N O A A

AQUACULTURE SURVEY

1972

Report To Participants

MARDELA CORPORATION
BURLINGAME, CALIFORNIA

NOAA
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Department of Commerce

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Summary Report to Participants

NOAA REGIONAL AQUACULTURE WORKSHOPS

1972

Project #A/a-01, Grant #2-35243 Mod 2,
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United States Department of Commerce
Washington, D. C.

This program was conducted by Mardela Corporation under contract to the National Oceanographic and Atmospheric Agency (NOAA) and was administered by the Sea Grant Program under an Agreement between Mardela Corporation and the Research Corporation of the University of Hawaii, dated February 1, 1972. All recommendations and data in this report are the responsibility of the contractor, and do not necessarily reflect the views of the United States Government.

MARDELA CORPORATION

Burlingame, California

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I. INTRODUCTION

This report contains a synopsis of opinions on problems and priorities in marine and brackish-water aquaculture, as expressed by approximately 180 participants from industry and scientific, educational, and government agencies, at 12 regional workshop conferences held in 1972.

A. BACKGROUND

The workshop program resulted from NOAA's recognition that current efforts to develop marine aquaculture are highly diffuse. Aquaculture in Europe, Asia, and other parts of the world has been established for centuries. Over 60,000 acres in the United States are currently used for commercial freshwater aquaculture (primarily catfish). Yet no marine species, except oysters, is currently commercially cultivated in the United States or its possessions. This situation is not the result of disinterest, since federal and state governments, universities and private companies have over the last decade collectively spent major funds in attempts to develop commercial aquaculture.

One of the reasons for the lack of a tangible return from this investment is that this work has been diffuse and largely uncoordinated. Federal agencies involved in such programs range from the Office of Sea Grant and the National Marine Fisheries Service (NMFS), to the Economic Development Administration, the Office of Economic Opportunity, the Agency for International Development, and others. For instance, approximately 120 marine aquaculture programs are identifiable in the federal government alone, to which should be added those conducted by states, universities, and private institutions.

Further evidence of the diversity and heterogeneity of marine research in this country is the number and growth of marine laboratories. According to a 1970 report of the American Institute of Biological Sciences, over the seven years from 1963 to 1970 the number of marine laboratories, not including federal laboratories or state-supported fish and game laboratories, rose from 50 to 88. In addition, 20 new facilities were in the planning stages in 1970. Assuming all such new facilities are completed by 1973, the number of such facilities will have more than doubled in the ten-year period.

Marine aquaculture is assumed to have extraordinary long-range potential, and certain developmental efforts in the field are beginning to show signs of commercial promise for the foreseeable future. Accordingly, in 1971 the National Oceanic and Atmospheric Administration (NOAA), under whose jurisdiction fall the two most active federal agencies involved in commercial aquaculture, NMFS and Sea Grant, requested Mardela Corporation, a private firm engaged in living marine resource development in the United States, Europe and the Middle East, to undertake a program to elicit and correlate the best opinions and judgments of some of the senior scientists, industrialists, and active entrepreneurs involved in the aquaculture field.

The project was commissioned by the office of the Associate Director of NOAA, directed on behalf of NOAA by the Sea Grant Program, and administered through the offices of the Research Corporation of the University of Hawaii.

B. OBJECTIVES AND SCOPE

The program's objective was to identify priorities for the advancement of marine aquaculture.

The overall objective was to define priority research areas in order to move from the laboratory to commercially viable aquaculture at the earliest possible time.

To fulfill this objective, 12 regional workshops were held. Each workshop was attended by selected individuals, who were asked to present their opinions with respect to any and all obstacles impeding the transition of aquaculture from the laboratory to commercial operations.

The scope of the workshop program was limited to marine, anadromous, and brackish-water species of potential economic interest to the United States. The program specifically excluded aquarium fish, as well as all exclusively freshwater species. As used throughout this report, the term "aquaculture" refers to marine or brackish-water thus defined.

The purpose of the program was not in any way to survey or evaluate past, current or proposed programs, or technical performance of individuals, nor to determine whether the federal government should continue its support of aquaculture activities.

C. WORKSHOP PROGRAM

The required data were obtained through structured workshop sessions and written contributions of participants.

The workshop program comprised 12 one-day meetings in spring and summer of 1972 at the following locations:

Newport, Oregon	Milford, Connecticut
Seattle, Washington	Kingston, Rhode Island
Galveston, Texas	Washington, D. C.
New Orleans, Louisiana	La Jolla, California
St. Petersburg, Florida	Burlingame, California
Miami, Florida	Honolulu, Hawaii

The workshops were attended by a total of approximately 180 invited representatives of universities, private companies, Sea Grant, NMFS, EPA, and other federal and state agencies. The criterion for the selection of invitees was to achieve a representative cross section of individuals and organizations active in the region. Attendance was held to a maximum of approximately 15 to allow active participation of all.

Prior to each meeting, each participant was mailed a questionnaire soliciting first, an evaluation of the relative importance of a broad range of research subjects applicable to species of particular concern, and second, recommendations for specific research on each item which the respondent chose as having high priority. In addition, formal position papers were requested. The response was excellent and has resulted in extensive data of value to NOAA in structuring detailed future research goals and plans.

The meetings themselves were conducted according to a structured agenda. At the outset, each participant presented a statement of opinion on obstacles, action required, and priorities. After these individual presentations, the chair conducted ad hoc discussions of specific subjects pertinent to the group and region.

On behalf of Mardela Corporation Mr. Charles A. Black assumed overall direction of the program, assisted by Mr. Valerio L. Giannini in all aspects of planning, coordination, documentation and general management.

A Steering Committee was formed to provide technical and economic counsel for the program, and included Dr. John E. Bardach, Director, Hawaii Institute of Marine Biology; Dr. Colin E. Nash, Director, Oceanic Institute; Dr. Jack R. Davidson, Director, Sea Grant Program, University of Hawaii; Mr. Taylor A. Pryor, President, The Oceanic Foundation; and Mr. Charles A. Black, President, Mardela Corporation. The many individual contributions of time and assistance from Steering Committee members is gratefully acknowledged.

Exceptional appreciation is due Dr. John E. Bardach, whose technical judgment, unstinting energies, and moderating influence are reflected in every aspect of program activity, and in the report which follows.

Finally, our collective thanks go to each participant, who gave so generously of his or her wisdom, opinion, and candor.

II. SUMMARY

A. BACKGROUND

Recognizing that federal efforts in the field of marine aquaculture appear highly diffuse and largely uncoordinated, in early 1972 NOAA commissioned a private firm, Mardela Corporation, to conduct a series of regional workshops to identify priorities for the development of commercially viable marine and brackish-water aquaculture.

