
# DEVELOPMENT OF RESEARCH PRIORITIES FOR AQUACULTURE PLANNING

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## ABSTRACT

This report describes a procedure for allocation of priorities among possible goal oriented research projects directed at enhancement of an aquaculture industry. The method is applied to further development of an industry based on culture of the freshwater prawn, *Macrobrachium rosenbergii*. A list of general factors, problem areas and possible research projects is developed and then prioritized by professionals from science and industry according to various criteria. The role of economic analysis for an existing industry and simulated economic analysis for a potential industry are discussed. Appendices contain complete project listings and priorities for the example *Macrobrachium* industry.

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# DEVELOPMENT OF RESEARCH PRIORITIES FOR AQUACULTURE PLANNING

The continued development of aquaculture in terms of economically viable industries requires research programs to gain understanding of the diverse steps involved and how they can be structured into practical, cost-effective production systems. The purpose of this report is to propose and examine a method to plan research devoted to the furtherance of aquaculture industries. The different disciplines and professional areas touched upon by an operating aquaculture-based industry are extremely diverse, especially in a society where technically trained persons tend inevitably to specialize rather than to gain broad general understandings of wide areas of knowledge. Research is any endeavor which attempts to further our knowledge of the workings of our environment (in the broad sense), or the ways in which we can manipulate it. Aquaculture is as broad an endeavor as agriculture, and research might include fields ranging from economics and marketing, pathology, genetics, developmental biology, microbiology to civil engineering and electronics, etc. Research projects are usually organized along the lines of such disciplines, in which one or a small number of specialists in the area either perform experiments or examine natural phenomena to discover new and original knowledge or put together existing knowledge in novel and creative ways to discover how to perform some task.

In aquaculture, the overall researchable question is "What are the most cost-effective measures to produce and market a (food) product based on domestic culture of an aquatic animal or plant?"*. This production must be done within certain constraints, such as conformance to applicable environmental regulations. With the consideration by Congress of a major legislative act to promote development of aquaculture, it is reasonable to consider the problem of determination of which facets of the many researchable problems in aquaculture should be approached first with what will always be a limited quantity of resources, both monetary, human and institutional. This is a report of a research project whose objective was to determine a method for setting priorities among potential research projects and to apply it to the development of an aquaculture industry for the fresh water prawn, Macrobrachium rosenbergii. The detailed results of this research prioritization can be found in the "Species Plan for Fresh-Water Prawns of the Genus Macrobrachium " (Glude, et al., 1977). The planning system for the NOAA aquaculture plan has been described by Glude (1977). The procedure described below is proposed as a part of that system and is designed to implement many of the considerations therein.

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*"Aquaculture: The culture or husbandry of aquatic animals or plants by private industry for commercial purposes or by public agencies for augmenting natural stocks." (World Mariculture Society definition) This paper addresses primarily the commercial aspects of aquaculture.

## PLANNING RATIONALE

In development of a planning rationale, a number of methods were considered and evaluated. The three major techniques which we will describe are the Program Evaluation and Review Technique (PERT), a comprehensive stepwise procedure for determination and prioritization of possible research areas and an economic analysis of an actual or hypothetical industry.

There are a number of considerations in development of an aquaculture plan which must be addressed by the planning method:

- The method must include an overview of all aspects of culture of a particular species group of concern.
- The method must consider the payoff of research in any of the relevant areas in terms of the enhanced production that would result from a successful solution of an identified problem, the probability of such success and the cost in terms of time, manpower and other resources required for the research.
- In recognition that the plan will be carried out by researchers from academia, industry and government and funded by federal funds, the planning method must have a procedure for input from those researchers with interests and/or expertise in aquaculture of the particular species group.
- The planning system must be flexible and allow for update as research results become available.

The purpose of the planning system is to identify a method for the orderly development of the industry via steps which are reasonably time and cost efficient. This means that the method must allow for the establishment of priorities for the allocation of limited resources at those points in the overall production system where they will have the greatest chance of producing a significant increment of benefit.

### PERT diagrams and analysis

The above considerations recognize that the planning and the ultimate prioritization of allocation of resources are primarily the result of the knowledge, interests and desires of people rather than any purely objective set of scientific facts which can be evaluated by some concrete mathematical procedure. Nevertheless, objectivity is an invaluable component of the process. The program evaluation and review technique (PERT) (see Johnson et al. 1972) is a procedure which is designed to aid in the planning of any multi-step program designed to accomplish a single end goal.

Pert is applicable primarily in programs where each step can be well planned with specific time and other resources allotted and where the probability of success is virtually 100% at each step. Modifications of PERT have been made to allow for probability of success but these require a quantification of the probability which is generally beyond the level possible for our applications. Moreover, PERT is oriented to the development of an entire process rather than the improvement of parts of the process. This latter aspect is frequently the goal in aquaculture related to research. Many types of research, especially in the biological area, involves stages where success is not at all certain nor is the time to success, if it is achieved, predictable, except within large limits. The PERT diagram (see Fig. 1) which indicates which elements of an overall program may occur in parallel (concurrently with each other) and which must occur in series (following one another) is an excellent way to develop an overview of the areas which must go into the development of all or one phase of an aquaculture industry. This approach has been applied in the NOAA Aquaculture Plan (Glude, 1977).

The mathematical analysis which usually accompanies the PERT procedure is designed to identify which stages will be critical or "bottleneck" stages for the overall program development. The method relies upon having a concrete measure of the time, money or other requirements at each stage. Some of these can be specified in the research stages of aquaculture industry development and some will be very difficult to specify. As a result, while PERT diagrams give an excellent overview of the stages required for development or enhancement of an industry, PERT mathematical analysis to identify bottlenecks is not necessarily feasible or necessary. In order to develop priorities, however, some measure of both probability of success and the value of that success if achieved must be developed. It is for this reason that the opinions of experts must be incorporated and averaged or in some way aggregated to come up with a measure of expected benefits and probability of success.

As a final comment on the applicability of PERT, a distinction should be made between a research project and a development project, though these frequently overlap and grade into each other. In research the emphasis is on discovery of new knowledge whereas in development the emphasis is on application of theoretically existing knowledge to establish practical means of performing a task or function. PERT is especially helpful, both diagrammatic and mathematical aspects, in development rather than research. For detailed mathematical analysis via PERT to be appropriate, the development task must be much more complex than that shown in Fig. 1. If the stages of Fig. 1 were labelled with a time, cost or other measure it would be a simple matter to pick out the critical path and stage. The ordering of stages shown in Fig. 1 is somewhat ambiguous due to the generality of the processes involved. At a later point in development, it might be possible to better define the stages and specify their order with greater certainty. At such a time, PERT would be a more helpful planning tool.

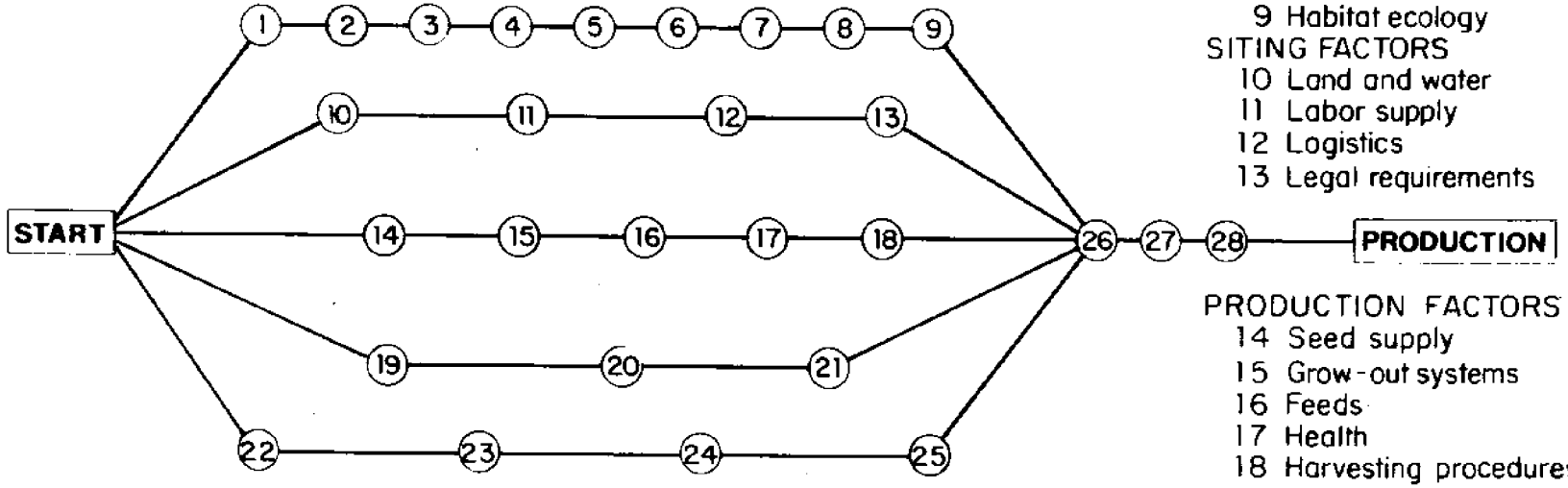


FIGURE 1. PERT diagram for generalized procedures in development of an aquaculture industry. From Glude et al. (1977).

SPECIES CHARACTERISTICS
- 1 Growth
- 2 Environmental requirements
- 3 Nutritional requirements
- 4 Disease and mortality
- 5 Sexual development
- 6 Reproduction
- 7 Genetics
- 8 Behavior
- 9 Habitat ecology

SITING FACTORS
- 10 Land and water
- 11 Labor supply
- 12 Logistics
- 13 Legal requirements

PRODUCTION FACTORS
- 14 Seed supply
- 15 Grow-out systems
- 16 Feeds
- 17 Health
- 18 Harvesting procedures

PRODUCT FACTORS
- 19 Preprocessing
- 20 Processing
- 21 Distribution and marketing

MARKET FACTORS
- 22 Supply
- 23 Demand
- 24 Location of markets
- 25 Price

INVESTMENT FACTORS
- 26 Economic analysis
- 27 Information dissemination
- 28 Investment capital

## STEP-WISE PROCEDURE

The following steps are intended to meet the above planning needs in a comprehensive and orderly manner. These steps and the methods to perform them will be discussed in the remainder of the paper and illustrated with examples drawn from the development process for the Macrobrachium species plan.

1. Develop an overview of the aquaculture production system(s), including alternatives.

2. Organize the production system into the major factors affecting production in terms of traditional scientific and professional areas.

3. Determine the major problem areas within each factor which might affect industry production or efficiency.

4. Organize each problem area into potential research projects which address elements of the problem.

5. Develop an evaluation of the problem areas and individual projects by as many persons with professional interest in, or knowledge of, the specific aquaculture industry as possible.

6. Revise the list of factors, problems and projects according to results of the evaluation.

7. Refine the evaluation to include expected benefits, probability of success and required resources for each project.

8. As new and pre-existing research projects develop knowledge and technology, revise the list of factors, problems and projects as appropriate.

9. Periodically summarize the project list in the order of maximum expected benefits as rated by different professional groups according to various benefit criteria.

### System overview and organization into projects

The first stage in the procedure is to develop an overview of the actual or potential production systems, including alternatives, which might go into a viable aquaculture production process. This should include all aspects of the process--from obtaining culture materials, growth, development, feeding, disease, environmental requirements, population measurement, harvesting, product preparation or processing, and marketing. This overview is perhaps best represented as a diagram or series of diagrams. Figure 2 shows such a diagram as it might be produced for a Macrobrachium culture industry. A diagram at this stage

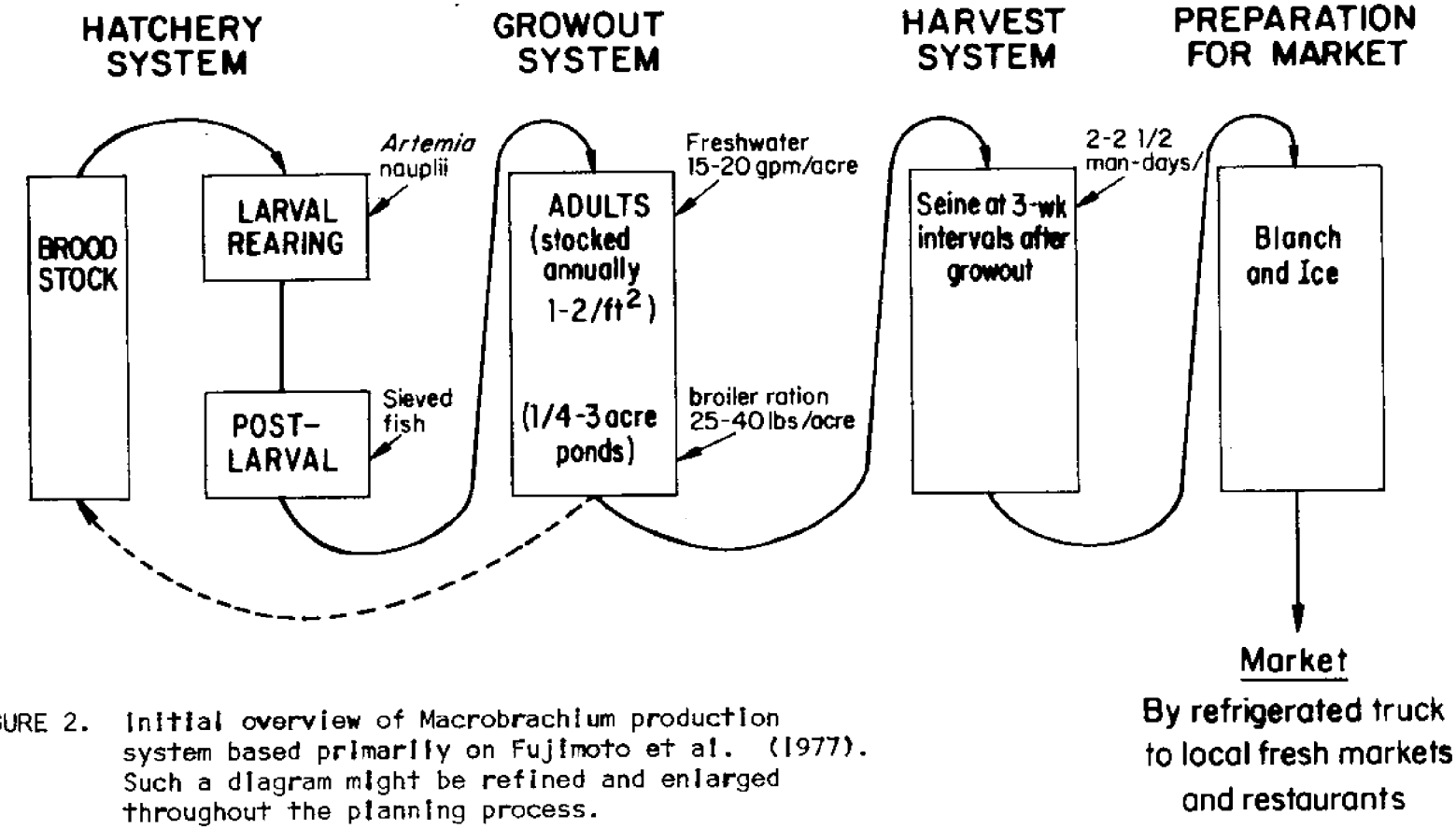


FIGURE 2. Initial overview of Macrobrachium production system based primarily on Fujimoto et al. (1977). Such a diagram might be refined and enlarged throughout the planning process.

but it should indicate a logical division of separate components of the production process which can be later refined.

Step two involves the identification of the major factors which affect operation of the industry at one or more points in the process. These factors should be developed along traditional professional and scientific disciplinary areas so as to guide the development of subsequent research projects. Table 1 shows a list of the factors developed for commercial Macrobrachium culture. The initial list is subject to revision and modification to produce an organization which best meets the needs of the species being considered.

Within each major factor it is necessary to determine the problems associated with that factor which are critical for the industry (step three). It is at this point that information about the status of scientific or technical knowledge is required on the part of the personnel developing the plan. The problems may represent the frontiers of knowledge as they affect the culture of the species or some other aspect of the industry. Alternatively, the problems might represent procedurally straight-forward questions for which standard methods have been developed. Table 2 illustrates with some problems associated with factors for the Macrobrachium industry. These problems might be stated as questions or simply as general areas for investigation.

Each problem area can be addressed by one or more projects designed to gain more information or improve technology (step four). Table 3 shows some examples. The projects should be selected so as to be practical to carry out, and to have a balance between probability of success of success and value of results. The results should be obtainable within a time frame appropriate to the development of the industry. Of course, problems will not always fit neatly into such categories. Some projects may require development of new technology requiring a longer period of time for accomplishment or requiring unusual inputs of funds, expertise, physical resources, etc. Inclusion of such projects should be based upon the increment of viability or productivity which success is likely to bring to the industry.

