nitrogen levels (Speece, 1981; Hackney and Colt, 1982; Marking, Dawson, and Crowther, 1983). A regenerative air blower system (described in Appendix 2) provides additional aeration of water.
The water used (as calculated in Appendix 3) is discharged without pretreament onto neighboring agricultural lands. Effluent water may require treaiment to meet state or Environmental Protection Agency water quality standards; however, this study does not consider alternative methods of eflluent treatment, nor the cosss of doing so.

## Appendix B: Biological Functions

The model's biological functions quantify the physical response of animals to the culture environment specified above. The biological functions in this study were based on data from the UC Davis aquaculture facility.

## Feed Requirements

The function estimating daily feed requirements per fish was provided by Doroshov (unpublished data from UC Davis aquaculture experiments).

> (2) Daily feed per fish (grams) $=0.056$ (Age) $)^{1.845}$
> ( $\mathrm{R}^{2}=.999$ )
> where age is expressed in months.

This feeding rate is based on ad libium feeding (i.e., animals are fed to satiety). Food ration and consumption levels are major determinants of body weight, however, given the assumption of ad libitum feeding, body weight may be expressed as a function of age. Hence the daily food ration is estimated so as to provide surplus food, and thus permit maximum weight gain rather than a particular rate of weight gain.

## Body Weight

「wo functions (estimated by ordinary least squares regression techniques) relate body weight of individual fish to age. The first applies to fish less than or equal to three months of age, the second to fish from three months to three years of age. (Data for estimation were supplied by UC Davis aquaculture facility.)
(3) Age $\leq 3$ mos: Ln weight (grams) $=-3.9674+$

23054 Age
( $\mathrm{R}^{2}=.9758$ )
(4) 3 mos. $<$ Age $\leq 3$ yrs: $\operatorname{Ln}$ weight (grams) $=$

$$
\begin{aligned}
& \ln 1.42+2.3888(\ln \text { Age }) \quad\left(\mathrm{R}^{2}=.9613\right) \\
& (.239)(.096)
\end{aligned}
$$

where age is expressed in months.
Body weight can be represented as a single exponential equation with relatively good statistical properties, however, equation 4 yields better predictive results for larger size fish. The body weights resulting from equations 3 and 4 closely coincide at the age of three months at which time the functions predict body weights of 19.08 and 19.59 grams respectively. The results from these equations describe exponential growth for the first three years of culture and are in general agreement with other data

Appendix Table 1
Tank and Water Requirements for Each Production Stage

| Activity | Tank | Hater Depth | Hater Volume | $\begin{gathered} \text { Water Flow } \\ \text { Rate } \end{gathered}$ | Dally Water Flow Per Tank | Ambient Hater Temperature |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | (feet) | (gallons/tank) | (dallons/min) | (gallons/day) | ( ${ }^{\circ} \mathrm{C}$ ) |
| Production Stage $I$ |  |  |  |  |  |  |
| Broodstock maintenance | 4* $\times 20^{\text {\% }}$ | 3.0 | 1,795 | 13.2 | 19,008 | 12-15 |
| Incubation (days 1-2) |  |  | $\begin{aligned} & \text { 3.4/incubation } \\ & \text { jar } \end{aligned}$ | 1.0 | $\begin{aligned} & \text { 1,400/incubation } \\ & \quad \text { jar } \end{aligned}$ | 14-16 |
| Incubation (days 3-7) |  |  | $\begin{aligned} & 3.4 / \text { incubation } \\ & \text { jar } \end{aligned}$ | 2.0 | $\begin{aligned} & \text { 2,880/incubation } \\ & \text { jar } \end{aligned}$ | 14-16 |
| Production Stage II | $6.6^{\prime} \times 6.6^{\prime}$ | 1.5 | 489 | 5.0 | 7,200 | 16-18 |
| Eroduction Stage III | 12* diameter | 1.5 | 1,269 | 10.0 | 14,400 | 12-20 |
| Eroduction Stage IV |  |  |  |  |  |  |
| 3-6 months | 12' diameker | 1.5 | 1,269 | 10.0 | 14,400 | 12-20 |
| 6-12 months | 30\% diameter | 2.5 | 13,218 | 40.0 | 57,600 | 12-20 |
| 12-24 months | 30* diameter | 3.5 | 18,507 | 51.4 | 76,016 | 12-20 |
| 24-36 months | $30^{\circ}$ diameter | 3.5 | 18,507 | 51.4 | 76,016 | 12-20 |

[^13]collected from growth experiments where white sturgeon were grown under similar conditions and fed natural (tubifex and Artemia salina), artificial or a combination of natural and artificial diets (Monaco, Buddington, and Doroshov, 1981). The present study does not address the issue of size distribution of fish at a given age; rather, expected values are utilized (i.e, all individuals of the same age are considered to be the same size). The data pertain to three annual cohorts of sturgeon; extrapolation of the biological functions beyond this age is inapproprate.

## Mortality

Based on experimental data from the UC Davis aquaculture program, most mortality was observed to occur within the first month posthatch (days $10-30$ ), the period when larvae most successfully initiate and maintain
external feeding on an artificial diet. After the age of 3.5 months (or a weight of approximately 30 grams) fish were relatively hardy and further mortality (through three years of growout) was negligible under the specified culure conditions. Mortality was fit by ordinary least squares regression as a logistic function of age in months with the following results:

Cumulative proportion dead $\mathrm{i}=\frac{53}{1+\mathrm{e}^{\mathrm{i} .7763}(20001 \mathrm{Am})}$
(.299)(.277)

$$
\mathrm{R}^{2}=.9171
$$

The cumulative proportion dead in month i becomes asymptotic to .53 ; thus, about 47 percent of the original hatch survive to 3 years of age.

Appendix Table 2
Aeration Syster Spectifations ${ }^{\text {a }}$

| Blower Size | Maximum Capacity Per Blower | Water Depth | Guble Feat A1. Per Tank | Fressuxe | $\operatorname{Cost}^{\text {b }}$ | KW Consumption |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| (horse pover) |  | (feet) |  | (psi) | (combars) |  |
| 2 | 12, $4^{\prime \prime} \times 20$, tanks | 3.0 | 9.0 | 2.5 | 2,075.88 | 2.7 |
| 3 | 17, 6.6' $\times 6.6^{\prime \prime}$ tanks | 1.5 | 6.0 | 1.6 | 1,707.43 | 1.9 |
| 3 | 8, 12' diam. tanks | 1.5 | 14.0 | 2.3 | 2,166.36 | 2.6 |
| 5 | 4. $30^{+}$diare \% ranks | 2.5-3.5 | 12.1 | 2.9 | 2,476,64 | 4.5 |

[^14]Annual Water Requirements for the Base Model Facilitya

| Activity | Annual Water Requirements |
| :---: | :---: |
| Production Stage I | (acre-feet) |
| Broodstock maintenance | 7.65 |
| Incubation | 1.73 |
|  |  |
| Production Stage II | 10.72 |
|  |  |
| Production Stage III | 139.18 |
|  |  |
| Production Stage IV |  |
| $3-12$ months | $1,563.28$ |
| $12-24$ months | $4,957.87$ |
| $24-36$ months | $11,435.12$ |

${ }^{\text {a Annual }}$ water requirements were calculated based on water flow rates, number and size of tanks and length of time tanks are occupied.