B. POLICY AND ORGANIZATION

Although a majority of the workshop participants were technical personnel, opinions on matters of policy and organization were as strong and extensive as those on technical subjects.

1. Goals: It was a dominant overall opinion that a major deficiency in current government aquaculture programs is the absence of clearly defined and stated goals, plans, and organization.

Suggestions as to what those goals should be and who should establish them varied widely, but it was agreed that such goals should be consistent with overall national objectives. A definition of goals included economic benefits of a profitable industry; research and education; support of natural resources; waste utilization; public health; and support of recreational fisheries. It was also stressed that aquaculture should be treated as part of a total coastal zone planning effort, as contemplated in the Coastal Zone Management Act of 1972.

2. Leadership and Centralization: Participants believed that NOAA should recover full initiative in the establishment of

national aquaculture goals and policies and should assume leadership in the required coordination among diffuse federal, state, and agency programs. Although centralization of planning responsibility and accountability was advocated, participants rejected notions of a total administrative or physical centralization. Rather, it was suggested that techniques be introduced to produce a basic series of aquaculture goals, and an administrative system to ensure coordination by species and subject area, even to include better liaison with appropriate agencies with jurisdiction in freshwater aquaculture.

In the establishment of goals and exercise of leadership, it was urged that NOAA draw heavily upon private industry as well as the scientific community. Mission-oriented research, as contrasted with discipline-oriented research, was strongly advocated. A more even balance between basic and applied research was urged, consistent with the goals established.

In effect, participants ask that, other than funding, federal participation in aquaculture research and development have three component parts: first, overall goals and general research objectives established in the context of NOAA executive administration; second, actual project execution by federal, state, or university labs, or private contractors under grant; and third, coordination of activities and appraisal of program progress at NOAA executive level.

Only a few isolated representatives of small business questioned whether a valid justification existed for federal participation in aquaculture.

3. Funding: Consistent criticism was raised that year-to-year funding, diffusion of funds among too many small programs, and onerous requirements for annual justification reduced both efficiency and effectiveness of research. It was observed, however, that these may be symptoms of a system without clearly defined leadership, and that establishment of long-range, coordinated programs would helpfully cure such deficiencies.

4. Communications: The absence of effective information retrieval and dissemination systems was deplored as a major obstacle to technical progress. Correction of this situation was felt to deserve the highest priority, even before the establishment of an overall national program.

Among suggestions for more effective communications were: designation of responsibility for data services; improved seminars for both technical and non-technical persons in government, universities, and the private sector; internships for federal, state, and private experts to work in government facilities; subscription services; reinforced field advisory services; and increased representation from the private sector on government advisory committees.

C. OTHER NON-TECHNICAL FACTORS

1. Legal: Legal and regulatory restraints were felt to be the greatest single inhibition to commercial aquaculture in the United States. Laws and regulations pertaining to the use of coastal land, water pollution, interference with navigation, and the possession of larvae and fry were cited as strong deterrents to many forms of aquaculture. Concern was expressed that the investment of public and private development dollars

might be towards impractical operations. To focus attention on aquaculture problems relating to local law and regulation, NOAA was urged to establish closer working relationship with major federal regulatory agencies, and to stimulate action from local and state governments and regional commissions.

2. Economic: The economic feasibility of many types of aquaculture operations in the United States was also questioned, citing negative economic factors of labor cost, land values, pollution, and public pressures.

Such considerations, combined with legal restraints, suggest that perhaps the only form of aquaculture feasible in the United States would utilize technologically intensive techniques, such as closed-cycle and intensive culture, and would involve products of only high value, thus warranting the high capital cost involved.

In addition, the concept was advanced that expertise, technology and equipment of U.S. origin might be joined with foreign growing facilities to realize economic benefits, while avoiding domestic practical and operating ineconomies.

3. Entrepreneurial: Increased participation by private companies in planning at the federal and state levels would be required to successfully develop commercial operations. At the same time, it was noted that an orderly appraisal of economic opportunities is being made more difficult by sensational or premature publicity, incomplete and misleading statements of fact, and by public confusion between overseas aquaculture opportunity and U.S.-based opportunity warranting federal expenditure.

Present programs to encourage industry to join with federally sponsored research were generally judged ineffective. However, if NOAA were to assume more vigorous control over aquaculture planning and seek industrial participation in the planning process, industrial enthusiasm may well change. Improved technical communications and some equitable form of protection for proprietary techniques developed in joint programs would be supportive. Considerable discussion centered on formulae for direct matching grants to private concerns willing to risk private capital in development projects. Suggestions included contractual participation in research tasks by universities or federal laboratories, under subcontract from the private grantee.

D. TECHNICAL NEEDS

Although the bulk of technical data arising from both workshops and participants' written contributions is highly specialized by species, region, and subject, and therefore not readily reduced to a general summary, certain general conclusions emerge:

1. Overall Goal: The overall goal of all technical research should be a thorough understanding of the life cycle of the animal, rather than attempting to separately approach interrelated problems of reproduction, nutrition, disease, and environment on an ad hoc basis.

2. Genetics: Basic genetic research to improve on wild stocks is the correct long-term approach to alleviate problems of survival, disease, and nutrition.

Although genetic upgrading is desirable, commercial operators pointed out that for their immediate purposes, current selective-breeding techniques and hatchery technology are adequate, and thus urged that priority emphasis be placed on other problems, such as disease and nutrition.

3. Disease: Disease was identified as the greatest single obstacle to commercial aquaculture. Clinical assistance was urgently requested by operators. At the same time, it was unanimously agreed that disease prevention, not solely treatment of symptoms, was the correct overall approach.

Genetic research, nutrition, and water flow-rates and quality control were felt to be key factors in such preventive efforts. The limited U.S. competence in saltwater animal pathology was noted, and the establishment of cooperative federal disease centers was suggested.

4. Nutrition: Nutritional problems are as much economic as technical, since in most cases technical formulations are adequate, but the cost of the food and not its non-existence presents the obstacle. The increased use of food processing or other waste products, even sewage, with a minimal cost basis would perhaps make large-scale production more interesting to food formulators. Continued research into development of effective, economical foods from all possible sources was felt to deserve priority attention.

5. Operations: Pilot farms are regarded as prerequisite to the translation of laboratory technology into commercial operations. Pilot hatchery operations exist for several species under federal or state sponsorship, but these generally serve a more narrow purpose than envisaged by participants. The primary objective of such pilot facilities would be development of necessary engineering skills in water mechanics, feeding, water quality, pollution control, and harvesting. Pilot operations would also serve as a model for determination of economic feasibility, and as an applied research laboratory.