Table 1. Major factors in *Macrobrachium* production corresponding to professional and/or scientific disciplines.

| General Category | Number | Factor Title |
|---|---|---|
| Special Characteristics | 01. | Growth |
| | 02. | Environmental Requirements |
| | 03. | Nutritional Requirements |
| | 04. | Disease and Mortality |
| | 05. | Sexual Development |
| | 06. | Reproduction |
| | 07. | Genetics |
| | 08. | Behavior |
| | 09. | Habitat Ecology |
| Siting Factors | 10. | Land and Water |
| | 11. | Labor Supply |
| | 12. | Logistics |
| | 13. | Legal Requirements |
| Production Factors | 14. | Seed Supply |
| | 15. | Grow-Out Systems |
| | 16. | Feeds and Feeding |
| | 17. | Health |
| | 18. | Harvesting Procedures |
| Product Factors | 19. | Preprocessing |
| | 20. | Processing |
| | 21. | Distribution and Marketing |
| Market Factors | 22. | Supply |
| | 23. | Demand |
| | 24. | Location of Markets |
| | 25. | Price |
| Investment Factors | 26. | Economic Analysis |
| | 27. | Information Dissemination |
| | 28. | Investment Capital |

Table 2. Problems in a *Macrobrachium* industry associated with two different factors of the production system.

| Factor Number | Factor Title | Problem Number | Problem Title |
|---|---|---|---|
| 02. | Environmental Requirements | 02.01. | Effects of mineral content of the water |
| | | 02.02. | Effects of salinity |
| | | 02.03. | Effects of dissolved oxygen |
| | | 02.04. | Effects of temperature |
| | | 02.05. | Effects ofpH level |
| 15. | Grow-Out Systems | 15.01. | Pond design and construction |
| | | 15.02. | Heating ponds to maintain adequate temperature for optimum growth |
| | | 15.03. | Water quality control |
| | | 15.04. | Pond management |
| | | 15.05. | Identify factors which must be considered in design and operation of intensive culture systems using tanks raceways, etc. |

Table 3. Projects in a *Macrobrachium* industry associated with two different problems under the Grow-Out System factor.

| Problem Number | Problem Title | Project Number | Project Statement |
|---|---|---|---|
| 15.01. | Pond design and construction | 15.01.01. | Develop criteria for locating *Macrobrachium* ponds at production site |
| | | 15.01.02. | Compare and evaluate substrate types. |
| | | 15.01.03. | Compare and evaluate methods of stabilizing banks. |
| | | 15.01.04. | Determine optimum slope of bank in relation to stability of soils. |
| | | 15.01.05. | Evaluate designs which would increase substrate area to increase stocking density. |
| 15.04. | Pond management | 15.04.01. | Develop methods for estimating number and size distribution of prawns in ponds. |
| | | 15.04.02. | Evaluate the utility of nursery systems for intensive culture of post larvae with artificial fertilization and special feeds for varying periods before stocking in ponds. |
| | | 15.04.03. | Determine optimum size of post-larvae for stocking in ponds. Hold post-larvae in small nursery ponds for various lengths of time. Compare costs of holding and survival rate. Measure effect on production. |
| | | 15.04.04. | Compare harvesting and restocking vs. continuous harvesting method. |
| | | 15.04.05. | Determine optimum stocking density. Stock system ponds with various levels of post-larvae. Compare rates of growth and survival. |

## Review by professionals

Although the preceeding steps may require referral to a large number of individuals with knowledge in various areas, at this stage it was considered appropriate to systematically poll a community of professional people with interest and/or expertise in some aspect of the industry (Step five). This evaluation is for the purpose of developing an initial prioritization of both the problem areas and the individual projects within each problem. For Macrobrachium this was accomplished using a questionnaire asking for a priority rating for both problems and projects. Special expertise in questionnaire development can be found in many professional organizations and universities. In this project, we requested both a simple quantifiable response on each potential project (a rating on a scale from 0 to 4, from "not needed" to "urgently needed") as well as a free-form prose commentary from each respondent. This allowed an objective method of preliminarily screening the list of projects for highest priority areas, culling of projects with a "not needed" concensus and the addition of some new projects to the topic list. The sixth step was then done primarily on the basis of the prose comments.

The seventh step identifies the expected benefit or payoff from the project, the probability of success of the project, and some indication of the resources--money, manpower, special expertise, facilities or equipment, etc.--which the project would require. It would also be useful to evaluate the institution, i.e., industry, academic, or private, which would be the most logical group for performance of the research. This type of detailed information could be developed either through a workshop with a small selected group of persons from the original list of respondents of the questionnaire or it could be developed by a follow-up questionnaire. Both methods were tried in development of the Macrobrachium research plan. Table 4 shows an example of the format used to develop this information at the workshop in December of 1976. Participants were selected to represent knowledge of both the scientific and professional areas involved as well as the logistic or administrative aspects of conduct of research. This latter aspect was particularly important as the rating categories relate to the tangible and intangible resources required by a project as well as to its technical execution. Participants who were aware of these needs and their importance to a successful result were an essential part of the project rating workshop.

Table 4. Example of project ratings developed at the Macrobrachium workshop, held by NOAA and the University of Washington, Center for Quantitative Science on December 13-14, 1976. A complete listing is given in Appendix B.

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Evaluation of Projects

The following criteria were used to discuss and evaluate the projects listed in this section:

1. What pay off would result?
2. When would the results be needed?
3. Can it be done (probability of success)?
4a. What facilities or equipment would be needed?
4b. What personnel skills would be required?
5. How long would it take?
6. What would it cost?
7. Overall priority rating.

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Example Rating

Project 1: Preliminary market survey

Conduct a preliminary survey to estimate the U.S. market for domestically produced freshwater prawns in various product forms, e.g., live, fresh chilled, cooked, frozen; whole vs. tails vs. meats (project 23.01.02 in revised listing).

Evaluation

1. Modify investment level
2. Immediate for decision making
3. Practical
4a. Standard for economic research group
4b. Market specialist
5. 1 year
6. $50,000 - $100,000
7. --

Comments

1. Must have product to do market studies.
2. Use Marketing Division of NMFS for studies.
3. Need to identify, separate and quantify market

## Monitoring of ongoing research

While this completes the initial survey of research needs and the information necessary for prioritization of that research, it is necessary to have more detailed information in order to keep abreast of the status of ongoing research (Step eight). Some research on the problems listed will be underway as the plan is formed; information on its status should be gathered via questionnaires and workshops at the same time as the priority information. The upkeep of such a listing of projects and priorities relevant to the development of an aquaculture area will require continual effort at revision of the list of priorities. Frequency of a comprehensive review and update probably need not be more often than every two years and generally less often than that if the task is handled by an office with resources sufficient to keep generally abreast of developments in the field.

## METHODOLOGY FOR INFORMATION DEVELOPMENT AND ANALYSIS

In addition to the usual needs of a program management office, there are three special requirements for a project to utilize the planning procedure described above. First, a program manager or advisor thereto who is a generalist with a broad overview of the operation of an aquaculture industry. This must be a person most probably with a biological background because of the very special, detailed knowledge required in animal or plant culture, but with an appreciation for and some knowledge of such diverse areas as economics, marketing and special types of engineering technology. A person who is not well balanced in a broad number of areas, in terms of experience, professional background and interest, will not have the perspective necessary to assure that all areas which might be bottlenecks for production in an industry get the required attention in accordance with available research resources.

The second requirement is the input of professional and scientific specialists with background and interest in the required areas. The mechanism for this input is via the above-mentioned questionnaires, interviews, and workshops. Without the cooperation of these people, the information necessary for Macrobrachium aquaculture research planning could not have been obtained.

Finally, it is important that the many different types of information developed be organized into an information system which has the capability of storing the data, providing access to it in raw form, analyzing it in various ways, and allowing for its periodic update or correction. This is best done with a scientific computer oriented toward remote access and a staff person with experience in user oriented computer information applications. The volumes of information which it must handle are not large by modern computer information standards and no special requirements in terms of exotic hardware or software are necessary. The computer software or programs which are required for access to the information are simple and straightforward to develop and the advantages of a specially tailored program are sufficiently great, that it is probably wise to go the route of some minimal software development rather than a general purpose information system. A general purpose system nearly always undershoots or overshoots the needs of a specific application. This results in inability to meet needs or in a complex and clumsy system which program managers refuse to learn to use (justifiably) or both.

A series of information manipulating computer programs have been developed in association with development of the Macrobrachium aquaculture plan. Table 5 gives an example of the type of analysis which one of these programs will provide for the first series of questionnaires associated with Step five. The purpose is to allow a quick overview of the priority ratings of the projects according to some

category of the respondents, in this case, those employed by industry as opposed to those employed by academic institutions or consultants. This summary is a method of implementing Step nine.

Another capability of the information system is the ability to access details on any factor, problem or project in terms of its priority ratings, probability of success, needed resources or status of existing research. Though this information may not be too voluminous to contain in a simple listing, the fact that it must be updated periodically to maintain currency of the plan makes it appropriate to use an on-line information system. The system developed for the Macrobrachium plan can be accessed with a lightweight portable computer terminal from anywhere that a telephone is available. Table 6 gives an example of the set of information associated with one project area as retrieved by the Macrobrachium information access system. Modification of this information is accomplished by using the standard system utility file editor which is available on most interactive computer systems. This utility does not require any special software development on the part of the user, nor does it require any special expertise for its use; any office worker can learn to operate the system efficiently with a few hours of training and practice, provided they have the motivation.

Table 5. Example of analysis output from information system designed for *Macrobrachium* plan development.

A. Tabular summaries of priority ratings from research survey. (Projects are numbered as in Appendix A.)

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AQUACULTURE RESEARCH INFORMATION SYSTEM
PAYOFF PRIORITY RATING SUMMARY--MACROBRACHIUM SURVEY
RATING: 4=MAJOR, 3=SIGNIFICANT, 2=MODERATE, 1=UNIMPORTANT
AVERAGED PRIORITY THRESHOLD LEVEL IS 1.0
THIS IS AN EXAMPLE SUMMARY FROM THE FIRST FEW PROJECTS

| PROJECT NO. | NUMBER OF RESPONDENTS | PERCENT BREAKDOWN BY PRIORITY RATING | | | |
|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 |
| 01.02.01 | 13 | 8 | 62 | 23 | 8 |
| 01.02.02 | 13 | 38 | 54 | 8 | 0 |
| 01.02.03 | 12 | 8 | 33 | 42 | 17 |
| 01.02.05 | 13 | 0 | 31 | 23 | 46 |
| 01.02.06 | 13 | 8 | 62 | 23 | 8 |
| 01.02.07 | 13 | 31 | 15 | 38 | 15 |
| 01.02.08 | 13 | 15 | 46 | 15 | 23 |
| 01.02.09 | 13 | 38 | 23 | 31 | 8 |
| 01.03.01 | 13 | 23 | 46 | 31 | 0 |
| 02.01.01 | 13 | 0 | 38 | 31 | 31 |
| 02.02.01 | 13 | 8 | 46 | 38 | 8 |
| 02.03.01 | 12 | 0 | 8 | 42 | 50 |
| 02.03.02 | 13 | 0 | 15 | 38 | 46 |
| 02.03.03 | 13 | 15 | 46 | 38 | 0 |
| 02.04.01 | 11 | 18 | 27 | 36 | 18 |
| 02.05.01 | 13 | 0 | 38 | 54 | 8 |
| 02.06.01 | 11 | 0 | 36 | 27 | 36 |
| 02.06.02 | 11 | 18 | 27 | 36 | 18 |
| 02.06.03 | 10 | 10 | 30 | 40 | 20 |
| 02.06.04 | 9 | 33 | 11 | 44 | 11 |

Table 5. Example of analysis output from information system designed for *Macrobrachium* plan development (continued)

9. Textual summaries of research survey results.
(Projects are numbered as in Appendix A.)

```
AQUACULTURE RESEARCH INFORMATION SYSTEM
SUMMARY OF MACROBRACHIUM RESEARCH SURVEY RESULTS
THIS IS AN EXAMPLE RETRIEVAL FROM THE FIRST FIVE RESPONDENTS

RESP.  1          ACADEMIC BIOLOGIST     INTENSIVE PRODUCER
  01.01.01 PRIORITY RATINGS:  PAYOFF.... 2   URGENCY... 2
                              PR SUCCESS 4   RESOURCES. 4
                              TIME FRAME 2   COST..... 3

RESP.  2        GOVERNMENT ECONOMIST         NOT A PRODUCER
  01.01.01 PRIORITY RATINGS:  PAYOFF.... 2   URGENCY... 1
                              PR SUCCESS 4   RESOURCES. 4
                              TIME FRAME 3   COST..... 4

RESP.  3                                   NOT A PRODUCER
  01.01.01 PRIORITY RATINGS:  PAYOFF.... 3   URGENCY... 4
                              PR SUCCESS 4   RESOURCES. 4
                              TIME FRAME 4   COST..... 4

RESP.  4        GOVERNMENT BIOLOGIST         NOT A PRODUCER
  01.01.01 PRIORITY RATINGS:  PAYOFF.... 2   URGENCY... 3
                              PR SUCCESS 4   RESOURCES. 4
                              TIME FRAME 3   COST..... 4

RESP.  5        INDUSTRIAL BIOLOGIST         NOT A PRODUCER
  01.01.01 PRIORITY RATINGS:  PAYOFF.... 2   URGENCY... 3
                              PR SUCCESS 4   RESOURCES. 4
```

Table 6. Example of project status summaries furnished by the Macrobrachium research information system. A complete compilation is given in Appendix B. Only seventeen high priority projects were evaluated for the research status file, however all projects are listed in Appendix A and their average priority ratings are given in Appendix C.

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AQUACULTURE RESEARCH INFORMATION SYSTEM
MACROBRACHIUM RESEARCH STATUS
PROJECTS FORMULATED AT THE MACROBRACHIUM WORKSHOP

23.01.02 PRELIMINARY MARKET SURVEY
         CONDUCT A PRELIMINARY SURVEY TO ESTIMATE THE U.S.
         MARKET FOR DOMESTICALLY PRODUCED PRAWNS IN VARIOUS
         PRODUCT FORMS
         STATUS:  NOT BEGUN RESEARCHER: NONE
  PRIORITY   RATING --COMMENTS--
   PAYOFF.... 2.43  MODIFY INVESTMENT LEVEL
   URGENCY... 2.50  IMMEDIATE FOR DECISION MAKING
   PR SUCCESS 2.86  PRACTICAL
   RESOURCES. 3.07  STANDARD FACILITIES, MARKET SPECIALIST
   TIME FRAME 2.86  1 YEAR
   COST...... 2.86  $50,000 TO $100,000

23.01.01 CHARACTERIZE DISTRIBUTION PATTERN AND MARKET IN
         U.S. DETERMINE DISTRIBUTION PATTERN OF IMPORTED
         PRAWN TAILS IN U.S. AND QUANTIFY MARKETS
         STATUS: NOT BEGUN RESEARCHER: NONE
  PRIORITY   RATING --COMMENTS--
   PAYOFF.... 2.43  IDENTIFY MARKET, BOLSTER MARKETING DECISION
                    DIFFERENTIATE DOMESTIC MARKET
   URGENCY... 2.57
   PR SUCCESS 3.00  PRACTICAL
   RESOURCES. 3.14  STANDARD
   TIME FRAME 2.93  LESS THAN 1 YEAR
   COST...... 2.93  MINIMAL