Appendix Table 4
Building and Outdoor Roofing Requirements

| Item | Building Space Per Itema | Outdoor Roofinga Per Item |
| :---: | :---: | :---: |
|  | ----------square |  |
| Broodstock tank (4' x 20') | 188 |  |
| Incubation system | 250 |  |
| Larval tank (6.6' x 6.6') | 100 |  |
| 12' diameter tank | 250 |  |
| 30' diameter tank |  | 1,600 |

[^15]
## Appendix Table 5

Labor Requif rements

| Activity | Number Hours Per Activity | Number of Persons Required | Total Number Labor Hours |
| :---: | :---: | :---: | :---: |
| Broodstock fishing ${ }^{\text {a }}$ | 12 | 3 | 36 |
| Spawning | 3 | 3 | 9 |
| Feeding larvae ${ }^{\text {b }}$ | 2 | 1 | 2 |
| Cleaning larval tanks ${ }^{\text {b }}$ | 1 | 1 | 1 |
| Transfer of fry from larval to $12^{\prime}$ diameter tank(s) ${ }^{\text {c }}$ | 1.5 | 2 | 3 |
| Transfer of fingerlings from $12^{\prime}$ to $12^{\prime}$ diameter tank(s)c | 1.5 | 2 | 3 |
| Transfer of fish from $12^{\prime}$ to $30^{\prime}$ diameter tank(s)c | 1.5 | 2 | 3 |
| Transfer of fish from $30^{\prime}$ to $30^{\prime}$ diameter tank(s)c | 1.5 | 2 | 3 |

[^16]
## Appendix 6a: Determination of Well Requirements and Costs

The cost of a well is comprised of: 1) the cost of digging a test and production hole, and 2) the cost of the pump. The model assumes for any size well, a flat fee of $\$ 5,625$ is charged for mobilization (moving of equipment to the well site) and the drilling and electric logging of the test hole.

Production capacity and the cost of drilling and the casing for the well vary with the size (diameter) of the well. They are estimated as follows:

| Well Diameter | Production Capacity | Cost |
| :---: | :---: | :---: |
| (inches) | (galion $/$ min) | $(\$ / \mathrm{ft})$ |
| 8 | 500 | 40 |
| 10 | 1,000 | 60 |
| 16 | 2,000 | 80 |

The model further specifies: 1) all wells are 400 feet deep, 2) a pump has an efficiency of 80 percent and can deliver 20 gallons of water per minute per hsp, and 3) purmp cost is estimated at $\$ 300$ per hsp.

Thus the number and total cost of wells required is estimated as follows:
(1) If the maximum water required (MWR) $\leq 500$ gallon/min:
(a) the number of wells requited $=1$
(b) well cost $=\$ 5,625+(\$ 40 / \mathrm{ft} \times 400 \mathrm{ft})$

$$
+\left(\frac{\text { MWR }}{20 \frac{\text { gallon } / \min }{\mathrm{hsp}}} \times \$ 300 / \mathrm{hsp}\right)
$$

(2) If 500 gallon $/ \mathrm{min}<\mathrm{MWR} \leq 1,000$ gallon $/ \mathrm{min}$ :
(a) the number of wells required=1
(b) well cost $=\$ 5,625+(\$ 60 / \mathrm{ft} \times 400 \mathrm{ft})$

$$
+\left(\frac{\mathrm{MWR}}{20 \frac{\text { gallon } / \mathrm{min}}{\mathrm{hsp}}} \times 8300 / \mathrm{hsp}\right)
$$

(3) If $1,000 \mathrm{gallon} / \mathrm{min}<\mathrm{MWR}$ :
(a) the number of wells required $=\mathrm{MWR} / 2,000$ gal$\mathrm{lon} / \min$ (rounded up to the next integer
(b) well cost $=$ ( Number of wells required $) \times(\$ 5,625$

$$
\begin{aligned}
& +(\$ 80 / \mathrm{ft} \times 400)+\left(\frac{\mathrm{MWR}}{20 \mathrm{gallon} / \mathrm{min}}\right. \\
& \times \$ 300 / \mathrm{hsp}))
\end{aligned}
$$

## Appendix 6b: KWH and KW Pumping Requirements

The model assumes:

1) Head (total feet well water is lifted) $=150$ feet
2) Efficiency of pump $\left(E_{p}\right)=0.80$
3) Efficiency of motor $\left(\mathrm{E}_{\mathrm{m}}\right)=0.80$
4) Overall efficiency of pumping ( $\left.\mathrm{E}_{\mathrm{p}} \times \mathrm{E}_{\mathrm{m}}=\mathrm{E}_{\mathrm{o}}\right)=0.64$
5) KWH required to pump $=1.024 \times \frac{\text { Head }^{4}}{\mathrm{E}_{0}}$

Hence $1.024 \times 150 / 0.64$ or 240 KWH are required to pump 1 acre foot ( 325,900 gallons) of water given the above assumptions. The annual KWH cost of pumping for a production stage can now be computed. For example, the annual water requirement for production stage II (base model facility) is 10.72 acre feet. Thus the associated KWH pumping cost is:

$$
\begin{aligned}
\$ 164.66= & 10.72 \text { acre feet } \times 240 \mathrm{KWH} / \text { acre foot } \\
& \times \$ 0.64 / \mathrm{KWH}
\end{aligned}
$$

The model determines KW demand as follows:
$10.92 \mathrm{KW}=10.72$ acre feet $\times 240 \mathrm{KWH} /$ acre foot $\times$
$4 \mathrm{KW} / 1,000 \mathrm{KWH}^{\mathrm{b}}$

[^17]Equipment Insurance Cost Schedule

| Equipment Value (EV) | Annual Cost of Insurance |
| :---: | :---: |
| EV < 50,000 | 350 |
| $50,000<\mathrm{EV} \leq 100,000$ | 650 |
| $100,000<\mathrm{EV} \leq 300,000$ | 1,050 |
| EV > 300,000 | $1,050+\$ 2$ per $\$ 1,000$ of equipment value in excess of $\$ 300,000$ |

Appendix Table 7b
Buflding Insurance Cost Schedule

| Buflding Value (BV) | Annual Cost of Insurance |
| :---: | :---: |
| BV $\leq 45,000$ | 415 |
| BV $>45,000$ | $415+$$\$ 9$ per $\$ 1,000$ of <br> buflding value fn <br> excess of $\$ 45,000$ |

Source: Industry estmates.

## Appendix Table 8a

## Unit Cost and Accelerated Cost Recovery Schedule (ACRS) Classification of Fixed Input Requirements

| Input Item | Unit Cost | ACRS Class |
| :---: | :---: | :---: |
|  | (dollars) | (years) |
| Boat | 16,000 | 5 |
| Fishing nets | 500 | 3 |
| Fish hauler | 1,100 | 5 |
| Broodstock tank | 1,595 | 5 |
| Broodstock tank aeration systen | 1,972 | 5 |
| Incubation system | 3,600 | 5 |
| Larval tank (6.6' $\times 6.6^{\prime}$ ) | 450 | 5 |
| Larval tank aeration system | 1,622 | 5 |
| Freezer | 600 | 5 |
| 12' diameter tank | 975 | 5 |
| 12' diameter tank aeration system | 2,059 | 5 |
| Automatic feeder | 345 | 5 |
| $30^{\prime}$ diameter tank | 5,000 | 5 |
| $30^{\prime}$ diameter tank aeration system | 2,353 | 5 |
| We 11 | See Appendix 6 a | 15 |
| Nitrogen stripping tower | 4,000 | 5 |
| Emergency generator | See Appendix 8c | 5 |
| Truck | 11,250 | 3 |

[^18]Accelerated Cost Recovery Schedule

| Year | ACRS Year Classification |  |  |
| :---: | :---: | :---: | :---: |
|  | 3 | 5 | 15 |
|  | Annual Percent Recoverable |  |  |
| 1 | 0.25 | 0.15 | 0.10 |
| 2 | 0.38 | 0.22 | 0.11 |
| 3 | 0.37 | 0.21 | 0.09 |
| 4 |  | 0.21 | 0.08 |
| 5 |  | 0.21 | 0.07 |
| 6 |  |  | 0.06 |
| 7 |  |  | 0.06 |
| 8 |  |  | 0.06 |
| 9 |  |  | 0.06 |
| 10 |  |  | 0.05 |
| 11 |  |  | 0.05 |
| 12 |  |  | 0.05 |
| 13 |  |  | 0.05 |
| 14 |  |  | 0.05 |
| 15 |  |  | 0.05 |

Source: Internal Revenue Service Publications 225 and 534 .