III. POLICY AND ORGANIZATION

A major deficiency is the absence of clearly stated and understood goals, within a defined overall aquaculture policy. Although a majority of the workshop participants were technical personnel, the workshop positions on matters of policy and organization were as strong and extensive as those on technical subjects. One unanimous opinion expressed is that prerequisite to effective progress in aquaculture is the establishment of clearly stated goals and policies by the government. The character of goals, policies and programs of the numerous federal, state, university and other entities detracts from overall advancement. Scientific representatives consider goal-setting necessary to provide the framework for the solution of technical problems. Industrial participants feel it is necessary to attract the private resources required to develop commercial enterprises.

Notwithstanding the variety of suggested goals, it was generally agreed that all aquaculture goals should tie in with overall national goals and objectives. In this context, aquaculture is seen as an activity complementing other major activities, rather than as an intriguing, isolated phenomenon.

Whatever goals are selected, the importance of their establishment and their conformance to national priorities was repeatedly emphasized. The need to make aquaculture more politically attractive was also noted. It was pointed out, however, that U.S. aquaculture operations cannot be considered a realistic means of feeding the world's underfed populations, since it will involve high-value edible species. The technology developed in this country might, nonetheless, be valuable in the solution to aquatic protein shortages elsewhere in the world.

A. GOALS

Included in suggested goals were:

1. Provision of a vehicle for research and/or education.
This concept was advocated by many who believe that considerable basic research is still required and that the field is not ready for commercialization. If this goal were pursued, commercialization would evolve naturally at a much later time, as the fundamental base of knowledge became sufficient to support it.

2. Support of natural commercial resources.
It was frequently suggested that aquaculture techniques could provide a solution to problems of diminishing natural stocks, by helping replenish the natural environment. Further emphasis should be placed on aquaculture as a source of bait-fish of use in pelagic fishing.

3. Enhancement of the economy resulting from a profitable industry.
Considerable precedent exists for government support of emerging industries that will further national economic interests. Aquaculture could provide benefits of employment and taxable profits, and also reduce growing dependence on foreign sources for high-value seafood imported into the United States.

4. Utilization of waste products.
A major obstacle to commercial aquaculture in many species is feed cost. Waste product disposal is an important national problem. Accordingly, it was suggested that a synergistic solution to both problems would be the use of waste products as a source of food for aquaculture. Sewage farming is currently conducted successfully in Eastern Europe and Asia, and aquaculture

operations in power plant effluent in this country show great promise. In addition to effectively utilizing waste products, aquaculture can perform a valuable "scrubbing" function to reduce contaminants and thereby enhance water quality.

5. Support of recreational fisheries.
Aquaculture techniques can support the standing resource of recreational fisheries, both in the natural environment and fishing impoundments, and can provide a new source of bait-fish, as indicated above (III-A-2).

6. Utilization in solutions to public health problems.
Aquaculture is a proven bioassay technique for measuring pollution by establishment of water-quality standards, in addition to the constructive uses indicated in III-A-4, above, thereby indirectly contributing to the solution of environmental problems. As a source of trace chemicals or pharmaceuticals, such as prostaglandins, aquaculture holds potential, but the high cost of getting drugs marketed deters development in this field.

7. Alignment with the socio-economic, political goals of the overall coastal zone planning effort.
The Coastal Zone Management Act of 1972, which cites aquaculture as one of the multiple uses of the coastal zone, should be noted as of critical influence in estuarine and coastal aquaculture, and any national program must recognize the importance of the Act's restrictions and potential.

B. LEADERSHIP AND POLICY CENTRALIZATION

1. NOAA should recover full initiative in establishing national aquaculture goals and policies.
One of the most frequently cited obstacles to the advancement of

aquaculture was the diffusion and ineffectiveness of federal government leadership in aquaculture, from the formulation of goals to administrative procedures.

The existence of independent aquaculture programs in different agencies may have been justifiable at their inception because of the different specific goals of these projects (e.g., Sea Grant/education; NMFS/fisheries support; EDA/Indian employment; FWLS and BSF/sportfish). As these programs advance, however, they face sophisticated common problems best approached by a common effort. To this end, marshalling these diverse resources under common leadership would appear to be the most effective means of solving problems and advancing the state-of-the-art.

However, it was not advocated that all operations relating to aquaculture should be brought under a single operating responsibility, but rather that the goal-setting, policy-making function should be coordinated and centralized. In fact, most participants objected to physical consolidation of presently separate entities, but emphasized that a master plan and program applicable to all was badly needed.

It was the consensus that responsibility for a national NOAA aquaculture program would probably best be located at the executive level of NOAA. Although both Sea Grant and NMFS have extensive capabilities and programs in aquaculture, their basic charters are somewhat restrictive. More importantly, the workshops made it clear that considerable intramural competition exists which might hinder the effectiveness of either one in carrying out total program responsibility. Subsequent to the workshops' conclusion, NOAA appointed Dr. Harold L. Goodwin, Deputy Director, Sea Grant Programs, as Director of Aquaculture

Programs for NOAA. This appointment is fully consistent with the urgent recommendations of workshop participants.

Equally as important as leadership within NOAA, however, is the question of leadership of cooperative efforts among the different federal and state agencies and universities with activities, capabilities or facilities related to aquaculture. It was particularly observed that NOAA might lead in correction of the illogical and too rigid separation of freshwater and saltwater skills in the federal government, particularly between the Fish & Wildlife Service and Bureau of Sports Fisheries of the Department of the Interior, and Department of Commerce activities.

Other agencies with which NOAA should achieve a higher level of effective cooperation include the Department of Agriculture, particularly in genetics; the EPA, because of its extensive interests in water quality and water-borne viral diseases; and the FDA, largely because of its ultimate authority with respect to any edible food product. In spite of the existing levels of cooperation among these agencies, it was felt that much more effective efforts are still required and possible.

It was further noted that state aquaculture activities in many areas duplicate and often conflict with direct federal programs, and that the two should be brought under control through the coordinating umbrella of NOAA. Under terms of the Coastal Zone Management Act of 1972, states will receive direct grants which may be used at each state's discretion for aquaculture objectives. NOAA has administrative responsibility for such grants, and therefore is a logical mechanism of project coordination, elimination of duplicating research, and interchange of technical data.

2. Goals, policies and programs must include, along with scientific criteria, those criteria imposed by commercial enterprise, the immediate beneficiary of scientific research. The workshop discussions pointed out the importance of a balance between scientific and commercial participation in the establishment of goals, policies and programs. Scientific representatives typically observed that their intimate understanding of the problems put them in the best position to judge what was required. Industrial representatives, however, invariably questioned the scientists' ability to judge what was required to achieve economic goals, and thus felt it was they who are best qualified to determine what should be done.

