Center for Policy Alternatives at the Massachusetts Institute of Technology

AN ANALYSIS OF THE POTENTIAL COMMERCIAL AND FOREIGN TRADE IMPACTS OF THE SEA GRANT PROGRAM

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by

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PREFACE

This report is the result of a project funded directly from the National Office of Sea Grant to the Center for Policy Alternatives at MIT. The study was designed to provide policy guidance to enhance the Sea Grant Program's positive contributions to domestic commerce and the nation's trade balance. We have been encouraged to take an independent and objective view of the Program by both the Director of the National Office and by local Sea Grant Program Directors. A special note of thanks is owed to Dr. Robert Wildman who generously gave of his time and encouragement, and also provided access to needed information and administrative support from the National Office throughout the eighteen month course of the project.

The work reported would not have been possible without the help of a large number of local Sea Grant Directors, principal investigators and managers of firms and associations, many of whom we interviewed on several occasions and often asked to provide further detailed information. Interviews were conducted on a strictly confidential basis and analyses were reported on an aggregate basis to allow us to deal with sensitive and sometimes proprietary information. We appreciate the splendid co-operation and high degree of interest of those who provided the data reported here and regret that we cannot thank them by name.

Dr. J. H. Hollomon, Director of the Center and principal investigator for the project, Dr. James M. Utterback, Dr. Blair McGugan and Dr. Linsu Kim are responsible for the report's contents. However, the work on which it is based was done by a larger group of research staff, students and faculty who are listed on the following pages. A brief note is given to acknowledge the special role of each contributor on whom we depended for the varied talents and research required to produce this result.

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ACKNOWLEDGMENTS

Project Staff

Ms. Jane Barden was responsible for communication and the organization of data throughout the project. She managed the preparation of the manuscript and edited the project reports and working papers.

Ms. Sally Gorski, JD, prepared studies of the legal and regulatory issues affecting the fishing fleet and the development of aquaculture as well as a preliminary study of environmental laws and regulations affecting seafood processors. Ms. Gorski is on the Research Staff at the Center for Policy Alternatives.

Mr. George Heaton, JD, generally supervised all inquiry into legal and regulatory issues. Mr. Heaton is a Research Associate at the Center for Policy Alternatives.

Dr. J. H. Hollomon, Principal Investigator and Director of the Center for Policy Alternatives, provided general supervision and guidance for the study. He also participated in the conduct of the project and sector interviews, and project evaluations.

Dr. Linsu Kim was responsible for the conduct of interviews in the food processing sector including both first and second stage processors of finfish and shellfish. He also conducted the comparative analysis of technological change in all of the sectors studied. Dr. Kim is a Research Associate at the Center for Policy Alternatives.

Dr. Blair McGugan generally supervised and directed the study of the sources, needs for and barriers to use of technology in industry; and was responsible for the selection of sectors and firms chosen for interviews. He led the firm interviews in the aquaculture area and also participated in some project interviews. He arranged and conducted early feedback sessions for some of the Program Directors who helped provide data for the project studies. Dr. McGugan is a Visiting Research Fellow at the Center for Policy Alternatives.

Dr. Joseph Miller was a consultant on sources of data on international trade and the evaluation of trade impacts particularly in the industry studies. He is Associate Professor of marketing at Indiana University.

Dr. Albert Murray was responsible for the literature review and firm interviews in the area of pharmaceuticals and chemicals, and also conducted the evaluation of projects in this sector. Dr. Murray was formerly Research Associate at the Center for Policy Alternatives.

Dr. Sam Pasternak chose the sample of Sea Grant projects studied, arranged and co-ordinated the project interviews and conducted some of the project and sector interviews. Dr. Pasternak was formerly Research Associate at the Center for Policy Alternatives.

Dr. James Utterback was responsible for the design of both the project and sector studies. He generally supervised the study of Sea Grant projects, the analysis of data and preparation of reports, and participated in all phases of the project. Dr. Utterback is a Research Associate at the Center for Policy Alternatives.

Mr. James Webber conducted the literature review and industry interviews in the fishing industry. He also assisted substantially in the design and coordination of the industry study in general. Mr. Webber was a Visiting Research Associate at the Center for Policy Alternatives.

Student Assistants

Ms. Carol Bloomberg, who has since received her MBA from the Harvard Business School, helped prepare the working paper describing the food processing sector.

Mr. Yar Ebadi, a doctoral candidate in management at Indiana University, conducted project interviews and also did a preliminary study of the leisure and land development sector.

Mr. Donald Hague assisted with the project impact evaluations and with the working paper describing the aquaculture sector, and also conducted some of the sector interviews. He is a candidate for the MS degree in international business at MIT's Sloan School of Management.

Mr. Rajendra Shah is completing both his engineer's degree in chemical engineering and MS in management at MIT. He conducted preliminary studies of the fishing and aquaculture sectors and helped with the project impact evaluations. He also participated in project interviews and evaluations.

Ms. Marsha Simon is a doctoral candidate in political science at MIT. She did the literature review and preliminary analysis of the food processing sector.

Mr. James Smurro holds an MS in environmental engineering and is a doctoral candidate in management of technology at the Harvard Business School. He conducted project interviews and assisted with the project impact evaluations and analysis of the project data. He also conducted a preliminary review of materials on the waste treatment sector.

Mr. Alvin Streeter is a doctoral candidate in political science at MIT. He conducted project interviews, assisted with project impact evaluations, reviewed the literature on the marine mining sector. He also assisted with preliminary data reduction and analysis.

Faculty Contributors

Dr. Judith T. Kildow, Associate Professor of Ocean Policy, Department of Ocean Engineering, MIT, provided guidance for the preliminary studies of the fishing, food processing, aquaculture, and leisure and land development sectors and contacts for the initial interviews in the fishing sector.

Dr. Henry Marcus, Associate Professor, Department of Ocean Engineering, MIT, provided guidance for the preliminary studies of the marine mining and construction sectors.

AN ANALYSIS OF THE POTENTIAL COMMERCIAL AND FOREIGN TRADE IMPACTS OF THE SEA GRANT PROGRAM

1.1 Introduction

What potential economic impacts, particularly in terms of foreign trade, might we anticipate from projects supported by the Sea Grant Program? An attempt to answer this question and to provide policy guidance to enhance the Program's general economic impact including balance of trade is reported here. It is clear that the Sea Grant Program has primary objectives and outcomes other than direct economic benefits. Educational, environmental and research activities in support of enlightened use of the oceans and coastal zones are of great importance regardless of any direct economic benefits. Yet many Sea Grant projects do have direct economic potential, and our analysis is based on a detailed study of a sample of projects with apparent commercial promise.

We also studied a sample of firms in related industrial sectors. This followed gaining a general appreciation of the sectors potentially involved and making a selection of those most directly associated with Sea Grant activities. The objectives were to ascertain their structure, sources of technology, need for technology and their innovative characteristics. The information obtained was used to evaluate and modify, as required, the results of the project analyses. The possible impacts on foreign trade were derived from an understanding of the domestic use of the knowledge and technology produced by Sea Grant.

As a consequence, we have learned not only something of Sea Grant's potential impact on foreign trade, but also:

- characteristics of projects such as their motivation and sources of technical information used, described in Chapter II;
- domestic economic consequences of projects such as creation of new products and new firms, described in Chapter III;

- differences between more and less successful projects, judged in commercial terms and implications for university-industry interaction, as noted in Chapter IV;

- size and distribution of firms, domestic and international market characteristics, current production processes and competitive issues in various industry sectors as summarized in Chapter V;

- the differing role of technology, the needs and opportunities for research, and technical support in the various industry sectors studied and suggestions for Program emphasis, as discussed in Chapter VI;

- finally, some speculations on possible new directions and areas of opportunity for future contributions to commerce and trade from Sea Grant Programs as outlined in Chapter VII.

I.2 Research Questions and Approach

How are Sea Grant projects having commercial potential initiated? What are their characteristics in terms of sources of matching funds, nature and timing of contact with industry, sources and use of technical information and consultation, and what research is being done elsewhere related to Sea Grant projects? To answer these questions, we studied a sample of 77 Sea Grant projects at 26 different institutions which project documents indicated had possible commercial importance. We then obtained a history of each project's development and key events and relationships which shaped its development. These data are reported and the above questions are addressed in Chapter II.

What is the commercial potential of Sea Grant projects? What might we expect from them in terms of the commercial form that results might take, growth of existing business and formation of new business, sales, profits and balance of trade? What barriers might limit the use of project results?

To answer these questions, we conducted an independent analysis of each project in our sample. Sources of data included primary interview data, project reports and publications, published sources and reference works, and further consultation with principal investigators and industry sources. We first attempted to estimate the maximum possible annual value of sales (or production in the case of a cost saving change) and costs expected to result from a project using optimistic assumptions. Then this estimate was reduced by taking into consideration existing competing alternatives, barriers to use, timing of market development and market share to arrive at the fraction of maximum possible sales that might actually be realized. An estimate then was made of each project's impact on foreign trade considering possible import substitution and possible creation or expansion of exports. These estimates were continually tempered by the background knowledge assembled about the industrial sectors involved. Finally, the sector studies were carried out in such a way as to allow both a general and a specific re-evaluation of the estimates. The resultant data are presented and the questions posed above are addressed in Chapter III.

What relationships exist among characteristics of Sea Grant projects, their timing and technical success and potential commercial results? What characteristics of the projects themselves might be related to their having greater or lesser commercial potential? How might an answer to this question help in selecting and encouraging particular projects and in assisting principal investigators?

To answer these questions we correlated various outcomes such as number of firms interested in using project results, formation of new firms, estimated sales, profits, export and balance of trade contributions with each project's characteristics, such as how it was initiated and funded and how important information was obtained. The current stage of projects' development and degree of technical success were considered as important parameters which would strengthen other relationships. The results of this analysis are presented in Chapter IV.

What patterns of change are apparent in different industrial sectors and what general guidelines do these suggest in terms of needs and opportunities in the sectors studied? What types of change and sources of change are most prominent in each sector, and what are the factors facilitating or impeding its progress? What is suggested in terms of broad program support and directions to be taken by Sea Grant?

We reviewed literature and reference sources to determine each sector's major markets and products, finance, organization (large corporations, cooperatives, family enterprises, etc.), sources and types of regulation, and other relevant factors. With this background knowledge at hand and drawing on the counsel of several knowledgeable members of the industrial community, a list was compiled including the firms mentioned in project interviews, firms participating in Sea Grant projects, appropriate associations and conference attendees. From this list and emphasizing species with importance in domestic markets and in foreign trade, interviews were arranged with senior managers in each of more than fifty firms and associations. These data are summarized in Chapter V.

The primary objectives of the sector studies were to discover the needs for technology in the selected industrial sectors and to validate as far as possible the economic and trade impacts observed in the project studies. However, the interviews also provided a comparative view of the pattern of product and process change in each sector and some consequential suggestions for the most appropriate type of Sea Grant support. This comparative analysis is presented in Chapter VI.

Each of the chapters, from II through VI, not only presents original descriptive data and findings, but also has implications for policy and suggests opportunities for the Sea Grant Program at large. These are the main themes of Chapter VII concluding this report. The primary purpose of our study was to describe and evaluate the foreign trade impacts of Sea Grant projects. It was sponsored directly by the National Office of Sea Grant to provide policy guidance. The resulting findings seem sufficiently varied and broad ranging to be useful to Program Directors, principal investigators and members of Sea Grant and other advisory services as well. Thus, we have attempted to frame a descriptive summary, normative statements about possible policy alternatives and speculation about opportunities offering high potential to interest each of these groups in the concluding chapter. In sum, the theme of Chapter VII is what opportunities are revealed by our study of projects and firms.

II. STUDY OF SEA GRANT PROJECTS

II.1 Introduction

The purposes of this chapter are to describe the methods used to study Sea Grant projects and to present the primary information obtained. Following chapters will analyse their potential commercial and foreign trade impacts and then discuss project characteristics that seem to be associated with high impact or its absence.

II.2 The Sample of Projects

Sea Grant projects funded during 1975 were initially screened on the basis of abstracts and other documentary evidence to identify those which suggested an economic impact was likely within five years. We did not consider projects which were of a longer-range or service nature. Interview data were ultimately obtained on a sample of 77 projects. About two-thirds of the projects concerned living marine resources; fishing, food processing, aquaculture, pharmaceuticals and fine chemicals. Most the remaining third related to marine mining and waste treatment (see Table II.2; Tables are numbered to correspond to sections of the text).

Projects were included from each of twenty-six institutions. The resulting sample is widely distributed and is very representative of Sea Grant coverage, over time, by species and by industrial sector. Its only bias, by design, is toward projects with early commercial results.

II.3 Conduct of the Study of Projects

Information was gathered in personal interviews with Principal Investigators and ranged from one to two hours and usually involved two persons associated with our project. A list of pre-selected topics and questions were used to conduct loosely structured, essentially open-ended interviews in order to gain as much as possible from the investigators'

TABLE II.2

DISTRIBUTION OF SAMPLED PROJECTS BY

INDUSTRIAL SECTOR

	Number of Projects
Aquaculture	21
Fishing	8
Food Processing	13
Pharmaceuticals and Fine Chemicals	11
Waste Treatment	8
Leisure and Land Development	2
Marine Mining	6
Marine Construction	6
Other	2
	77

own insights and views of a project. The second participant in an interview was to check that all areas of interest were covered and to take notes.

Principal investigators for each sampled project were asked to describe the motivation for their project, its nature and results, their own assessment of the areas and extent of its commercial importance, and various specific indications of the interest of industry or other organizations in using the project results. Essentially we obtained a history of the key events and relationships which shaped each project's development.

The data reported below are a description of the characteristics of the projects studied including the sector and use toward which each project was directed, how each was initiated and funded, how important information was obtained and the nature of related work being pursued elsewhere, technical obstacles encountered and technical results accomplished or expected, the principal investigator's own assessment of the economic outcome of his work, its stage of development and timing of market development.