Appendix Table 8c<br>Eme rgency Generator Cost Schedule

| Emergency Generator Capacity | $\frac{\text { Cost/KW }}{(\mathrm{KW})}$ |
| :---: | :---: |
| KW capacity $\leq 15$ | 438 |
| $15<\mathrm{KW}$ capacity $\leq 60$ | 300 |
| $60<\mathrm{KW}$ capaity $\leq 125$ | 230 |
| $125<\mathrm{KW}$ capacity $\leq 500$ | 158 |
| $500<\mathrm{KW}$ capacity $\leq 1,000$ | 120 |

Source: Industry estimates.

```
        Appendix Table 9a
Production From a Five Broodstock Capacity Facility \({ }^{\text {a }}\) (Per Cohort of Fish)
```

Marketing Strategy: 50 percent

| Age | Body Weight | Number Produced | Number Sold | Production ${ }^{\text {b }}$ |
| :---: | :---: | :---: | ---: | ---: |
|  | (grams/fish) |  |  | $(\mathrm{kg})$ |
| Hatchling | $0.016^{\mathrm{c}}$ | 404,291 | 202,146 | 3.23 |
| 1 month | 0.19 | 127,003 | 63,502 | 12.06 |
| 3 months | 19.08 | 47,510 | 23,755 | 453.24 |
| 6 months | 102.60 | 23,571 | 0 | $2,436.85$ |
| 12 months | 537.32 | 23,571 | 0 | $12,761.85$ |
| 18 months | $1,415.41$ | 23,571 | 0 | $33,617.40$ |
| 24 months | $2,814.08$ | 23,571 | 0 | $66,837.21$ |
| 30 months | $4,795.52$ | 23,571 | 0 | $113,898.39$ |
| 36 months | $7,412.82$ | 23,571 | 23,751 | $176,061.89$ |

${ }^{\text {a }}$ For all stages after hatch, the number produced takes into account mortality and any previous production sold.
broduction retained for continued culture or sold at the end of 36 months growout.
cbased on mean weight of 12 larvae at hatch (Beer, 1981).

## Appendix Table 9b

Production From a 15 Broodstock Capacity Facility ${ }^{\text {a }}$ (Per Cohort of Fish)

Marketing Strategy: 50 percent

| Age | Body Weight | Number Produced | Number Sold | Production ${ }^{\text {(grams } / \mathrm{fish})}$ |
| :---: | :---: | :---: | ---: | ---: |
|  |  |  |  | (kg) |
| Hatchling | $0.016^{\mathrm{C}}$ | $1,212,873$ | 606,437 | 9.70 |
| 1 month | 0.19 | 381,011 | 190,506 | 36.19 |
| 3 months | 19.08 | 142,533 | 71,267 | $1,359.74$ |
| 6 months | 102.60 | 71,255 | 0 | $7,310.76$ |
| 12 months | 537.32 | 71,255 | 0 | $38,286.74$ |
| 18 months | $1,415.41$ | 71,255 | 0 | $100,855.04$ |
| 24 months | $2,814.08$ | 71,255 | 0 | $200,517.27$ |
| 30 months | $4,795.52$ | 71,255 | 0 | $341,704.78$ |
| 36 months | $7,412.82$ | 71,255 | 71,255 | $528,200.49$ |

[^19]Production From a 20 Broodstock Capacity Facility ${ }^{\text {a }}$ (Per Cohort of Fish)

Marketing strategy: 50 percent

| Age | Body Weight | Number Produced | Number Sold | Production ${ }^{\text {b }}$ |
| :---: | :---: | :---: | :---: | :---: |
|  | (grams/fish) |  |  | (kg) |
| Hatchling | $0.016^{\text {c }}$ | 1,617,165 | 808,583 | 12.94 |
| 1 month | 0.19 | 508,015 | 254,008 | 48.26 |
| 3 months | 19.08 | 190,044 | 95,022 | 1,813.02 |
| 6 months | 102.60 | 95,007 | 0 | 9,749.72 |
| 12 months | 537.32 | 95,007 | 0 | 51,049.16 |
| 18 months | 1,415.41 | 95,007 | 0 | 134,473.86 |
| 24 months | 2,814.08 | 95,007 | 0 | 267,357.30 |
| 30 months | 4,795.52 | 95,007 | 0 | 455,607.97 |
| 36 months | 7,412.82 | 95,007 | 95,007 | 704,269.79 |

[^20]Equipment Requirenents

Total Number of Broodstock: 5
Marketing Strategy: 50 percent

| Equipment | Number Required for Years 1-10 | Total Cost |
| :---: | :---: | :---: |
|  |  | (dollars) |
| Production Stage I |  |  |
| Boat | 1 | 16,000 |
| Fishing nets | 30 | 15,000 |
| Fish hauler | 1 | 1,100 |
| Brood tanks | 2 | 3,190 |
| Incubation system | 1 | 3,600 |
| Aeration system | 1 | 1,972 |
| Total |  | 40,862 |
| Production Stage II |  |  |
| Larval tanks | 5 | 2,250 |
| Freezer | 1 | 600 |
| Aeration system | 1 | 1,622 |
| Total |  | 4,472 |
| Production Stage III |  |  |
| 12-foot diameter tanks | 67 | 65,325 |
| Automatic feeders | 134 | 46,230 |
| Aeration system | 9 | 18,531 |
| Total |  | 130,086 |
| Production Stage IV |  |  |
| 12-foot diameter tanks | 67 | 65,325 |
| 30-foot diameter tanks | 225 | 1,125,000 |
| Automatic feeders | 584 | 201,480 |
| Aeration system (12-foot tanks) | 8 | 16,472 |
| Aeration system (30-foot tanks) | 57 | 134,121 |
| Total |  | 1,542,398 |

## Appendix Table 9e

Equipment Requirements

Total Number of Broodstock: 15
Marketing Strategy: 50 percent

| Number Required for |  |  |
| :---: | :---: | :---: |
|  |  | (dollars) |
| Production Stage I |  |  |
| Boat | 1 | 16,000 |
| Fishing nets | 30 | 15,000 |
| Fish hauler | 1 | 1,100 |
| Brood tanks | 6 | 9,570 |
| Incubation system | 1 | 3,600 |
| Aeration syster | 1 | 1,972 |
| Total |  | 47,242 |
| Production Stage II |  |  |
| Larval tanks | 13 | 5,850 |
| Freezer | 1 | 600 |
| Aeration system | 1 | 1,622 |
| Total |  | 8,072 |
| Production Stage III |  |  |
| 12-foot diameter tanks | 202 | 196,950 |
| Automatic feeders | 404 | 139,380 |
| Aeration system | 26 | 53,534 |
| Total |  | 389,864 |
| Production Stage IV |  |  |
| 12-foot diameter tanks | 202 | 196,950 |
| 30-foot diameter tanks | 677 | 3,385,000 |
| Automatic feeders | 1,758 | 606,510 |
| Aeration system (12-foot tanks) | 25 | 51,475 |
| Aeration system (30-foot tanks) | 170 | 400,010 |
| Total |  | 4,639,945 |