20.05.01 DETERMINE CAUSES OF QUALITY VARIATION
         STATUS:  NOT BEGUN   RESEARCHER:  NONE
  PRIORITY   RATING --COMMENTS--
   PAYOFF.... 2.71  GUARANTEES CONSISTENT QUALITY
   URGENCY... 2.93  3-5 YEARS DEPENDING ON INDUSTRY PROGRESS
   PR SUCCESS 2.86  50 PER CENT
   RESOURCES. 3.00  FOOD TECH LAB, FOOD TECH, BIOCHEMIST
   TIME FRAME 2.64  3 TO 5 YEARS
   COST...... 2.93  $60,000 TO $100,000 PER YEAR
```

## ECONOMIC ANALYSIS AND SIMULATION

For an industry which presently is in operation an economic analysis of unit costs associated with each stage of the production process and factors limiting production at each stage is an essential concomitant of the above research planning process. Economic analysis is in fact one of the factors listed in Table 1. Such an analysis calculates the total variable cost of production as a sum of variable unit costs times the number of units of production plus fixed costs for a given production range. Appropriate modifications can be made to consider economics of scale which occur for different production levels and alternative production methods can also be evaluated. R. A. Shleser (1977, personal communication) has performed such an analysis for the Macrobrachium industry in Hawaii. This approach is especially suited to examination of a specific aquaculture operation in a specific location, as opposed to the broader planning problem which seeks to determine the operations and locations which are optimal. Examples of the applications of this technique to lobster aquaculture can be found in Shuur et al. (1974) and Hand (1977). An analysis of closed-cycle oyster culture cause found in Opportunity Brief No. 7 of the MIT Sea Grant Program (1977).

In the economic analysis as described the parameters for cost and volume of production are derived from observation of the actual industry. In a similar approach for an industry not yet in operation, the parameters can be developed through study of similar systems, research results, cost surveys and the imagination and experience of the planner. The result is very nearly the same except that the answers have only the weight of the best judgment of the planner and his information sources rather than the weight of practical experience. In any event, any person or corporation planning to invest capital in an aquaculture operation (or any other operation) would be well advised to perform such an analysis.

A related technique appropriate for aquaculture projects which have been proposed and are in planning stages is simulation. The economic analysis with simulation is appropriate only for aquaculture industries in an advanced planning stage such that it is possible to envision every step of the production process. It is essential also to have the cooperation of experts familiar with research or prototype production results for all or most of the production stages. The simulation need not be the elaborate mathematical construction usually implied by the term when it is applied to engineering projects or research in natural ecosystems. It can be little more complicated than the economic analysis described above, but might be expected to grow more complex as more detailed analyses are performed. The articles by Shuur et al. (1974) and Hand (1977) also illustrate the simulation approach to Lobster aquaculture planning.

Figure 3 shows a diagrammatic plan for an economic analysis with simulation for a hypothetical oyster culture operation. Solid lines show flow of biomass from one production stage to another whereas dotted lines show the sources of information on costs and production volumes. Because of the uncertainties associated with growth of biological material, the diagram shows the inclusion of failure probabilities. Not shown on the diagram are numerous small information inputs (system parameters), such as market price, labor cost, material cost, etc. Output of the system is a simulated balance sheet showing costs of returns for a given time period. The method can be most easily used if the cost summations and products of unit costs times production volumes are programmed for a computer. A programmable calculator was used for the simple system of Fig. 3, without the probabilistic features. By changing assumptions about parameters such as price and labor costs at various stages, critical points for a profitable industry can be determined. Sensitivity analysis is the technical term for this process. By utilizing the probabilistic data, the expected variability in net returns can also be examined. Simulation gives the same results as a one-time one-configuration economic analysis but the simulation is more versatile and can be repeated for various configurations to give a broader planning perspective.

The stepwise survey procedure and the economic analysis give results which are complementary to each other and not duplicative. The survey is a subjective method designed to give due accord to the opinions of many professionals who may not completely agree. The economic analysis is a more objective method which will help assure that research results contribute effectively to optimal industry development. Additionally, economic analysis is more appropriate for detailed review of specific proposed production operations whereas the survey gives a broader view. The two approaches can not be expected to give identical results.

Shleser's analysis reveals that availability of fresh water and costs of labor for the harvesting operation are two of the most critical areas for further expansion of Macrobrachium in Hawaii. This can be contrasted with the high priority of some economic analysis (e.g. market research) projects determined in this project. Availability of adequate fresh water did not show up as a critical problem via the methods of this project but might be identified as a result of a project to examine possible locations for Macrobrachium culture (Factor 10, Land and Water).

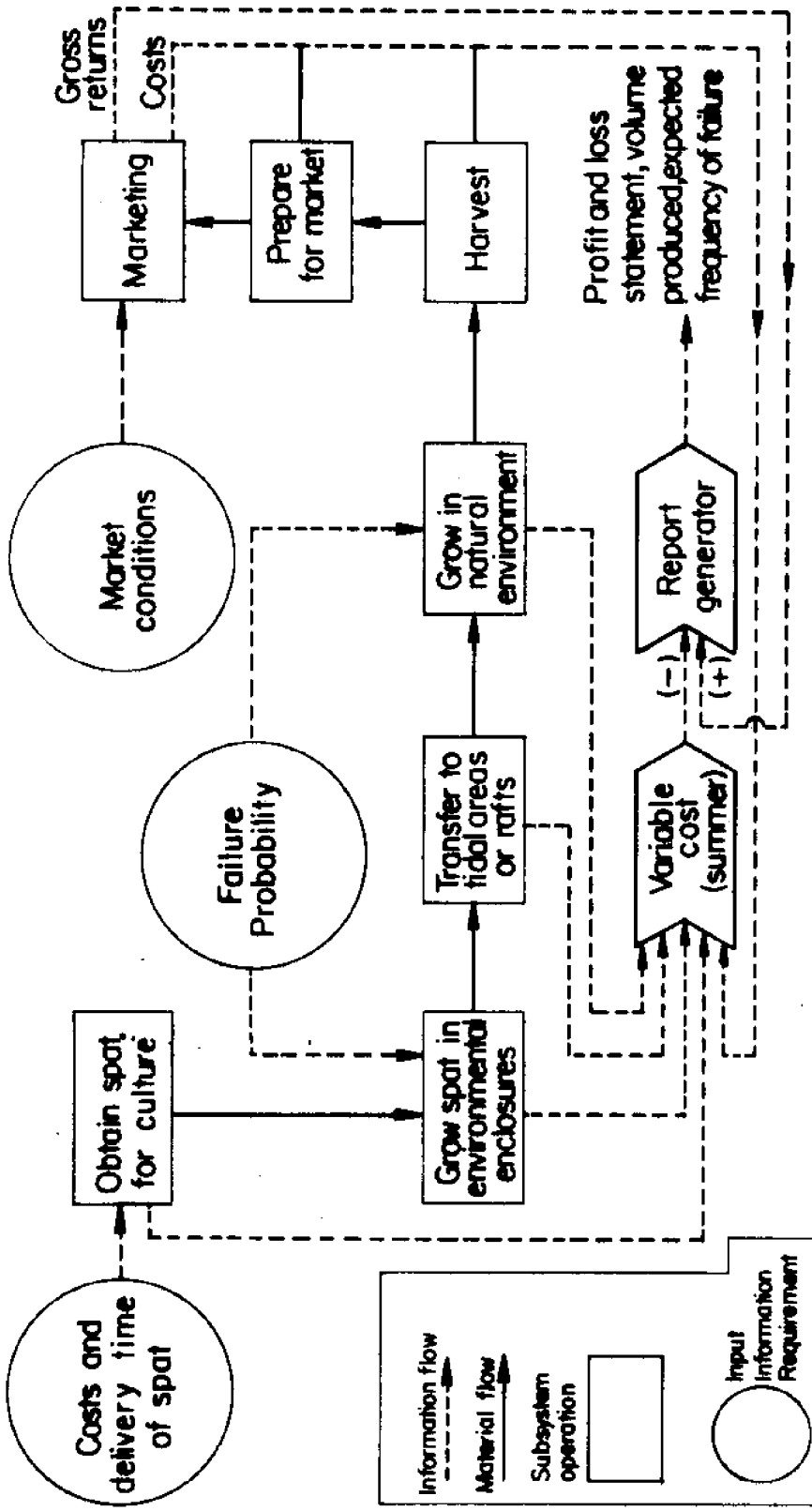


FIGURE 3. Simulation with economic analysis for one alternative method of oyster aquaculture. Each sub-system operation has a time for completion of a specified volume of material and calculates the cost of its operation. Output of the system is volume of material per unit time and an expected profit-loss statement. A separate sub-system would evaluate investment capital requirements.

## SUMMARY AND RECOMMENDATIONS

This report describes three aids to the planning of research intended to promote the development of an aquaculture industry: the program evaluation to review (PERT) technique, a step-wise procedure for obtaining and evaluating advice from experts on a comprehensive array of possible research projects and an economic analysis of an aquaculture industry for a particular species group. The PERT analysis is intended to obtain an overview of the general areas where research and development is needed for species groups and to identify potential bottlenecks in that development from a preliminary perspective.

The step-wise procedure is intended to comprehensively prioritize research in all aspects of aquaculture for a particular species group, as these areas are seen by experts in the field. This procedure involves organization of all factors concerning production of a species group into research projects which are then evaluated by experts in the field. The expert evaluation is then summarized and refined to determine those projects regarded as having highest overall priority. Finally, the information developed in the survey is used as the basis for an information system to keep track of progress in industry development. The procedure is illustrated by development of research priorities for a Macrobrachium industry; the twelve highest priority projects to come out of this analysis are shown in Table 7. The logistics for production of such a survey are described in the section entitled "Methodology for Information Development and Analysis."

Finally, an economic analysis is discussed as a mechanism for pinpointing economic bottlenecks in an industry. A more complex version of economic analysis involving simulation of the production process is also discussed and briefly illustrated (Figure 3). The three methods described are intended to be complimentary to each and each would be appropriate as part of an aquaculture planning task. The results of the three methods are not duplicative in nature; for example, the step-wise procedure may give general research priorities for an industry in an overall sense, whereas an economic analysis may give critical factors for development of an industry utilizing particular culture methods in a particular geographic area.

The approaches described are not designed to replace human judgment in making decisions concerning allocation of scarce research resources; they are designed to summarize and organize information concerning research needs and present it in the most effective way to persons making such decisions. A method of comparison of the views of experts from various areas so as to arrive at a concensus concerning research priorities has always been a difficult problem for public agencies which sponsor research. The methods described above are offered as an aid in this area.

Table 7. The twelve highest priority projects based on average rating in the payoff category. Priority rating is a number from 1 to 4, meaning "not needed" to "urgently needed", respectively. Averages are calculated over all categories of respondents.

| Project No. | Description | Average Priority Ratings | No. of Respondents |
|---|---|---|---|
| 14.04.05 | Develop alternative larval food | 3.69 | 13 |
| 14.04.02 | Increase supply of *Artemia* | 3.61 | 13 |
| 02.03.01 | Determine optimum levels of dissolved oxygen | 3.42 | 12 |
| 15.04.02 | Evaluate utility of nursery systems | 3.42 | 12 |
| 15.04.05 | Determine optimum stocking density | 3.34 | 12 |
| 15.04.06 | Manage pond operations at adequate production at acceptable costs | 3.34 | 9 |
| 16.02.05 | Evaluate commercially available feeds | 3.34 | 12 |
| 28.01.02 | Conduct prototype testing to validate laboratory results | 3.30 | 10 |
| 02.03.02 | Evaluate methods of maintaining oxygen levels | 3.28 | 13 |
| 14.04.01 | Improve feeding procedures of *Artemia* | 3.28 | 12 |
| 16.03.01 | Establish relationship between amount fed and amount utilized | | |
| 20.02.01 | Identify best methods of freezing product | 3.28 | 12 |

Appendix A lists the entire set of factors, problems and projects finally decided upon for the Macrobrachium Aquaculture Development Plan. Appendix B lists the complete set of project parameters suggested for a Macrobrachium industry at the December 13, 1976, workshop. Appendix C contains the results of a follow-up questionnaire which considered a broader array of projects than was possible at the workshop. Table 7 lists the 12 highest priority projects which were determined from the second questionnaire based upon the average rating in the six categories over all categories of respondents. Summaries of this type can be easily produced by the information system for different categories of respondents, for example, academic versus industrial, to allow the decision maker to examine differences of opinion concerning the best approach to industry development.