We received splendid cooperation and interest from the principal investigators and other project personnel whom we contacted. All data were obtained on a confidential basis and are reported here in either an aggregated or disguised form.

The interviews emphasized the technical aspects of each project. We first asked about research goals, problems and obstacles as well as the timing of the project and adequacy of funding. This was designed as a way of opening the interview on the principal investigator's own ground, to help us get acquainted and to check our understanding of each project developed from available documents. Finally, we obtained the principal investigator's own assessment of the project's commercial potential.

Interview notes were organized and recorded on a special form under specific headings following each interview. We often checked back with the principal investigator to obtain additional material or to verify items. Finally, each project was classified using a number of explicit characteristics and categories, previously established.

II.4 Initiation of Sea Grant Projects

Responses to questions about the motivation for and initiation of projects confirm the idea that project sources are highly individual, diverse and decentralized. This fact lends Sea Grant much of its character and has implicit strengths and weaknesses to be discussed in subsequent chapters.

Principal investigators were the originators of project ideas in two-thirds of the cases, more than five times the frequency of any other potential source (see Table II.4). The principal investigator usually saw himself as the sole originator. Multiple sources were cited in only 20 percent of the projects sampled. The next most frequently cited source was the Sea Grant Program Office (in 13 percent or 10 of the cases) followed by industry or trade associations. Domestic and foreign firms were involved in the initiation of 7 cases (9.1 percent of the sample).

As might be expected, most projects were essentially an extension of the principal investigators' existing area of research interest (see Table II.4). Few projects were a change to initiate a new area of research (11 cases or 14.3%) or apply findings in an unfamiliar area (9 cases or 11.7%); (for example, an expert in poultry nutrition might work on nutritional problems of a marine animal). Finally, about equal emphasis was given to hardware as to concepts. The projects sampled were about evenly divided between those pursuing investigation of new concepts, demonstration or verification of research results, or application of existing research techniques and those involving development or improvement of products or processes (see Table II.4).

TABLE II.4

INITIATION OF SEA GRANT PROJECTS

	Number	Percent
The project concept originated with:		
Principal Investigator	52	67.5
University Sea Grant Office	10	13.0
NOAA Office of Sea Grant	1	1.3
Industry/Trade Association	8	10.4
Domestic Firm	6	7.8
Foreign Firm	1	1.3
Other	10	13.0
Base for Percentage	77	*
Project effort involves:		
Continuation of principal investigator's existing area of research	38	49.4
Application of research findings in the principal investigator's area of interest	21	27.3
Initiation of research in area new to the principal investigator	11	14.3
Application of research findings in area new to the principal investigator	9	11.7
Base for Percentage	77	*
Project goals focus on:		
Investigation of new concepts	28	36.4
Demonstration or verification of previous results	8	10.4
Application of existing research techniques	14	18.2
Development of new product	14	18.2
Development of new process	19	24.7
Improvement of existing product	6	7.8
Improvement of existing process	12	15.6
Base for Percentage	77	*

*Percentages total more than 100.0 due to multiple responses

II.5 Sources of Additional Funds and Resources

Principal investigators sought additional funds from a variety of sources as can be seen from Table II.5. The university, industry and all levels of government were given major consideration as potential sources of additional funds. Foundations and foreign sources were considered in relatively few cases. The data in Table II.5 include all sources of additional funds and not only matching funds as formally defined. If another federal agency was approached for assistance at some stage in a project (in several cases prior to Sea Grant funding or following its termination) then this was noted, even though such funds could not be used as matching funds. Table II.5 shows that Sea Grant's funding is clearly amplified from many other sources.

The role of the matching fund requirements in Sea Grant programs was mentioned from a number of perspectives in our interviews. For example, some respondents felt it was invaluable in providing greater independence at both the project and local program level, and helpful in initiating some projects on an exploratory or interim discretionary basis. Others noted the amplification of federal funds received with the result that a larger number of ocean-related projects were pursued. Still others complained about the additional administrative complexity involved. We were interested, however, in the potential of the matching fund requirement as a means of creating a link between the personnel of a project and a potential user and in creating a commitment on the part of a potential user to the use of project results.

Industry was approached as a possible source of matching funds in nearly two-thirds of the sample cases (47 cases, 61 percent) and provided funds for about one-third of them (27 cases, 35 percent). We discovered only 11 cases in which there seemed to be no contact with industry, while information on project results was requested and industry facilities were used (to some extent) in a majority of the projects. The categories in Table II.5 are not mutually exclusive. We can see that funds were often sought from multiple sources and industry expressed interest in some projects in several ways, for example, by providing matching funds, facilities and technical personnel.

TABLE II.5

SOURCES OF ADDITIONAL PROJECT FUNDING

	Number	Percent
Principal investigator sought additional funds/services from:		
Industry	47	61.0
University	51	66.2
Foundations	8	10.4
Federal agencies	22	28.6
State and local government	37	48.1
Foreign sources	2	2.6
Other	2	2.6
Base for Percentage	77	*

	Number	Percent
Industry expressed interest:		
No	11	14.3
By requesting information	53	68.8
By providing consulting personnel	20	26.0
By providing facilities	44	57.1
By providing funds	27	35.1
Base for Percentage	77	*

* Percentages total more than 100.0 due to multiple responses

Because our sample was chosen to emphasize projects expected to generate industrial potential, these levels of industry interest may be higher than for Sea Grant projects in general. However, in themselves, they would seem to represent more, and more substantive industry involvement than is typical of most government research support programs.

Different sources of added funds tended to be used for different types of projects with university funding going to the more exploratory and long range projects. Industry concentrated its interest on the more applied projects, on those closer to fruition and on projects with a high perceived potential for sales and profitability.

II.6 Communication

Past studies of the successful initiation of product development and the use of research results have stressed the crucial part played by informal communication at every step in the process [1]. Knowledge of the problems and the needs of potential users and the interchange needed for successful transfer of research results depends mainly on face-to-face contact as does the effective acquisition of technical information [2]. To explore this area, we asked specific questions about key sources of information and consultation throughout the course of the projects studied (see Table II.6).

Many projects received inputs from several sources outside the university. Choices of alternative technical objectives and solutions were often influenced by the contributions of personnel outside the immediate project group. A high degree of contact was maintained with potential beneficiaries in roughly half of the cases, and the principal investigator was highly and personally involved in disseminating the results of his project in a similar proportion of the projects studied. Communication with industry was highly correlated with receipt of matching funds and other assistance.

II.7 Related Research

In the course of discussing project events and communication, we asked the principal investigator to name specific sources, individuals,

TABLE II.6

COMMUNICATION

	Number	Percent
Principal investigator utilized outside personnel for consultation:		
Yes, from within same university	28	36.4
Yes, from outside same university	25	32.5
Yes, industrial/trade association	5	6.5
Yes, industrial firms	25	32.5
Yes, from foreign countries	11	14.3
No	27	35.1
Base for Percentage	77	*
External personnel made useful contributions in establishing the direction of the project:		
Yes	33	42.9
No	41	53.2
No information	3	3.9
Base for Percentage	77	100.0
Frequency of contact with potential beneficiaries of the research was:		
Minimal	18	23.4
Moderate	19	24.7
High	40	51.9
Base for Percentage	77	100.0
Efforts to disseminate information about the project have proceeded through:		
Sea Grant advisory services	49	63.6
Submission of papers for publication	53	68.8
University publicity office reseases	14	18.2
Personal cortact with trade/public media	43	55.8
Other	39	50.6
Base for Percentage	77	*

* Percentages total more than 100.0 due to multiple responses

and organizations with whom he or she had communicated about the project under discussion. Thus we can say something not only about the frequency of outside contact, as above, but also about the sources of contacts as seen by the principal investigators.

Table II.7 shows that the principal investigators were more familiar with similar or related work being pursued in other universities than with research going on in government-sponsored organizations or in both domestic and foreign firms. The investigators appeared to have a broad knowledge of related research activities. Only a small number of the projects studied (11 cases, 14.3 percent) benefitted directly from foreign contacts, though investigators knew of related work abroad in many more cases.

II.8 Technical Obstacles and Outcomes

The probability of accomplishing the technical objectives of a project is often enhanced by greater levels of funding [3]. Conversely, lower levels of funds often require that project activities and schedules be stretched out. Thus questions were posed about the sufficiency of funding and its relation to the accomplishment of technical objectives within the time proposed (see Table II.8). Three-quarters of the principal investigators interviewed stated that they had sufficient funds to achieve the objectives of the project in question on time, and these two measures are highly correlated as would be expected. In some cases where time and/or money were insufficient, a project was essentially an initial effort and not a complete piece of work by itself, with the response being framed in terms of the longer range goals envisioned. In most cases where time and funds were insufficient, the technical problems encountered had proven to be formidable or unexpected difficulties had arisen.

Few of the projects were of a technically risky nature. In one-quarter of the cases (19 cases, 24.7 percent) the technical obstacles to be overcome were formidable and the major focus of the project (see Table II.8). As might be expected, such projects are more likely to need additional time and funds than those with fewer technical difficulties.

TABLE II.7

LOCATIONS OF RELATED RESEARCH
RECOGNIZED BY PRINCIPAL INVESTIGATORS

	Number	Percent
Similar/related work is being pursued by:		
Other universities with Sea Grant funding	44	57.1
Other universities without Sea Grant funding	15	19.5
Other federal research programs	20	26.0
Commercial R&D laboratories	26	33.8
None	13	16.9
Unknown	3	3.9
Base for Percentage	77	*
Similar/related work is being pursued outside of the United States by:		
Universities	19	24.7
Foreign government research programs	32	41.6
Commercial R&D laboratories	24	31.2
None	14	18.2
Unknown	12	15.6
Base for Percentage	77	*

* Percentages total more than 100.0 due to multiple responses

TABLE II.8

TECHNICAL OBSTACLES AND OUTCOMES
AS SEEN BY PRINCIPAL INVESTIGATORS

	Number	Percent
Project goals can be achieved with current level of funding:		
Yes	57	74.0
No	20	26.0
Base for Percentage	77	100.0
Project goals are expected to be accomplished within time frame of current project:		
Yes	54	74.0
No	19	26.0
Base for Percentage	73	100.0
Technical obstacles to be overcome are:		
Essentially non-existent	27	35.1
Moderate because of existing well-known technology	31	40.3
Formidable--will be primary project focus	19	24.7
Base for Percentage	77	100.1
Degree of technical success at present or as estimated at present:		
Complete failure technically	0	--
Low success technically	8	10.4
Moderate success technically	22	28.6
High success technically	27	35.1
Too early to evaluate	20	26.0
Base for Percentage	77	100.0

Only eight of the sampled projects were acknowledged to be disappointing in terms of technical success, and none were termed a complete failure. Conversely, a large proportion (27 cases, 35.1 percent) were more successful than the principal investigator had expected at the outset. In twenty cases (26.0 percent) the principal investigator thought it too early to make an evaluation of the possible technical outcome. In sum, the projects we studied were generally highly successful and free of major technical problems or unexpected roadblocks.

II.9 Principal Investigator Views of Economic Outcomes

We asked a number of questions directed toward the principal investigator's economic assessment of his project. These included questions about possible uses and advantages of the project results, and any economic estimates made of market, profit and trade potential.

Industry was viewed as a potential user of most project's results, but government was also viewed as a potential market in a third of all cases (24 projects, 31 percent) (see Table II.9). Three projects (4 percent of the sample) were directed solely toward foreign markets, but fully half of all the projects (40 cases, 52 percent) were ones which the principal investigator thought would have potential in foreign as well as domestic markets. In sum, the principal investigators viewed 43 cases (or 56 percent) as having foreign trade potential.

To make a realistic assessment of market potential we asked specifically about what alternative means for meeting the same end value, function or service currently exist or are under active development. The principal investigators were generally optimistic with 47 percent reporting that the results expected from their projects would have great advantages over competing approaches. Twenty-four percent either did not report competing approaches or advantages or did not think their project had any particular advantages over other alternatives, while the remaining 29 percent reported moderate advantages.

TABLE II.9

PRINCIPAL INVESTIGATOR'S VIEW OF ECONOMIC OUTCOME

	Number	Percent
End users of project results will be:		
Consumer	4	5.2
Industry	68	88.3
Government	24	31.2
Other	2	2.6
Base for Percentage	77	*
Market locations will include:		
Domestic	32	41.6
Foreign	3	3.9
Both	40	51.9
Unknown	2	2.6
Base for Percentage	77	100.0
Relative advantage of outcome of research over alternatives:		
No special advantage	18	24.0
Moderate advantage	22	29.3
Great advantage over competing approaches	35	46.7
Base for Percentage	75	100.0
Principal investigator estimates market size to be:		
No attempt made to estimate	36	48.6
Too early to estimate	4	5.4
Uncertain	14	18.9
Less than one million dollars	3	4.1
One million to 10 million dollars	9	12.2
Greater than 10 million dollars	8	10.8
Base for Percentage	74	100.0
Has principal investigator related break-even calculations with market potential:		
Yes--lucrative	15	20.3
Yes--marginal	12	16.2
Yes--unfavorable	3	4.1
No	44	59.5
	74	100.0

Only a few of the respondents had thought about the commercial outcomes of their work in a formal way. Twelve of them had published economic evaluations of their work in project reports or papers. In several cases, these included a detailed breakdown of costs and returns for different types of use or operation. One case even included estimates of local and federal taxes generated by use of a project's results. On the other hand as can be seen in Table II.9, 60 to 70 percent of the respondents had not thought even informally in quantitative terms about the possible returns to investment in their project's results or of its annual or total market potential respectively. Some projects, to be sure, were of a sufficiently novel or exploratory nature that these were not sensible questions to ask, but in most cases they were.

II.10 Stage of Development of Projects and Timing of the Use of Project Outcomes

In looking at commercial potential we must consider not only the magnitude of costs and revenues, but also their timing and pattern. Essentially, we need to know the time that it will take to develop an idea from the initiation of a research effort to first commercial application, and also something of the timing of the diffusion of the results in the market at large [4]. These are difficult questions in any context, including the case of Sea Grant. This is due, in part, to the fact that a "project" may have been initiated or continued with other sources of funds. Thus, it is difficult to identify the point at which support for a particular stream of work started or stopped or its total amount.