Equipment Requirements

Total Number of Broodstock: 20
Marketing Strategy: 50 percent

| Equipment | Number Required for Years 1-10 | Total Cost |
| :---: | :---: | :---: |
|  |  | (dollars) |
| Production Stage I |  |  |
| Boat | 1 | 16,000 |
| Fishing nets | 30 | 15,000 |
| Fish hauler | 1 | 1,100 |
| Brood tanks | 8 | 12,760 |
| Incubation system | 1 | 3,600 |
| Aeration system | 1 | 1,972 |
| Total |  | 50,432 |
| Production Stage II |  |  |
| Larval tanks | 17 | 7,650 |
| Freezer | 1 | 600 |
| Aeration system | 1 | 1,622 |
| Total |  | 9,872 |
| Production Stage III |  |  |
| 12-foot diameter tanks | 270 | 263,250 |
| Automatic feeders | 540 | 186,300 |
| Aeration system | 34 | 70,006 |
| Total |  | 519,556 |
| Production Stage IV |  |  |
| 12-foot diameter tanks | 269 | 262,275 |
| 30-foot diameter tanks | 903 | 4,515,000 |
| Automatic feeders | 2,344 | 808,680 |
| Aeration system (12-foot tanks) | 34 | 70,006 |
| Aeration system (30-foot tanks) | 226 | 531,778 |
| Total |  | 6,187,739 |

Appendix Table 9g
Land and Building Requirements
Total Number of Broodstock: 5 Marketing Strategy: 50 percent

| Production Period | Land |  |  | Building and Roofing |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Acres Required | Total Cost | Annual Tax | Square Feet Required | Total Cost | Annual Tax |
|  |  |  |  |  |  |  |
| Hatch production | 0.01 | 43.12 | 1 | 626 | 15,650 | 157 |
| Hatch to 1 month growout | 0.01 | 34.44 | 1 | 500 | 12,500 | 125 |
| 1 to 3 month growout | 0.38 | 1,153.74 | 12 | 16,750 | 418,750 | 4,188 |
| 3 month to 1 year growout | 2.59 | 7,766.22 | 78 | 80,750 | 741,830 | 7,418 |
| 1 to 2 year growout | 2.92 | 8,761.54 | 88 | 84,800 | 428,081 | 4,281 |
| 2 to 3 year growout | 7.27 | 21,821.18 | 218 | 211,200 | 1,066,164 | 10,662 |
| Office and lab building | 0.07 | 206.64 | 2 | 2,400 | 139,872 | 1,399 |
| Total | 13.25 | 39,786.88 | 400 | 397,026 | 2,822,847 | 28,230 |

# Appendix Table 9 h <br> Land and Building Requirements 

Total Number of Broodstock: 15
Marketing Strategy: 50 percent

| Production Period | Land |  |  | Building and Roofing |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | $\begin{gathered} \text { Acres } \\ \text { Required } \end{gathered}$ | Total Cost | Annual Tax | Square Feet Required | Total Cost | Anmual Tax |
|  | -----dollars -mmo-m |  |  |  | -----dollars----m |  |
| Hatch production | 0.03 | 94.92 | 1 | 1,378 | 34,450 | 345 |
| Hatch to 1 month growout | 0.03 | 89.54 | 1 | 1,300 | 32,500 | 325 |
| 1 to 3 month growout | 1.16 | 3,478.44 | 35 | 50,500 | 1,262,500 | 12,625 |
| 3 month to 1 year growout | 7.88 | 23,646.50 | 236 | 245,700 | 2,247,894 | 22,479 |
| 1 to 2 year growout | 8.76 | 26,284.61 | 263 | 254,400 | 1,284,243 | 12,842 |
| 2 to 3 year growout | 21.82 | 65,463.55 | 655 | 633,600 | 3,198,492 | 31,985 |
| Office and lab building | 0.07 | 206.64 | 2 | 2,400 | 139,872 | 1,399 |
| Total | 39.75 | 119,264.20 | 1,193 | 1,189,278 | 8,199,951 | 82,000 |

Total Number of Broodstock: 20 Marketing Strategy: 50 percent

| Production Period | Land |  |  | Building and Roofing |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Acres Required | Total Cost | Annual Tax | Square Feet Required | Total Cost | Annual Tax |
|  |  |  |  |  |  |  |
| Hatch production | 0.04 | 120.82 | 1 | 1,754 | 43,850 | 439 |
| Hatch to 1 month growout | 0.04 | 117.10 | 1 | 1,700 | 42,500 | 425 |
| 1 to 3 month growout | 1.55 | 4,649.40 | 46 | 67,500 | 1,687,500 | 16,875 |
| 3 month to 1 year growout | 10.53 | 31,595.26 | 316 | 328,300 | 3,004,051 | 30,041 |
| 1 to 2 year growout | 11.68 | 35,046.14 | 350 | 339,200 | 1,712,324 | 17,123 |
| 2 to 3 year growout | 29.09 | 87,284.73 | 873 | 844,800 | 4,264,656 | 42,647 |
| Office and 1 ab building | 0.07 | 206.64 | 2 | 2,400 | 139,872 | 1,399 |
| Total | 53.00 | 159,020.09 | 1,589 | 1,585,654 | 10,894,753 | 108,949 |

## Appendix Table 9 j

Joint Equipment Requirements

Total Number of Broodstock: 5
Marketing strategy: 50 percent

| Joint Equipment | Number Requifred for Yeaxs 1-10 | Total Cost |
| :---: | :---: | :---: |
|  |  | (dollars) |
| Emergency generator | 1 | 48,237 |
| Wells | 5 | 324,014 |
| Scripplng towers | 5 | 20,000 |
| Office and laboratory equipment |  | 10,000 |
| Small tools |  | 2,000 |
| Trucks | 2 | 22,500 |
| Total |  | 426,751 |

## Appendix Table $9 k$

Joint Equipment Requirements

Total Number of Broodetock: 15
Marketing Strategy: 50 percent

| Joint Equipment | Number Required for Years 1-10 | Total Cost |
| :---: | :---: | :---: |
|  |  | (dol1ars) |
| Emergency generator | 1 | 108,264 |
| Wells | 15 | 968,280 |
| Stripplng towers | 15 | 60,000 |
| Offlee and laboratory equipmenc |  | 10,000 |
| Small tools |  | 2,000 |
| Trucks | 2 | 22,500 |
| Tocal |  | 1,171,044 |

## Appendix Table 91

## Joint Equipment Requirements

Total Number of Broodetock: 20
Marketing Strategy: 50 percent

| Joint Equipment | Number Required <br> for Yeare $1-10$ | Tocal Cost |
| :---: | :---: | :---: |
|  |  | (dollars) |
| Emergency generator | 1 | 143,808 |
| Wells | 20 | 1,290,414 |
| Stripping towers | 20 | 80,000 |
| Office and laboratory equipment |  | 10,000 |
| Small tools |  | 2,000 |
| Trucks | 2 | 22,500 |
| Total |  | 1,548,722 |