## Recommendations

The planning of research for development of such a diverse set of industries as aquaculture is a task of considerable complexity. This report has attempted to show a method whereby a systematic, comprehensive and orderly evaluation of possible research and development areas can be made. It is ultimately the task of federal government, possibly including several cabinet-level agencies, to perform this planning process, and indeed the process will involve much more than simply development of research priorities. We feel that the office ultimately assigned major responsibility in this planning task could utilize some of the techniques explored in this project, and we make the following recommendations to that office:

1) That a systematic and comprehensive procedure for development and evaluation by experts of researchable topics (such as described above) be utilized for each priority species group according to the NOAA Aquaculture Plan;

2) That an information system derived from that procedure and research projects be maintained and updated as necessary for each priority species group;

3) That economic analysis be utilized to identify critical problems with specific types of operation in specific locations;

4) That a staff with the necessary technical background in both information organization and substantive aquaculture-related scientific areas be developed in pursuit of recommendations 1 through 3;

5) That both the subjective results of 1 above as well as the more objective results of 3 be utilized as part of the criteria for research project proposal requests and funding allocations.

A major objective of an aquaculture plan is to help those entering the industry to realistically identify the problems with which they will be confronted. The planning system described is designed to accomplish this goal within a framework of systematic evaluation of a comprehensive array of research topics. It should allow a research sponsoring institution to request proposals in specific areas which they feel are most urgently needed. At the same time the system will give researchers

an idea of where best to address their work for high probability of an applied payoff and, simultaneously, enhanced probability of proposal funding. The system should represent a good compromise between an objective method for research project prioritization and a subjective method capable of taking into account a broader array of factors including, particularly, professional and scientific opinion.

# LITERATURE CITED

Fujimoto, Michael, Takuji Fujimera and Ken Kato. 1977. An idiot's guide to prawn farming. Book II, Chapter VI in Hanson and Goodwin (1977).

Glude, J. B. (ed.). 1977. NOAA aquaculture plan. National Oceanic and Atmospheric Administration/National Marine Fisheries Service and Office of Sea Grant. U. S. Government Printing Office. Washington, D. C. 41 pp.

Glude, J. B., R. A. Shleser and L. J. Bledsoe. 1977. Species plan for freshwater prawns of the genus Macrobrachium. National Oceanic and Atmospheric Administration. Draft manuscript. 88 pp.

Hand, Cadet. 1977. Development of aquaculture systems. University of California, Sea Grant Report SG-58, 554 Hutchinson Hall, Davis, California 95616.

Hanson, Joe A. and Harold L. Goodwin (eds.). 1977. Shrimp and prawn farming in the western hemisphere. Dowden, Hutchinson and Ross, Inc., Strandsburg, Penn. 439 pp.

Johnson, Richard A., William T. Newell and Roger C. Vergin. 1972. Operations Management: A systems concept. Houghton-Miffiin Co., N. Y. 546 pp.

MIT Sea Grant Program. 1977. Closed cycle aquaculture. Opportunity Brief No. 7. Marine Industry Advisory Services, Massachusetts Institute of Technology Sea Grant Program. Rep. 77-15. Cambridge, Mass. 02139. 30 pp.

Shleser, R. A. 1977. Personal communication, Aquaculture planning and development study, State of Hawaii, Office of Planning and Economic Development, Honolulu.

Shuur, A. M., P. G. Allen, and L. W. Botsford. 1974. An analysis of three factors for the commercial production of Homarus americanus. Technical Paper 74-5517. American Society of Agricultural Engineers, Chicago, December 10-13, 11 pp.

## Appendix A

List of factors, problems and projects with their indexing numbers which were utilized in the *Macrobrachium* research priorities survey.

AQUACULTURE RESEARCH INFORMATION SYSTEM
MACROBRACHIUM RESEARCH CLASSIFICATION SYSTEM

01. GROWTH
  01.01. IS THE MAXIMUM SIZE OF VARIOUS SPECIES OF MACROBRACHIUM ADEQUATE FOR A MARKETABLE PRODUCT+
    01.01.01. DETERMINE MAXIMUM SIZE OF VARIOUS SPECIES OF MACROBRACHIUM UNDER VARIOUS CONDITIONS.
  01.02. EFFECT OF ENVIRONMENTAL FACTORS ON GROWTH RATE
    01.02.01. DETERMINE GROWTH RATE OF VARIOUS SPECIES UNDER VARIOUS CONDITIONS.
    01.02.02. STUDY THE EFFECT OF PHOTOPERIOD ON GROWTH RATE.
    01.02.03. COMPARE GROWTH RATES OF MALES AND FEMALES AND DEVELOP STRATEGY FOR UTILIZING THE GROWTH DIFFERENTIAL TO INCREASE PRODUCTION.
    01.02.04. STUDY THE FUNCTIONS OF THE X AND Y GLANDS AND DETERMINE IF IT IS POSSIBLE TO INCREASE THE GROWTH PROCESS BY SHUTTING OFF THE PRODUCTION OF A MOLT INHIBITING SUBSTANCE BY THE X GLAND.
    01.02.05. DETERMINE THE RELATION OF DENSITY TO GROWTH RATE. ARE PHEROMONES PRESENT IF SO ARE THEY RELATED TO REPORTED REDUCTION IN GROWTH RATE WHEN PRAWNS ARE CROWDED+
    01.02.06. DETERMINE VARIABILITY OF GROWTH WITHIN FAMILIES AND CAUSES.
    01.02.07. STUDY THE EFFECT OF TEMPERATURE ON GROWTH RATE.
    01.02.08. EVALUATE GROWTH PROMOTING PRODUCTS OR HORMONES.
    01.02.09. EVALUATE INCREASE IN WEIGHT VS. AGE.
  01.03. NEED FOR UNDERSTANDING OF DIGESTIVE PHYSIOLOGY.
    01.03.01. CONDUCT RESEARCH TO DESCRIBE PHYSIOLOGICAL MECHANISM OF VARIOUS SPECIES.
02. ENVIRONMENTAL REQUIREMENTS
  02.01. EFFECTS OF MINERAL CONTENT OF THE WATER
    02.01.01. IDENTIFY TYPES AND AMOUNTS OF MINERALS FOUND IN PRODUCTION PONDS. EXAMINE CONCENTRATION OF VARIOUS IONS. DETERMINE EFFECT ON GROWTH AND SURVIVAL.
  02.02. EFFECTS OF SALINITY
    02.02.01. DETERMINE SALINITY RANGE THAT MAY LIMIT SURVIVAL, GROWTH AND PRODUCTION OF LARVAE, JUVENILES, AND ADULTS.
  02.03. EFFECTS OF DISSOLVED OXYGEN
    02.03.01. DETERMINE OPTIMUM LEVELS OF DISSOLVED OXYGEN AND LEVELS THAT MAY LIMIT SURVIVAL, GROWTH AND PRODUCTION OF LARVAE, JUVENILES, AND ADULTS.
    02.03.02. EVALUATE METHODS OF MAINTAINING OXYGEN LEVELS (E.G. AERATION VS. FLOW THROUGH SYSTEM) AS TO GROWTH AND SURVIVAL.
    02.03.03. DETERMINE LONG-TERM SUBLETHAL EFFECTS OF VARIOUS OXYGEN LEVELS ON GROWTH RATE, FOOD CONVERSION, ETC.
  02.04. EFFECTS OF TEMPERATURE
    02.04.01. DETERMINE TOLERANCES AND OPTIMUM TEMPERATURES FOR VARIOUS SPECIES UNDER VARIOUS CONDITIONS.
  02.05. EFFECTS OF PH LEVEL
    02.05.01. DETERMINE GROWTH RATE, SURVIVAL, FOOD CONVERSION AT PH LEVELS LIKELY TO BE ENCOUNTERED UNDER CONDITIONS OF CULTURE. DETERMINE OPTIMUM PH FOR CULTURE OF LARVAE, JUVENILES, ADULT

PRAWNS.

02.06. EFFECTS OF CONTAMINANTS (PESTICIDES, ORGANIC COMPOUNDS, HEAVY METALS AND CHEMICALS)

02.06.01. DETERMINE EFFECTS OF VARIOUS LEVELS OF PESTICIDES COMMON IN AREAS WHERE PRAWN FARMING IS DONE ON LARVAE, JUVENILES, AND ADULTS.

02.06.02. DETERMINE EFFECTS OF VARIOUS LEVELS OF HEAVY METALS, ORGANIC COMPOUNDS ON LARVAE, JUVENILE, AND ADULT PRAWNS.

02.06.03. DETERMINE EFFECTS OF CHEMICALS USED IN POND MANAGEMENT ON THE PRAWNS.

02.06.04. DETERMINE EFFECTS OF OTHER CONTAMINANTS LIKELY TO BE PRESENT ON LARVAE, JUVENILES, AND ADULTS.

02.07. EFFECTS OF METABOLIC WASTES (AMMONIA, NITRITE, NITRATE)

02.07.01. DETERMINE EFFECT OF AMMONIA ON GROWTH, FOOD CONVERSION AND SURVIVAL OF LARVAE, JUVENILES, AND ADULTS.

02.07.02. DETERMINE EFFECT OF NITRITE ON GROWTH, FOOD CONVERSION AND SURVIVAL OF LARVAE, JUVENILES, AND ADULTS.

02.07.03. DETERMINE EFFECT OF NITRATE ON GROWTH, FOOD CONVERSION AND SURVIVAL OF LARVAE, JUVENILES, AND ADULTS.

02.07.04. DETERMINE EFFECT OF PHOSPHATE ON GROWTH, FOOD CONVERSION AND SURVIVAL OF LARVAE, JUVENILES, AND ADULTS.

02.09. EFFECTS OF OTHER ENVIRONMENTAL FACTORS

02.08.01. DETERMINE EFFECTS OF VARIOUS OTHER ENVIRONMENTAL FACTORS ON SURVIVAL, GROWTH AND PRODUCTION OF VARIOUS SPECIES OF MACROBRACHIUM.

03. NUTRITIONAL REQUIREMENTS

03.01. DETERMINING THE BASIC NUTRITIONAL REQUIREMENTS FOR GROWTH SURVIVAL AND HEALTH OF VARIOUS SPECIES AT VARIOUS LIFE STAGES.

03.01.01. DETERMINE ESSENTIAL AND NON-ESSENTIAL AMINO ACID REQUIREMENTS FOR LARVAE, JUVENILES, AND ADULTS AND LEVELS NEEDED FOR ADEQUATE GROWTH AND GOOD HEALTH.

03.01.02. DETERMINE ESSENTIAL AND NON-ESSENTIAL FATTY ACID REQUIREMENTS FOR LARVAE, JUVENILES, AND ADULTS AND LEVELS NEEDED FOR ADEQUATE GROWTH AND GOOD HEALTH.

03.01.03. DETERMINE CARBOHYDRATE REQUIREMENTS FOR LARVAE, JUVENILES, AND ADULTS AND LEVELS NEEDED FOR ADEQUATE GROWTH AND GOOD HEALTH.

03.01.04. DETERMINE THE OPTIMUM RATIO OF PROTEIN TO FAT TO CARBOHYDRATE FOR LARVAE, JUVENILES, AND ADULTS.

03.01.05. DETERMINE VITAMIN REQUIREMENT FOR LARVAE, JUVENILES, AND ADULTS AND LEVEL NEEDED FOR ADEQUATE GROWTH AND GOOD HEALTH.

03.01.06. DETERMINE MINERAL REQUIREMENTS FOR LARVAE, JUVENILES, AND ADULTS AND LEVELS NEEDED FOR ADEQUATE GROWTH AND GOOD HEALTH.

03.01.07. DETERMINE THE SIGNIFICANCE OF DIETARY FIBER IN THE DIET OF JUVENILES AND ADULTS.

04. DISEASE AND MORTALITY

04.01. EFFECT OF PATHOGENS

04.01.01. STUDY BLACK SPOT, EPISTYLIS, AND OTHER DISEASES CAUSED BY PATHOGENS. DETERMINE MODE OF INFECTION AND TRANSMISSION.

04.02. EFFECTS OF STRESS-RELATED DISEASES
04.02.01. STUDY THE EFFECT OF TEMPERATURE FLUCTUATION AND WATER QUALITY FACTORS LISTED IN FACTOR 02 (ENVIRONMENTAL REQUIREMENTS) ON SUSCEPTIBILITY TO VARIOUS KINDS OF DISEASES.
04.02.02. STUDY THE EFFECT OF HANDLING ON SURVIVAL OR POSSIBLE INFECTION BY ORGANISMS PRESENT IN THE CULTURE ENVIRONMENT.
04.02.03. STUDY THE EFFECT OF MULTIPLE HARVESTING ON SURVIVAL. DETERMINE IF PRAWNS WHICH HAVE PASSED THROUGH NETS ARE INJURED AND SUCCUMB TO DISEASE OR DIE BECAUSE OF INJURY.
04.02.04. STUDY THE EFFECTS OF MALNUTRITION ON SURVIVAL. IMPROPER DIET MAY STRESS ANIMALS AND MAKE THEM SUSCEPTIBLE TO DISEASE. STUDY INCIDENCE OF DISEASE WITH VARIOUS RATIONS HAVING DIFFERENT COMPONENTS.
04.02.05. STUDY THE EFFECT OF CROWDING ON SURVIVAL. DETERMINE DENSITIES AT WHICH DISEASE MAY OCCUR IN GROW-OUT SITUATIONS.
04.03. EFFECTS OF PREDATORS
04.03.01. DETERMINE EXTENT OF PREDATION BY FISH, BIRDS AND OTHER FORMS.
04.04. EFFECTS OF COMPETITORS AND PESTS
04.04.01. DETERMINE EFFECT OF COMPETITORS SUCH AS FISH.
04.04.02. EVALUATE EFFECT OF ALGAE IN PONDS.
04.05. EFFECTS OF OTHER FACTORS WHICH MAY CAUSE MORTALITY OR ILL HEALTH
04.05.01. DETERMINE EFFECTS OF VARIOUS FACTORS.
04.06. NEED TO UNDERSTAND NORMAL HISTOLOGY AS BASIS FOR EVALUATING EFFECTS OF DISEASES.
04.06.01. ESTABLISH REFERENCE COLLECTION OF NORMAL HEALTHY TISSUES.
05. SEXUAL DEVELOPMENT
05.01. EFFECTS OF CHARACTERISTICS OF VARIOUS SPECIES OF MACROBRACHIUM ON THEIR CULTURE IN AQUACULTURE SYSTEMS.
05.01.01. STUDY METHODS OF SEX RATIO MODIFICATION. EXPOSE ANIMALS IN CULTURE TO THE PRESENCE OF HORMONES IN AN ATTEMPT TO ALTER SEXUAL DEVELOPMENT. INVESTIGATE POSSIBILITY OF PRODUCTION OF MONOSEXUAL POPULATIONS.
05.01.02. STUDY MECHANISM OF BULL DEVELOPMENT. INVESTIGATE THE CIRCUMSTANCES OR POSSIBLE MECHANISM THAT MAY INHIBIT YOUNG MALES FROM BECOMING LARGE-CLAWED BULL PRAWNS OR FACTORS WHICH PROMOTE THIS CHANGE.
05.01.03. EVALUATE FACTORS WHICH MAY EFFECT THE RATIO OF MALES TO FEMALES AND DETERMINE MECHANISMS INVOLVED.
05.01.04. DETERMINE IF THE RATIO OF MALES, FEMALES AND BULLS IS A TRAIT WHICH SEGREGATES IN POPULATIONS OR IF IT CAN BE MODIFIED BY CHANGES IN THE ENVIRONMENT.
06. REPRODUCTION
06.01. EFFECTS OF VARIOUS FACTORS ON REPRODUCTION IN CAPTIVITY AND THEIR CONTROL.
06.01.01. STUDY EFFECT OF PHOTOPERIOD ON REPRODUCTION. DETERMINE IF REPRODUCTION IS ENHANCED BY PHOTOPERIODS OF CERTAIN DURATION OR MAY BE INHIBITED BY MODIFICATION OF PHOTOPERIOD.
06.01.02. STUDY EFFECTS OF TEMPERATURE ON REPRODUCTION.
06.02. NEED TO UNDERSTAND REPRODUCTIVE PHYSIOLOGY OF PRAWNS.

06.02.01. CONDUCT RESEARCH TO DESCRIBE PHYSIOLOGICAL MECHANISMS RELATED TO REPRODUCTION FOR VARIOUS SPECIES.