It was further noted by representatives of the private sector that almost all programs that exist today under whatever jurisdiction are based on criteria established by scientifically oriented persons. In their view, a major deficiency remains the lack of inputs from private commercial interests, those who must finally face problems of making aquaculture viable commercially.

The thesis of criticism from the private sector was that heretofore NOAA funding too frequently followed narrow interests of federal and academic researchers, and ignored the commercial requirements of entrepreneurs, actual or proposed.

Scientific and academic professionals generally observed, however, that basic biological, physical and genetic problems must be solved before the pragmatic approach advocated by private entrepreneurs can be attempted, far less achieved.

This dilemma became less troublesome to participants during discussion of a proposed shift of federal funding to a mission-

oriented basis and away from a disciplinal basis. Formulation of realistic aquaculture goals can only occur in the context of a consistent and thorough contribution from both scientific and entrepreneurial interests. The workshops indeed contributed to the positions becoming more complementary than conflicting.

3. Mission-oriented research was strongly advocated.
It was a general opinion that aquaculture program planning now tends to be done at various technical research levels, irrespective of heroic efforts elsewhere to better organize the total effort. Decisions with respect to what work should be done seem often to have been made by the individual researcher, based on his particular research interests, and generally outside the context of nationwide needs. As a result, a great deal of work is being done today, particularly in universities, which is deemed marginally pertinent to the overall problems, and often counter-productive. This situation was generally felt inconsistent with the best, most effective means of achieving major goals. Institution of mission-oriented research was strongly advocated as a remedial solution.

Mission-oriented research under federal sponsorship must by definition clearly satisfy national goals, or clearly be an unrestricted grant-in-aid. Such grants are presumed outside the scope of the workshops. Therefore, it became clear to participants that national missions should be set by national authority, and that NOAA should assume this responsibility for aquaculture.

Concurrent with such discussions were extensive examinations of the roles and importance of basic and applied research. Representatives of the scientific and academic community expressed fears that emphasis on mission-oriented research might

erode funding required for basic research vital to advancement in the field. Conversely, participants involved in commercial or quasi-commercial operations felt that preoccupation with basic research effectively stalls movement of commercially profitable concepts from the public laboratory to private development.

In the context of mission-oriented aquaculture, it was believed an appropriate balance could easily be struck between basic and applied aspects of research. Inasmuch as the various species with aquaculture potential are more or less close to economic exploitability, some requiring more and others less basic research, it was felt the discussion would be of long life.

4. Research programs should be coordinated on the basis of species and subject area.

Once the NOAA administrative authority is clarified and the mission approach adopted, difficulties in implementation are anticipated within existing diffuse and overlapping jurisdictions. Representatives of many of those jurisdictions met one another for the first time at the workshops, although working in the same scientific areas and living within the narrow region served by the workshop. It is worthwhile to note, however, that the concept of NOAA having centralized authority for program development received very strong endorsement from those participants. Their reservations concerned possible reactions at other executive levels.

The suggestion was made to organize research by species and subject area. This would maximize chances of successful implementation, and also provide for most efficient use of available funds for the highest level of technical results.

A rigid linear structure by either species or subject is not reasonable because of the overlap of many technical facets. Rather, the structure must be multidimensional by both species and subject, and in certain instances, also by region. For example, certain disease and nutrition research is common to several species. Possible exceptions to this principle exist in the subject area of genetics.

At the same time, there must be centralized species responsibility for shrimp, lobster and oysters to correct present duplication of effort and difficulty of communication. Assumption of this responsibility would involve proposal and progress review; coordination of information retrieval and dissemination; preparation and updating of the mission-oriented national species program; maintenance of contact with the private sector; and other activities of similar importance to the specific species.

In effect, this division of responsibility will provide an identifiable national focus for knowledge of the subject area or species, and for ultimate program direction. Individuals assuming such responsibilities preferably would be physically located at sites where significant work is already underway.

It should be stressed that administrative centralization as advocated does not require organizational transfers of operating responsibilities as they currently exist. To the contrary, a further distribution of operating authority to decentralized laboratories and universities was advocated. The recommended centralization concerns only policy, broad program formulation, and program coordination, with requisite responsibility and authority vested at the NOAA executive level.

C. FUNDING

1. Annual-funding philosophies inhibit quality of research, and unnecessarily distract scientists to non-productive tasks. Among the most criticized aspects of the current research system were those relating to funding on a fiscal-year basis. The magnitude of research problems can seldom be accommodated within a fiscal year; if funds are restricted too early, the initial investment is largely lost.

Annual-funding problems may be a symptom of the present decentralized system, and not a basic problem. If a national aquaculture program is developed along the lines discussed earlier, such funding problems may resolve themselves. Under such a program, the work to be performed would be delineated and budgeted in the form of a three- to five-year plan, as is done by the National Science Foundation or the National Institutes of Health. Work would not commence unless it was part of that plan.

This proposed plan will relieve some of the excessive pressure to demonstrate near-term results, because criteria for continuation would be milestones delineated in the master plan under which the work was commissioned.

Although funding would still be subject to annual authorization and appropriations, continuity should be committed, subject only to a major program redirection affecting such research, or budget reductions affecting the overall program. The continuity principle need not assure that one researcher will perform the continuous research, but only that such research will be performed where the best job can be done.

While sharply critical of annual-funding philosophies, most opinions were equally firm that funding should never be extended

or continued if current contractual requirements have not been precisely fulfilled. For example, although written progress reports were regarded as a serious distraction to sustained research, once this requirement was part of the contract, the obligation should be met, or either the follow-on funding denied or the contract terms rescinded.

2. Proposal and performance review systems need overhaul.
The size and quality of reviewing panels were criticized, and an extension and revitalization of the panels was recommended by addition of qualified individuals and wider distribution of proposals for review. With a more authoritative review and approval at the outset, it is believed that interim project reviews will be eased, and the annual refunding process expedited. The proposed centralization of program responsibility by species and subject area should also alleviate complaints concerning unqualified reviewers, as a higher level of technical competence should result from pooling of skills and knowledge in a structure organized by species or subject.

3. Excessive diffusion of research funds is counter-productive to research excellence.
Criticism was expressed that too often funds are allocated on the basis of political realities rather than research capabilities. The result is a system of overlapping and uncoordinated projects, all of which are underfinanced for optimum results.

Resolution of this problem depends on complex factors beyond the scope of the workshops. However, the critical nature of the problem was drawn into sharp focus, with an urgent request for correction.