Annual Operating Costs

Total Number of Broodstock: 5
Marketing Strategy: 50 percent

| Growout Period | Annual Operating $\operatorname{Cost}$ |
| :---: | :---: |
|  | (dollars) |
| Hatch Production |  |
| Fishing labor | 432 |
| Spawning labor | 162 |
| Fishing fuel | 134 |
| Pituitary extract | 185 |
| Water pumping | 80 |
| Water aeration | 275 |
| Maintenance | 204 |
| Total | 1,472 |
| Hatch to 1 Month Growout |  |
| Larval labor | 3,696 |
| Larval feed | 129 |
| Water pumping | 91 |
| Water aeration | 783 |
| Maintenance | 22 |
| Total | 4,721 |
| 1 to 3 Month Growout |  |
| Fry labor | 1,206 |
| Fry feed | 560 |
| Water pumping | 1,161 |
| Water aeration | 928 |
| Autofeeder operation | 193 |
| Maintenance | 650 |
| Total | 4,698 |
| 3 Month to 1 Year Growout |  |
| Finger labor | 1,926 |
| Finger feed | 14,458 |
| Water pumping | 13,156 |
| Water aeration | 14,426 |
| Autofeeder operation | 1,594 |
| Maintenance | 1,896 |
| Total | 47,456 |
| 1 to 2 Year Growout |  |
| Labor | 954 |
| Feed | 91,777 |
| Water pumping | 41,837 |
| Water aeration | 43,126 |
| Autofeeder operation | 2,709 |
| Maintenance | 1,673 |
| Total | 182,076 |
| 2 to 3 Year Growout |  |
| Labor | 2,376 |
| Feed | 231,304 |
| Water pumping | 96,683 |
| Water aeration | 97,109 |
| Autofeeder operation | 6,260 |
| Maintenance | 4,144 |
| Total | 437,876 |

Annual Operating Costs

Toral Number of Broodstock: 15
Marketing Strategy: 50 percent


## Appendix Table 90

Annual Operating Costs

Total Number of Broodstock: 20
Marketing Strategy: 50 percent
$\frac{\text { Growout Period }}{\text { Annual Operaring Cost }}$

| Hatch Production | 1,512 |
| :--- | ---: |
| Finhing labor | 648 |
| Spaming labor | 470 |
| E1shing fuel | 739 |
| Pituttary extract | 318 |
| Water pumping | 275 |
| Water aeration | 252 |
| MaIntenance | 4,214 |


| Hatch to 1 Month Growott |
| :--- |
| Laryal labor |
| Larval feed |$\quad 14,784$

arval feed ..... 517
Nater pumplig ..... 363
water aeration ..... 3,132
Malntenance ..... 49
Total ..... 18,845
1 to 3 Month Growout

| Fry labor | 4,860 |
| :--- | :--- |
| Fry fead | 2,239 |

Water pumplng ..... 4,732
ater aeration ..... 3,579
Autofeeder operation ..... 788
Maintenance ..... 2,598
Total ..... 18,796

| 3 Month to 1 Year Growout |  |
| :--- | ---: |
| Finger labor | 7,776 |
| Pinger feed | 58,192 |
| Water pumplny | 53,225 |
| Water aeration | 55,754 |
| Autofeeder operation | 6,435 |
| Maintenance | 7,709 |

Total189,091

| 1 ro 2 Yesr Growout |  |
| :--- | ---: |
|  | 3,816 |
| Feed | 167,118 |
| Water punping | 168,463 |
| Water aeration | 168,221 |
| Autofeeder operation | 10,908 |
| Malntenance | 6,655 |
| Total | 725,181 |


| 2 to 3 Year Growout | 9,504 |
| :--- | ---: |
| Labor | 925,247 |
| Feed | 387,924 |
| Water pumplog | 386,449 |
| Water aeration | 25,118 |
| Autofeeder operation | 16,575 |
| Matntenance | $1,750,817$ |

Production Under a 10 Percent Marketing Strategya (Per Cohort of Fish)

Number of Broodstock: 10

| Age | Body Weight | Number Produced | Number Sold | Production ${ }^{\text {b }}$ |
| :---: | :---: | :---: | :---: | ---: |
|  | (grams/fish) |  |  | $(\mathrm{kg})$ |
| Hatch1ing | $0.016^{\mathrm{c}}$ | 808,582 | 80,858 | 11.64 |
| 1 month | 0.19 | 457,213 | 45,721 | 78.18 |
| 3 months | 19.08 | 307,872 | 30,787 | $5,286.78$ |
| 6 months | 102.60 | 277,041 | 0 | $28,424.41$ |
| 12 months | 537.32 | 277,041 | 0 | $148,859.67$ |
| 18 months | $1,415.41$ | 277,041 | 0 | $392,126.60$ |
| 24 months | $2,814.08$ | 277,041 | 0 | $779,615.54$ |
| 30 months | $4,795.52$ | 277,041 | 0 | $1,328,555.66$ |
| 36 months | $7,412.82$ | 277,041 | 277,041 | $2,053,655.07$ |

$\mathrm{a}_{\text {For }}$ all stages after hatch, the number produced takes into account mortality and any previous production sold.
bproduction retained for continued culture or sold at the end of 36 months growout.
$c_{\text {Based }}$ on mean weight of 12 larvae at hatch (Beer, 1981).

Appendix Table 10b
Production Under a 25 Percent Marketing Strategy ${ }^{\text {a }}$ (Per Cohort of Fish)

Number of Broodstock: 10

| Age | Body Weight | Number Produced | Number Sold | Production ${ }^{\text {b }}$ |
| :---: | :---: | :---: | ---: | ---: |
|  | (grams/fish) |  |  | (kg) |
| Hatchling | $0.016^{c}$ | 0.19 | 808,582 | 202,146 |
| 1 month | 19.08 | 381,012 | 95,253 | 9.70 |
| 3 months | 102.60 | 213,800 | 53,450 | 54.29 |
| 6 months | 537.32 | 160,324 | 0 | $3,059.48$ |
| 12 months | 160,324 | 0 | $16,449.34$ |  |
| 18 months | $1,415.41$ | 160,324 | 0 | $26,145.83$ |
| 24 months | $2,814.08$ | 160,324 | 0 | $451,925.61$ |
| 30 months | $4,795.52$ | 160,324 | 0 | $768,841.74$ |
| 36 months | $7,412.82$ | 160,324 | 160,324 | $1,188,460.37$ |

[^21]Production Under a 75 Percent Marketing Strategya (Per Cohort of Fish)

Number of Broodstock: 10

| Age | Body Weight | Number Produced | Number Sold | Production ${ }^{\text {b }}$ |
| :---: | :---: | :---: | :---: | ---: |
|  | (grams/fish) |  |  | $(\mathrm{kg})$ |
| Hatchling | 0.016 c | 808,582 | 606,437 | 3.23 |
| l month | 0.19 | 127,003 | 95,252 | 6.03 |
| 3 months | 19.08 | 23,754 | 17,816 | $3,190.07$ |
| 6 months | 102.60 | 5,937 | 0 | 609.14 |
| 12 months | 537.32 | 5,937 | 0 | $3,190.07$ |
| 18 months | $1,415.41$ | 5,937 | 0 | $8,403.29$ |
| 24 months | $2,814.08$ | 5,937 | 0 | $16,707.19$ |
| 30 months | $4,795.52$ | 5,937 | 0 | $28,471.00$ |
| 36 months | $7,412.82$ | 5,937 | 5,937 | $44,009.91$ |
|  |  |  |  |  |

${ }^{a}$ For all stages after hatch, the number produced takes into account mortality and any previous production sold.
${ }^{b}$ Production retained for continued culture or sold at the end of 36 months growout.
${ }^{\text {c Based on mean weight of } 12 \text { larvae at hatch (Beer, 1981), }}$

## Appendix Table 10d

Production Under a 90 Percent Marketing Strategya (Per Cohort of Fish)