To understand the development status of projects in our sample, we asked about both their current stage of development and about the timing of the first expected use of possible results (see Table II.10). Most of the projects were at the applied development or prototype stage (35 cases 55 percent). Eighteen (28 percent) were currently involved in first commercial trials or pilot scale operations. A few (11 cases, 17 percent) were in a more vaguely defined exploratory phase.

TABLE II.10

STAGE OF PROJECT DEVELOPMENT

	Number	Percent
Where does the project now stand in the development process:		
Inactive or no data	13	--
Exploratory work	11	17.2
Applied development	21	32.8
Prototype	14	21.9
First commercial trial	18	28.1
Base for Percentage	64	100.0
Project is expected by principal investigator to have economic impact within		
0-2 years	28	36.8
2-5 years	20	26.3
More than 5 years	28	36.8
Base for Percentage	76	99.9

Percentages may not total 100.0 due to rounding.

By far the majority of projects in our sample (48 cases, 63 percent) were expected by principal investigators to have an economic impact within five years, most of these (28 cases) within two years. This reflects our sample selection criteria which emphasized projects nearer fruition. As would be expected, projects in early stages of development were also further from expected economic impact. The two sets of data in Table II.10 are essentially different descriptions of the same aspect of a project. In the following chapter, the timing of market development is one dimension in our analysis of potential commercial and foreign trade impacts.

In the following chapter, we will use the information obtained from principal investigators as a base on which to build an independent and more detailed view of each project's commercial and trade potential, and use these estimates to obtain an idea of the aggregate potential of the projects studied.

FOOTNOTES FOR CHAPTER II

1. James M. Utterback, "Innovation in Industry and the Diffusion of Technology," Science, Vol. 183, 15 February 1974, pp. 620-626.

2. T. J. Allen, "Information Needs and Uses," Annual Review of Information Science and Technology, edited by C. A. Cuadra, Volume 4, Chicago: Encyclopaedia Britannica, 3-31, 1969.

3. D. G. Marquis and D. M. Straight Jr., "Organizational Factors in Project Performance," in Research Program Effectiveness, M.C. Yovits, et al, eds., New York: Gordon and Breach, 1966, pp. 441-458.

4. James M. Utterback, 1974.

III. POTENTIAL COMMERCIAL AND FOREIGN TRADE IMPACTS

III.1 How the Analysis Was Conducted

In this chapter, the methods used and the results obtained from an analysis of the potential commercial and foreign trade impacts of the Sea Grant projects investigated are presented. What is the commercial potential of a Sea Grant project? What might we expect from them in terms of the commercial form that results might take; growth of existing business, the formation of new business, sales, profits and balance of trade. What barriers might limit the use of project results?

Determination of the first order estimates were assigned to members of the project team on an industry sector basis. If the project in question aided the development of a particular product, process, material or resource we then asked what would be the maximum potential revenues that it would be reasonable to expect annually from the development when fully implemented. To do this, data were required on the current size and growth trends of the markets in which the development might be introduced.

The next step was to determine costs including expected costs of ownership (fixed costs) if any, expected operating costs, as well as employment and operating profits when the business is fully developed. This step depended critically on assumptions made about alternative ways of entering the business, optimal plant size, equipment size, etc., and the number of enterprises entering. In some cases several alternatives were compared before making a determination. The employment generated proved to be the most difficult variable to estimate due to rapid productivity improvements and changes in operations in the early stages of business development, and the novelty of some of the operations involved. Sources of data included primary interview data, project reports and publications, published sources and reference works, and further consultation with principal investigators and industry sources.

Having estimated an upper limit for a project's potential, we asked what realistic expectations one might have in terms of the share of the total market that might be captured or replaced by the new product or process (or improvement), material or resource in question. This involved tempering our optimistic estimate with qualitative judgments about a number of limiting factors. Do technical problems remain which will persist or will limit the use of project results in some parts of the market? Does it have any real advantage over competing alternatives in the same market? Has industry expressed any tangible interest in the results of the project? Have any new companies or divisions been formed to put the results in use? What other barriers such as financial resources, legal or institutional constraints, limits on sources of supply at the prices assumed, etc., might limit development of ultimate potential? There was a quantitative judgment made for each project as reported and summarized in the following sections.

Finally, we estimated possible impacts on balance of trade. This is a complex issue and the results are more tenuous than the estimates of total sales and operating profits. For example, under what conditions will production of a new product for export occur in the United States, and under what conditions will production simply occur abroad to meet demand there? Some projects might result in increased imports, say of materials to produce a product which is then exported. Others might result in increased production abroad by subsidiaries of domestic firms with the resulting production being sold in the U.S. The question of how to consider interactive or secondary effects was worked out on a case-by-case basis. Generally, we considered impacts in two broad categories: those which might reduce imports and those which might expand exports.

To summarize the aggregate impact of our sample, a presentation is made of estimates of "certain" and "uncertain" total annual sales and trade impacts expected in 1980.

The intermediate data and assumptions are of interest equal to the estimates themselves. These include descriptions of the form that expected results might take (product, process or material), the context of use of the results, and specific limitations to use. These will be discussed in turn before presenting sales and foreign trade impacts.

The analysis of each project followed the broad outline stated above although the details were tailored to meet the specific case. From this perspective, several classes of projects were recognizable. For example, a process improvement might have a clearly defined potential use, but technical uncertainties and production costs are a major concern. Or a product innovation might have clear technical advantages and initial production costs, but market volume and duration might be highly uncertain[1]. The evaluation of the first project would hinge on costs and technology while the second would revolve around estimates of market development and revenues.

III.2 Description of Project Results

A majority (41 cases or 53% of the projects studied) were aimed at producing new products materials, processes or other valuable services, resources and information. These projects fall into the first three categories in Table III.2 describing the form that commercial use of project results would take. Of the remaining cases, 22 involved slight improvements in existing products or processes, use of by-products to gain additional revenue, or expanding sources of materials for existing operations. The "unlucky" 13 cases had no conceivable use or market, and so could not be pursued in any detail.

Finally, we attempted to determine whether projects also broadened the range of options or choices faced by the producer or user [2]. Table III.2 shows one-third (26 cases, 34%) might create a result seen as new or previously unattainable by users. All projects aimed at minor changes in cost, quality or source of supply would be excluded here, however useful they might be in a particular application, because users would not view this as novel.

TABLE III.2

DESCRIPTION OF EXPECTED COMMERCIAL RESULTS

	Number	Percent
What form would the commercial use of the results take?		
New product or material existing, new venture or change in an existing product	23	29.9
New process - existing or new venture	8	10.4
Services, resources and information	10	13.0
A marginal change or cost reduction for an existing operation	11	14.3
Vertical integration/expanded sources of material for an existing operation	11	14.3
No evident use	13	16.9
Other	1	1.3
Base for Percentages	77	100.1

	Number	Percent
Does the project broaden the range of options or choices for the user?		
No	46	63.9
Yes	26	36.1
Base for Percentages	72	100.0

In tabulations for which the sample size is less than 77 the remaining cases were omitted because data were unavailable.

III.3 Context of Use of Project Results

The data shown in Table III.3 describe the intensity and type of industrial interest in project results and provide a helpful check on the validity of our impact evaluations. These figures as well as those which follow on sales and trade impacts were validated by interviews with key participants in user or potential user organizations. In all, visits were made to over 50 firms as described in detail in Chapter V. Some firms were selected because they were named in project interviews, while others not named by principal investigators were selected as potential users based on general studies of each sector. The primary purpose of our industry visits was to check and adjust figures for project commercial and foreign trade impact. We can confidently say that one or more firms expressed an active interest in the use of project results (in terms of actually planning or starting operations) in 33 cases or 44% of those studied. Further, the results of 11 projects have been instrumental or helpful in starting 16 new ventures (one of which has been a failure).

Roughly half the projects would be of use only to a large firm or to a government agency. The other half could conceivably be useful to a small business.

TABLE III.3

USE OF PROJECT RESULTS BY FIRMS

	Number	Percent
How many firms have expressed an active interest in the use of project results?		
None	42	56.0
One or two	20	26.7
Three or more	13	17.3
Base for Percentage	75	100.0

	Number	Percent
Have any new firms or ventures been formed to carry the project results into practice?		
No	65	85.5
Yes	11	14.5
Base for Percentage	76	100.0

	Number	Percent
Would commercial use of the project results be likely to occur in the context of a proprietorship or small business?		
No	40	54.1
Yes	34	45.9
Base for Percentage	74	100.0

III.4 Factors Limiting the Use of Project Results

It was difficult to arrive at a reasonable scheme for classifying all of the different specific barriers or constraints which came up as important concerns in our interviews with principal investigators and subsequent economic analyses [3]. Table III.4 portrays the main ideas expressed in the many statements about barriers to use of project results. Of course, some projects encountered several, so the total number of observations in Table III.4 is independant of the number of projects studied. Technical complexity, limitations and variations in sources of supply, lack of public and official interest, industry structure, and lack of available capital fall lower in the list in Table III.4, than do lack of an adequate market, channels of distribution or means for market development and high or highly uncertain production costs.

Legal constraints and concern over environmental impacts and safeguards are high on the list. This is even more striking when we note that an additional six projects were stimulated by regulations, either for measurement and control purposes or to provide means to meet requirements. A majority of the principal investigators (39 cases, 51 percent) perceived the degree of involvement of regulatory agencies to be very significant in the development or use of the results of their projects.

Perhaps the simplest way to summarize the data in Table III.4 would be to say that legal, regulatory and environmental issues were of greatest importance accounting for 24 mentions. Consumer issues were next at 18 times, and production factors third at 14 times. Technical complexity was fourth with 9 cases, and none of the more traditional barriers seemed very important. These rankings may reflect in part the particular perspective of principal investigators.

TABLE III.4

FACTORS VIEWED AS LIMITING USE OF PROJECT RESULTS

	Number of Projects
Market Demand	14
Production Costs & Economics	14
Legal Constraints	13
Environmental Impacts & Safeguards	11
Technical Complexity	9
Limitations or Variations of Supply	6
Industry Structure	4
Lack of Public and Official Interest	4
Capital Requirements	4
Consumer Behavior and Preferences	3
Risk and Return Considerations	2

III.5 Estimated Annual Sales Potential

In order to aggregate estimates of potential sales of our sample of projects, one would need to know the amount of revenues expected to be generated by each project, the timing of the revenue stream, and the probability or certainty with which we might expect the estimate to hold [4]. By assuming an appropriate interest rate we could then discount revenues, and compute an expected present value for each project. To perform such a calculation, however, would overstate both the level of detail and the accuracy of many (by no means all) of our data and estimates. We shall see that this is an unnecessary refinement and would add little to the meaning and interpretation of our data.

Alternatively, a value at any year in the future could be computed. These figures would be additive and would provide a valid total value of revenues for each project in that year. We believe that a five year period is a reasonable period in which to expect projects to have reached their commercial potential. Thus, the time dimension has been considered by viewing annual sales five years in the future for all projects. The probability with which we expect a given level of revenues to be generated has been handled by simply grouping estimates as relatively certain or relatively uncertain. This is based both on our expectation as to whether a particular level of sales will be reached and the timing of market development.

Table III.5 shows the estimates of 1980 sales for our sample of Sea Grant projects. Sales potential was estimated as negligible for 39 of the 77 projects, as uncertain for additional 21, and as relatively certain for 17 projects. Total estimated sales potential for these 38 projects would be 122 million dollars annually in 1980. A more conservative estimate of the total impact would be the 82 million dollars for the 17 project estimates judged relatively certain.

But there is more to the story. A glance at the Table shows that three quarters of the potential impact (74 of 122 million dollars) results from only two projects. At the other extreme, the 25 projects ranked under $1 million account for only a total of 10 million dollars of estimated sales. In the $1-10 million classification, 13 projects average only 3 million dollars each to account for 38 million dollars. The estimates for the top 15 projects were carefully rechecked and validated in the light of data gathered in the Sector Studies and are considered highly reliable in terms of the ranges used in Table III.5.

The two projects with the largest potential have many interesting common characteristics. They result in new products or materials. The results will be used by industry. They will have great secondary benefits to their users resulting from higher productivity, quality, etc. They will result in something which is qualitatively new, that opens new choices to users. Some failures as well as successes were experienced in early commercial efforts and a sustained effort was required to reach their current level of development. Both benefitted from significant investment in their early stages, by Sea Grant and in later stages by other organizations. Both have resulted in the formation of new ventures.

It would be tempting at this point to make some sort of comparison between the "costs" of our sample of projects or of the Sea Grant Program as a whole and the "benefits" as measured by estimated sales, profits, employment , etc. There are a number of reasons why this would be fallacious. First, we are looking at only a part of the Sea Grant Program. Second, it is often difficult to attribute the potential sales estimated only to the project in question rather than to a series of related projects and other sources of research inputs. Third, other sources of funding and investment were used as well as Sea Grant and often were predominant. Finally, many of the most valuable benefits in terms of broader understanding of the oceans, training of personnel, and secondary benefits to users are not included in our analysis. Rather, it should be taken as illustrative of some of the commercial and foreign trade potentials of the Program. What is clear is that Sea Grant has produced results with significant commercial potential. The bulk of these are concentrated in a few projects.

TABLE III.5

ESTIMATED ANNUAL SALES POTENTIAL OF 77 SEA GRANT PROJECTS IN 1980

	Sales Uncertain		Sales Reasonably Certain		Category Totals	
Range of Sales in Category	Number of Projects	Millions of $'s in 1980	Number of Projects	Millions of $'s in 1980	Number of Projects	Millions of $'s in 1980
None	--	--	--	--	39	0
Less than $1 million	14	6	9	4	23	10
$1 million to $10 million	6	14	7	24	13	38
More than $10 million	1	20	1	54	2	74
Total	21	$40	17	$82	77	$122

Comparison with other R&D support programs would also be of great interest and of particular value to those responsible for the Sea Grant program. Unfortunately, even roughly comparable data are not known to be available for other programs. Our impressions are that Sea Grant has higher overhead costs but does promote greater university-industry interaction with a greater degree of commercial use and more rapid commercial use as a consequence.