In this respect, concern was expressed that research emphasis of scientists would be required to conform to national interests, rather than individual interests, and that the combination or elimination of overlapping research programs under a program to reduce diffusion would narrow the base for training and employment. However, such speculations did not appear to modify overall enthusiasm for the prompt assumption of leadership by NOAA, and the creation of a mission-oriented perspective for research.

Inherent in these discussions was recognition that federal procedures which encourage competition in research for the sake of competition may be a luxury that aquaculture cannot afford. Diffusion of funds for the sake of diffusion may have now reached counter-productive limits.

It was repeatedly stressed that the best results will be achieved by more precise program definition, more critical appraisal of proposals by more qualified reviewers, fewer research participants, more demanding performance review, and insistence on elimination of overlap and unjustified duplication.

D. COMMUNICATIONS

Inadequate professional communications and inadequate data availability on aquaculture are regarded as a major deficiency. Recognizing that this problem is symptomatic of the scattered and disparate character of current research activity, its solution is relatively easy. Corrective steps need not wait for other organizational and policy changes, but simply constitute administrative decisions.

1. Designate responsibility for active data collection, retrieval, and service on relevant aquaculture research subjects.

A simple organization of existing data in NOAA, Sea Grant, NMFS, and foreign translations may be the first step, with proper cross-indexing and cataloging for reference. It was suggested that the Environmental Data Service or the National Oceanographic Data Center could be used to establish the aquaculture subclassification.

2. Establish a Subscription Service, to which not only public but private individuals may subscribe. This could follow the lines of an abstracting journal, comparable to current biological abstracts, but would cover both technical and non-technical subjects.

3. Stimulate regular technical exchanges on aquaculture for government, state and academic personnel, providing a technical bridge between the Departments of Commerce and Interior, for example, and between the federal government and the states. Such seminars need not be completely new meetings, but the subject of aquaculture should be included as a normal agenda item on existing gatherings of scientists under government auspices.

4. Create an Interne Exchange Program under Sea Grant/University/NMFS joint auspices for federally sponsored scientists and technicians to serve on an exchange basis in appropriate labs, such as NMFS or University facilities. This was regarded as a fundamental step in bringing greater cohesiveness to Sea Grant and NMFS activities in the field.

5. Establish a separate Research Internship Program for scientists from interested private sectors, permitting them to study, on a fee basis, in appropriate labs, such as NMFS or University facilities.

6. Organize a Public Seminar Program on the state-of-the-art in aquaculture, open to all interested citizens and self-supported through admission fees.

7. Reinforce the Field Technical Advisory Services available to the private sector, particularly in clinical aspects of disease.

8. Establish a mechanism for regular advice from commercial enterprises to NOAA executive administration on matters affecting aquaculture. A number of advisory committees already exist, and a new one need not be formed for this purpose alone. However, it was urged that NOAA seek aquaculture advice more directly and extensively from the private commercial sector than heretofore. The establishment was advocated of a permanent ad-hoc national aquaculture advisory panel to second the individual in NOAA who will ultimately be responsible for broad overall program planning and coordination.

IV. OTHER NON-TECHNICAL FACTORS

A. LEGAL

Legal and regulatory restraints pertaining to water ownership and use are the greatest single inhibition to U.S. commercial aquaculture. The risks in attempting to solve technical problems can be evaluated objectively, but the final answers to certain legal and regulatory questions are indeterminable at this time. Private investment under such circumstances is highly speculative, and continuing federal and state investment in techniques which may thus prove impractical in this country may be unjustified.

Major existing or anticipated legal problems cited include: local regulations controlling use of coastal land and adjacent public water; Army Corps of Engineers regulations pertaining to navigation, and other matters under Corps jurisdiction; EPA and state water-quality and environmental-impact criteria; state laws pertaining to taking and possessing marine animals; and civil actions by conservation groups or other private individuals.

This list suggests that locating on private land and utilizing intensive culture techniques may help circumvent many of these problems. Participants seemed to reach the same conclusion from many economic and technical standpoints.

Despite potential legal problems, few accounts of actual legal difficulties were reported, possibly because present operations are small and limited in number. The infrequency of reports of problems with pollution control was attributed to the indistinct character of existing regulations, and preoccupation by the EPA

and state water quality agencies with major pollutors. Of particular concern to those few operators using once-through heated power plant effluent was the potential impact of requirements on the public-utility industry for closed-cycle or evaporative cooling systems.

It was recognized that most of the legal questions come under state jurisdiction. It is understood that NOAA cannot provide legal advice to the public or serve as an advocate in dealings with federal or state agencies. It was felt, nonetheless, that NOAA should stimulate or commission studies of the current legal situation in various regions and make these data available.

Additionally, NOAA should emphasize its coordination with the EPA in the area of estuarine and coastal pollution, and with the FDA on use of chemical additives and therapeutic drugs in aquaculture operations. Recognizing the profound implications for aquaculture of the Coastal Zone Management Act of 1972, NOAA executive programming should reflect a current and compatible view of law and regulations emerging under this Act.

B. ECONOMICS

In spite of the professional and/or financial commitment of most workshop participants, serious questions were raised with respect to the future economic viability of many forms of commercial aquaculture in the United States. Even in cases of high-value species where a return is anticipated to justify the capital expended, considerations of labor cost, land values, pollution, competition for water use, and public pressures in this country may create an intolerable economic climate.

It was pointed out that the example of successful aquaculture operations in countries such as Japan is not necessarily applicable to

the U.S. because of differences in basic economic factors. The general conclusion reached was that economic factors in the United States, combined with legal and technical inhibitions, indicate that technologically intensive closed-cycle systems would eventually provide the best chance for U.S. aquaculture operations.

Despite extensive discussions of economic feasibility, the workshops produced little "hard" data useful in projecting economic trade-offs. Economic justification was often simply a rough production-cost-versus-gross-income estimate, with inadequate attention to other vital aspects, such as market demand, distribution costs, price sensitivity, and competition. Such estimates are of limited use as a basis for investment decisions in a commercial operation. Pilot farms were suggested as a means of obtaining more refined economic information (see V-C-4). It was noted that significant commercial investors were unlikely to move without such data. It was further suggested that the government should have such information itself before continuing to invest taxpayers' money in the field.

C. INDUSTRY PARTICIPATION

Efforts should be made to increase industrial involvement if aquaculture is to become commercially viable in the foreseeable future. In spite of the involvement of some companies, many more potential participants appear to be taking a passive attitude.

To attract further interest from the private sector, NOAA should accomplish the following:

1. Establish a definitive government program for aquaculture. A major factor contributing to indecision in the private sector has been absence of a clearly defined government program. Private companies generally expressed reluctance to commit themselves when the government had not yet committed itself to

overall goals and a national course of action. Of added concern was the lack of information exchange, lest by its absence private companies inadvertently repeat mistakes that already have been made with government sponsorship.