Number of Broodstock: 10

| Age | Body Weight | Number Produced | Number Sold | Production ${ }^{\text {b }}$ |
| :---: | :---: | :---: | :---: | :---: |
|  | (grams/fish) |  |  | (kg) |
| Hatchling | $0.016^{\text {c }}$ | 808,582 | 727,724 | 1.29 |
| 1 month | 0.19 | 50,801 | 45,721 | 0.97 |
| 3 months | 19.08 | 3,800 | 3,420 | 7.25 |
| 6 months | 102.60 | 379 | 0 | 0.04 |
| 12 months | 537.32 | 379 | 0 | 0.20 |
| 18 months | 1,415.41 | 379 | 0 | 0.54 |
| 24 months | 2,814.08 | 379 | 0 | 1.07 |
| 30 months | 4,795.52 | 379 | 0 | 18.17 |
| 36 months | 7,412.82 | 379 | 379 | 28.09 |

[^22]
## Equipment Requirements

Total Number of Broodstock: 10
Marketing Strategy: 10 percent

| Equipment | Number Required for Years 1-10 | Total Cost |
| :---: | :---: | :---: |
|  |  | (dollars) |
| Production Stage I |  |  |
| Boat | 1 | 16,000 |
| Fishing nets | 30 | 15,000 |
| Fish hauler | 1 | 1,100 |
| Brood tanks | 4 | 6,380 |
| Incubation system | 1 | 3,600 |
| Aeration system | 1 | 1,972 |
| Total |  | 44,052 |
| Production Stage II |  |  |
| Larval tanks | 15 | 6,750 |
| Freezer | 1 | 600 |
| Aeration system | 1 | 1,622 |
| Total |  | 8,972 |
| Production Stage 111 |  |  |
| 12-foot diameter tanks | 437 | 426,075 |
| Automatic feeders | 874 | 301,530 |
| Aeration system | 55 | 113,245 |
| Total |  | 840,850 |
| Production Stage IV |  |  |
| 12-foot diameter tanks | 1,137 | 1,108,575 |
| 30-foot diameter tanks | 2,635 | 13,175,000 |
| Automatic feeders | 7,544 | 2,602,680 |
| Aeration system (12-foot tanks) | 142 | 292,378 |
| Aeration system (30-foot tanks) | 659 | 1,550,627 |
| Total |  | 18,729,260 |

Total Number of Broodstock: 10
Marketing Strategy: 25 percent

| Number Required for |  |  |
| :---: | :---: | :---: |
|  |  | (dollars) |
| Production Stage I |  |  |
| Boat | 1 | 16,000 |
| Fishing nets | 30 | 15,000 |
| Fish hauler | 1 | 1,100 |
| Brood tanks | 4 | 6,380 |
| Incubation system | 1 | 3,600 |
| Aeration system | 1 | 1,972 |
| Total |  | 44,052 |
| Production Stage II |  |  |
| Larval tanks | 13 | 5,850 |
| Freezer | 1 | 600 |
| Aeration system | 1 | 1,622 |
| Total |  | 8,072 |
| Production Stage III |  |  |
| 12-foot diameter tanks | 304 | 296,400 |
| Automatic feeders | 608 | 209,760 |
| Aeration system | 38 | 78,242 |
| Total |  | 584,402 |
| Production Stage IV |  |  |
| 12-foot diameter tanks | 606 | 590,850 |
| 30-foot diameter tanks | 1,525 | 7,625,000 |
| Automatic feeders | 4,262 | 1,470,390 |
| Aeration system (12-foot tanks) | 76 | 156,484 |
| Aeration system (30-foot tanks) | 382 | 898,846 |
| Total |  | 11,741,570 |

## Appendix Table 10 g

Equipment Requirements

Total Number of Broodstock: 10
Marketing Strategy: 75 percent

| Number Required for |  |  |
| :---: | :---: | :---: |
|  |  | (dollars) |
| Production Stage I |  |  |
| Boat | 1 | 16,000 |
| Fishing nets | 30 | 15,000 |
| Fish hauler | 1 | 1,100 |
| Brood tanks | 4 | 6,380 |
| Incubation system | 1 | 3,600 |
| Aeration system | 1 | 1,972 |
| Total |  | 44,052 |
| Production Stage II |  |  |
| Larval tanks | 5 | 2,250 |
| Freezer | 1 | 600 |
| Aeration system | 1 | 1,622 |
| Total |  | 4,472 |
| Production Stage III |  |  |
| 12-foot diameter tanks | 33 | 32,175 |
| Automatic feeders | 66 | 22,770 |
| Aeration system | 5 | 10,295 |
| Total |  | 65,240 |
| Production Stage IV |  |  |
| 12-foot diameter tanks | 0 | 0 |
| 30-foot diameter tanks | 56 | 280,000 |
| Automatic feeders | 112 | 38,640 |
| Aeration system (12-foot tanks) | 0 | 0 |
| Aeration system (30-foot tanks) | 14 | 32,942 |
| Total |  | 351,582 |

Equipment Requirements
Total Number of Broodstock: 10
Marketing Strategy: 90 percent

| Equipment | Number Required for <br> Years 1-10 | Total Cost |
| :---: | :---: | :---: |
| (dollars) |  |  |

Production Stage I
Boat 11
Fishing nets 30
Fish hauler
1
Brood tanks 4
Incubation system 1
Aeration system
1
16,000
15,000
1,100
6,380
3,600
1,972
Total
44,052
Production Stage II
Larval tanks 200
Freezer 1 600

Total 3,122
Production Stage III
12-foot diameter tanks $\quad 5 \quad 4,875$
Automatic feeders $\quad 10 \quad 3,450$
Aeration system 1
2,059
Total
10,384
Production Stage IV
12-foot diameter tanks $\quad 0 \quad 0$
30-foot diameter tanks 10,000
Automatic feeders $\quad 4 \quad 1,380$
Aeration system (12-foot tanks) 00
Aeration system (30-foot tanks) $1 \quad 2,353$
Total 13,733

## Joint Equipment Requixements

Joint Equipment Requirements

Total Number of Broodstock: 10
Harketing Strategy: 10 percent

| Joint Equipment | Number Required |  |
| :---: | :---: | :---: |
|  | for Years $1-10$ | Tora 1 Cost |
|  |  | (dollars) |
| Emergency generator | 1 | 417,876 |
| Wells | 58 | 3,732,416 |
| Stripping towers | 58 | 232,000 |
| Office and laboratory equipment |  | 10,000 |
| Small tools |  | 2,000 |
| Trucks | 2 | 22,500 |
| Total |  | 4,416,792 |

## Appendix Table 10k

Joint Equipment Requirements

Total Number of Broodstock: 10
Marketing Strategy: 75 percent

|  | Number Requitred |  |
| :---: | :---: | :---: |
| Joint Equipment | for Yeare 1-10 | Total Cost |
|  |  | (dollars) |
| Emergency generator | 1 | 18,538 |
| Wells | 2 | 109,366 |
| Stripping towers | 2 | 8,000 |
| Office and laboratory equipment |  | 10,000 |
| Small tools |  | 2,000 |
| Trucks | 2 | 22,500 |
| Total |  | 170,404 |

Total Number of Broodstock: 10
Marketing Strategy: 25 percent

| Jolnt Equipment | Number Required for Years 1-10 | Total Cost |
| :---: | :---: | :---: |
|  |  | (dollars) |
| Energency generator | 1 | 242,400 |
| Wells | 34 | 2,178,055 |
| Stripping rowers | 34 | 136,000 |
| Office and laboratory equipment |  | 10,000 |
| Small tools |  | 2,000 |
| Trucks | 2 | 22,500 |
| Total |  | 2,590,955 |