III.6 Estimated Annual Trade Impact

In order to estimate the potential additions to trade resulting from Sea Grant projects, we generally considered their impacts in two broad categories as noted above: those which might reduce imports and those which might expand exports [5]. We then proceeded to determine the part of total sales that would represent displaced imports or the part of total sales that would be exported from the United States respectively for projects in each of these categories. Seventeen projects (22 percent) were viewed as largely having the potential to reduce imports. This might result either from finding or expanding resources to meet domestic demands, or from reducing costs or improving quality of existing production to make it more competitive with imports. Eight projects (10 percent) were viewed as largely having the potential to create or expand exports. The remaining 52 projects (68 percent) were judged to have no potential trade impact.

Estimates were then aggregated as were sales figures above, in terms of annual potential in 1980 which appeared as "certain" or "uncertain" on the basis of market development and timing. The results of this analysis of net trade potential are similar to the results for sales potential in general. Table III.6 shows that trade potential was uncertain for 13 projects, and relatively certain for 12 projects. The estimated net trade impact for these 25 projects would be a positive addition of approximately 93 million dollars annually to the U.S. balance of trade. A more conservative estimate would be the 28 million dollars addition for the 12 project trade estimates judged relatively certain.

TABLE III.6

ESTIMATED ANNUAL FOREIGN TRADE POTENTIAL OF A SAMPLE OF
77 SEA GRANT PROJECTS IN 1980*

Range of Trade in Category	Net Trade Uncertain		Net Trade Reasonably Certain		Category Totals	
	Number of Projects	Millions of $'s in 1980	Number of Projects	Millions of $'s in 1980	Number of Projects	Millions of $'s in 1980
Less than $1 Million	5	1	6	2	11	3
$1 Million to $10 Million	7	18	5	13	12	31
More than $10 Million	1	46	1	13	2	59
Total	13	65	12	28	25	93

* 52 projects were estimated to have no potential balance of trade impact or to have no trade potential within the period under consideration.

The same two projects which accounted for most of the sales potential of the sample also account for two-thirds of the total potential trade impact (59 of 93 million dollars).

One project is relatively certain in terms of its market development and timing with a total sales potential of 54 million dollars. Of this we expect 41 million in domestic sales in 1980 and 13 million in exports.

The other project is uncertain in terms of market development and timing with a sales figure of 20 million dollars in 1980 and an estimated trade impact of 46 million dollars. This large trade impact arises from consideration of secondary effects which the product resulting from this project would have on trade. It will probably be used by manufacturers in a way that will increase the productivity of a manufacturing process. A secondary result of the productivity improvement could be a reduction in imports of the manufactured product of about 46 million dollars in 1980.

In sum, there are clear and positive trade benefits expected to result from Sea Grant projects. While most expected total sales are relatively certain, most estimated trade impacts are grouped as uncertain. Finally, as was the case for total sales, the greatest trade potential is concentrated in the results of a small number of projects.

Several projects will probably have an important impact in foreign markets which is not reflected in the statistics above. This is because their use is easily copied or because project results are freely available and transferred in accordance with federal policy. Competitive advantages in trade from Sea Grant projects must be based largely on the availability of people trained in the course of the projects and closer cooperation and informal communication between project personnel and domestic firms rather than on proprietary information.

III.7 Summary

The following chapter addresses relationships among characteristics of Sea Grant projects as described in Chapter II and their potential commercial results as presented above. Before moving ahead to this topic a brief summary of descriptive results seems in order.

Project Characteristics

Projects were included in the study from each of twenty-six institutions. The sample of 77 projects is widely distributed and is very representative of Sea Grant coverage over time, by species, and by industrial sector. Its only bias, by design, is toward projects with early commercial results. About two-thirds of the projects are in the general area of living resources.

Principal investigators are usually the sole originators of project ideas, and projects most frequently are a continuation of existing lines of research.

A substantial fraction of Sea Grant projects receive matching funds from industry, and most projects receive industry help when use of facilities and exchange of information are considered. This would seem to represent more, and more substantive industry involvement than is typical of most government research support programs.

A high degree of contact was maintained with potential beneficiaries in roughly half of the cases, and the principal investigator was highly and personally involved in disseminating the results of his project in a similar proportion of the projects studied. Communication with industry was highly correlated with receipt of matching funds and other assistance.

Few of the projects studied were of a technically risky nature. They were generally highly successful and free of major technical problems or unexpected constraints.

While industry was generally viewed as the user of project results, government was also viewed as a potential user in a third of all cases. Projects were generally expected to have a commercial impact within five years. This reflects our sample selection criteria which emphasized projects nearer fruition.

Potential Project Results

One or more firms have expressed a direct interest in using the results of 33 of the projects studied, and 11 projects have led or contributed to the formation of new firms or ventures to exploit their results.

Legal constraints and concern over environmental impacts and safeguards were most frequently viewed as limiting the use of project results. Market and production related factors were often mentioned, while technical complexity and other issues were less frequently cited.

It is clear that Sea Grant has produced results with significant commercial potential. The bulk of these are concentrated in a few projects. Further, our impressions are that Sea Grant has higher overhead costs but does promote greater university-industry interaction with more, and more rapid, commercial use of project results as a consequence.

Positive additions to trade are also expected from the use of results of the projects studied. Estimates of these are more tenuous and uncertain than are estimates of total sales potential. As was the case for total sales, the greatest trade potential is concentrated in a small number of projects.

FOOTNOTES FOR CHAPTER III

1. Robert E. Seiler, Improving the Effectivness of Research and Development, New York: McGraw-Hill, 1965

2. Louis T. Wells (ed.), The Product Life Cycle in International Trade, Boston: Harvard University Graduate School of Business Administration Division of Research, 1972.

3. For example see Arthur D. Little, Inc., "Barriers to Innovation in Industry," prepared for the National Science Foundation, Cambridge, Mass: September 1973.

4. Richard de Neufville and Joseph H. Stafford, Systems Analysis for Engineers and Managers, New York: McGraw-Hill, Inc., 1971. (Especially Chapter 8, "Evaluation of Projects, and references.)

5. Charles P. Kindleberger, International Economics (5th ed.), Homewood, Illinois: Irwin, 1973.

IV. COMMERCIAL POTENTIAL RELATIVE TO CHARACTERISTICS OF SEA GRANT PROJECTS

This chapter discusses relationships between project characteristics and potential commercial results. How can we describe projects which have greater or lesser commercial potential? How might answers to this question be useful in selecting or encouraging particular projects and in assisting principal investigators? Under what conditions might assistance be most effective? These are the issues addressed in the following sections.

IV.1 Characteristics of Projects with Potential

How can we describe projects which have greater commercial potential? To address this question we will briefly summarize the most striking contrasts between the 38 projects having positive sales potential as indicated by our independent estimates and interviews with firms, and the 39 projects having no apparent sales potential (see Table III.5). Then this analysis will be generalized to measures of success other than sales such as net additions to balance of trade. Finally, we will focus on the unique characteristics of a dozen projects which appear to offer the greatest promise of success.

A successful innovation or change in a product, process or material requires the synthesis of a requirement or need and a means or technical alternative which will meet the recognized need in an acceptable way. But this obvious statement implies a number of more subtle questions. How can needs be recognized? How can we best search for or generate technical alternatives? What are the requirements for an effective synthesis?

We know that generally a majority of successful technological innovations are responses to recognized needs and that a smaller number of commercially successful changes result from pursuit of what might be termed technical opportunities [1]. We also know that attention to market needs is among the most important factors distinguishing between commercially successful projects and failures [2]. The key role of users, especially in initiating major changes in products has also been recognized [3].

Most of the projects judged commercially "successful" in our sample were similarly motivated or initially directed toward a market or production related need or problem rather than by scientific interest or opportunity.* This does not mean that the technical challenges involved were any less, and often quite the opposite seemed true. It means that the principal investigator's choice of a particular project related to his larger scientific or technical interests was strongly influenced by market considerations. Responding to a new need may well carry one into new areas and challenges[4]. Persons outside the immediate groups or department tended to influence the objectives and direction of more successful cases to a greater extent than was true for cases with lower estimated potential. Successful projects involved the development of new products more frequently than new concepts, and applications in areas which were new for the principal investigator or initiation of work in a new area rather than evolving directly from a continuing line of investigation [5].

Recognition of the need for a project's results often comes from the involvement of a potential user with the principal investigator, his department or university's extension service. Potential users in industry and government were involved in and interested in most successful projects at an early stage, and they often contributed funds, facilities and personnel as well as information. Of course we cannot say that this is an absolute key to success. Quite possibly projects with real commercial potential will attract early user interest, so the direction of cause and effect is not clear. There is very likely a strong mutual relationship. But the absence of direct help from potential users is almost a sure sign of a weak project judged in commercial terms.

While choice of a problem and direction for a project and obtaining the necessary resources all required external communication to be

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* By "successful" we mean that estimated potential annual sales are positive as explained above.

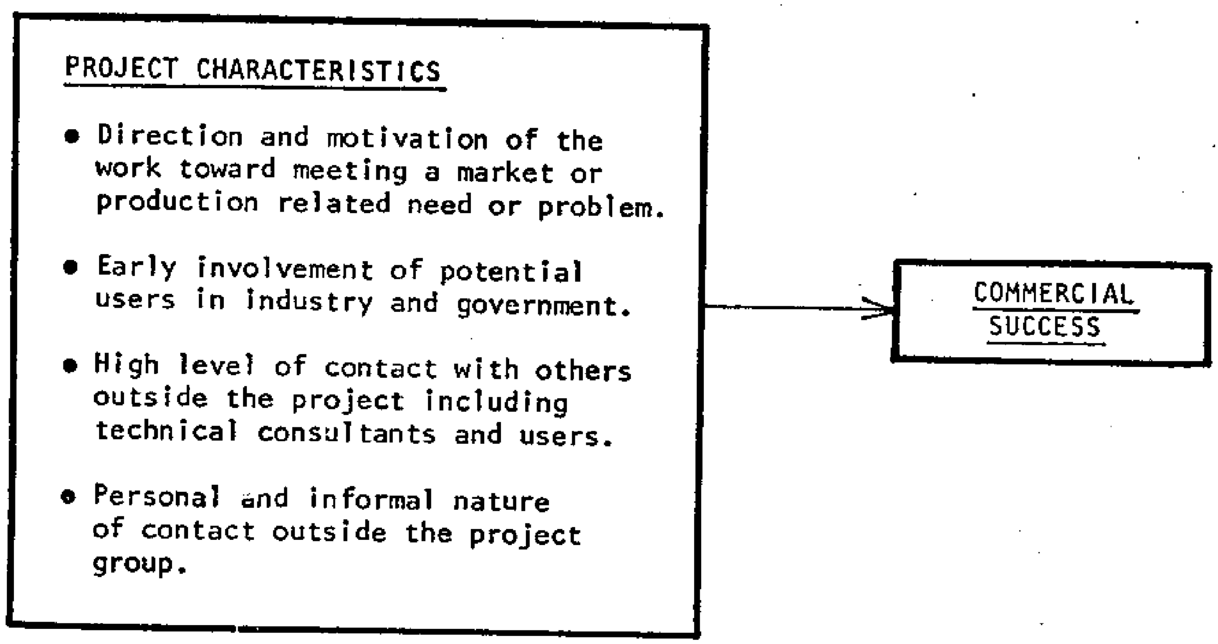
successful, continuing communication outside the project group may be even more important to realizing a project's full potential [6]. We know that successful projects had a higher level of outside communication and more consistent outside communication than did others. This includes technical and consulting contacts as well as contact with potential users. The nature of outside contacts was generally more personal and informal in the case of successful projects judged in both technical and commercial terms. These findings are in line with earlier research which indicates that the timing, nature and sources of communication strongly influence technical success as well as ultimately the commercial success of the technical effort. Usually informal channels of communication are found to be more effective than formal channels [7].

Of course communication does not necessarily lead to high performance or commercial potential. In fact, it is probably more correct to say that competent performance attracts communication [8]. But it certainly is true that lack of adequate informal communication will decrease the chances for technical and commercial success. Sea Grant certainly does facilitate communication in many ways and may wish to devote additional resources to this purpose.

In sum, projects directed toward the market have the highest likelihood of commercial success, and this often involves development of new products and processes as opposed to concepts or techniques, direct requests by industry as opposed to other sources, and application of research findings, often in an area new to the principal investigator, as opposed to extension of an existing avenue of work. Early involvement of potential users as contributors to a project, a high level of technical contact with other researchers outside the project group, and greater levels of personal and informal communication all appear to contribute to a higher likelihood of success. These findings are summarized in Figure IV.1.

FIGURE IV.1

A FEW CHARACTERISTICS OF PROJECTS STRONGLY RELATED TO COMMERCIAL SUCCESS



An adequate level of success in meeting technical goals for any project would logically be a pre-requisite to commercial success [9]. Different sources of uncertainty and thus possible failure arise as a project proceeds through successive steps. We would expect technical success to increase as a project nears commercial trial, with weaker projects having dropped out along the way. Technical success in each phase of a project from exploratory work through first commercial trial might be considered as a necessary condition for commercial potential to be developed [10].

The converse would not be expected to hold, because problems posed without a well defined market need may be equally successful on technical grounds [11]. Some projects which respond to well defined problems and stimulate early user interest may result in no commercial potential due to technical failures along the way. Projects in which a high level of informal outside contact is maintained are more likely to succeed technically. Projects in which users are involved at an early stage are more likely to reach commercial trial. For the sampled projects we find that the more successful is a project technically the more likely is its commercial use. The closer a project is to commercial use, the more likely is its commercial success.