06.03. NEED FOR A METHOD OF ARTIFICIAL INSEMINATION.

06.03.01. CONDUCT RESEARCH TO DEVELOP RELIABLE METHODS.

07. GENETICS

07.01. EVALUATE GENETICS OF VARIOUS STOCKS OF SELECTED SPECIES.

07.01.01. COLLECT NEW STOCKS OF M. ROSENBERGII FROM VARIOUS PARTS OF THE WORLD. EVALUATE GROWTH, SURVIVAL, FOOD CONVERSION AND ECONOMIC CHARACTERISTICS. IDENTIFY STRAINS BEST SUITED FOR CULTURE.

07.01.02. ESTIMATE GENETIC VARIATION OF STOCKS OF M. ROSENBERGII BY ELECTROPHORETIC ANALYSIS FOR USE IN SELECTIVE CROSSING.

07.01.03. COLLECT OTHER SPECIES OF MACROBRACHIUM AND COMPARE PERFORMANCE, GROWTH, SURVIVAL, AND OTHER FACTORS WITH M. ROSENBERGII.

07.02. SELECTIVE CROSSING (HYBRIDIZATION)

07.02.01. CROSS SELECTED STOCKS OF M. ROSENBERGII. PERFORM SELECTED MATINGS TO INCREASE HETEROZYGOCITY AND HYBRID VIGOR.

07.02.02. CROSS SELECTED STOCKS OF OTHER SPECIES AND EVALUATE.

07.02.03. ATTEMPT SELECTED MATINGS OF M. ROSENBERGII WITH OTHER MACROBRACHIUM SPECIES. STUDY CHARACTERISTICS OF PROGENY WHICH MAY HAVE ECONOMIC ADVANTAGES.

07.03. SELECTIVE BREEDING FOR MONOSEX CULTURE

07.03.01. CONDUCT PARTHENOGENETIC SELECTION TO PRODUCE ONLY FEMALES. ALL FEMALE OFFSPRING MAY BE ADVANTAGEOUS FOR PRODUCTION, E.G. LIMITING CANNIBALISM ALLOWING MORE CROWDING. INVESTIGATE MEANS OF PRODUCING ALL FEMALE POPULATION.

07.03.02. CONDUCT PARTHENOGENETIC SELECTION TO PRODUCE MALES. INVESTIGATE MEANS OF PRODUCING ALL MALE POPULATIONS.

07.04. SELECTIVE BREEDING TO IMPROVE GROWTH RATES

07.04.01. CONDUCT HERITABILITY STUDIES. DETERMINE THE PERCENTAGE OF SELECTED CHARACTERISTICS THAT WOULD BE PASSED ON FROM GENERATION TO GENERATION. DEVELOP BREEDING FOR TRAITS WHICH OFFER ECONOMIC ADVANTAGES.

07.04.02. SELECT FOR UNIFORM GROWTH RATE. DEVELOP A POPULATION THAT CAN BE HARVESTED ALL AT ONE TIME. THIS MIGHT LEAD TO SELECTION FOR MORE UNIFORM GROWTH RATE.

07.04.03. SELECT FOR RAPID GROWING STRAINS. CARRY OUT MASS SELECTIVE EXPERIMENTS TO DEVELOP RAPID GROWING STRAINS.

07.05. SELECTIVE BREEDING FOR INCREASED SIZE

07.05.01. INVESTIGATE METHODS OF INCREASING POLYPLOIDY. POLYPLOIDY MAY YIELD ≠GIANT≠ ANIMALS AS A RESULT OF INCREASED NUMBER OF THE GENES OR FASTER GROWTH RATES BECAUSE MORE ENZYMES ARE PRESENT.

07.05.02. SELECT FOR ALTERATION OF HEAD-TO-TAIL RATIO. ATTEMPT TO BREED STOCKS WITH MORE TAIL AND LESS HEAD WHICH WOULD BE ADVANTAGEOUS IN MARKETING.

07.06. SELECTIVE BREEDING FOR IMPROVED CHARACTERISTICS OF LARVAE

07.06.01. SELECT FOR REDUCTION IN LARVAL DEVELOPMENT TIME OR FOR ELIMINATION OF STAGES IN LARVAL DEVELOPMENT.

07.06.02. SELECT FOR SIMPLICITY OF LARVAL CULTURE AND PROPA-

GATION. SELECT STRAINS WHICH HAVE LESS STRINGENT REQUIREMENTS FOR CULTURE, E.G. UTILIZE DRY FOOD, DON'T REQUIRE BRINE SHRIMP, ETC.

08. BEHAVIOR
    08.01. IDENTIFICATION OF BEHAVIOR PATTERNS OF VARIOUS SPECIES AND STOCKS OF PRAWNS
        08.01.01. INVESTIGATE MIGRATION PATTERNS IN POND. OBSERVE WHETHER ANIMALS MIGRATE DURING THE DAY. IDENTIFY ORIENTATION TO SUN AND WIND.
        08.01.02. STUDY EFFECTS OF VARYING THE SEX RATIO OF ANIMALS IN POND AND OBSERVE CHANGES IN BEHAVIOR, SUCH AS MORE OR LESS AGGRESSION, MATING BEHAVIOR AND EFFECT ON POPULATION.
        08.01.03. COMPARE BEHAVIOR OF ALL MALE AND ALL FEMALE POPULATIONS AND THE EFFECT ON TOTAL PRODUCTION.
        08.01.04. STUDY CHANGES IN BEHAVIOR ASSOCIATED WITH INCREASING DENSITY AT DIFFERENT STAGES OF GROWTH. (TERRITORIALITY)
        08.01.05. EVALUATE RESPONSE TO SOUND. THIS MAY LEAD TO METHODS TO ATTRACT PRAWNS TO FEEDING AREAS.
        08.01.06. EVALUATE RESPONSE TO LIGHT. STUDIES WITH LIGHT MAY LEAD TO BEHAVIOR MODIFICATION OR TO USE OF NATURAL RESPONSES IN CULTURE SYSTEMS.
        08.01.07. EVALUATE RESPONSE TO TEMPERATURE CHANGE. DETERMINE IF PRAWNS WILL MIGRATE IN A POND IN RESPONSE TO WARM OR COLD WATER.
        08.01.08. IDENTIFY FEEDING BEHAVIOR.
09. HABITAT ECOLOGY
    09.01. IDENTIFICATION OF ECOLOGICAL FACTORS IN PONDS OR OTHER CULTURE SYSTEMS AND THE RELATION TO VARIATIONS IN PRAWN PRODUCTION.
        09.01.01. STUDY PLANT BIOCOMMUNITIES IN PONDS. IDENTIFY SPECIES ASSOCIATED WITH PLANTS IN PONDS AND EVALUATE THEIR COMBINED EFFECT ON PRODUCTION AND FOOD CONVERSION.
        09.01.02. STUDY SLUDGE BIOCOMMUNITIES IN PONDS. CHARACTERIZE THE SLUDGE CHEMICALLY AND IDENTIFY ASSOCIATED ORGANISMS. RELATE SLUDGE COMMUNITY TO POND PRODUCTIVITY.
        09.01.03. EVALUATE PHYSICAL AND CHEMICAL CHARACTERISTICS OF WATER IN PONDS AND DETERMINE THE EFFECT ON PRODUCTIVITY.
        09.01.04. EVALUATE EFFECT OF SOIL COMPOSITION ON POND PRODUCTIVITY.
        09.01.05. EVALUATE EFFECT OF POND AGING ON PRODUCTIVITY.
        09.01.06. EVALUATE EFFECTS OF POND CONFIGURATION AND LOCATION ON PRODUCTIVITY.
    09.02. IDENTIFICATION OF POTENTIAL SPECIES FOR POLYCULTURE.
        09.02.01. EXPERIMENT WITH PLANT AND ANIMAL SPECIES THAT CAN BE GROWN BENEFICIALLY WITH PRAWNS.
10. LAND AND WATER
    10.01. LAND AND WATER AREAS IN LOCATIONS WHERE PRAWNS CAN BE GROWN SUCCESSFULLY ARE NEEDED FOR AQUACULTURE BUT COMPETING USES MAY MAKE SPACE UNAVAILABLE OR TOO EXPENSIVE. THIS MAY AFFECT SITE SELECTION.
        10.01.01. DETERMINE AVAILABILITY AND COST OF LEASING OR PURCHASING LAND AND WATER AREAS FOR VARIOUS SITES SELECTED FOR AQUACULTURE VENTURES.
11. LABOR SUPPLY
    11.01. MOST AQUACULTURE VENTURES ARE LABOR-INTENSIVE SO AVAILABILITY, PRODUCTIVITY, AND COST OF LABOR ARE IMPORTANT CON-

SIDERATIONS IN SITE SELECTION.
11.01.01. DETERMINE AVAILABILITY, COST AND PRODUCTIVITY OF LABOR IN AREAS SELECTED FOR EVALUATION AS SITES FOR AQUACULTURE VENTURES.
11.01.02. ESTABLISH CULTURE SYSTEMS THAT MINIMIZE MANPOWER REQUIREMENTS.

12. LOGISTICS
12.01. COSTS OF UTILITIES AND COST OF TRANSPORTING SUPPLIES TO PRODUCTION AREA, PREPARING THE PRODUCT AND SHIPPING IT TO MARKET MUST BE CONSIDERED IN SELECTING SITES.
12.01.01. DETERMINE LOGISTICS COSTS OF VARIOUS SITES SELECTED FOR AQUACULTURE VENTURES.

13. LEGAL REQUIREMENTS
13.01. PRAWN FARMERS MUST OBTAIN PERMITS AND LICENSES AND COMPLY WITH REQUIREMENTS OF VARIOUS REGULATORY AGENCIES AT FEDERAL, STATE, OR LOCAL LEVELS.
13.01.01. DETERMINE REQUIREMENTS OF VARIOUS REGULATORY AGENCIES AND DISSEMINATE THIS INFORMATION TO POTENTIAL PRAWN FARMERS.
13.01.02. ANALYZE COST OF MEETING REQUIREMENTS OF REGULATORY AGENCIES. USE THIS INFORMATION IN DETERMINING THE ECONOMICS OF PRAWN CULTURE AT VARIOUS LOCATIONS.
13.01.03. DEVELOP UNIFORM STATE REQUIREMENTS AND SIMPLIFY PROCEDURES FOR OBTAINING PERMITS.

14. SEED SUPPLY
14.01. BROODSTOCK MAINTENANCE
14.01.01. DETERMINE REQUIREMENTS AND COSTS
14.02. MATURATION OF ADULTS AND SPAWNING IN CAPTIVITY.
14.02.01. DETERMINE REQUIREMENTS AND COSTS
14.03. HATCHERY DESIGN AND CONSTRUCTION
14.03.01. DESIGN HATCHERY HEATING SYSTEM FOR YEAR-ROUND OPERATION WITH ACCEPTABLE COST OF OPERATION. DEVELOP AN INSULATED RECIRCULATED WATER SYSTEM FOR LARVAE. INVESTIGATE THE USE OF SOLAR HEAT EXCHANGERS.
14.03.02. DESIGN WATER SYSTEM TO CONTROL QUALITY AND FLOW RATES IN HATCHERIES.
14.03.03. INVESTIGATE MODIFICATION OF ENVIRONMENTAL CONDITIONS TO SHORTEN TIME REQUIRED FOR LARVAL DEVELOPMENT.
14.03.04. DESIGN AND CONSTRUCT HATCHERIES TO MINIMIZE LABOR REQUIREMENTS AND TO MAINTAIN OPTIMUM CONDITIONS FOR LARVAE. (SEE ALSO FACTOR 02. ENVIRONMENTAL REQUIREMENTS)
14.04. LARVAL FOODS
14.04.01. DEVELOP FEEDING PROCEDURES TO IMPROVE EFFICIENCY IN THE USE OF ARTEMIA.
14.04.02. INCREASE SUPPLY OF HIGH QUALITY ARTEMIA CYSTS FROM NATURAL SOURCES.
14.04.03. COMPARE AND EVALUATE NEW VARIETIES OF BRINE SHRIMP AS LARVAL FOOD. FEED VARIOUS SPECIES OF BRINE SHRIMP NAUPLII TO LARVAE DURING DEVELOPMENT PERIOD. EXAMINE GROWTH RATES AND SURVIVAL.
14.04.04. DEVELOP PROCEDURES FOR REARING ARTEMIA THROUGH THEIR LIFE CYCLE AT HATCHERY SITES TO PROVIDE CONTINUOUS SUPPLY OF NAUPLII.
14.04.05. DEVELOP AN ARTIFICIAL LARVAL FOOD AS REPLACEMENT FOR BRINE SHRIMP. TEST EXISTING FORMULATIONS FOR LARVAL SHRIMP AND LOBSTER FOOD IN FLAKE OR OTHER FORM. EXAMINE GROWTH RATE, SURVIVAL, AND LABOR

REQUIREMENTS, ETC.

14.05. HATCHERY MANAGEMENT

14.05.01. DEVELOP METHODS FOR ESTIMATING NUMBER OF LARVAE IN CULTURE TANKS.

14.05.02. DETERMINE AND COMPARE LARVAL DEVELOPMENT REQUIREMENTS FOR M. ROSENBERGII WITH M. TENELLUM AND OTHER SPECIES AND RELATE TO ECONOMICS OF PRODUCING VARIOUS SPECIES.

14.05.03. MANAGE HATCHERY OPERATIONS TO MAINTAIN ADEQUATE PRODUCTION OF POST LARVAE AT ACCEPTABLE COSTS.

14.05.04. DETERMINE WHEN POST LARVAE SHOULD BE TRANSFERRED FROM HATCHERY TO GROW-OUT FACILITIES FOR BEST SURVIVAL AND GROWTH.

14.05.05. DEVELOP METHODS FOR SORTING POST LARVAE AND JUVENILES BY SEXES TO FACILITATE MONOSEX CULTURE.

15. GROW-OUT SYSTEMS (SEE ALSO FACTOR 09. HABITAT ECOLOGY)

15.01. POND DESIGN AND CONSTRUCTION

15.01.01. DEVELOP CRITERIA FOR LOCATING MACROBRACHIUM PONDS AT PRODUCTION SITE.

15.01.02. COMPARE AND EVALUATE SUBSTRATE TYPES.

15.01.03. COMPARE AND EVALUATE METHODS OF STABILIZING BANKS. IDENTIFY BEST GRASS TO PLANT ON BANK. DETAIL METHODS OF MAINTAINING BANKS. EVALUATE OTHER METHODS OF STABILIZATION SUCH AS SOIL CEMENT.

15.01.04. DETERMINE OPTIMUM SLOPE OF BANK IN RELATION TO STABILITY OF SOILS.

15.01.05. EVALUATE DESIGNS WHICH WOULD INCREASE SUBSTRATE AREA TO INCREASE STOCKING DENSITY.

15.01.06. DEVELOP METHODS OF LIGHT CONTROL. TEST SUN SCREENS WHICH TRANSMIT VARIOUS AMOUNTS OF LIGHT TO PROVIDE SHADING IN ABSENCE OF ALGAE AND TO CONTROL WATER QUALITY.

15.01.07. COMPARE AND EVALUATE COSTS OF CONSTRUCTION FOR PONDS OF DIFFERENT SIZE, SHAPE AND DEPTH AND COMPARE CONFIGURATIONS WITH PRODUCTION BENEFITS.

15.02. HEATING PONDS TO MAINTAIN ADEQUATE TEMPERATURE FOR OPTIMUM GROWTH

15.02.01. ESTABLISH RELATIONSHIP OF FLOW RATE AND WATER TEMPERATURE TO HEATING METHOD.

15.02.02. ESTABLISH RELATIONSHIP OF POND CONFIGURATION TO TEMPERATURE MAINTENANCE.

15.02.03. COMPARE AND EVALUATE METHODS AND COSTS OF INCREASING POND TEMPERATURE INCLUDING USE OF POWER PLANT THERMAL EFFLUENT OR GEOTHERMAL WATER.

15.02.04. DESIGN HEATING SYSTEMS WITH HEAT EXCHANGERS IN BOTTOM OF PONDS FOR USE WITH THERMAL EFFLUENTS OR GEOTHERMAL WATERS.

15.02.05. DETERMINE RELATIONSHIP OF LIGHT INTENSITY TO TEMPERATURE CONTROL. DETERMINE THE EFFECT OF A SUN SCREEN ON POND TEMPERATURE AND EVALUATE PRODUCTION COSTS AND BENEFITS.

15.03. WATER QUALITY CONTROL (SEE ALSO FACTORS 02 ENVIRONMENTAL REQUIREMENTS AND 09 HABITAT ECOLOGY)

15.03.01. DETERMINE EFFECTS OF ARTIFICIAL NUTRIFICATION WITH NITRATE, PHOSPHATES, POTASSIUM, ETC. ON THE AMOUNTS OF FOOD, REQUIRED PRODUCTION LEVELS AND WATER QUALITY.

15.03.02. ESTABLISH RELATIONSHIP OF FLOW RATE TO WATER QUALITY. MODIFY FLOW RATE TO STUDY EFFECT ON NUTRIENT LEVELS, DISSOLVE OXYGEN LEVELS, AND

ALGAE (SHADING).

15.03.03. EVALUATE THE EFFECT OF SLUDGE ON WATER QUALITY AND PRODUCTION. DESCRIBE THE CHEMICAL CONTRIBUTION OF SLUDGE TO WATER QUALITY. IDENTIFY ELEMENTS THAT AFFECT GROWTH METABOLISM, FOOD CONVERSION, ETC. CHARACTERIZE RELATIONSHIP OF SLUDGE TO OVERALL WATER QUALITY.

15.04. POND MANAGEMENT

15.04.01. DEVELOP METHODS FOR ESTIMATING NUMBER AND SIZE DISTRIBUTION OF PRAWNS IN PONDS.

15.04.02. EVALUATE THE UTILITY OF NURSERY SYSTEMS FOR INTENSIVE CULTURE OF POST LARVAE WITH ARTIFICIAL FERTILIZATION AND SPECIAL FEEDS FOR VARYING PERIODS BEFORE STOCKING IN PONDS. SET UP POST LARVAE IN INTENSIVE CULTURE SITUATIONS. DETERMINE WHETHER USE OF NURSERY PONDS INCREASES GROWTH RATES, IMPROVES FEED CONVERSION AND ENHANCES SURVIVAL TO MARKET SIZE.

15.04.03. DETERMINE OPTIMUM SIZE OF POST LARVAE FOR STOCKING IN PONDS. HOLD POST LARVAE IN SMALL NURSERY PONDS FOR VARIOUS LENGTHS OF TIME. COMPARE COSTS OF HOLDING AND SURVIVAL RATE. MEASURE EFFECT ON PRODUCTION.