2. Overhaul the present structure of joint Industrial/Sea Grant programs.

Industrial participants expressed disappointment with Sea Grant/Industry joint participation programs. Although such programs did afford a preliminary exposure to the field, the benefits and penalties of continued participation made further investment unwarranted. Particularly noted were restrictions on ownership of proprietary data, and academic dominance.

Industrial participants felt that some system by which they could benefit from patent rights would make participation more attractive. The principle of joint federal-private developmental programs is widely used in other government departments, where the government is granted a royalty-free non-exclusive patent right to developments arising under joint auspices.

The present policy of denying proprietary rights to industrial firms might be fair in development contracts in which the government bears the full cost of the program, but was considered inequitable when the private concern shared in the expense. It was suggested that some means be devised whereby industrial participants could gain proprietary interests in developments in proportion to their contribution to the joint program.

A suggestion to overcome academic dominance of joint programs was that grants be made directly to private companies, with a stipulation that portions of such projects be subcontracted to universities.

3. Increase the basic economic data available to potential entrepreneurs.

Even if all industry requests for government leadership, industrial participation in planning, increased information dissemination and patent rights are met, the fundamental business criterion of profit potential remains. Just as the speculative appeal of aquaculture is high, so are the financial risks. Data available today are usually considered insufficient to justify more than token participation. Until the risks are more clearly defined, large-scale financial commitments should not be expected.

Risk capital is available, but only on a reasonable projected return-on-investment. For evaluation of risk and return factors, some underlying economic data must be available from research projects. Other data, such as market analyses, are rightly the responsibility of the investor. It is the paucity and unreliability of the former category which were noted.

If the government wishes to rapidly stimulate successful industrial participation, it should look to organizations already engaged in related activities, such as commercial fishing, animal feeds, land ownership, or electric power generation, either as operators or suppliers of key elements. For such companies, participation may be achieved with minimal cash investment through application of existing capabilities or facilities, and with the financial risk spread over the existing overhead of a going operation.

4. Promote wider understanding of the concept of private, proprietary, technical data.

Private companies were criticized for restricting communications of their scientific staff and for failing to make public distri-

bution of fundamental data, but at the same time turning to university or government laboratories for assistance. Others involved in such discussions noted contrary experience, saying that qualified individuals who requested permission to visit private facilities were usually granted access unless there was a direct conflict of interest, and even then were permitted access after executing a standard non-disclosure agreement. It was believed that institution of the suggested recommendations, especially with respect to commercial representation at the planning level, will narrow this communication gap with industry.

5. Present aquaculture publicity in more realistic tones. It was the consensus of both commercial and scientific participants that much of the current publicity in the field of aquaculture has caused significant harm. The natural appeal of the aquaculture concept, combined with unrealistic encouragement, has resulted in many disappointments. Researchers especially stated that they are continually having to discourage overenthusiastic entrepreneurs who come prepared to invest in an aquaculture venture which is usually beyond the state-of-the-art and which is almost always beyond their experience and ability.

The participants urged that NOAA recognize this difficulty and refrain from any publicity that might be interpreted as false encouragement. NOAA should identify itself as a source of aquaculture information, but should continue to resist pressures to speculate on the economic potential of aquaculture ventures.

V. TECHNICAL NEEDS

Although one of the objectives of the workshop program was to identify overall research priorities, a simple listing of problem areas would not in itself be meaningful. The research problems identified cover a broad spectrum of interrelated subjects which differ according to species and region.

There were, nonetheless, certain general conclusions reached which are presented herein, together with a synopsis of responses to the workshop questionnaires and worksheets, and a general discussion of technical needs in major subject areas.

A. GENERAL CONCLUSIONS

Despite the complexities of the technical problems, the workshop participants reached some general conclusions which span discrete subject areas and are applicable to most species and regions:

1. A thorough understanding of the entire life cycle of the animal was cited as the all-inclusive goal of aquaculture research.

2. Survival encompasses inseparably related subjects of disease, nutrition and larval development, and should be approached as one basic problem.

3. Water quality, in the broadest sense, was singled out as the major common denominator to all aspects of survival.

4. Intensive culture techniques were believed to be the only long-range solution to the myriad technical problems of aquaculture.

Natural systems, such as embayments, do not allow sufficiently for control of critical parameters, and thus involve high risk and questionable chances of success. Such techniques will probably not be competitive with intensive cultivation, once developed.

5. Pilot farms were considered to be overdue for many species, as a means of performing research on a spectrum of interrelated problems in a realistically complex environment. Equally important, pilot programs would provide a vehicle for development of requisite engineering skills.

6. Polyculture was acknowledged as desirable, but more appropriately considered after solution of more immediate, basic problems of monoculture.

B. QUESTIONNAIRE RESPONSES

Prior to each workshop, the invitees were requested to complete detailed questionnaires on research priorities and to include recommended work statements in those areas which they feel warrant priority attention. This solicitation resulted in a large volume of detailed data on problems related to individual species in different regions, and specified tasks of importance in a national aquaculture program. A summary of the responses is presented in Table 1, which provides details, in percentage, of those areas deserving prime attention.

In the case of shrimp, for example, roughly two-thirds of the participants felt that adult nutrition required major attention, while they deemed juvenile nutrition to be of even higher priority.

TABLE I
NOAA REGIONAL AQUACULTURE WORKSHOPS
SYNOPSIS OF HIGHEST RESEARCH PRIORITY NEEDS
EXPRESSED IN % OF RESPONSES
(Numbers in parentheses = no. of respondents for each species)

	Salmonids (26)	Pompano (5)	Other mar.fish (16)	Penaeid shrimp (18)	Lobster (7)	Macro-brachium (6)	Oysters (25)	Scallops (7)	Clams (16)	Abalone (6)	Other Bivalves (10)	Macro-algae (7)
Reproduction												
Spawning	12	40	56	44	14	17	0	29	25	67	20	29
Hatcheries	15	60	38	17	14	17	38	71	31	33	30	14
Genetics	54	0	31	33	29	50	38	14	38	17	40	
Nutrition												
Larval	24	90	75	31	55	60	37	43	45	58	15	
Juvenile	24	40	75	72	70	60	50	29	25	80	20	
Adult	18	40	56	66	46	75	50	21	12	33	15	
Environmental factors:												
Disease												
Larval	26	60	50	67	71	67	28	57	50	50	40	
Juvenile	65	40	50	61	86	67	28	71	44	0?	60	
Adult	31	40	50	50	71	67	38	57	44	0?	40	
Water Quality												
Larval	25	50	38	16	30	30	25	40	44	30	30	57
Juvenile	37	50	38	24	21	30	25	50	44	17	20	43
Adult	25	30	30	18	21	30	44	40	63	17	30	57
Operations:												
Production system	43	60	18	56	57	20	46	57	56	50	40	29
Equipment	24	25	12	34	29	40	38	14	50	30	36	42
Management	30	44	12	44	57	18	13	14	12	17	20	60
Economic and legal factors:												
Marketing economics	50	40	12	17	0	67	18	14	30	0	80	43
Production economics	73	30	12	56	70	50	38	86	44	83	40	71
Site-related problems	50	20	6	11	70	25	31	43	44	17	30	43