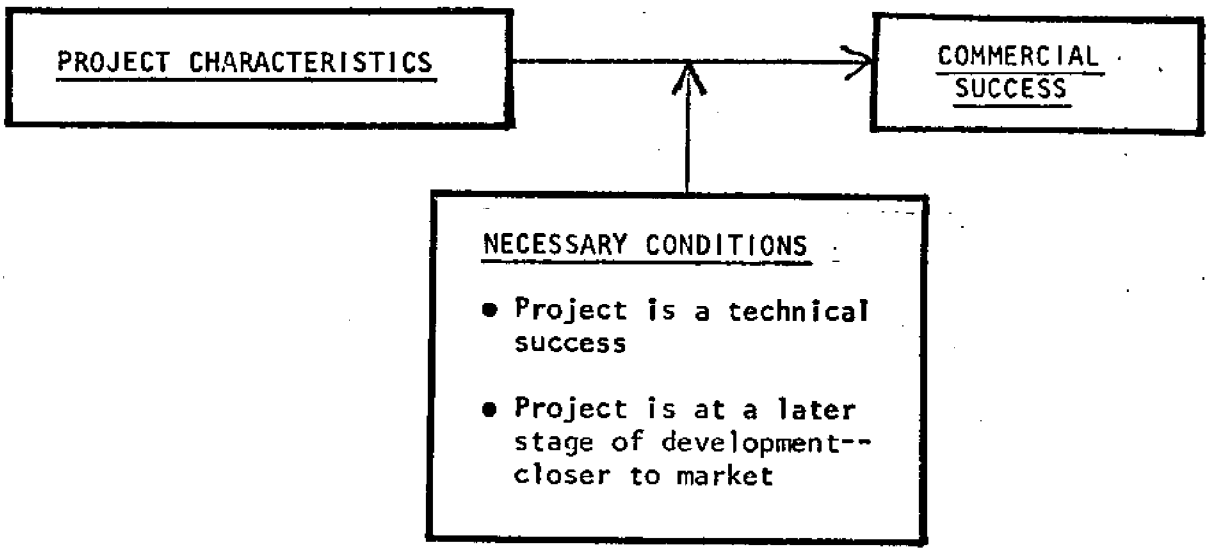
When projects have achieved technical success, and when they are later in the development process, the relationships between other characteristics and commercial success is amplified as illustrated in Figure IV.2.

All of the statements made so far about characteristics of successful projects measured in terms of estimated potential sales can be generalized to other measures of success. Early in our analysis of factors related to project potential a clear pattern began to emerge no matter which measure of project potential was used. We checked on estimated sales and profits, the number of firms interested in using project results, formation of new firms, creation of export possibilities, and net balance of payment contributions all with similar results.*

* Data on job creation were available on too few cases to permit analysis.

FIGURE IV.2

TECHNICAL SUCCESS AND DEVELOPMENT CLOSE TO MARKET ARE REQUIRED FOR COMMERCIAL SUCCESS



In essence, potential project impacts measured from a number of perspectives are highly correlated with one another. This result gives us greater confidence in the consistency of our evaluations. It also simplifies further analysis, as we can speak of project potentials in general terms knowing that in most instances each statement will apply as well to each measure. This is illustrated in Figure IV.3.

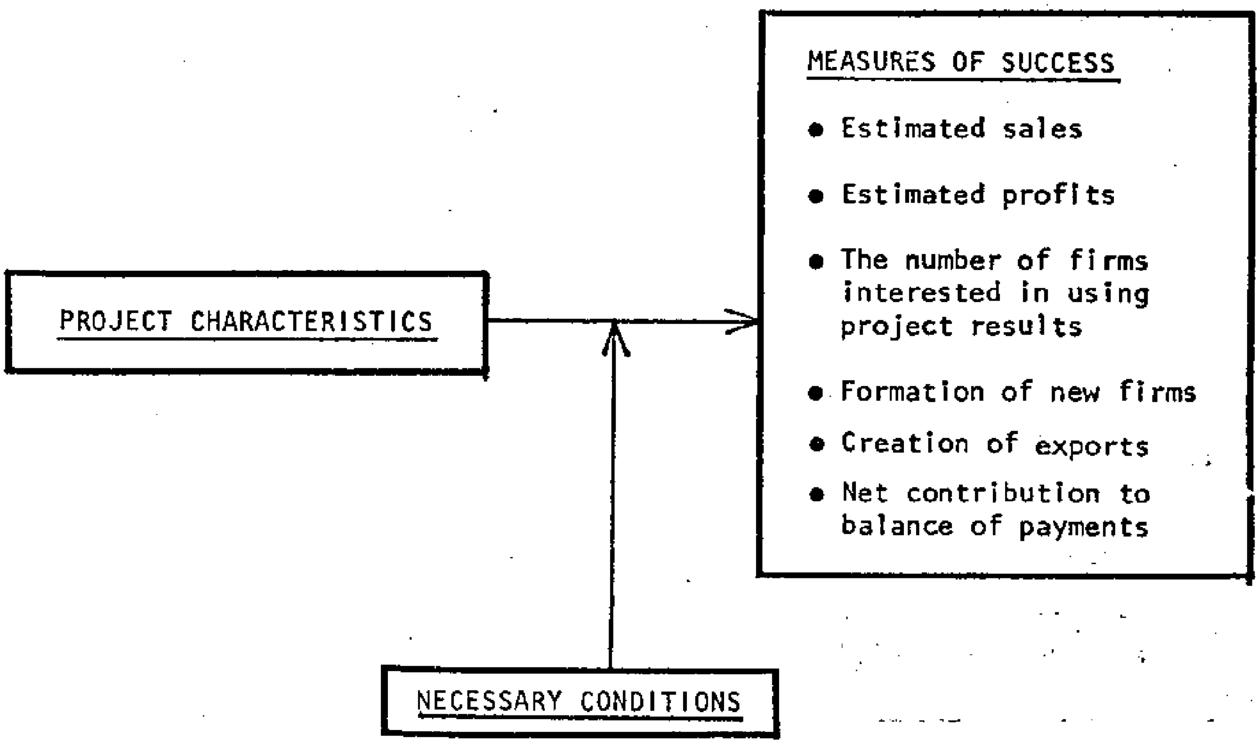
A number of questions repeatedly singled out a set of about a dozen projects for futher examination. These questions included: What are the characteristics of projects which have reached first commercial trial? What are the characteristics of those which have resulted in qualitatively new products, options and choices for the user? Which projects have led to the formation of new firms or ventures to exploit their results? Which have created substantial export potentials as opposed to substituting for imports [12]?

We soon realized that posing these questions singly obscured the compelling message in the interview data. That is, that those projects in our sample which led to the creation of qualitatively new products or options for the user also have moved rapidly to commercial trial, have resulted in the formation of most of the new firms and ventures and have most of the export potential! Only one in six of the projects we sampled falls into this group, and yet the group accounts for almost 70 million dollars or two-thirds of the annual estimated sales.

As a group they seem to be in an extreme position for each of the characteristics noted above with a few noteworthy exceptions. They tend to be directed toward market needs, but more often than usual are initiated by the principal investigator and are an application of work in an earlier area of research interest. Industry and industry associations have provided facilities, personnel and matching funds, and

FIGURE IV.3

MEASURES OF SUCCESS ARE STRONGLY RELATED

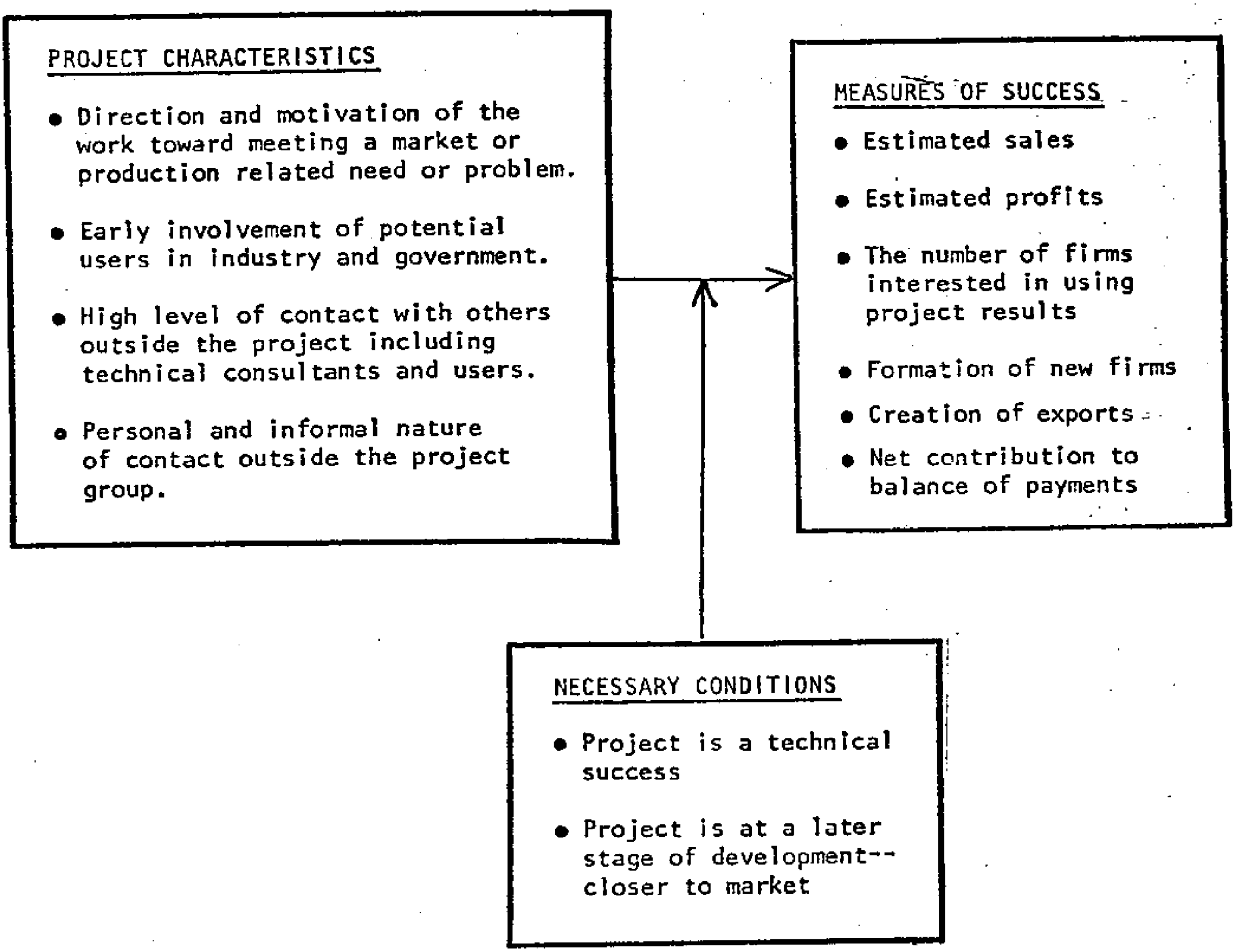


similar work is frequently being pursued in firms. Outside communication in all categories is extremely high especially with potential users, and there is a high degree of use of publication and personal contact by the principal investigator in disseminating project results. Most of the projects are seen as highly successful in technical terms. Government is viewed as an initial market more often than the average, perhaps providing a means of entry for the firm in the commercial market [13].

The relationships between project characteristics, necessary conditions and measures of project impact are summarized in Figure IV.4. The most successful few projects uniformly follow the pattern described there.

FIGURE IV.4

SUMMARY OF RELATIONSHIPS BETWEEN PROJECT CHARACTERISTICS, NECESSARY CONDITIONS AND MEASURES OF SUCCESS



IV.2 Contrasts Between Successful Projects and All Projects Sampled

Most Sea Grant projects studied were initiated by principal investigators (52 projects; see Table II.4). Fewer projects were initiated by firms (6 projects) or industry associations (8 projects). About two-thirds of the industry initiated projects were successful as opposed to about half of all principal investigator initiated projects and lower proportions for all other sources. These are high success rates by any standard. Most principal investigators were enthusiastic about the potential of their project and anxious to have its results put into use. But there is an indication here that actions to enhance investigator's perceptions of industry's needs and their knowledge of the technical experience and information available from industry might enhance their chances of success. We observed that the Sea Grant approach appeared to be most successful at institutions with strong extension services. In many cases, agents served to call attention to emerging needs as well as in diffusing project results. Other research has shown that faculty who consult for firms are far more successful than others in generating ideas having commercial potential [14]. The key element here is synthesis of investigators' interests with potential applications.

Most of the projects studied were a continuation of a principal investigator's current line of research (38 projects; see Table II.4). Fewer projects involved application of research findings in an area which was new to the principal investigator (9 projects). Yet applications in a new area enjoyed a frequency of success nearly twice as great as did continued effort in an established area. These projects appeared to be among the most exciting and technically challenging to the investigators involved. Other studies have shown that diverse experiences and an even balance between basic and applied work lead to the most creative and effective projects by university faculty judged in both technical and commercial terms [15]. Our data indicate that Sea Grant might enhance its impact by further encouraging investigators to work on problems and applications related to, but different from their prior experience.

About half of all projects reported a high level of contact with potential users (40 projects; see Table II.5). But this variable sharply divided successful and unsuccessful projects. Those with little user contact were uniformly unsuccessful, while potential successes almost always involved a number of specific and continuing contacts. This finding is strongly congruent with past research [16]. National and Local Sea Grant Offices clearly are already doing an outstanding job in this area both formally, through council and committee structures, and informally through encouragement of work with industry. It appears that activities to facilitate communication are far from reaching diminishing returns, however.

Most projects focused on investigation of new concepts (28 projects; see Table II.4), while fewer (14 projects) were aimed at development of new products. But product developments were judged to be potential successes far more frequently than were investigations of new concepts (7 of the 28 concept investigations and 10 of the 14 product developments are expected to result in sales). Of course, these need not be mutually exclusive categories. Product developments which are conceptually new and which serve latent markets are thought to have far greater commercial and export potential than do incremental changes and improvements [17]. Often further funding of a new concept can carry it forward as a product development. The key element here appears to be creating greater awareness of the market and of possible applications of new concepts in product developments.