## Appendix Table 10m

Annual Operating Costa

Total Number of Broodstock: 10
Marketing Strategy: 10 percent

| Growout Period | Anntal Operating Cost |
| :---: | :---: |
|  | (dollars) |
| Hatch Production |  |
| Fishing labor | 864 |
| Spawning labor | 324 |
| Flshing fuel | 269 |
| Pituitary extract | 370 |
| Water pumping | 159 |
| Water aeration | 275 |
| Maintenance | 220 |
| Total | 2,481 |
| Hatch to 1 Month Growout |  |
| Larval labor | 13,398 |
| Latval feed | 466 |
| Water pumplna | 327 |
| Water aetation | 2,819 |
| Maintenance | 45 |
| Total | 17,055 |
| 1 to 3 Month orowout |  |
| Fry labor | 7,866 |
| Pry feed | 3,627 |
| Water pumping | 7,690 |
| Water aecation | 5,767 |
| Autofeeder operation | 1,280 |
| Maintenance | 4,204 |
| Total | 30,454 |
| 3 Month to 1 Yeat Growout |  |
| Finger labor | 29,016 |
| Finger feed | 169,687 |
| Water pumping | 155,391 |
| Water aeration | 161,125 |
| Autofeader operation | 18,786 |
| Maintenance | 25,841 |
| Total | 559,846 |
| 1 to 2 Year Growout |  |
| Labor | 11,160 |
| Feed | 1,070,518 |
| Water pumplng | 491,958 |
| Water aeration | 489,981 |
| Autofeeder operation | 31,855 |
| Maintenance | 19,463 |
| Total | 2,114,935 |
| 2 to 3 Year Growout |  |
| Labor | 27,720 |
| Feed | 2,698,025 |
| Water pumping | 1,131,865 |
| Water aeration | 1,125,091 |
| Autofeeder operation | 73.289 |
| Maintenance | 48,343 |
| Total | $5,104,333$ |

Total Number of groodstock: 10
MarketIng Stratefy: 25 percent


| Hatch Production |  |
| :--- | :--- |
| Fishing labor | 864 |
| Spawning labor | 324 |
| Fishing fuel | 269 |
| Pituitary extract | 370 |
| Water pumping | 159 |
| Water aeration | 275 |
| Maintenance | 220 |


| Larval labor | 11,088 |
| :---: | :---: |
| Larval feed | 388 |
| Water pumping | 272 |
| Water aeration | 2,349 |
| Maintenance | 40 |
| Total | 14,137 |
| 1 to 3 Month Growout |  |
| Fry labor | 5,472 |
| Fry feed | 2,519 |
| Water pumping | 5,331 |
| Water aeration | 4,064 |
| Autofeeder operation | 887 |
| Masutenance | 2,922 |
| Total | 21,195 |


| 3 Month to 1 Year Growout |  |
| :--- | ---: |
| Finger labor | 15,858 |
| Finger feed | 98,199 |
| Water pumping | 89,863 |
| Watar aeration | 93,684 |
| Autofeeder operation | 10,865 |
| Maintenance | 14,463 |
| Total | 322,932 |


| 1 to 2 Year Growout | 6,462 |
| :--- | ---: |
| Labor | 619,514 |
| Feed | 284,544 |
| Hater pumping | 283,376 |
| Water aeration | 18,425 |
| Autofeeder operation | 11,272 |
| Malntenance | $1,223,593$ |
| Total |  |


| 2 to 3 Year Growout | 16,038 |
| :--- | ---: |
| Labor | $1,561,360$ |
| Feed | 654,840 |
| Hater pumping | 651,473 |
| Water aeration | 42,402 |
| Autofeeder operation | 27,973 |
| Mafncenance | $2,954,086$ |
| Total |  |

Annual Operating Costs

Total Number of Broodstock: 10
Marketing strakegy: 75 percent

| Growout Period | Anmual Operatiog Cost |
| :---: | :---: |
|  | (dallars) |
| Hatch Production |  |
| Fishing labor | 864 |
| Spawning labor | 324 |
| Fishing fuel. | 269 |
| Pituftary extract | 370 |
| Water pumping | 159 |
| Water aeration | 275 |
| Maintenance | 220 |
| Total | 2,481 |
| Hatch to 1 Month Growout |  |
| Laryal labor | 3,696 |
| Laryal feed | 129 |
| Water pumping | 91 |
| Water aeration | 783 |
| Maintenance | 22 |
| Total | 4,721 |
| 1 to 3 Month Growout |  |
| Fry labor | 594 |
| Fry feed | 280 |
| Water pumping | 562 |
| Water aeration | 574 |
| Autofeeder operation | 93 |
| Maintenance | 326 |
| Total | 2,429 |
| 3 Hoath to 1 Year Growout |  |
| Finger labor | 180 |
| Finger feed | 3,636 |
| Water pumplog | 3, 175 |
| Water acration | 3,990 |
| Autofeeder operation | 386 |
| Malntenance | 320 |
| Total | 11,687 |
| I to 2 Year Growout |  |
| Labor | 234 |
| Feed | 22,941 |
| Water pumping | 10,238 |
| Water aeration | 11,164 |
| Autofeeder operation | 663 |
| Maintenance | 405 |
| Total | 45,645 |
| 2 to 3 Year Gromout |  |
| Labor | 594 |
| Feed | 57,819 |
| Water pumplag | 23,940 |
| Water aeration | 24,621 |
| Autofeeder operation | 1,550 |
| Haintenance | 1,033 |
| Total | 109,557 |


| Appendix Table <br> Annual Operating | $10 p$ <br> Costs |
| :---: | :---: |
| Total Number of Broodstock: 10 Marketing strategy: 90 percent |  |
| Growout Period | $\frac{\text { Annal Operatlug Cost }}{(\text { dollars })}$ |
| Hatch Eroduction |  |
| Fishing labor | 864 |
| Spawning labor | 324 |
| Fishing fuel | 269 |
| Pltultary extract | 370 |
| Water pumping | 159 |
| Water aeration | 275 |
| Maintenance | 220 |
| Total | 2,481 |
| Hatch to 1 Month Growout |  |
| Larval laber | 1,386 |
| Larval feed | 52 |
| Water pumpligg | 36 |
| Water aeration | 313 |
| Maintenance | 16 |
| Total | 1.803 |
| 1, to Month Growout |  |
| Fry labor | 90 |
| Fry feed | 45 |
| Water pompling | 75 |
| Water aeracton | 177 |
| Autofeeder operation | 12 |
| Maintenance | 52 |
| rotal | 451 |
| 3 Month to 1 Year Growouk |  |
| Finger labor | 0 |
| Finger feed | 233 |
| Water pumping | 60 |
| Water aeration | 309 |
| Autofeeder operation | 10 |
| Haintenance | 0 |
| Total | 612 |
| 1 to 2 Year Growout |  |
| Laber | 18 |
| Feed | 1,464 |
| Water pumping | 308 |
| Water aeration | 1,223 |
| Autofeeder operation | 20 |
| Maintenance | 40 |
| Total | 3,073 |
| 2 to 3 Year Growout |  |
| Lahor | 18 |
| Feed | 3.691 |
| Water pumping | 1,155 |
| Hater aeration | 2,753 |
| Autofeeder operation | 75 |
| Maintenance | 28 |
| Total | 7,720 |