15.04.04. COMPARE HARVESTING AND RESTOCKING VS. CONTINUOUS HARVESTING METHOD. EVALUATE THE ECONOMICS OF HARVESTING AN ENTIRE POND BY DRAINING COMPARED WITH FREQUENT SEINING AND PERIODIC RESTOCKING WITHOUT HARVESTING THE ENTIRE CROP.

15.04.05. DETERMINE OPTIMUM STOCKING DENSITY. STOCK SYSTEMS PONDS WITH VARIOUS LEVELS OF POST LARVAE. COMPARE RATES OF GROWTH AND SURVIVAL. MONITOR WATER QUALITY. EVALUATE ECONOMIC TRADEOFFS IN PRAWN SIZE VS. NUMBERS.

15.04.06. MANAGE POND OPERATIONS TO MAINTAIN ADEQUATE PRODUCTION OF HARVESTABLE PRAWNS AT ACCEPTABLE COSTS.

15.05. IDENTIFY FACTORS WHICH MUST BE CONSIDERED IN DESIGN AND OPERATION OF INTENSIVE CULTURE SYSTEMS USING TANKS, RACEWAYS, ETC.

15.05.01. DEVELOP DESIGN CRITERIA FOR INTENSIVE CULTURE SYSTEMS

15.05.02. TEST VARIOUS INTENSIVE CULTURE SYSTEMS AT LABORATORY AND PROTOTYPE SCALE.

15.05.03. ANALYZE RESULTS TO DETERMINE A RELATIVE COST OF PRODUCTION IN POND AND INTENSIVE CULTURE SYSTEMS.

16. FEEDS AND FEEDING (SEE ALSO FACTOR 03. NUTRITIONAL REQUIREMENTS)

16.01. A STANDARD LABORATORY RATION IS NEEDED AS A BASE LINE FOR TESTING VARIOUS FEEDS.

16.01.01. DEVELOP A STANDARD LABORATORY RATION.

16.02. FORMULATION OF RATIONS WHICH WILL PRODUCE ACCEPTABLE GROWTH AND MAINTAIN HEALTH WITHIN ACCEPTABLE COST LIMITS.

16.02.01. COMPARE AND EVALUATE FEED TEXTURES AND CONSISTENCIES. PREPARE AND EVALUATE FOODS WHICH HAVE THE SAME NUTRIENT COMPOSITION BUT VARY IN FORMULATION, SUCH AS HARD VS. SOFT TEXTURE TO DETERMINE WHAT FORMS ARE MOST EFFICIENTLY USED BY THE ANIMAL.

16.02.02. EVALUATE FOOD BINDERS AND PROCESSING TECHNIQUES TO CONTROL SOLUBILITY OF FOODS.

16.02.03. COMPARE AND EVALUATE FOOD SHAPES AND SIZES. PREPARE AND EVALUATE FOODS WITH SAME NUTRIENT COMPOSITION BUT VARY IN SHAPE AND SIZE. DETERMINE

WHAT FORMS ARE MOST ATTRACTIVE TO ANIMALS. FEED DIFFERENT SIZED PARTICLES AT SAME TIME IN MIXED CULTURES.

16.02.04. IDENTIFY AND EVALUATE ATTRACTANTS THAT STIMULATE FEEDING. PREPARE AND EVALUATE FOODS WITH SAME NUTRIENT COMPOSITION WITH VARIOUS TYPES OF ATTRACTANT OR WITHOUT AN ATTRACTANT.

16.02.05. EVALUATE COMMERCIALLY AVAILABLE FEEDS IN COMPARISON WITH THE STANDARD LABORATORY RATION. ANALYZE CHICKEN BROILER STARTER AND OTHER COMMERCIALLY AVAILABLE FEEDS AND DETERMINE IF ITS FORMULATION COULD BE ALTERED TO FEED PRAWNS AT LOWER COST.

16.02.06. DEVELOP ALTERNATIVE FEED COMPOSITION ON THE BASIS OF COSTS OF INGREDIENTS WHICH ARE INTERCHANGEABLE. IDENTIFY ALTERNATIVE COMPONENTS IN FEED FORMULATION ON THE BASIS OF LOCAL COSTS. INCLUDE COST OF FORMULATION.

16.02.07. DEVELOP ALTERNATIVE FEED COMPOSITION ON BASIS OF AVAILABILITY. IDENTIFY ALTERNATIVE COMPONENTS IN FEED FORMULATION ON THE BASIS OF LOCAL AVAILABILITY USING FEED FORMULATION TABLES TO BE DEVELOPED FOR LOCAL INGREDIENTS.

16.03. FEED UTILIZATION

16.03.01. ESTABLISH RELATIONSHIP BETWEEN AMOUNT FED AND AMOUNT UTILIZED. CALCULATE THE WASTE-FEED RATIO FOR VARIOUS DIETS TO DETERMINE WHICH FOODS ARE MOST EFFICIENT.

16.03.02. DETERMINE CONTRIBUTION OF UNEATEN OR UNDIGESTED FOOD TO FERTILIZATIONOF PONDS.

16.03.03. DETERMINE RATE OF FOOD CONVERSION. CONDUCT STUDIES TO ESTABLISH FOOD CONSUMPTION AND CONVERSION FOR VARIOUS STAGES OF PRAWN IN CULTURE.

16.04. FEED DISTRIBUTION

16.04.01. DETERMINE OPTIMUM FREQUENCY OF FEEDING. DETERMINE FOOD UTILIZATION AND CONVERSION USING DIFFERENT FEEDING FREQUENCIES.

16.04.02. DETERMINE OPTIMUM TIME OF FEEDING. CONDUCT STUDIES TO DETERMINE IF FEEDING AND CONVERSION IS FAVORED BY FEEDING AT VARIOUS TIMES OF DAY.

16.04.03. IMPROVE EFFICIENCY OF FEEDING BY UTILIZING BEHAVIOR PATTERNS.

17. HEALTH (SEE ALSO FACTOR 04 DISEASE AND MORTALITY)

17.01. CONTROL OF FACTORS WHICH CAUSE MORTALITY OR POOR HEALTH IN CULTURE SYSTEMS

17.01.01. MONITOR STOCKS IN CULTURE SYSTEMS TO DETECT PATHOGENIC DISEASES AND APPLY TREATMENTS.

17.01.02. MODIFY CULTURE PROCEDURES TO MINIMIZE STRESS.

17.01.03. DEVELOP AND APPLY PROCEDURES TO CONTROL PREDATORS

17.01.04. DEVELOP AND APPLY PROCEDURES TO CONTROL COMPETITORS

17.01.05. DEVELOP AND APPLY PROCEDURES TO CONTROL ALGAE, WEEDS, AND OTHER ADVERSE ENVIRONMENTAL FACTORS IN PONDS

17.01.06. PUBLISH A MANUAL ON HEALTH AND DISEASES OF MACROBRACHIUM, AND TREATMENT PROCEDURES.

18. HARVESTING PROCEDURES

18.01. POND HARVESTING STRATEGY

18.01.01. DETERMINE THE OPTIMUM TIME AND FREQUENCY OF HARVESTING. VARY FREQUENCY OF HARVEST OF PRAWNS ABOVE AN ESTABLISHED MINIMUM SIZE. RELATE FOOD

CONSUMPTION VS. SIZE TO DETERMINE MOST ECONOMICAL STRATEGY.

18.02. POND HARVESTING METHODS.

18.02.01. COMPARE AND EVALUATE CURRENT METHODS OF HARVESTING INCLUDING POND DRAINAGE, NETTING, ETC. EVALUATE POND DESIGN AS A MEANS OF INCREASING HARVESTING EFFICIENCY.

18.02.02. DETERMINE THE EFFECT OF SLUDGE ACCUMULATION ON EFFICIENCY OF HARVESTING.

18.02.03. DESIGN IMPROVED NETS FOR HARVESTING. DESIGN NEW NETS FOR EXISTING METHODS OF OPERATION THAT WOULD REDUCE THE NUMBER OF SMALL PRAWNS KILLED OR INJURED, IMPROVE EFFICIENCY AND REDUCE LABOR.

18.02.04. DEVELOP MECHANIZED OR AUTOMATED METHODS OF HARVESTING. DESIGN RACEWAYS, CIRCULAR PONDS, ETC. TO ACCOMMODATE MECHANIZED OR AUTOMATED EQUIPMENT.

18.02.05. INVESTIGATE UTILIZATION OF PRAWN BEHAVIOR PATTERNS SUCH AS MIGRATION AND RESPONSE TO LIGHT TO IMPROVE METHODS OF HARVESTING.

19. PREPROCESSING

19.01. HANDLING PRAWNS FROM HARVEST TO PROCESSING TO MINIMIZE QUALITY LOSS.

19.01.01. DEVELOP METHOD OF RAPIDLY TRANSFERRING PRAWNS FROM PONDS TO PROCESSING UNIT.

19.01.02. DETERMINE ACCEPTABLE TIME UNTIL PROCESSED. STUDY EFFECTS ON QUALITY OF CHILLING VS. HOLDING AT ROOM TEMPERATURE.

19.01.03. DEVELOP STANDARD PROCEDURES FOR HANDLING PRIOR TO PROCESSING TO PREVENT LOSS OF QUALITY.

20. PROCESSING

20.01. PROCEDURES AND ECONOMICS OF MARKETING LIVE PRAWNS

20.01.01. DEVELOP STANDARD PROCEDURES FOR LIVE MARKETING OF PRAWNS.

20.01.02. IDENTIFY COSTS AND THE CONDITIONS UNDER WHICH IT IS IS ECONOMICAL TO MARKET LIVE PRAWNS.

20.02. PROCEDURES AND ECONOMICS OF MARKETING FROZEN PRAWNS

20.02.01. IDENTIFY METHODS OF FREEZING THAT RESULT IN HIGHEST QUALITY PRODUCT AND DEVELOP STANDARD PROCEDURES, E.G. DOES BLANCHING, HEADS-ON OR HEADS OFF IMPROVE THE FROZEN PRODUCT. EVALUATE FLASH FREEZING AND RAPID FREEZING USING SUPER COOLING AS COMPARED TO TRADITIONAL METHODS.

20.02.02. IDENTIFY COSTS AND THE CONDITIONS UNDER WHICH IT IS ECONOMICAL TO MARKET FROZEN PRAWNS.

20.03. PROCEDURES AND ECONOMICS OF MARKETING COOKED PRAWNS

20.03.01. DETERMINE METHODS OF COOKING THAT RESULT IN THE HIGHEST QUALITY PRODUCT WITH BEST TASTE AND TEXTURE AND DEVELOP STANDARD PROCESSING AND MARKETING PROCEDURE.

20.03.02. IDENTIFY COSTS AND THE CONDITIONS UNDER WHICH IT IS ECONOMICAL TO MARKET COOKED PRAWNS.

20.04. PROCEDURES AND ECONOMICS OF PACKAGING PRAWNS FOR THE MARKET.

20.04.01. DEVELOP IMPROVED METHODS OF PACKAGING LIVE, FROZEN OR COOKED PRAWNS AND IDENTIFY THE COSTS.

20.05. A SMALL PERCENTAGE OF PRAWNS PRODUCED IN SOME AREAS HAVE A SOFT MUSHY TEXTURE.

20.05.01. DETERMINE CAUSES OF QUALITY VARIATION SUCH AS SOFT TEXTURE.

20.05.02. DEVELOP PROCESSING PROCEDURES TO MINIMIZE QUALITY VARIATIONS, SUCH AS SOFT TEXTURE.

20.06. NEED FOR QUALITY STANDARDS AS A BASIS FOR QUALITY CONTROL AND INSPECTION PROGRAMS.
20.06.01. DEVELOPMENT OF QUALITY STANDARDS BY INDUSTRY OR BY GOVERNMENT AT REQUEST OF INDUSTRY.

21. DISTRIBUTION AND MARKETING
21.01. PROCEDURES AND ECONOMICS OF SHIPPING, STORAGE AND DISTRIBUTION OF PRAWNS IN VARIOUS PRODUCT FORMS.
21.01.01. DETERMINE SHIPPING, STORAGE AND DISTRIBUTION AND RETAILING PROCEDURES WHICH WILL RETAIN QUALITY AT ACCEPTABLE COST.
21.01.02. DETERMINE MAXIMUM STORAGE TIME UNDER VARIOUS CONDITIONS CONSISTENT WITH QUALITY RETENTION AND EVALUATE COST.
21.02. PRODUCT SAFETY
21.02.01. DETERMINE SAFETY OF THE PRODUCT FOR HUMAN CONSUMPTION BY ANALYZING FOR HEAVY METALS, PESTICIDES, CHEMICAL CONTAMINANTS AND BACTERIAL OR VIRAL CONTAMINATION, ETC.
21.03. NUTRITIONAL VALUE OF PRAWNS FOR HUMAN CONSUMPTION
21.03.01. DETERMINE PROXIMATE COMPOSITION, CHOLESTEROL, ETC.

22. SUPPLY
22.01. DETERMINING CURRENT AND PROJECTING ANTICIPATED PRODUCTION FROM AQUACULTURE AND LANDINGS FROM HARVEST OF WILD STOCKS IN VARIOUS LOCATIONS AND TRANSPORT TO MARKETS.
22.01.01. OBTAIN STATISTICS PERIODICALLY TO IDENTIFY CURRENT PRODUCTION FROM AQUACULTURE AND HARVEST OF WILD STOCKS IN U.S. AND ABROAD.
22.01.02. PROJECT ANTICIPATED PRODUCTION FROM AQUACULTURE HARVEST OF WILD STOCKS.
22.01.03. ENCOURAGE LABELING OF IMPORTED FRESHWATER PRAWNS TO DIFFERENTIATE FROM THE DOMESTIC PRODUCT.

23. DEMAND
23.01. DETERMINING CURRENT AND PROJECTING FUTURE DEMAND FOR VARIOUS PRODUCT FORMS.
23.01.01. DETERMINE DISTRIBUTION PATTERN IN U.S. OF IMPORTED FRESHWATER PRAWN TAILS AND IDENTIFY AND QUANTIFY MARKETS.
23.01.02. CONDUCT A PRELIMINARY SURVEY TO ESTIMATE THE U.S. MARKET FOR DOMESTICALLY PRODUCED FRESHWATER PRAWNS IN VARIOUS PRODUCT FORMS (E.G. LIVE, FRESH CHILLED, COOKED, FROZEN, WHOLE VS. TAILS VS. MEATS).
23.01.03. WHEN ADEQUATE SUPPLIES ARE AVAILABLE CONDUCT TEST MARKETING OF VARIOUS PRODUCT FORMS IN REPRESENTATIVE LOCATIONS AND EVALUATE TO INCLUDE ESTIMATION OF INCOME AND PRICE ELASTICITY.
23.01.04. CONDUCT A PRELIMINARY SURVEY TO ESTIMATE FOREIGN MARKETS FOR FRESHWATER PRAWNS PRODUCED IN U.S.
23.01.05. DETERMINE OTHER USE FOR FRESHWATER PRAWNS SUCH AS BAIT OR AS AN INGREDIENT FOR COMPOSITE PRODUCTS.
23.02. SELECTING AS STANDARD TRADE NAME FOR MACROBRACHIUM
23.02.01. DETERMINE APPROVAL BY U.S. FOOD AND DRUG ADMINISTRATION AND REACH INDUSTRY AGREEMENT ON A STANDARD NAME.
23.03. COMPETITION BETWEEN FRESHWATER PRAWNS AND MARINE SHRIMP IN U.S. MARKET
23.03.01. DETERMINE THE RELATIVE MARKET ACCEPTABILITY OF FROZEN TAILS OF FRESHWATER PRAWN AND MARINE SHRIMP.
23.03.02. DETERMINE ECONOMICS OF MARKETING FRESHWATER PRAWNS

AS FROZEN TAILS VS. OTHER PRODUCT FORMS.

24. LOCATION OF MARKETS
    24.01. DETERMINING GEOGRAPHICAL, ECONOMIC AND ETHNIC MARKETS FOR PRAWNS.
        24.01.01. IDENTIFY GEOGRAPHICAL AND ETHNIC MARKETS IN U.S. AND ABROAD
        24.01.02. DEVELOP STRATEGY FOR EXPANDING MARKETS AND ESTIMATE COSTS.

25. PRICE
    25.01. SELLING PRICE FOR VARIOUS PRODUCT FORMS BY AREAS AS RELATED TO COMPETING PRODUCTS.
        25.01.01. ANALYZE CURRENT PRICES FOR WHOLE MACROBRACHIUM AND COMPETING PRODUCTS.
        25.01.02. ESTIMATE PRICE FOR MACROBRACHIUM TAILS IN COMPARISON WITH PENAEID SHRIMP.
        25.01.03. PROJECT PRICE TRENDS FOR VARIOUS PRODUCT FORMS.

26. ECONOMIC ANALYSIS
    WHAT ARE THE COSTS OF PRODUCING MACROBRACHIUM IN RELATION TO SELLING PRICE? COSTS ASSOCIATED WITH SUCH FACTORS AS LABOR, HEATING, FEED, CONSTRUCTION HAVE BEEN IDENTIFIED UNDER PREVIOUS TOPICS. THIS SECTION COVERS THE ENTIRE RANGE OF FACTORS MUST BE CONSIDERED BEFORE INVESTING IN FRESHWATER PRAWN CULTURE.
    26.01. STRUCTURE OF THE PRAWN FARMING INDUSTRY
        26.01.01. PROJECT THE IMPACT OF LARGER COMPANIES ON THE SMALL PRAWN FARMER I.E. WILL ENTRANCE OF LARGER COMPANIES WITH DIFFERENT PROFIT MOTIVES AFFECT SMALL PRODUCERS. THIS IS RELATED TO SIZE OF LOCAL AND INTERNATIONAL MARKETS.
        26.01.02. STUDY THE POTENTIAL OF USING CO-OPS FOR HARVESTING AND MARKETING TO IMPROVE THE ECONOMICS OF SMALL PRODUCERS.
        26.01.03. STUDY THE ECONOMICS OF SCALE ASSOCIATED WITH POND PRODUCTION. DETERMINE OPTIMAL LEVEL OF PRODUCTION OR MAXIMIZE PROFIT.
        26.01.04. DETERMINE THE MINIMUM SIZE FARM NEEDED TO SUSTAIN AN INDIVIDUAL AS A FULL OR PART TIME OCCUPATION. DETERMINE CAPITAL REQUIREMENTS.
        26.01.05. DETERMINE THE SIZE OF A PRODUCING UNIT NECESSARY TO ATTRACT CAPITAL INVESTMENT BY LARGE CORPORATIONS. DETERMINE CAPITAL REQUIREMENTS.
    26.02. PRODUCTION ECONOMICS
        26.02.01. DEVELOP AN ECONOMIC MODEL OF PRODUCTION. THE MODEL SHOULD BE BROAD ENOUGH TO SHOW THE INTERRELATIONSHIP OF THE FACTORS AFFECTING PRODUCTION SUCH AS LABOR, POWER, CONSTRUCTION, EQUIPMENT, FEED, AND OPTIMUM PRAWN SIZE. THE MODEL SHOULD RELATE SCALE TO TOTAL COST OF PRODUCTION.