Another way to state this is that most projects (46 cases; see Table III.2) do not result in a qualitative change as viewed by the user, but are essentially incremental improvements in the ways or efficiency of producing things or are small changes in design. However, potential success is clearly concentrated in those ideas that represent greater change and that offer completely new choices or ways of doing things [18].

A fair summary of all of the contrasts above would be that the more challenging the project to the principal investigator, the more likely is its success. Outstanding projects often come from unexpected sources, are the result of wide ranging contacts by the principal investigator, take him or her into a new area of investigation and application, and are not incremental extensions of the past.

IV.3 Implications Drawn from These Findings

How might what we know about successful projects be useful in selecting or encouraging particular projects and in assisting principal investigators? Under what conditions might assistance be most effective?

Clearly, the Sea Grant National and Program Offices should encourage experiences for principal investigators which might stimulate them to work in new areas. More contact with challenging user problems and contact with potential users early in the development of a project should be facilitated to an even greater extent than at present. Sea Grant might support studies of market requirements and more projects aimed at market development. The Program should stimulate technical interchange in general, and more should be done to support ways of acquiring and disseminating knowledge of foreign work in particular. However, our impression is that much is already done effectively in these areas on a project-by-project basis.

A more important question is, how can Sea Grant enhance the effectiveness of its activities in technology development taken as an integrated whole? This involves looking at success not just on a project-by-project basis but in terms of possible ventures or new industrial activities which might be based on a group of projects taken together. Many projects of great value in a larger context might be omitted if we restrict ourselves solely to the criteria used in the analysis above.

One can group Sea Grant projects for analysis by (1) considering relationships among only currently funded projects or by (2) considering relationships among projects in our sample which have implications for decision processes at both the program and national level.

<u>A Portfolio of Only Currently Funded Projects</u>

Within the <u>first category</u> projects may be grouped by sector of application, by type of changes attempted or by relationship with other projects. For example, projects in the aquaculture sector tended to show a higher than average potential for sales, and profit than those in other sectors. Recognition of market need was usually clear and contact with potential beneficiaries frequent, and a relatively greater number of new ventures have been created based on project results in aquaculture. Work in pharmaceuticals and in waste treatment, on the other hand, tended to involve longer range efforts following established lines of inquiry rather than following market demand and to reflect a lower apparent economic potential at present (though they may well meet other objectives).

Distinct types of projects include, for example, those which may generate new products, choices and options for users, those which represent marginal improvements in cost, quality, resource availability, etc., and those which have high value in use but low sales potential. New products generally have higher economic potential, but require more time to develop than marginal improvements which also may have a more immediate pay-back. Projects which have a high value in use, but low sales potential include instrumentation, data processing and modelling efforts, and services which may be a necessary base for the development of an industry or application.

Some groups of projects appeared to pursue parallel approaches to the same problems. In one area, three different technical approaches were being attempted in separate projects with different timing and levels of risk; the most uncertain of these, if successful, would clearly dominate the others. In another area, two techniques were being developed to measure the same property, one of which required inexpensive locally available equipment, but expensive testing procedures; the other an expensive central laboratory and inexpensive test procedures. Clearly, the use of both procedures by a State government, for example, would not be effective and to some extent the approach implemented might depend on the sequence of funding and development. It might be reasonable to fund a number of competing approaches where the time value or urgency of project results is high and where uncertainty about outcomes is also high [19]. In other cases, focusing resources on a sustained project could produce surer results.

Of greater interest are projects which appeared to reinforce one another if brought together, or to have the potential to produce major results if one or two added projects were undertaken. These tend to fall in the aquaculture area, but some cut across the sectors noted in Table II.2. One example is work funded on the sources, production, properties and uses of chitin and chitosan [20]. Others involve species propagation, nutrition, pathology and methods for controlling growth in closed and open aquaculture systems, as well as methods for processing and for obtaining valuable by-products from processing operations. How might Sea Grant best attempt to identify gaps in funding in these efforts and to bring together project results as a basis for commercially viable ventures? Should some funds be added and reserved in the Sea Grant budget for focused efforts bringing together several projects? In general, how might areas for continuity of effort and increasing levels of funding be decided? Answers to these questions will require further analysis of the decision process at the National and Regional level.

A Portfolio of Projects Funded Over Time

Within the second category a sequence of projects can be grouped or linked together over time. This may require a longer planning horizon and sustained effort involving an increasingly greater proportion of applied (and more expensive work) as an idea is carried closer toward the market. It may require a more directed set of national priorities in spending a fraction of the Sea Grant budget or more joint work with other agencies.

The mix of Sea Grant projects in our sample in terms of their current stage of development was shown in Table II.10. While industry interest in using project results is greater for those projects in advanced stages of development and with shorter times to expected realization of their economic potential, it is clear that many of these are in areas where

Sea Grant has made a sustained commitment. On what basis can a balanced mix of projects in various stages of development be maintained? How can choices between projects with potentially higher payoff but having a longer "incubation period" and those with potentially lower but shorter term payoff best be made?

Many other questions also arise in the dynamic context. What program resources might be available to develop technologies having high value in use but low sales and profit potential? What mechanisms ensure support for low profit but essential services? The present study may provide some tentative ideas, but a more detailed look is required to provide considered answers.

Regulatory agencies were significantly involved in some way in the development of over half of the projects (39 of 77 cases) which we have analysed. Further, in assessing the constraints on the use of project results in our sample as shown in Table III.4, legal constraints and environmental impacts and safeguards were among the most frequently noted. (They are also a significant reason for starting particular projects or selecting design alternatives.) What alternatives might be considered to help principal investigators assess incentives and constraints on use arising from regulation, to incorporate these in project approaches and proposals, to obtain needed approvals, etc.

More rapid responses in developing fruitful areas of work were noted in several cases based on a Program Director's discretionary funds. Perhaps modest increases here could yield disproportionately high rewards in initiating valuable lines of research.

Assistance with foreign patents and licenses for technology transfer, provision of initial market guarantees (e.g., purchasing of small initial production quantities) and demonstration grants might also produce substantial increases in the Program's commercial potential for a modest investment.

IV.4 Differences in Project Potentials and Innovation in Different Sectors

To this point we have discussed project success in terms of the entire range of Sea Grant activities. There are good reasons to expect substantial variations in needs for technology, project potentials and factors related to successful initiation and development of projects among different sectors. The final two chapters of this report view possible directions for Sea Grant in greater detail and in the context of the sectors toward which their results are directed.

What patterns of change are apparent in different industrial sectors and what general guidelines do these suggest in terms of needs and opportunities in the sectors studied? What types of change and sources of change are most prominent in each sector, and what are the factors facilitating or impeding its progress? What is suggested in terms of broad program support and directions to be taken by Sea Grant?

We reviewed literature and reference sources to determine each sector's major markets and products, finance, organization (large corporations, cooperatives, family enterprises, etc.), sources and types of regulation, and other relevant factors. With this background knowledge at hand and drawing on the counsel of several knowledgeable members of the industrial community, a list was compiled including the firms mentioned in project interviews, firms participating in Sea Grant projects, appropriate associations and conference attendees. From this list and emphasizing species with importance in domestic markets and in foreign trade, interviews were arranged with senior managers in each of more than fifty firms and associations. These data are summarized in Chapter V.

The primary objectives of the sector studies were to discover the needs for technology in the selected industrial sectors and to validate as far as possible the economic and trade impacts observed in the project studies. However, the interviews also provided a comparative view of the pattern of product and process change in each sector and some consequential suggestions for the most appropriate type of Sea Grant support. This comparative analysis is presented in Chapter VI.

FOOTNOTES FOR CHAPTER IV

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14. Peters, 1968.

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16. Evidence for this statement is given in each of references 1-7 above.

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20. N.A. Ashford, D. Hattis, A. Murray, Industrial Prospects for Chitin and Protein from Seafood Wastes, CPA-76-7, Center for Policy Alternatives, MIT, Cambridge, MA, August 1976.

V. CHARACTERISTICS OF INDUSTRY SECTORS IMPACTED BY SEA GRANT PROJECTS

The preceding chapters present an analysis of Sea Grant projects essentially looking from inside the Program. To assure a complete and balanced view we must also examine the industry setting of the projects studied. The objectives of this juxtaposition of views is to explore the real economic factors--both structural and dynamic--which determine the ultimate commercial and trade impact of Sea Grant projects assuming they are well designed from a technical viewpoint.

To this end we conducted interviews with 57 firms, as well as background discussions with trade associations, NMFS personnel and informed individuals. The specific objectives of the sectoral studies were to validate the economic and trade impacts observed in the associated project studies, and secondarily to understand the needs, prospects and constraints that affect technological innovation in those industrial sectors and relate these to the Sea Grant Program.

The scope of these sectoral analyses was narrowed to four sectors in the renewable marine resources area most relevant to Sea Grant research support activities: Aquaculture, Biochemicals, Fishing and Fish Processing. Individual market segments within these four sectors were selected according to importance of their domestic economic value, import/export weight, and the possible relevance of Sea Grant research to technological innovation in these sub-sectors. Within each sector, both product and process innovation of a technological nature has been emphasized, set against the background of major social, political and economic constraints to such innovations prevailing in the sector.

V.1 Sample Selection and Data Collection

In selecting the segments to be studied, the value of domestic catch and the importance of foreign trade were considered. We chose shrimp, tuna and crab, the top three edible species in value and catch. Together they account for about 45% of value as well as edible catch. Shrimp imports account for 23% of imported value, tuna adds another 16%. In addition, shrimp exports are 23% of $262 million exported. Thus shrimp aquaculture, fishing and processing were a major focus of the study.

Menhaden, although relatively low in value of domestic catch (7%) accounts for 40% of the volume. Shellfish studied, other than shrimp and crab, were oysters and to a lesser extent, clams. These last two account for 8% of domestic value. The North Atlantic groundfish fishery, particularly flounder, was part of the sample. The decline of this fishery and its reduced role in foreign trade qualified it for our study.

Species which might have been studied included catfish, trout, wild stocks of salmon, lobster and imported blocks and slabs. The last category is almost 100% imported from Canada, Iceland, Norway and Denmark. It is crucial to the foreign trade picture, but the participants are too distant for the scope of this project.

The number of interviews conducted was small for such a diversity; the information obtained should be considered as reality testing of our project sales estimates. Table V.1 presents an overview of the segments selected, the number of interviews conducted and the geographic locations visited.

TABLE V.1

SEGMENTS INCLUDED IN SAMPLE

SECTOR	SPECIES	GEOGRAPHIC AREAS	NUMBER OF INTERVIEWS
Aquaculture	Salmon Shrimp (Panaeid) Prawns (fresh water) Perch Oysters	Pacific, Maine Gulf Coast Florida, California Great Lakes Maine, Delaware	17
Fishing	Shrimp Menhaden N. Atlantic Groundfish Edible Finfish Shellfish (other than shrimp)	Gulf Coast Mid-Atlantic New England Gulf Coast Mid-Atlantic	9*
Processing Filleting/Preparing Fabrication Cooking Freezing Canning	Shrimp Shellfish (other than shrimp) Edible Finfish Tuna Menhaden	Gulf Coast, Maine Mid-Atlantic Gulf Coast Pacific Gulf Coast, Mid-Atlantic	24
Pharmaceuticals and Fine Chemicals Pharmaceuticals Misc. Biologicals and biochemicals Marine Polymers Misc. Industrial Chemicals	Not Applicable	Scattered	7
		Total Interviews	57

* Note that seven of the processing firms were integrated into fishing.

Background studies were conducted prior to planning the collection of data from firms to identify key participants in each sector. Then in selecting firms for interviews we included many firms which had been associated with sampled projects. Most interviews were conducted by the study leaders independently and with the most senior member of the firm available. While telelphone interviews were necessary occasionally, either as the sole or supplementary source of information, most were conducted on the firm's premises and included an inspection of the facilities. With few exceptions, industrial personnel were receptive to the visits and generous with their time and information. Not unexpectedly, there was a great variation in the awareness of interviewees of general industry issues, of developments in other areas or related activities, and of government and university support such as Sea Grant.

The analysis phase included a thorough review of the interview results against the background of the preliminary project results and impact estimates. In some cases, emerging results were discussed with senior industry personnel consulted earlier for general orientation. Ultimately, the results included a valid-tion or adjustment of the estimates of project impact, and working papers were prepared on each sector. Hopefully these provide unique views of the status of technological development in these marine resource fields that can be used as background for interpreting the present impact of Sea Grant research support and as a guide in future studies of how the Sea Grant program might be strengthened.

The sector studies summarized in the following section will be a helpful introduction for the general reader, but those familiar with the structure and products of each sector may wish to turn directly to the comparative analysis in Chapter VI. Each summary gives a brief discussion of the important factors which will be analyzed later: industry structure (number, size, distribution and integration of firms), production processes (technology in use, capital and labor requirements), market situation (products, prices, promotion and physical distribution), competitive issues, raw material supply situation (availability, seasonality, an so on), and needs for technological innovation including factors facilitating and constraining changes in products and processes. Details and references are contained in the working papers listed at the end of the chapter.

V.2 Aquaculture

Structure and Resources of the Industry

Aquaculture in the U.S. embraces a limited number of species of finfish, crustaceans, shellfish and seaweeds and spans a considerable range of intensity of culture and degree of commercial development. Organisms are generally reared in fairly high density in ponds or enclosures of natural waters, but range from extremes of no confinement to tanks, silos, etc.

Trout, catfish and crawfish are the presently signficant commercial crops, while shrimp, salmon, and prawns are in an earlier stage of commercial development. Other species and methods, such as salt pond culture of seaweeds and ocean ranching of salmon, are still in an experimental stage. As a whole, the industry is small, but viewed as having major growth potential, and much of this growth is expected to come from those species which, like shrimp, appear to be approaching technically feasible high volume production. It should be noted, however, that part of this growth is taking place off shore by U.S. firms seeking better growing conditions.