Total Number of Broodstock: 10
Marketing Strategy: 75 percent

| Joint Equipment | Year of Operation |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Emergency generator | 2,642 | 3,874 | j,698 | 3.698 | 3,698 | 0 | 0 | 0 | 0 | 0 |
| We11s | 10,390 | 11,429 | 9,351 | 8,312 | 7,273 | 6,234 | 6,234 | 6,234 | 6,234 | 5,195 |
| Stripping towers | 760 | 836 | 684 | 608 | 532 | 456 | 456 | 456 | 456 | 380 |
| Office and lab building | 13,987 | 15,386 | 12,588 | 11,190 | 9,791 | 8,392 | 8,392 | 8,392 | 8,392 | 6,994 |
| Office and lab equipment | 1,425 | 2,090 | 1,995 | 1,995 | 1,995 | 0 | 0 | 0 | 0 | 0 |
| Small tools | 285 | 418 | 399 | 399 | 399 | 0 | 0 | 0 | 0 | 0 |
| Trucks (2) | 5,625 | 8,550 | 8,325 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 35,114 | 42,583 | 37,040 | 26,202 | 23,688 | 15,082 | 15,082 | 15,082 | 15,082 | 12,569 |

## Appendix Table $10 r$

## Annual Joint Equipment Depreciation Costs

Total Number of Broodstock: 10
Marketing Strategy: 90 percent

| Joint Equipment | Year of Operation |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|  |  |  | --- | ----- | -dolla |  |  |  | - | --- |
| Emergency generator | 730 | 1,071 | 1,022 | 1,022 | 1,022 | 0 | 0 | 0 | 0 | 0 |
| Wells | 2,202 | 2,422 | 1,982 | 1,762 | 1,541 | 1,321 | 1,321 | 1,321 | 1,321 | 1,101 |
| Stripping towers | 380 | 418 | 342 | 304 | 266 | 228 | 228 | 228 | 228 | 190 |
| Office and lab building | 13,987 | 15,386 | 12,580 | 11,190 | 9,791 | 8,392 | 8,392 | 8,392 | 8,392 | 6,994 |
| Office and lab equipment | 1,425 | 2,090 | 1,995 | 1,995 | 1,995 | 0 | 0 | 0 | 0 | 0 |
| Small tools | 285 | 418 | 399 | 399 | 399 | 0 | 0 | 0 | 0 | 0 |
| Trucks (2) | 5,625 | 8,550 | 8,325 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 24,634 | 30,355 | 26,653 | 16,672 | 15,014 | 9,941 | 9,941 | 9,941 | 9,941 | 8,285 |


[^0]:    The Giannini Foundation Research Report Series is designed to communicate research resulis to specific professional audiences interested in applications. The first Research Report was issued in 1961 as No. 246, condinuing the numbering of the GF Mimsograph Report Series which the Research Report replaced. Other publications of the Foundation and all publications of Foundation members are listed in the Giamini Reporter issued periodically.

    Single copies of this Rescarch Report or the most recent Giamini Reporter may be requested from Agriculture and Natural Resources Publications, 6701 San Pablo Avenue, Cakland CA 94608.

[^1]:    ${ }^{1}$ Sex Allen a af, for a comprehersive review of modeling methods and their appliation in the examination of economic aspects of aquaditure of varine organisms.

[^2]:     withun that age range. As additionat cata bosone available, the saxnomic coss and benefits of growitg fish to langer weights ean be anatyzed.

[^3]:    ${ }^{3}$ In this study the federal income lax rate is not a function of gross taxable income; instead, it is fixed at the maximum marginal corporate income tax rate. State income laxes are not considered.

[^4]:    ${ }^{4}$ This is a reasonable assumptim for onice und laboratury equipment, suall kois, and tucks in futue sudies if would be were realistie to apporion the cost of the emergency gencrator, wells, and stripping towers among the four production stages according to the proportion of equipment capacity reguined by a particular slage of production

[^5]:    aFor all stages after hatch, the number produced takes into account mortality and any previous production sold.
    $b^{b}$ roduction retained for continued culture.
    cbased on mean welght of 12 larvae at hatch (Beer, 1981).

[^6]:    ${ }^{\text {a }}$ Excludes 30 percent overhead assessment for benefits.

[^7]:    ${ }^{5}$ Discussion of comparative rates of retum will be deferred until the final sets of simulations are presented.

[^8]:    ${ }^{6}$ These percentages were calculated using the values of ATC in Table 15. For example, the 26.8 percent difference in ATC per fry is calculated as: ( $\$ .228-\$ .167$ )/\$.228.
    ${ }^{7}$ Some coonomies undoubledly arise simply as a result of the means by which joint costs are alfocated. Any such allocation procedure is admittedly arbitrary.

[^9]:    ${ }^{6}$ Calculated from water umation cost information in Appeadices 100 and 119: $\left.1-18177 / 3574\right\}=6916$ perome.

[^10]:    aprices are specified as hatchling $\$ .15$ each, fry $\$ .45$ each, fingerlings $\$ 1.25$ each, and 3 year-old fish $\$ 4$ per pound.

[^11]:    ${ }^{\text {aprices }}$ are specified as hatchling $\$ .15$ each, fry $\$ .45$ each, fingerling $\$ 1.25$ each and 3 -year-old fish $\$ 3$ per pound.

[^12]:    ${ }^{9}$ See Appendix 1 for a list of the types of lanks or other containers used in each phase of production and the termperature, depth, volume, and flow rate of water associated with each.

[^13]:    Source: U.C. Davis Aquaculture Program and industry estimates.

[^14]:    a This information is based on industry sources. An aeration syatem is comprised of a regenerative blower
     pore size of 20 microns of $\quad$ (-1/ $10^{*} x 3 / 16^{\prime \prime}$ wall with average pore size of 35 merons) through which air diffuses.
    Oinclades the cose of blowar secessories and diffuser tubtng.

[^15]:    ${ }^{\text {a }}$ Total building and roofing requirements were calculated based on this information. For example, the 1,002 square feet building requirement for hatch production in the base model facility (in Table 4) was calculated as: ( 4 broodstock tanks x 188 square feet/broodstock tank) + (1 incubation system $\times 250$ square feet/incubation system).

[^16]:    ${ }^{\text {a }}$ Requirement per fishing trip including roundtrip travel time (4 hours) to fishing site.
    bTotal hours required per tank per day.
    ${ }^{\text {CTotal }}$ hours required per tank to tank transfer.
    Source: U.C. Davis Aquaculture Program and industry estimates.

[^17]:    ${ }^{2}$ Frum Univesity of Califomia Agricultural Extensiun Ruletin. July 1978, Itrigation Pumping Coxs.
    ${ }^{3}$ The relationship of 4 KW per $1,000 \mathrm{KWH}$ was baset on Pacific Gas and Elecric Company estimates.

[^18]:    Source: Internal Revenue Service Publications 225 and 534.

[^19]:    aFor all stages after hatch, the number produced takes into account mortality and any previous production sold.
    $b_{\text {Production }}$ retained for continued culture or sold at the end of 36 months growout.
    chased on mean weight of 12 larvae at hatch (Beer, 1981).

[^20]:    afor all stages after hatch, the number produced takes into account mortality and any previous production sold.
    bproduction retained for continued culture or sold at the end of 36 months growout.
    

[^21]:    ${ }^{\text {a For }}$ all stages after hatch, the number produced takes into account mortality and any previous production sold.
    bproduction retained for continued culture or sold at the end of 36 months chrowed on mean weight of 12 larvae at hatch (Beer, 1981).

[^22]:    ${ }^{\text {a }}$ For all stages after hatch, the number produced takes into account mortality and any previous production sold.
    ${ }^{\text {b }}$ Production retained for continued culture or sold at the end of 36 months growout.
    CBased on mean weight of 12 larvae at hatch (Beer, 1981).