Scanning Table 1 reveals that aquaculture of several potentially marketable species is still hampered by some unsolved biotechnical problems, such as disease, nutrition, and larval survival. It further reveals that aquaculture endeavors with species for which the hatching and cultivation problems are essentially under control, such as salmon and oysters, are now beset with legal difficulties and problems of site selection and system operation. In fact, existence of the latter problems seems inversely proportional to existing or incipient commercial rearing successes, indicating that both marketing and production economics require increased attention for the majority of species.

Not apparent from Table 1, but nevertheless worthy of mention, are opinions derived from the detailed work statements accompanying the questionnaires. Their consensus indicates that biotechnological skills involved in rearing aquatic organisms are fairly specific to individual species. From this one might assume some degree of confirmation for the earlier recommendation that aquaculture programs should be organized by species.

Expertise and experience of respondents lay mostly in the biological disciplines. In view of the apparent importance of non-biological problems in aquaculture (see bottom categories in Table 1), NOAA may well seek more vigorous participation in aquaculture research by persons with economic, legal and engineering expertise.

C. FEASIBILITY EVALUATION RESPONSES

During each meeting, participants completed a feasibility evaluation sheet to delineate the state-of-the-art of various facets of aquaculture in each participant's area of specialty. Table 2 contains a summary of the worksheets. Participants were asked to complete the sheets only for those species with which they were familiar, and to attempt to reduce their intuitive feelings with respect to the state-of-the-art to an arithmetic scale of one-to-ten.

This compilation was intended to complement the research priority questionnaire, Table 1. The thrust of Table 1 is to ascertain weak or strong factors of the several species selected for their superior market potential. Whereas Table 1 suggests what future research needs to be conducted, Table 2 attempts to indicate where research stands today.

The following points are to be especially noted in the interpretation of Table 2:

1. A score of less than 5 generally means that there are not extant enough research and development results at the research-station level to evaluate the factor in question (e.g., maturation of shrimp and crabs).

2. Non-availability of satisfactory feeds on the commercial market at this time generally reduces the potential of success for most of the species listed on the table. Experiments with artificial oyster feeds notwithstanding, the feeding habits of juvenile mollusks are such that the development of commercial feeds is probably neither as satisfactory nor economic as the development of better means to increase natural food supply.

TABLE 2

FEASIBILITY EVALUATION

The following is a summary of responses by participants in 12 NOAA-sponsored aquaculture workshops, conducted during 1972.

SCORE - 0 to 10

0 = Low; virtually impossible at this time

10 = High; ideal; no obstacle at this time

	(No. of Responses)	Controlled spawning	Simple larval development	Fast growth rate	High conversion efficiency	Satisfactory feeds known	In higher price range	Commercial feeds available	Hardy	Disease resistance	Density potential	Market
MOLLUSCS												
Bay scallop	(23)	7.7	7.6	7.5	5.8	5.7	7.7	NA	5.1	5.9	7.1	8.6
Oyster	(61)	9.2	8.2	7.1	5.9	5.4	7.1	NA	7.0	5.6	8.1	7.0
Clam	(49)	8.0	8.0	6.5	5.8	5.0	6.7	NA	7.3	6.3	7.9	8.3
Abalone	(7)	6.7	7.0	3.4	5.1	4.4	9.4	NA	7.9	8.0	8.4	9.3
CRUSTACEA												
Lobster (Homarus)	(27)	6.5	6.8	5.2	5.6	5.2	9.6	4.2	5.4	5.4	3.3	9.8
Crab	(33)	4.8	5.1	5.2	4.9	4.9	7.4	2.9	6.4	5.1	4.3	8.0
Shrimp (Penaeus)	(52)	4.3	6.8	7.0	5.1	5.3	8.5	4.8	5.7	5.7	6.2	8.9
Freshwater prawn	(25)	8.6	7.4	7.4	6.0	6.0	8.6	5.4	7.3	6.7	5.6	7.7
FINFISH												
Salmon	(34)	8.3	8.7	9.3	7.5	7.8	8.2	8.2	6.8	5.7	7.4	8.4

Format adopted from Aquaculture, A New England Perspective, Thomas Gaucher, ed.

3. A score below 5 in several categories renders the species unsuitable for early culture implementation; crabs are a case in point.

4. The market category does not necessarily take into account factors of market size or price elasticity. Obviously, the size and stability of a potential market strongly influence the magnitude of research support allocated to such areas as development of commercial feeds pinpointed earlier as bottlenecks to rapid commercial culture.

5. In Table 2 the consistently high score of virtually all categories of salmon culture feasibility is, in fact, confirmed by recent successful mariculture of plate-sized salmon. By the same token, the mixture of high and intermediate scores in the case of the lobster is good supporting evidence for such statements as that made at another NOAA-sponsored workshop in Mariculture of the New England Lobster at Woods Hole, Mass., in spring of 1972, that: "Commercial investment in lobster mariculture should not be encouraged at present, but the possibility of commercially-viable mariculture within two to five years, depending on the success of pilot-scale efforts, appears strong."

It should be noted that cumulative scores for each species have not been totaled, since this would invite invalid numerical comparison between species. The 11 parameters listed are not necessarily of equal importance when considering a given species, nor is their importance necessarily consistent from one species

to another. Further, cumulative totals would be misleading because a species with a high total might have low scores in one of the critical parameters, thereby classifying it unsuitable for cultivation. Mussels, for instance. Although not included on the evaluation sheet, mussels would probably have received a high cumulative score, in spite of the fact that they are not candidates for U. S. aquaculture because of absence of an economic market.

In reviewing both statistical summaries, it should be noted that they are approximations which should not be rigidly interpreted. They do not, for example, take into acount differences among subspecies or regions, and they are not weighted according to the qualifications of the individual respondent. The raw data compiled appear, nonetheless, quite valuable and will be extensively analyzed.

D. SPECIFIC TECHNICAL PROBLEMS

Although the technical information developed was highly specialized and does not lend itself to generalization, certain discussions of specific subjects can be summarized.