27. INFORMATION DISSEMINATION
    27.01. THE DISSEMINATION OF GENERAL AND SPECIFIC INFORMATION CONCERNING MACROBRACHIUM FROM PUBLISHED AND UNPUBLISHED SOURCES TO USERS OR POTENTIAL USERS. THIS INFORMATION MAY BE UPDATED PERIODICALLY DEPENDING ON THE PROGRESS IN THE FIELD AND IMPROVEMENT IN THE STATE OF THE ART. IN TOTAL IT WILL PROVIDE A BASIS FOR INVESTMENT DECISIONS AND A GUIDE FOR PRODUCERS.
        27.01.01. PRODUCE AND DISTRIBUTE CULTURE MANUALS AND PERIODIC REPORTS ON PRAWN CULTURE.
        27.01.02. LIST PUBLISHED AND AVAILABLE UNPUBLISHED LITERATURE IN NATIONAL AQUACULTURE INFORMATION SER-

VICE COMPUTERIZED BIBLIOGRAPHY WHERE IT IS READILY AVAILABLE AT A NOMINAL COST.

27.01.03. PREPARE AND DISTRIBUTE A LIST OF ONGOING RESEARCH PROJECTS CONCERNING MACROBRACHIUM AND UPDATED PERIODICALLY.

27.01.04. ESTABLISH AN ADVISORY SERVICE TO PROVIDE ON-SITE PROBLEM ASSESSMENT AND TO COMMUNICATE TECHNICAL INFORMATION TO PRODUCERS, PROCESSORS AND MARKETERS.

28. INVESTMENT CAPITAL

28.01. MACROBRACHIUM CULTURE LIKE MOST AQUACULTURE VENTURES INCLUDES RISKS WHICH ARE GREATER THAN FOR AGRICULTURE. THIS MAKES IT DIFFICULT TO OBTAIN ADEQUATE CAPITAL IN MANY CASES.

28.01.01. ESTABLISH GOVERNMENT OBLIGATION GUARANTEE PROGRAM AS PROPOSED IN AQUACULTURE BILL NOW BEFORE CONGRESS.

28.01.02. CONDUCT PROTOTYPE TESTING TO VALIDATE COMMERCIAL APPLICABILITY OF LABORATORY RESULTS.

28.01.03. REQUIRE INSURANCE.

28.02. TIME REQUIRED TO GET AN ACCEPTABLE RETURN ON INVESTMENT.

28.02.01. GOVERNMENT LOAN OR OBLIGATION GUARANTEE PROGRAM.

## Appendix B

The seventeen research projects and their associated parameters determined at the Dec. 13, 1976 workshop. Ratings are those given in the follow-up survey subsequent to the workshop. Project descriptions may not match exactly with those listed in Appendices A and C because of revisions between the workshop and the final survey. Ratings are averages over all respondents on a scale of 1 (not needed) to 4 (urgent). Ratings were requested to be made separately on each of six categories: Payoff, urgency, probability of success, resources, time frame and cost. The items "status" and "researcher" have not been entered into the data base. This causes these data items to default to "NOT BEGUN" and "NONE" in the table below.

AQUACULTURE RESEARCH INFORMATION SYSTEM
MACROBRACHIUM RESEARCH STATUS
PROJECTS FORMULATED AT THE MACROBRACHIUM WORKSHOP

01.02.00 DETERMINE EFFECT OF ENVIRON FACTORS ON GROWTH
DETERMINE ENVIRON VARIABLES AND THEIR EFFECT
ON GROWTH AND AS RELATED TO SEX RATIO
STATUS: NOT BEGUN RESEARCHER: NONE

| PRIORITY | RATING | --COMMENTS-- |
|---|---|---|
| PAYOFF.... | 2.17 | VARIABLE |
| URGENCY... | 2.06 | VARIABLE |
| PR SUCCESS | 2.64 | HIGH TO MEDIUM |
| RESOURCES. | 2.75 | VARIABLE |
| TIME FRAME | 2.32 | 1-5 YEARS |
| COST..... | 2.44 | VARIABLE |

02.06.01 DETERMINE EFFECTS OF ENVIRONMENTAL CONTAMINANTS.
DETERMINE THROUGHPUT RATES AND FATE OF
ENVIRONMENTALLY PRESENT CHEMICALS ON THE ANIMAL.
STATUS: NOT BEGUN RESEARCHER: NONE

| PRIORITY | RATING | --COMMENTS-- |
|---|---|---|
| PAYOFF.... | 3.08 | SITE SELECTION INSURANCE |
| URGENCY... | 3.38 | USEFUL NOW AT PRODUCTION SCALE UP |
| PR SUCCESS | 3.62 | PRACTICAL |
| RESOURCES. | 3.08 | LABORATORY STANDARD |
| TIME FRAME | 3.23 | 1-5 YEARS |
| COST..... | 3.08 | $40,000 - $60,000 |

02.06.03 DETERMINE EFFECTS OF CHEMICALS USED IN POND MGT
STATUS: NOT BEGUN RESEARCHER: NONE

| PRIORITY | RATING | --COMMENTS-- |
|---|---|---|
| PAYOFF.... | 2.71 | PRODUCTION CONTROL |
| URGENCY... | 2.86 | AT PRODUCTION SCALE UP |
| PR SUCCESS | 3.29 | PRACTICAL |
| RESOURCES. | 2.64 | LABORATORY STANDARD |
| TIME FRAME | 2.79 | 1-2 YEARS |
| COST..... | 2.79 | $40,000 - $60,000 |

03.01.00 DETERMINE BASIC NUTRITIONAL REQUIREMENTS
DETERMINE BASIC NUTRITIONAL REQUIREMENTS FOR
GROWTH, SURVIVAL AND HEALTH OF VARIOUS SPECIES
AT EACH LIFE STAGE
STATUS: NOT BEGUN RESEARCHER: NONE

| PRIORITY | RATING | --COMMENTS-- |
|---|---|---|
| PAYOFF.... | 2.80 | COST REDUCTION, LOWER HAZARDS |
| URGENCY... | 2.87 | AS SOON AS POSSIBLE |
| PR SUCCESS | 3.11 | PRACTICAL |
| RESOURCES. | 2.76 | BIOCHEM LAB, BIOCHEMIST, NUTRITIONIST |
| TIME FRAME | 2.23 | 8 YEARS/LONG TERM |
| COST..... | 1.74 | $300,000 TO $500,000 PER YEAR |

05.01.00 DETERMINE EFFECTS OF SEXUAL DEVELOPMENT VARIATION
DETERMINE EFFECTS OF CHARACTERISTICS OF VARIOUS
SPECIES OF MACROBRACHIUM ON THEIR CULTURE
STATUS: NOT BEGUN RESEARCHER: NONE

| PRIORITY | RATING | --COMMENTS-- |
|---|---|---|
| PAYOFF.... | 2.00 | VARIABLE |
| URGENCY... | 2.04 | VARIABLE |
| PR SUCCESS | 2.09 | LOW |
| RESOURCES. | 2.38 | VARIABLE |

| | | |
|---|---|---|
| TIME FRAME | 1.96 | LONG RANGE |
| COST..... | 2.02 | VARIABLE |

07.01.00 PERFORM STOCK EVALUATION
EVALUATE GENETICS OF VARIOUS STOCKS
STATUS: NOT BEGUN RESEARCHER: NONE

| PRIORITY | RATING | --COMMENTS-- |
|---|---|---|
| PAYOFF.... | 2.05 | LOWER COST HIGHER PRODUCTION |
| URGENCY... | 1.98 | WHEN AVAILABLE |
| PR SUCCESS | 2.62 | MEDIUM |
| RESOURCES. | 2.67 | COMMERCIAL PONDS, BIOLOGIST |
| TIME FRAME | 1.93 | 5 YEARS |
| COST..... | 2.14 | $30,000 - $90,000 |

08.01.00 IDENTIFY BEHAVIOR PATTERNS OF VARIOUS SPECIES AND STOCKS OF PRAWNS
DETERMINE FEEDING, MIGRATION, TERRITORIALITY, AND MATING BEHAVIOR OF PRAWNS
STATUS: NOT BEGUN RESEARCHER: NONE

| PRIORITY | RATING | --COMMENTS-- |
|---|---|---|
| PAYOFF.... | 2.08 | WILL LOWER COST |
| URGENCY... | 2.24 | USEFUL ANYTIME |
| PR SUCCESS | 2.54 | HIGH |
| RESOURCES. | 2.62 | RESEARCH PONDS OR TANKS, GRAD STUDENT BEHAVIORAL BIOLOGIST |
| TIME FRAME | 2.71 | 2-5 YEARS |
| COST..... | 2.30 | $20,000 - |

09.01.00 DEFINE POND ENVIRONMENT
IDENTIFY ECOLOGICAL FACTORS IN PONDS OR OTHER CULTURE SYSTEMS AND THEIR RELATION TO VARIATIONS IN PRAWN PRODUCTION.
STATUS: NOT BEGUN RESEARCHER: NONE

| PRIORITY | RATING | --COMMENTS-- |
|---|---|---|
| PAYOFF.... | 2.17 | DOUBLE PRODUCTION, SCIENTIFIC REARING |
| URGENCY... | 2.26 | AS SOON AS POSSIBLE |
| PR SUCCESS | 2.37 | MEDIUM |
| RESOURCES. | 2.31 | COMMERCIAL PONDS/MONITORING INSTRUMENTS, BIOLOGICAL TECH, STAT ANALYST, 10 PER CENT RESEARCH SCIENTIST |
| TIME FRAME | 2.18 | 2-10 YEARS |
| COST..... | 2.29 | $60,000 - $120,000/YEAR |

14.01.01 IMPROVE UTILIZATION OF ARTEMIA
DEVELOP FEEDING PROCEDURES TO IMPROVE EFFICIENCY IN THE USE OF ARTEMIA
STATUS: NOT BEGUN RESEARCHER: NONE

| PRIORITY | RATING | --COMMENTS-- |
|---|---|---|
| PAYOFF.... | 3.00 | STABILITY OF HAZARD REDUCTION |
| URGENCY... | 3.15 | AS SOON AS POSSIBLE |
| PR SUCCESS | 3.00 | HATCHERY |
| RESOURCES. | 3.15 | PRACTICAL |
| TIME FRAME | 2.92 | 1 TO 2 YEARS |
| COST..... | 2.92 | $60,000 |

14.04.02 INCREASE SUPPLY OF ARTEMIA
INCREASE SUPPLY OF HIGH QUALITY ARTEMIA CYSTS FROM NATURAL SOURCES. DEVELOP PROCEDURES FOR REARING ARTEMIA THROUGH THEIR LIFE CYCLE AT HATCHERY SITES TO PROVIDE A CONTINUOUS SUPPLY OF NAUPLII.

STATUS: NOT BEGUN RESEARCHER: NONE

| PRIORITY | RATING | --COMMENTS-- |
|---|---|---|
| PAYOFF.... | 3.36 | STABILITY OF HAZARD REDUCTION |
| URGENCY... | 3.36 | AS SCON AS POSSIBLE |
| PR SUCCESS | 2.64 | PRACTICAL |
| RESOURCES. | 2.64 | LAB |
| TIME FRAME | 2.79 | 2 YEARS |
| COST..... | 2.64 | $100,000 |

14.04.05 FIND SUBSTITUTE FOR ARTEMIA
DEVELOP AN ARTIFICIAL LARVAL FOOD AS REPLACEMENT FOR BRINE SHRIMP
STATUS: NOT BEGUN RESEARCHER: NONE

| PRIORITY | RATING | --COMMENTS-- |
|---|---|---|
| PAYOFF.... | 3.43 | STABILITY OF HAZARD REDUCTION |
| URGENCY... | 3.36 | AS SOON AS POSSIBLE |
| PR SUCCESS | 2.64 | HIGH |
| RESOURCES. | 3.00 | FOOD LAB, HATCHERY, FOOD TECH |
| TIME FRAME | 2.57 | 2 TO 4 YEARS |
| COST..... | 2.36 | $100,000 |

15.04.01 DEVELOP COST EFFECTIVE COUNTING METHODS FOR PRAWNS
DEVELOP METHODS FOR ESTIMATING POPULATION AND SIZE DISTRIBUTION OF PRAWNS IN PONDS
STATUS: NOT BEGUN RESEARCHER: NONE

| PRIORITY | RATING | --COMMENTS-- |
|---|---|---|
| PAYOFF.... | 2.71 | PRODUCTION STABILITY |
| URGENCY... | 3.00 | AS SOON AS POSSIBLE |
| PR SUCCESS | 2.71 | HIGH |
| RESOURCES. | 2.71 | COMMERCIAL PONDS STATISTICIAN, ELECTRONICS TECH |
| TIME FRAME | 2.57 | 1-2 YR (SAMPLING) 1-4 YR (INSTRUMENTS) |
| COST..... | 2.71 | $25,000 $50,000 - $80,000 |

15.04.02 DEVELOP STOCKING STRATEGY TO INCREASE PRODUCTION
EVALUATE UTILITY OF NURSERY SYSTEMS. DETERMINE OPTIMUM SIZE OF POST LARVAE FOR STOCKING IN PONDS. DETERMINE OPTIMUM STOCKING DENSITY. DETERMINE OPTIMUM STOCKING TIME AND FREQUENCY.
STATUS: NOT BEGUN RESEARCHER: NONE

| PRIORITY | RATING | --COMMENTS-- |
|---|---|---|
| PAYOFF.... | 2.93 | |
| URGENCY... | 3.07 | |
| PR SUCCESS | 3.14 | |
| RESOURCES. | 3.00 | |
| TIME FRAME | 2.64 | |
| COST..... | 2.50 | |

16.03.01 COMPARE EFFICIENCY OF FEEDING PROCEDURES
ESTABLISH RELATIONSHIP BETWEEN AMOUNT FED AND AMOUNT UTILIZED, DETERMINE CONTRIBUTION OF UNDIGESTED FOOD TO FERTILIZATION OF PONDS.
STATUS: NOT BEGUN RESEARCHER: NONE

| PRIORITY | RATING | --COMMENTS-- |
|---|---|---|
| PAYOFF.... | 2.79 | COST REDUCTION |
| URGENCY... | 2.86 | AS SOON AS POSSIBLE |
| PR SUCCESS | 2.79 | PRACTICAL |
| RESOURCES. | 3.29 | PONDS, NUTRITION TECH, POND MANAGER |
| TIME FRAME | 2.86 | 1 TO 4 YEARS |
| COST..... | 3.07 | $60,000 |

20.05.01 DETERMINE CAUSES OF QUALITY VARIATION
STATUS: NOT BEGUN RESEARCHER: NONE

| PRIORITY | RATING | --COMMENTS-- |
|---|---|---|
| PAYOFF.... | 2.71 | GUARANTEES CONSISTENT QUALITY |
| URGENCY... | 2.93 | 3-5 YEARS DEPENDING ON INDUSTRY PROGRESS |
| PR SUCCESS | 2.86 | 50 PER CENT |
| RESOURCES. | 3.00 | FOOD TECH LAB, FOOD TECH, BIOCHEMIST |
| TIME FRAME | 2.64 | 3 TO 5 YEARS |
| COST..... | 2.93 | $60,000 TO $100,000 PER YEAR |

23.01.01 CHARACTERIZE DISTRIBUTION PATTERN AND MARKET IN U.S. DETERMINE DISTRIBUTION PATTERN OF IMPORTED PRAWN TAILS IN U.S. AND QUANTIFY MARKETS
STATUS: NOT BEGUN RESEARCHER: NONE

| PRIORITY | RATING | --COMMENTS-- |
|---|---|---|
| PAYOFF.... | 2.43 | IDENTIFY MARKET, BOLSTER MARKETING DECISION, DIFFERENTIATE DOMESTIC MARKET |
| URGENCY... | 2.57 | |
| PR SUCCESS | 3.00 | PRACTICAL |
| RESOURCES. | 3.14 | STANDARD |
| TIME FRAME | 2.93 | LESS THAN 1 YEAR |
| COST..... | 2.93 | MINIMAL |

23.01.02 PRELIMINARY MARKET SURVEY
CONDUCT A PRELIMINARY SURVEY TO ESTIMATE THE U.S. MARKET FOR DOMESTICALLY PRODUCED PRAWNS IN VARIOUS PRODUCT FORMS
STATUS: NOT BEGUN RESEARCHER: NONE

| PRIORITY | RATING | --COMMENTS-- |
|---|---|---|
| PAYOFF.... | 2.43 | MODIFY INVESTMENT LEVEL |
| URGENCY... | 2.50 | IMMEDIATE FOR DECISION MAKING |
| PR SUCCESS | 2.86 | PRACTICAL |
| RESOURCES. | 3.07 | STANDARD FACILITIES, MARKET SPECIALIST |
| TIME FRAME | 2.86 | 1 YEAR |

## Appendix C

Complete list of average ratings for all projects in *Macrobrachium* priorities survey. See Appendix C caption for explanation of rating system.

AQUACULTURE RESEARCH INFORMATION SYSTEM
SUMMARY OF MACROBRACHIUM RESEARCH SURVEY PRIORITY RATINGS

| PROJECT | SAMPLE SIZE | --AVERAGE RATINGS-- PAYOFF | URGENCY | PROB OF SUCCESS | RESOURCES | TIME | COST |
|---|---|---|---|---|---|---|---|
| 010101 | 14 | 1.93 | 1.64 | 3.36 | 3.07 | 2.43 | 3.07 |
| 010201 | 14 | 2.14 | 2.00 | 3.00 | 2.86 | 2.14 | 2.36 |
| 010202 | 14 | 1.57 | 1.21 | 2.43 | 2.29 | 2.29 | 2.50 |
| 010203 | 14 | 2.29 | 2.00 | 2.50 | 2.79 | 2.50 | 2.50 |
| 010204 | 14 | 2.00 | 1.50 | 2.14 | 2.71 | 1.93 | 2.36 |
| 010205 | 14 | 2.93 | 2.86 | 3.00 | 2.93 | 2.79 | 2.64 |
| 010206 | 14 | 2.14 | 1.86 | 2.36 | 2.50 | 1.64 | 2.79 |
| 010207 | 14 | 2.21 | 2.86 | 3.50 | 3.43 | 3.21 | 3.07 |
| 010208 | 14 | 2.29 | 2.21 | 1.93 | 2.57 | 1.86 | 2.00 |
| 010209 | 14 | 1.93 | 2.07 | 2.86 | 2.71 | 2.50 | 2.71 |
| 010301 | 14 | 1.93 | 1.86 | 2.71 | 2.21 | 1.64 | 1.86 |