The industry is structured by species and method of culture, each representing a substantial degree of differentiation, and consists of a small number of enterprising individuals and some large firms. New combinations of species and methods have encountered technical problems, and delays in reaching development goals have often required the initial entrepreneur to give up equity and control to an investor willing and able to supply the necessary financing. In a few cases, large companies have been the initiators, but in most cases, these and other entering firms come from sectors not related to fisheries or seafood.

The attraction to investors includes the expectation of high returns, based on the efficiency with which aquatic animals convert simple feeds into flesh, and on the anticipated growth of demand for aquaculture products. However, the biological efficiency of conversion is presently offset by high labor input and by other inefficiencies that should be reduced as techniques are improved and scale economies introduced.

Markets

Catfish and crayfish enjoy traditional regional markets in the South and sales are gradually expanding into other regions. Prawns are also edging into the market but, like shrimp or lobster, are expected to expand sales to other areas as production volumes improve. About $23 M in salmon was exported in 1974, and the products of ocean ranching will eventually compete for this market as well as the larger domestic one. On the other hand, the future of pan-size, pen-reared salmon is less certain, primarily because it must compete with lower cost trout and with more uncertainty in eventual production costs, must find its own market.

The market for oysters is more predictable in so far as cultured ones substitute for traditional natural crops. Cultivated forms, especially the "culch-less" approach offer a standard of quality and appearance that is ideal for the half-shell trade and, for next five to ten years, may be wholly absorbed by this premium market. Since a particularly fastidious and appreciative market exists in Europe, some believe that a lively export trade could develop for the presently small scale, labor-intensive culchless oyster industry. In any case, the U.S. appears to have a technical advantage in seed production and both types of seed are in routine commercial production and some are already being exported.

Overall, domestic aquaculture, valued at about $60 million, presently accounts for about 2% of U.S. fish consumption, but is projected to reach $375 million in the early 1980's if technical and other problems can be satisfactorily reduced. A large portion of shrimp however will come from offshore areas.

Technical Problems and Prospects

The considerable differences in species and culture methods presently used in aquaculture present a wide variety of technical problems. Practical commercial methods for raising trout, catfish and crayfish are well in hand and wait for helpful, but not crucial, refinements. such as improvements in disease control. Somewhat more problematic is the pen-rearing of shrimp or salmon in natural bodies of water, where the departure from the wild condition is minimized. But the difficulties of effective containment and the effects of predators and unnatural confinement or crowding need technical improvements which are actively being sought.

As the growth environment of these cultures departs further from the natural environment, artificial growing conditions cause technical problems to multiply. Problems with water quality, engineered controls, animal behavior, food conversion and disease control intensify. Where ocean ranching of salmon entails the simple selection of best species and size, plus imprinting with special chemicals to improve return, more artificial conditions for the totally enclosed perch, shrimp or oyster factory require detailed and coordinated engineering of the entire plant and its operation. Since this must be tailored to poorly known and very complex physiological and behavioral characteristics of the animals, a complete systems engineering heavily dependent on cut and try methods is likely to need much time and experimentation. Hence, it would be reasonable to expect that aquaculture development will produce a sequence of commercially feasible schemes, the timing of which will be largely dependent upon how long development has been going on and how radically the system differs from the natural habitat and normal population densities.

However, it should be observed that one of the most serious barriers facing aquaculture development are legal and environmental regulations limiting the areas where and conditions under which aquaculture can operate. The effect of many of these regulations has been to drive extensive aquaculture efforts offshore or into highly sophisticated closed systems.

V.3 Pharmaceuticals and Biochemicals

This group of ocean products encompasses a small group of diverse industrial segments which may be categorized as follows:

- Pharmaceuticals: Drugs for human use
- Miscellaneous biologicals and biochemicals: Including veterinary preparations and products for aquaculture
- Marine polymers: Mostly gums and other polysaccharides, including chitin and derivatives

Each of the segments is characterized by differences in scale, organization, state of development and innovative character.

Pharmaceuticals

Clinical drugs have been derived from ocean sources primarily by systematic screening. These drugs are products of large pharmaceutical firms who have the resources for clinical testing and the expensive process of obtaining necessary approval of the U.S. Food and Drug Administration. Most of these products are now synthesized artifically and are no longer dependent on the original marine source.

Marine organisms represent a vast resevoir of unknown compounds and several large firms are systematically screening many of these organisms for clinical value and market potential. So far, interest has centered on antibiotics and heart drugs, whose market potential is exceptional, but other elements are also of clinical and economic interest. The technological problems of screening for selected function and of determining chemical structure and methods of synthesis are relatively straightforward. However, coupled with systematic clinical testing for ultimate government approval, they represent a very large investment, and therefore a practical barrier to discovery or adoption.

Miscellaneous Biologicals and Biochemicals

This industrial segment is more a potential than an actuality. Only two companies, to our knowledge, are presently producing products in this subsector. One is test marketing a new substance for use as a chemical indicator for calcium determinations in clinical chemistry; the other is marketing vaccines for the successful rearing of aquatic animals. In the latter case, the demand for effective materials is expected to parallel the development of the aquaculture industry. However, whether the preferred materials will turn out to be vaccines, antibiotics or other chemicals, is yet to be observed. In either case, since the substances will be either synthesized or cultured, there are not likely to be any serious problems in scaling up an adequate supply.

One of the principal uncertainties in this sector remains the future course of the aquaculture industry. If momentum is obtained in the latter, the demand for these biochemicals for controlling the environment of aquatic animals may be very large. As in the case of all pharmaceuticals, however, such biochemical products must be submitted to expensive testing procedures required by the U.S. Food and Drug Administration. Hence, financial and technical problems combine to pose a significant constraint to technological innovation and commercial exploitation of new biochemical products.

Marine Polymers

These substances include colloidal polysaccharides such as algin, agar and carageenan, and other potential entrants such as chitin. At present, four substantial U.S. companies are engaged in the extraction and marketing of soluble colloids and two small enterprises, with the assistance of a large chemical firm, are attempting to develop a market for chitin derivatives.

The soluble colloids are widely employed as food additives, as ingredients in pharmaceuticals and in the laboratory culture of bacteria. Minor industrial applications in stabilized gels, sizings and other nonedible products are becoming increasingly important. As this trend continues, the resulting demand could easily exceed the present supply and is already giving impetus to developments in resource management, seaweed cultivation, utilization of new species, or other means of enlarging the supply. Technological advances have been made in harvesting management, artificial cultivation and in the use of more abundant species. At the same time, developments are continuing toward new applications and the stimulation of new sources of supply.

V.4 Fishing

Structure of the Industry

Fishing is an exceptionally fragmented industry, segmented by species specialization, geographic characteristics, local or ethnic traditions and generally weak trade organizations. On one hand, it is characterized by small firms, often single boats or ships; on the other, large fleets and corporate interests are evident. These differing industry characteristics are largely determined by species and regional factors that make segments quite different from one another. There is little in common between the Pacific tuna fleet, the Gulf shrimpers, the Chesapeake Bay watermen or the Atlantic groundfish trawlers.

The tuna industry is served by a number of independent fishing boats and traders who purchase fish in remote ports, and by large company fleets owned by canners and integrated food companies. Most of the primary product is marketed under nationally-known brands. By-products, which consist of waste meat, oil, meal and solubles, are sold through brokers or to pet food manufacturers, or incorporated into pet foods of their own brand.

The menhaden fishery is similar to tuna in some respects, including the coexistance of independent boats and processors along with company fleets operated by vertically integrated divisions of medium-size corporations. While tuna is destined almost inevitably for canning, menhaden is invariably rendered into fish meal, oil and solubles. Menhaden serves a commercial commodity market in animal feeds rather than a consumer or retail market.

The trend in company ownership of fishing fleets and in other methods of attaching fishing operations more firmly to packing and processing operations was once evident in the shrimp fishery, but is less so now. Fewer shrimp packing houses own their own boats and newer, less paternal operating arrangements are more common between packers and fishermen. These changes have brought about a greater degree of independence in shrimp fishing but, as in other fisheries, this relationship is determined by some basic demand supply factors. If demand outstrips supply, processors are motivated to take control of the fishing operations. But, when market conditions slacken, packers tend to seek greater efficiency by restricting their responsiblity to on-shore operations that are easier to control and manage efficiently.

Shellfish and crabs are generally harvested by small boats which are independently owned and operated. Shallow water species which are not amenable to large volume harvests, are generally sold fresh, and the fishery is not vertically integrated. Deep water or "surf" clams on the other hand are landed from larger craft and processed in much larger volumes. They are destined for institutional or packaged foods, and exhibit a degree of on-shore integration that ties primary shuckers and packers to the large consumers and secondary processors. If the recently developed gap between demand and supply continues to widen, then integration might be extended to include the fishing boats as well.

North and Middle Atlantic fisheries are conducted by individual trawlers and small, family-owned fleets, displaying a considerable variation in hull size and design. While some are new, many are old, but fitted with modern power deck equipment and electronic gear. Many of these vessels operate from a single port, and fish for a variety of species, depending upon season, relative abundance and demand. They sell their catch directly to packers, or at open auctions or through fishermen's cooperatives which perform auctioning or other marketing functions.

Production Methods

Production methods, with few exceptions, have changed very little over the years. Innovations such as the stern trawler, fiberglass hull, power block, or electronic navigation equipment, have usefully served, but not greatly altered the traditional methods of fishing. Similarly, the use of pumps and lifts for bringing fish aboard ship, or for unloading at dockside, have made incremental improvements on the traditional methods.

Changes which have had a significant impact on the efficiency of harvest may be found in the use of spotter planes, as employed in locating menhaden, the setting of seines on porpoise schools to catch tuna which school below them, and the use of dredges or other lifts for crab and clam fishing in States where that is permitted.

Supply Problems

Most welcome innovations have been, and are likely to continue to be, those that increase the ability to locate and efficiently harvest greater catches, but the combined effect of all efforts and changes in the past twenty years has only slightly increased the total U.S. catch. The underlying phenomenon, which has limited the increase, and which characterizes virtually all fisheries, is that stocks of all commercial species are being depleted in the areas traditionally harvested. Many different reasons have been advanced to explain the decline, including pollution and foreign competition, but it is difficult to avoid the observation that intensive fishing by American boats has been instrumental if not decisive in precipitating the decline of many species. Examples may be found in the enormous number of American shrimp boats operating in certain areas of the Gulf, the recently-condemned practice of fishing the shrimp spawning grounds, the concentration of salmon fleets at the mouths of salmon spawning rivers, and the exhaustive harvesting and destruction of the Atlantic surf clam beds.

Demand Trends

Decreasing stocks have been concurrent with increasing demand in response to population growth, and as a consequence of other factors which have affected the American and international markets. Great changes have occurred in particular species and products. Tuna consumption has risen enormously, partly at the expense of salmon whose decreasing supply and higher price provide no effective competition. Likewise, the importation of inexpensive frozen blocks of groundfish fillets has supported the marketing of tasty and conveniently precooked portions which now supply 85% of Americans' fish diet. Institutional use of frozen portions, either pre-breaded or pre-cooked, has added to the consumer demand and has supported a substantial increase in the market for frozen shrimp products as well. Similarly, new methods of using surf clam meat have produced a commercial and institutional demand that cannot be sustained by present harvesting practices.

Institutional and consumer preferences for frozen and precooked packaged products could have had a devastating impact on the demand for fresh fish if other factors had not intervened. Improved refrigeration and modern transportation increased the shipping range well beyond coastal areas, opening up interior markets previously inaccessible to fresh seafoods. Clam bakes in the Midwest absorb most of the output of at least some Chesapeake Bay shellfish packers. Live lobsters shipped from Boston in the morning can be in Honolulu restaurants in the evening. The result is that despite the relative dominance of frozen and cooked products in the market, total demand for fresh fish has increased. And the premium price supported by this enlarged demand removes incentives for Atlantic fisheries to compete with imported frozen blocks. They serve quite different market segments.

International Competition

While domestic fresh products of North Atlantic fisheries appear to have an ample market and are not threatened by imported frozen blocks, they are threatened at the source. Vessels of other nations, including Russia, Japan and Northern European countries, have been fishing the North Atlantic in larger numbers and often with more efficient vessels. Frozen blocks of fillets made from their catch and imported from Canada, Iceland and Scandinavia supply the major portion of all fish consumed here. In the Pacific, Japan, Korea and other nations are giving increasing competition and their Pacific mackeral, salmon and tuna compete well in the U.S. consumer market. International agreements have been negotiated to keep Japanese salmon fishermen further from Alaskan waters, but the value of such arrangements is still seriously questioned, since the salmon migrate across the negotiated fishing boundary.

Tuna fishing is now a world-wide enterprise and an international market in whole, frozen tuna has developed. A substantial amount of that which is canned in the U.S. is caught or purchased in areas as far away as the Indian Ocean. Shrimp is also an international product. U.S. boats fish off the shores of Mexico and Central America, in competition with the boats of other registry, and frozen blocks of shrimp are imported from as far away as India.

Technological Development and Potential

Opinion has often been advanced by observers outside the industry that the U.S. fishing industry is technologically backward and could benefit from appropriate technical innovations. They point to the development by other countries of innovations like the stern trawler or the factory ship concept, and to the slowness of adoption of such ideas by U.S. fishermen. American fishing spokesmen, on the other hand, contend that U.S. vessels are modern enough in terms of power plant and deck gear, and that hull design, storage and refrigeration concepts are advanced as needed or as can be profitably adopted. They point to subsidy by foreign governments of the modern vessels with which U.S. craft are unfavorably compared and suggest that without such subsidy, foreign catches would prove to be no more economically efficient than our own.

The presence of such strongly contrasting opinions suggests that generalizations on the state or need of technological advancement should be made with caution and that specific qualifications are likely to apply. Certainly it is clear that the modern tuna seiner is an example of an important investment in up-to-date ship design. In the Atlantic fishery, a great variation in hull designs has produced no outstanding breakthrough as yet, but what they have may be suited to the conditions under which they operate, especially with respect to species diversity.