1. Reproduction

A common thesis was that genetic improvement of wild stock is imperative. Such improvement was felt to be the best means of solving basic problems of reproduction and survival, as well as producing better end products. Without such

advancement, it was felt that aquaculture would be doomed to an uncertain future. Comparative successes in poultry genetics were frequently cited.

There was, however, some disagreement as to whether selective breeding was preferable to genetic research. In spite of some excellent results, such as those with trout at the University of Washington, several scientists felt that such practices were potentially dangerous because one really did not understand the fundamental chromosome genetics. Such scientists strongly advocated basic work in genetics to provide the foundation for attempts at improving nature.

At the other extreme, many entrepreneurs felt that available strains are satisfactory, and current hatchery technology in oysters, clams, salmon, shrimp and lobster is sufficiently advanced to support commercial operations. Although efforts to upgrade hathery operations should continue, it was felt that the highest priority should be given to more pressing, immediate obstacles, such as disease or nutrition.

If a consensus existed, it was that basic genetic research and systems involving selective breeding and current hatchery technology should receive equal significant attention. Pragmatic selective breeding was still felt by most to be a highly desirable and effective approach with near-term promise.

A related concern of several scientists was that the preoccupation with hatchery technology might result in neglect of

the natural spawning and rearing grounds. Such grounds and their genetic resources are a vital part of the ecosystem, and serious damage could result from their deterioration.

Beyond these generalizations, discussion of reproduction was primarily addressed to problems in individual species. In shrimp, for instance, a major problem is achieving sexual maturation in captivity, whereas in pompano maturation and spawning are under control, but aquaculture efforts are limited by problems of larval survival. Each species and region has its unique reproduction problems, most of them directly related to other factors, such as nutrition, disease, or environmental control.

2. Disease

Disease was felt by most to be the greatest single technical obstacle to commercial aquaculture.

Most operators and some experimenters stressed immediate needs for clinical assistance. However, researchers pointed out that disease prevention, primarily through nutrition, genetics, and waterflow rates and quality control, is a preferable approach to treatment of symptoms.

The need for basic research was acknowledged, but caution was urged in delving deeply into the complexities of disease for the sake of knowledge of diseases and parasites itself.

Greater concern was expressed for pragmatic cures, many of which are available short of complete knowledge and understanding of the pathological organism; for example, use of variable salinities in pathogen control and disease treatment.

The conduct of disease research in an operational environment rather than an isolated situation was strongly urged, recognizing the inseparable relation of disease to other environmental factors.

It was noted, however, that competence in pathology of saltwater animals in this country is limited, and that which exists is widely distributed and difficult to muster. A particular need was voiced for access to freshwater disease laboratories of the Bureau of Sport Fisheries and Wildlife.

A primary requirement exists for strong centralized leadership in disease research, possibly through cooperative disease centers comparable to the Danish Trout Growers Cooperative Disease Laboratory. Such centers could engage in both basic research and clinical pathology, coordinating their activities with research programs in nutrition, genetics and environmental control.

3. Nutrition

Nutritional problems cited were more economic than technical. Foods are apparently available which can provide nutrition,

acceptable food conversion rates, and growth irrespective of cost, but considerable need was noted for feeds or feed supplements which would allow economical commercial production. Shrimp, for example, thrive on artemia and later on squid, and lobsters prosper on a diet of clams. The cost of such feeds, however, makes them totally unsuitable for competitive commercial operations, in which feed is one of the largest elements of expense.

Certain commercial agricultural feed suppliers have been active in the field, helping both researchers and growers in feed development. In spite of successes with trout and catfish feeds, which are proven commercial products, comparable progress in marine animal feeds is lacking. A question raised was whether the incremental gain that might be expected from improvement in feeds would justify the investment required to achieve it.

A related problem is that the production quantities required to achieve a cost comparable to that of agricultural feed are orders of magnitude greater than the anticipated aquaculture demand in the foreseeable future.

Participants with interest in various species agreed that a multipurpose food would be most desirable, but ecological and physiological factors inherent in animal evolution make it unlikely that such a food can be developed.

The palatability of the food to the marine animal, which is determined by its odor, taste, texture, consistency, size, shape and color, is as important as nutritional value. Accordingly, many participants advocated behavioral studies concerning natural diets and eating habits as a key approach to the problem of feed and feed supplement development.

An ideal solution to problems of nutritional economics might be the use of waste products with the least possible cost base. Fish wastes are already used and might readily be joined by other food processing or industrial wastes, including thermal effluent.

The use of sewage as an aquatic food source, the subject of experiments in the United States, is actively practiced in Asia. If economies of scale permit, such methods might be cost effective, assuming that consumers and health officials find the product acceptable. A high priority was advocated for investigations of any promising uses of waste products.

4. Pilot-Farms

As a prerequisite to commercial operations the workshops recommended establishment of pilot-farms to translate laboratory technology into operational techniques. Until such farms are established, extrapolation of economically viable operations from laboratory results is largely speculative.

The type of pilot-farms advocated were operations that incorporate all the elements of a commercial operation. Such farms would be designed and planned to serve not just as a scaled-up laboratory, but also as a vehicle for the development of engineering skills and "hard" economic data. Thus, these pilot projects would go beyond the university grow-out experiments that have been conducted in many species and which most participants felt should not be repeated.

It was further suggested that a pilot-farm might be privately-owned and managed. Under such an arrangement, private firms, universities, federal and state governments could contract for the use of the facilities as required.

A primary objective of a full-scale pilot-farm would be development of required engineering skills. Scientists themselves stated that they have meagre information on what equipment is needed for pumping, feed distribution, water quality and pollution control. Nor do they know precisely what it will cost, nor what is required to make it function as an integrated system. The field of aquaculture was felt to be overdue for system and production engineers who possess a thorough understanding of the relevant biological constraints.

Agricultural engineering was singled out as a discipline with similar requirements from which qualified candidates might be recruited. Additionally, the existence of engineering talents associated with existing trout and catfish operations was noted with approval.

An important byproduct of a pilot-farm would be development of realistic economic operating data not available today. In addition, such an operation could continue to serve the researcher as a large-scale laboratory with conditions much closer to the ones which will be faced in commercial operations than those available in the laboratory.

Of necessity, the preceding Summary Report is more general than specific. A precise technical evaluation of participants' observations is outside the scope of the NOAA assignment, and is left to the careful judgement of those with highly specialized skills. Nor do the comments infer unanimity of opinion among participants. Indeed, many observations reported here were mentioned infrequently in the workshops. In the judgement of the writers, our prime objective was not to represent a consensus, but to report accurately all recommendations of practical substance.

APPENDIX

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