| 010302 | 2 | 2.00 | 2.50 | 3.50 | 3.50 | 4.00 | 4.00 |
| 020101 | 14 | 2.71 | 2.57 | 3.07 | 3.00 | 2.43 | 2.71 |
| 020201 | 14 | 2.29 | 2.57 | 3.36 | 3.07 | 2.93 | 2.71 |
| 020301 | 15 | 2.73 | 2.80 | 3.07 | 2.73 | 2.60 | 2.40 |
| 020302 | 14 | 3.07 | 3.21 | 3.50 | 3.14 | 3.14 | 3.07 |
| 020303 | 14 | 2.07 | 2.29 | 2.86 | 2.71 | 2.50 | 2.43 |
| 020401 | 14 | 2.00 | 2.14 | 2.86 | 2.57 | 2.43 | 2.36 |
| 020501 | 14 | 2.50 | 2.86 | 3.21 | 3.00 | 2.93 | 2.93 |
| 020601 | 13 | 3.08 | 3.38 | 3.62 | 3.08 | 3.23 | 3.08 |
| 020602 | 15 | 2.53 | 2.73 | 3.13 | 2.53 | 2.53 | 2.33 |
| 020603 | 14 | 2.71 | 2.86 | 3.29 | 2.64 | 2.79 | 2.79 |
| 020604 | 13 | 2.15 | 2.08 | 2.77 | 2.46 | 2.38 | 2.54 |
| 020701 | 14 | 2.64 | 2.86 | 3.21 | 3.07 | 3.00 | 3.00 |
| 020702 | 14 | 2.57 | 2.93 | 3.14 | 3.07 | 2.93 | 2.93 |
| 020703 | 14 | 2.50 | 2.71 | 3.14 | 3.07 | 2.93 | 3.00 |
| 020704 | 14 | 2.36 | 2.64 | 3.14 | 3.00 | 2.93 | 2.00 |
| 020801 | 14 | 2.07 | 2.21 | 2.36 | 2.14 | 1.79 | 1.50 |
| 030101 | 14 | 2.86 | 2.93 | 3.14 | 2.86 | 2.21 | 1.86 |
| 030102 | 14 | 3.00 | 3.00 | 3.21 | 2.86 | 2.29 | 2.00 |
| 030103 | 14 | 2.79 | 2.86 | 3.07 | 2.71 | 2.36 | 2.00 |
| 030104 | 14 | 2.86 | 2.86 | 3.07 | 2.71 | 2.21 | 1.93 |
| 030105 | 14 | 2.64 | 2.79 | 3.07 | 2.71 | 2.14 | 1.79 |
| 030106 | 14 | 2.64 | 2.79 | 3.07 | 2.71 | 2.14 | 1.86 |
| 040101 | 14 | 2.00 | 2.21 | 2.57 | 2.29 | 1.93 | 2.14 |
| 040201 | 14 | 2.21 | 2.29 | 2.21 | 2.36 | 2.07 | 2.07 |
| 040202 | 14 | 2.07 | 2.14 | 2.29 | 2.50 | 2.57 | 2.50 |
| 040203 | 14 | 2.64 | 2.57 | 2.79 | 2.71 | 2.86 | 2.57 |
| 040204 | 14 | 1.93 | 1.93 | 2.29 | 2.50 | 2.21 | 2.29 |
| 040205 | 14 | 2.57 | 2.64 | 3.07 | 2.93 | 2.79 | 2.57 |
| 040301 | 14 | 1.86 | 1.93 | 2.79 | 2.93 | 2.43 | 2.50 |
| 040401 | 14 | 2.14 | 2.21 | 2.86 | 2.93 | 2.64 | 2.64 |
| 040402 | 14 | 2.64 | 2.86 | 2.71 | 2.93 | 2.50 | 2.57 |
| 040501 | 14 | 1.14 | 1.14 | 1.43 | 1.43 | 1.14 | 1.00 |
| 040601 | 14 | 1.86 | 1.71 | 2.79 | 2.36 | 2.64 | 2.79 |
| 050101 | 14 | 2.07 | 2.00 | 2.07 | 2.43 | 1.93 | 1.79 |
| 050102 | 14 | 2.07 | 2.14 | 2.29 | 2.50 | 2.07 | 2.07 |
| 050103 | 14 | 1.86 | 1.79 | 2.07 | 2.21 | 1.86 | 2.00 |
| 050104 | 14 | 2.00 | 2.21 | 1.93 | 2.36 | 1.93 | 2.21 |
| 060101 | 14 | 1.57 | 2.00 | 2.86 | 2.93 | 2.64 | 2.71 |
| 060102 | 14 | 2.07 | 2.14 | 3.21 | 3.00 | 2.93 | 2.93 |
| 060201 | 14 | 1.50 | 1.64 | 2.21 | 2.21 | 2.00 | 1.93 |

| PROJECT | SAMPLE SIZE | PAYOFF | URGENCY | PROB OF SUCCESS | RESOURCES | TIME | COST |
|---|---|---|---|---|---|---|---|
| 060301 | 14 | 1.64 | 1.36 | 1.79 | 2.07 | 1.79 | 1.93 |
| 070101 | 14 | 2.36 | 2.36 | 3.14 | 2.79 | 1.93 | 2.14 |
| 070102 | 14 | 2.00 | 1.93 | 2.29 | 2.64 | 1.86 | 2.21 |
| 070103 | 14 | 1.79 | 1.64 | 2.43 | 2.57 | 2.00 | 2.07 |
| 070201 | 14 | 2.36 | 2.07 | 2.57 | 2.57 | 2.00 | 2.50 |
| 070202 | 14 | 1.71 | 1.57 | 2.21 | 2.57 | 2.00 | 2.29 |
| 070203 | 14 | 1.79 | 1.57 | 2.14 | 2.43 | 2.00 | 2.21 |
| 070301 | 14 | 1.79 | 1.43 | 1.64 | 2.07 | 1.43 | .64 |
| 070302 | 14 | 2.07 | 1.79 | 1.93 | 2.14 | 1.43 | 1.64 |
| 070401 | 14 | 2.36 | 2.00 | 2.57 | 2.71 | 1.71 | 1.86 |
| 070402 | 14 | 2.29 | 2.14 | 1.93 | 2.50 | 1.57 | 1.86 |
| 070403 | 14 | 2.79 | 2.57 | 2.43 | 2.71 | 1.71 | 2.36 |
| 070501 | 14 | 2.36 | 2.07 | 1.64 | 2.29 | 1.43 | 1.93 |
| 070502 | 14 | 2.43 | 2.21 | 1.57 | 2.29 | 1.29 | 1.93 |
| 070601 | 14 | 2.07 | 2.07 | 2.00 | 2.71 | 1.86 | 1.86 |
| 070602 | 14 | 1.93 | 2.00 | 1.93 | 2.79 | 1.50 | 1.93 |
| 080101 | 14 | 1.86 | 1.93 | 2.43 | 2.64 | 2.57 | 2.50 |
| 080102 | 14 | 2.07 | 2.14 | 2.50 | 2.79 | 2.71 | 2.57 |
| 080103 | 14 | 2.21 | 2.50 | 2.93 | 2.79 | 2.79 | 2.71 |
| 080104 | 13 | 2.46 | 2.62 | 2.77 | 2.85 | 2.85 | 2.62 |
| 080105 | 14 | 1.86 | 1.86 | 2.14 | 2.29 | 2.57 | 2.36 |
| 080106 | 14 | 2.00 | 2.29 | 2.36 | 2.57 | 2.86 | 2.57 |
| 080107 | 14 | 1.79 | 1.93 | 2.21 | 2.29 | 2.57 | 2.29 |
| 080108 | 14 | 2.57 | 2.86 | 3.14 | 2.93 | 2.93 | 2.79 |
| 090101 | 14 | 2.43 | 2.21 | 2.57 | 2.79 | 2.43 | 2.64 |
| 090102 | 13 | 2.00 | 1.92 | 2.23 | 2.31 | 2.15 | 2.23 |
| 090103 | 14 | 2.21 | 2.50 | 2.43 | 2.50 | 2.21 | 2.36 |
| 090104 | 14 | 2.07 | 2.36 | 2.29 | 2.21 | 2.21 | 2.29 |
| 090105 | 14 | 2.14 | 2.36 | 2.43 | 2.14 | 2.00 | 2.21 |
| 090106 | 14 | 2.14 | 2.21 | 2.29 | 1.93 | 2.07 | 2.00 |
| 090201 | 14 | 2.21 | 2.21 | 2.79 | 2.57 | 2.36 | 2.07 |
| 090402 | 1 | 2.00 | 2.00 | 3.00 | 4.00 | 3.00 | 4.00 |
| 100101 | 14 | 2.07 | 2.21 | 3.14 | 3.29 | 2.93 | 3.21 |
| 110101 | 14 | 1.79 | 2.00 | 2.86 | 3.07 | 2.57 | 2.93 |
| 110102 | 14 | 2.36 | 2.21 | 2.43 | 2.71 | 2.21 | 2.21 |
| 120101 | 15 | 1.67 | 2.00 | 3.00 | 3.40 | 2.80 | 3.20 |
| 130101 | 14 | 2.93 | 3.21 | 3.86 | 3.86 | 3.64 | 3.71 |
| 130102 | 13 | 2.38 | 2.54 | 3.69 | 3.46 | 3.00 | 3.08 |
| 130103 | 14 | 2.64 | 2.64 | 2.86 | 3.36 | 2.93 | 3.07 |
| 140101 | 15 | 2.07 | 1.93 | 2.93 | 3.13 | 2.73 | 2.87 |
| 140102 | 1 | 3.00 | 3.00 | 3.00 | 4.00 | 3.00 | 3.00 |
| 140201 | 14 | 1.79 | 1.79 | 2.50 | 2.79 | 2.36 | 2.50 |
| 140301 | 15 | 2.40 | 2.27 | 3.07 | 2.60 | 2.60 | 2.47 |
| 140302 | 11 | 2.18 | 2.00 | 2.91 | 2.45 | 2.82 | 2.55 |
| 140303 | 14 | 2.43 | 2.50 | 2.93 | 2.79 | 2.79 | 2.79 |
| 140304 | 13 | 2.62 | 2.54 | 2.92 | 2.54 | 2.69 | 2.31 |
| 140401 | 13 | 3.00 | 3.15 | 3.00 | 3.15 | 2.92 | 2.92 |
| 140402 | 14 | 3.36 | 3.36 | 2.64 | 2.64 | 2.79 | 2.64 |
| 140403 | 14 | 2.57 | 2.86 | 3.00 | 3.14 | 3.07 | 3.07 |
| 140404 | 13 | 2.54 | 2.69 | 2.23 | 2.46 | 2.38 | 2.23 |
| 140405 | 14 | 3.43 | 3.36 | 2.64 | 3.00 | 2.57 | 2.36 |
| 140501 | 14 | 2.36 | 2.64 | 2.86 | 3.29 | 3.00 | 3.14 |
| 140502 | 14 | 1.57 | 1.86 | 2.36 | 2.57 | 2.14 | 2.50 |
| 140503 | 15 | 2.20 | 2.33 | 2.53 | 2.87 | 2.27 | 2.40 |
| 140504 | 14 | 2.14 | 2.36 | 2.71 | 2.64 | 2.43 | 2.50 |
| 140505 | 14 | 2.14 | 1.93 | 1.50 | 2.36 | 2.36 | 2.43 |
| 150101 | 15 | 2.00 | 2.20 | 2.60 | 2.47 | 2.20 | 2.53 |

| PROJECT | SAMPLE SIZE | PAYOFF | URGENCY | PROB OF SUCCESS | RESOURCES | TIME | COST |
|---|---|---|---|---|---|---|---|
| 150102 | 14 | 2.14 | 2.29 | 2.71 | 2.50 | 2.21 | 2.43 |
| 150103 | 14 | 1.86 | 2.21 | 2.86 | 2.64 | 2.50 | 2.86 |
| 150104 | 14 | 1.36 | 1.43 | 2.36 | 2.29 | 2.07 | 2.36 |
| 150105 | 14 | 2.36 | 2.36 | 2.50 | 2.57 | 2.36 | 2.64 |
| 150106 | 14 | 1.71 | 1.79 | 2.07 | 2.50 | 2.21 | 2.43 |
| 150107 | 14 | 2.36 | 2.43 | 2.86 | 2.71 | 2.21 | 2.29 |
| 150201 | 14 | 1.64 | 1.57 | 2.00 | 1.93 | 1.93 | 1.93 |
| 150202 | 14 | 1.93 | 2.00 | 2.29 | 2.14 | 2.14 | 2.07 |
| 150203 | 14 | 2.07 | 1.93 | 2.21 | 1.86 | 1.93 | 1.86 |
| 150204 | 14 | 1.57 | 1.50 | 1.57 | 1.79 | 1.64 | 1.57 |
| 150205 | 14 | 1.79 | 1.93 | 2.36 | 2.57 | 2.57 | 2.64 |
| 150301 | 14 | 2.50 | 2.43 | 2.64 | 2.93 | 2.07 | 2.50 |
| 150302 | 14 | 2.29 | 2.50 | 2.71 | 2.86 | 2.29 | 2.50 |
| 150303 | 14 | 2.14 | 2.14 | 2.43 | 2.79 | 2.36 | 2.64 |
| 150401 | 14 | 2.71 | 3.00 | 2.71 | 2.71 | 2.57 | 2.71 |
| 150402 | 14 | 2.93 | 3.07 | 3.14 | 3.00 | 2.64 | 2.50 |
| 150403 | 14 | 2.79 | 3.00 | 3.07 | 3.00 | 2.71 | 2.64 |
| 150404 | 14 | 2.43 | 2.71 | 3.07 | 2.86 | 2.43 | 2.50 |
| 150405 | 14 | 2.86 | 3.00 | 3.21 | 3.00 | 2.57 | 2.50 |
| 150406 | 14 | 2.14 | 2.21 | 2.21 | 2.36 | 2.00 | 1.86 |
| 150501 | 12 | 1.50 | 1.42 | 2.17 | 2.00 | 1.75 | 1.83 |
| 150502 | 14 | 1.79 | 1.57 | 2.29 | 1.93 | 1.79 | 1.64 |
| 150503 | 14 | 1.79 | 1.93 | 2.36 | 2.21 | 2.29 | 2.29 |
| 151501 | 1 | 4.00 | 2.00 | 3.00 | 4.00 | 2.00 | 2.00 |
| 160101 | 14 | 2.43 | 3.07 | 3.14 | 3.36 | 3.00 | 2.93 |
| 160103 | 1 | 4.00 | 4.00 | 4.00 | 3.00 | 3.00 | 0 |
| 160201 | 14 | 2.36 | 2.57 | 2.79 | 3.07 | 2.71 | 2.86 |
| 160202 | 14 | 2.71 | 2.93 | 2.93 | 3.21 | 2.79 | 2.93 |
| 160203 | 14 | 2.36 | 2.64 | 3.00 | 3.21 | 2.86 | 3.07 |
| 160204 | 14 | 2.50 | 2.64 | 2.50 | 2.93 | 2.36 | 2.50 |
| 160205 | 14 | 2.86 | 3.07 | 3.21 | 3.36 | 2.79 | 3.07 |
| 160206 | 14 | 2.71 | 2.93 | 3.29 | 3.21 | 2.79 | 3.00 |
| 160207 | 14 | 2.71 | 2.79 | 2.93 | 3.21 | 2.64 | 3.07 |
| 160301 | 14 | 2.79 | 2.86 | 2.79 | 3.29 | 2.86 | 3.07 |
| 160302 | 14 | 2.14 | 2.07 | 2.14 | 2.64 | 2.21 | 2.50 |
| 160303 | 14 | 2.71 | 2.86 | 3.07 | 3.21 | 2.71 | 3.00 |
| 160401 | 14 | 2.43 | 2.64 | 3.00 | 3.29 | 2.86 | 3.00 |
| 160402 | 14 | 2.29 | 2.57 | 2.64 | 3.21 | 2.86 | 3.07 |
| 160403 | 14 | 2.29 | 2.50 | 2.29 | 3.07 | 2.64 | 2.79 |
| 170101 | 14 | 1.79 | 1.93 | 2.36 | 2.86 | 2.14 | 2.50 |
| 170102 | 14 | 2.00 | 2.21 | 2.36 | 2.86 | 1.79 | 2.07 |
| 170103 | 14 | 1.71 | 1.86 | 1.93 | 2.36 | 2.00 | 2.00 |
| 170104 | 14 | 1.50 | 1.71 | 2.00 | 2.36 | 2.00 | 2.21 |
| 170105 | 14 | 2.29 | 2.36 | 2.14 | 2.50 | 1.86 | 2.29 |
| 170106 | 14 | 1.36 | 1.50 | 2.36 | 2.29 | 2.14 | 2.50 |
| 170302 | 1 | 4.00 | 4.00 | 4.00 | 4.00 | 3.00 | 4.00 |
| 180101 | 14 | 2.64 | 2.71 | 3.00 | 3.14 | 2.50 | 2.86 |
| 180201 | 14 | 2.64 | 2.79 | 3.07 | 3.14 | 2.71 | 2.86 |
| 180202 | 14 | 1.36 | 1.50 | 2.21 | 2.71 | 2.50 | 2.71 |
| 180203 | 14 | 2.07 | 2.36 | 2.57 | 3.00 | 2.57 | 2.71 |
| 180204 | 14 | 2.14 | 2.07 | 2.71 | 2.71 | 2.36 | 2.14 |
| 180205 | 14 | 2.14 | 2.21 | 2.07 | 2.79 | 2.36 | 2.79 |
| 190101 | 14 | 1.57 | 1.79 | 3.21 | 3.14 | 3.07 | 3.29 |
| 190102 | 14 | 2.64 | 2.71 | 3.07 | 3.14 | 2.86 | 3.21 |
| 190103 | 14 | 2.50 | 2.86 | 3.36 | 3.36 | 3.07 | 3.36 |
| 200101 | 14 | 2.21 | 2.43 | 2.86 | 2.86 | 2.86 | 3.14 |
| 200102 | 14 | 2.43 | 2.64 | 2.93 | 2.86 | 2.93 | 3.07 |

| PROJECT | SAMPLE SIZE | PAYOFF | URGENCY | PROB OF SUCCESS | RESOURCES | TIME | COST |
|---|---|---|---|---|---|---|---|
| 200201 | 14 | 2.79 | 2.86 | 3.14 | 3.21 | 2.93 | 2.93 |
| 200202 | 14 | 2.21 | 2.43 | 2.86 | 3.07 | 2.86 | 2.93 |
| 200301 | 14 | 1.79 | 2.07 | 3.07 | 3.14 | 3.00 | 3.21 |
| 200302 | 14 | 1.71 | 2.00 | 3.00 | 3.21 | 3.00 | 3.36 |
| 200401 | 14 | 2.14 | 2.36 | 3.14 | 3.21 | 2.86 | 3.07 |
| 200501 | 14 | 2.71 | 2.93 | 2.86 | 3.00 | 2.64 | 2.93 |
| 200601 | 14 | 2.21 | 2.29 | 2.71 | 3.14 | 2.64 | 2.79 |
| 210101 | 14 | 2.00 | 2.43 | 3.14 | 3.07 | 2.86 | 3.00 |
| 210102 | 14 | 2.36 | 2.64 | 3.14 | 3.14 | 2.57 | 3.07 |
| 210201 | 14 | 1.93 | 2.21 | 3.07 | 3.14 | 2.57 | 2.86 |
| 210301 | 14 | 1.86 | 1.79 | 2.71 | 2.71 | 2.50 | 2.71 |
| 220101 | 15 | 2.13 | 2.27 | 2.93 | 3.40 | 2.93 | 3.20 |
| 220102 | 13 | 1.31 | 1.23 | 1.62 | 2.08 | 1.92 | 2.38 |
| 220103 | 14 | 2.14 | 2.14 | 2.07 | 2.79 | 2.71 | 3.07 |
| 230101 | 14 | 2.43 | 2.57 | 3.00 | 3.14 | 2.93 | 2.93 |
| 230102 | 14 | 2.43 | 2.50 | 2.86 | 3.07 | 2.86 | 2.86 |
| 230103 | 14 | 2.50 | 2.36 | 2.86 | 2.79 | 2.57 | 2.79 |
| 230104 | 14 | 2.14 | 2.21 | 2.79 | 3.14 | 3.00 | 3.00 |
| 230105 | 14 | 1.57 | 1.64 | 2.07 | 2.36 | 2.07 | 2.64 |
| 230201 | 14 | 1.93 | 2.36 | 2.36 | 2.71 | 2.64 | 3.00 |
| 230301 | 14 | 2.29 | 2.43 | 3.00 | 2.86 | 2.64 | 2.93 |
| 230302 | 14 | 2.57 | 2.50 | 3.14 | 2.93 | 2.79 | 2.93 |
| 240101 | 14 | 2.21 | 2.07 | 2.71 | 2.79 | 2.43 | 2.57 |
| 240102 | 13 | 2.00 | 2.00 | 2.62 | 2.62 | 2.38 | 2.77 |
| 250101 | 14 | 1.79 | 2.14 | 2.71 | 2.79 | 2.64 | 2.79 |
| 250102 | 14 | 1.86 | 2.00 | 2.43 | 2.71 | 2.64 | 2.79 |
| 250103 | 14 | 1.71 | 1.64 | 2.14 | 2.50 | 2.29 | 2.50 |
| 260101 | 14 | 1.79 | 1.79 | 2.21 | 2.79 | 2.57 | 2.71 |
| 260102 | 14 | 2.00 | 1.93 | 2.36 | 2.93 | 2.50 | 2.79 |
| 260103 | 12 | 2.25 | 2.42 | 2.58 | 3.08 | 2.83 | 3.08 |
| 260104 | 14 | 2.14 | 2.21 | 2.43 | 2.79 | 2.50 | 2.71 |
| 260105 | 14 | 2.07 | 2.14 | 2.50 | 2.93 | 2.50 | 2.64 |
| 260201 | 14 | 2.36 | 2.50 | 2.64 | 3.00 | 2.57 | 2.79 |
| 270101 | 14 | 2.43 | 2.57 | 2.93 | 3.00 | 2.71 | 3.00 |
| 270102 | 14 | 2.29 | 2.57 | 3.29 | 3.21 | 3.00 | 3.00 |
| 270103 | 14 | 2.50 | 2.71 | 3.14 | 3.14 | 2.79 | 3.07 |
| 270104 | 14 | 2.57 | 2.43 | 2.71 | 2.71 | 2.50 | 2.50 |
| 280101 | 14 | 1.93 | 1.86 | 1.43 | 2.07 | 1.57 | 1.07 |
| 280102 | 14 | 2.36 | 2.21 | 2.36 | 2.14 | 1.71 | 1.50 |
| 280103 | 14 | 1.36 | 1.14 | 1.07 | 1.29 | 1.14 | 1.21 |
| 280201 | 14 | 1.57 | 1.36 | 1.14 | 1.21 | 1.14 | 1.21 |