Minor or incremental improvements have been made, in the adoption of fiber glass hulls or changes in trawling gear, and further changes in storage designs will probably continue in all fisheries. At present, some of the shrimp boats and Atlantic ground fish vessels may be somewhat too large for optimum economy, given the present size of the catches, and adjustments will be needed as resources vary. There seems to be no reluctance to adopt modern electronic navigation equipment, and any advances to locate fish effectively are certain to be incorporated quickly by the industry.

With these observations in mind, it appears that innovations that have clear economic advantage are readily enough adopted. With a few exceptions, technical changes have been incremental, rather than revolutionary, but revolutionary changes are not being held back by any apparent inherent conservatism on the part of the industry. What is of greater concern and appears to have greater influence on technical advancement are economic realities of efficient operation, return on investment and problems with diminishing resources.

V.5 Fish Processing

Structure and Production Methods of the Industry

Like fishing, the processing sector is segmented in several ways, generally according to species. Some species are primarily marketed fresh, while other varieties are canned or prepared for cooking and then frozen. Many industry characteristics, including structure, technology and demand, tend to vary from species to species, and accurate descriptions of the industry must be rather specialized along these species lines.

Primary processing prepares seafood for the wholesale market or for secondary processors. It is generally performed by the dockside purchaser and consists of grading, heading,, shucking or filleting operations as appropriate to the species. The products are iced for shipment to fresh markets or to secondary processors, or if from the market, are subjected to secondary processing in the same or a neighboring plant.

Secondary processing consists of the remaining steps up to and including packaging and many entail peeling and de-veining of shrimp, sawing and portion shaping from frozen blocks of fillets, and any appropriate combinations of breading, battering, frying, freezing, curing or canning. Secondary processors tend to be larger firms possessing recognizable brand names, and their integration with other aspects of the seafood business often includes affiliation with primary processing divisions. Primary processors, or "packers", operate much smaller plants. They range from independent single units to groups of plants, owned by integrated seafood companies, and distributed regionally to cover appropriate seasons and species.

Many of the operations in all stages of processing are performed by machines, and effort is continually directed toward further elimination of handwork. Nevertheless, it is as a whole still a labor-intensive industry. In many instances, particularly with shellfish, the value of the product makes relatively small quantity losses intolerable and sets tolerances not presently achieved by full automation. In other cases, especially with shrimp, the discrimination required for precise portion control and quality assurance has so far needed a considerable amount of human supervision. In addition, other operations have simply defied technological solution.

Tuna and menhaden processing is highly mechanized and both industry segments are characterized by a few large food companies or multi-division conglomerates. Several of the seven U.S. tuna companies cooperate in processing each other's brands of tuna or pet food. Reduction of menhaden to meal, oil and solubles is a fully automatic continuous process, while tuna processing requires much manual attention but becomes more automatic as the product approaches the canning operations. Waste trimmings and carcasses of tuna are also subjected to rendering by a process similar to that used for menhaden, but are processed in smaller plants owned by the tuna canners.

In earlier stages of tuna processing, technical demands are rather primitive and current developments center on such examples as automated air skinning to replace knives and the use of electric knives for slicing loins. Five of the seven U.S. tuna companies support the Tuna Research Foundation, but its attention tends to be focused on problems encountered in fishing and quality control of the fresh or frozen carcasses.

The Market for Processed Fish

Overall, consumption of shellfish has risen gradually and reached a plateau in recent years, with some species decreasing and other increasing. Selected species, such as surf clams, have taken large jumps in price, but the demand for all species readily supports the fairly high prices generally required by the small scale and largely manual methods of production. By projecting trends of consumer and institutional preference for breaded and packaged shrimp, the penetration of the Midwest market by steamer clams and the rise in demand for raw surf clams, it appears that shellfish demand will increase faster than population growth for a while, and put increasing pressure on resources that already are showing signs of strain and decline.

The demand for fresh Atlantic finfish is also strong and sustaining a price much higher than can be obtained for prepared seafoods, so that very little of the Atlantic catch goes through anything beyond primary processing. With the entire interior of the continent now within reach of fresh fish shipments, it does not seem likely that domestic finfish will see much secondary processing unless new domestic species are introduced which are better suited to fried sticks and portions than to the fresh fish market.

Demand for tuna has resulted in a steady increase in consumption over the past ten years, and a steady increase in imported fresh and frozen tuna and partly pre-processed meat. Most recently, tuna canned in brine instead of oil has been gaining some favor with consumers at least partly as the result of a price advantage, and shifts in preference seem to reflect a rather delicate sensitivity to price. This style of canned product has been increasingly adopted by domestic canners to maintain their competitive position vis-a-vis imported brands. Representatives of the industry are fearful that imported brands may soon gain an even greater price advantage resulting from modification of U.S. fishing practices to protect porpoises in compliance with the Marine Mammals Act.

Demand for pet foods has increased and new varieties using tuna by-products are able to sustain relatively high price levels. These developments have encouraged diversion of some of the large volume of tuna waste to pet foods rather than to the rendering process. Tuna canners produce pet foods on contract or under their own brand, and some have developed new pet food uses for the solubles produced from the rendering process.

Technological Changes in the Sector

Technological change is evident in all segments of the fish processing industry, aiming principally at minimizing or elminiating manual labor in order to remain cost competitive. This objective in process change has resulted in widespread adoption of mechanized conveyor systems and in the introduction of relatively simple machinery to replace manual operations in both primary and secondary processing. Special requirements of differing species and relatively low volumes of material handled at the primary or packer stage have made these segments slower to advance than those concerned with secondary processing, but concepts such as automatic shuckers, successfully employed on some species, are slowly being adapted or substituted for use on others.

At the secondary processing level, some species differences persist in certain instances, like shrimp, and continue to place difficult requirements on handling processes and machinery. But for other operations such as breading and freezing, or for standardized shapes and portions made by cutting, extruding or molding, food processing technology is more transferrable and adaptable among different foods. When added to the advantages of larger size and process volume, the economics of integration and transferability of technology enjoyed by secondary processors provide more stimulus for technological advancement, and result in plants which are somewhat more sophisticated and less dependent on hand labor. Nevertheless, the present level of technology is relatively unsophisticated, and there is considerable room for process innovation in all segments of the processing industries.

V.6 Discussion

The preceding sections show widely varied characteristics and patterns of change within the various sectors studied. In the following Chapter, we will compare the sectors and discuss their needs for research and technology.

FOOTNOTES FOR CHAPTER V

The summaries in this chapter are based on a series of working papers which contain more detailed notes and references. Each paper provides background information rather than original concepts or research findings. They were initially prepared from secondary sources. Later, information from industry interviews was added.

The papers listed below are not a part of the final project report, although a limited number of copies are available for the use and convenience of other investigators through either the National Office of Sea Grant or the Center for Policy Alternatives.

Blair M. McGugan and Donald Hague, Technology and Innovation in the U.S. Aquaculture Industry

Sally Gorski, The Response of the Legal System to Technological Innovation in Aquaculture: A Comparative Study of Mariculture Legislation in California, Florida and Maine

Albert E. Murray, Technology and Innovation in the Marine-Derived Pharmaceuticals and Chemicals Industry in the U.S.

James B. Webber, Technology and Innovation in the U.S. Fishing Industry

Sally Gorski, A Legal Analysis of Financing Modernization of U.S. Fishing Vessels

Linsu Kim, Technology and Innovation in the U.S. Fish Processing Industry

VI. A COMPARATIVE ANALYSIS OF PATTERNS OF CHANGE AND NEEDS FOR TECHNOLOGY IN INDUSTRY SECTORS

How are the competitive and market issues involved in each sector and the resources required for production related to needs for research and technology? In particular, what factors can be capitalized on through technological changes in a given sector--one which introduces a new product for which demand is assured, one which reduces the costs of production substantially so as to alter the competitive picture, one which improves the supply potential where supply is a limiting factor to industry growth, and so on?

Analysis of the four sectors selected for study showed a consistent pattern of change in products and processes related to levels of economic and technological development. The industry data and interviews produced important facts about current needs for technology. Some precise areas for effective technical support were highlighted in the sector analysis. These issues are dealt with in turn below. Included are some, but by no means all, areas where Sea Grant support could result in substantial commercial development.

VI.1 Regularities in Patterns of Product and Process Change

A growing understanding of the dynamics of change in industry allows us to make some predictions about kinds of change that will be vital in different situations. The consistency of the innovative process in different settings makes it possible to point out gaps in current technical resources as well as to speculate about the directions in which needs for technology will develop for particular lines of business.

In general the conditions necessary for rapid innovative change are much different from those required for high levels of output and efficiency in production. The pattern of change observed within a productive unit will often shift from innovative and flexible to standardized and inflexible under demands for higher levels of output and productivity.* Conversely, disruptive external forces such as increasing competition across industry and national boundaries, rapidly changing prices for imports, introduction of production processes having drastically lower costs or direct government intervention through regulation may be associated with a shift toward more innovative conditions [1].

The type of innovation observed in a productive unit will ordinarily shift over time from frequent and novel product change stimulated by users and market factors, to periodic changes in the product line accompanied by an increase in major process change, predominantly stimulated by changing technological possibilities. At the extreme there will be little innovation. The unit will be highly productive and efficient, but stagnant and vulnerable to competition from new entrants to the industry and from unexpected directions. Cost stimulated incremental innovation will be expected to predominate. Novel changes will be costly, involving simultaneous product and process innovation and will be infrequently introduced [2].

Market uncertainty and stimuli for change will predominate at first, but will diminish as experience with the use of a new product increases and as production volume rises. At first, product performance will be stressed, unit profit margins will tend to be high and demand inelastic upward but elastic with reductions in price. Eventually, products will often become standardized and compete mainly on the basis of cost and quality. Products will be expected to be developed over time in a predictable manner with the initial emphasis on product performance and user needs (as in the case of gourmet products for example) then shifting to emphasis on product variety and later to product standardization and costs.

Initially, innovations will originate in units with intimate knowledge of users and user needs. The critical input is not state-of-the-art technology but is new insight about needs [3]. Later, when needs are well

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* By <u>productive unit</u> we refer to a firm producing a related line of products and the associated production process. For a larger or diversified firm, a productive unit would usually be a separate division or operation.

defined and easily stated, the innovative unit will often be the one that brings new technological skills to the problem. This may be an internal engineering or R&D group, an equipment company or some other outside source. In brief, we may expect a shift in the locus of major innovation from user to manufacturer to equipment supplier as a productive unit becomes more highly developed.

The performance criteria that serve as a primary basis for competition change from ill-defined and uncertain targets for innovation to well articulated design objectives. In emerging product areas there is a proliferation of product performance dimensions. These frequently cannot be stated quantitatively, and the relative importance or ranking of the various dimensions may be quite unstable. Manufacturers are likely to produce an innovation where the performance requirements are clearly specified, but that users are likely to introduce the innovation where performance requirements are ambiguous. Radical product change is often the result of the addition of entirely new performance dimensions such as regulatory requirements to a previously stable set of dimensions [4].

At first, though the total amount of research and development (R&D) in a sector may be substantial, its focus will be diffuse. Many lines of inquiry will be followed and many technical alternatives developed. As performance requirements become better understood, technical efforts become more focused and cumulative in importance.

Reduction in uncertainty, as markets and product uses become more highly understood, increases the salience of R&D as a stimulus for innovation. In an emerging market needs are ill-defined and can only be stated broadly. So there is uncertainty about the relevance of outcomes that might be achieved, even if investments of R&D resources were made to bring about such outcomes. This has been called target uncertainty [5]. The expected value from any R&D investment is reduced by the combined effect of target uncertainty and technical uncertainty. The decision-maker has little incentive to invest in risky R&D efforts as long as target uncertainty is high.

As the productive unit develops, however, uncertainty about markets and appropriate targets for R&D is reduced. Therefore, R&D projects bearing the same level of technical risk are increasingly made more attractive, and larger R&D investments are justified. At some point before the cost of implementing technological innovation becomes prohibitively high, and before increasing cost competition erodes margins below levels that can support large indirect expense categories, it would be anticipated that the benefits of large R&D efforts would reach a maximum.

As a production process develops over time toward levels of improved output productivity, it will become more capital intensive, direct labor productivity will improve through greater division of labor and specialization, the flow of materials within the process will take on more of a straight-line configuration and process scale will become larger. At first, production will be small scale and located near a technology source or a user. There will be low level of backward integration and the productive unit will have little influence over its suppliers. Later, facilities will be larger and located to achieve low factor input costs and/or to facilitate distribution [6].

In its initial phases an emerging sector may be characterized by a few small firms sharing both high risks and rewards in a rapidly expanding market with relatively inelastic prices. Production technology is largely adapted from general purpose equipment and involves a high degree of skilled labor input. As the industry evolves, an increasing fraction of its product innovations are stimulated by possibilities seen in its expanding technological capabilities as opposed to market needs. These are often improvements or additions to current products. Process innovations become important as output expands, and some special purpose tooling and automation is typically introduced. New firms enter the industry at this stage with production oriented, imitative strategies and product variations. As the industry continues to develop, products become more and more standardized. Process innovations predominate, and innovations are typically cost stimulated, incremental improvements. Only a few firms that succeed in driving down production costs survive. Competitors may enter but only by making large investments in plant. In terms of innovation, the industry may stagnate or it may be forced to change through functional competition and invasion of its markets by other industries and firms [7].

When both productive units and the entire business are small generally available inputs which may be highly variable will be used. Later on uniformity of inputs will become more critical, and productive units will demand uniform specialized materials (as in the case of frozen blocks for secondary fish processors) from suppliers or will attempt to produce needed inputs themselves. Steady rates of output, and thus of supply will also be critical as productive units grow in size.

Innovation generally occurs closest to affluent markets in the early stages of development of a sector. In the last stages of development labor, materials and transportation costs probably are the strongest variables in determining location. In terms of foreign trade this typically means that the innovation process begins by U.S. firms developing products for the U.S. market with export a minor consideration. Then export to large markets such as Europe and Japan becomes important. As these exports are displaced by local production, U.S. firms may expand the focus of exports to include developing areas. Later competition may develop from European and Japanese firms for both U.S. and developing markets and production begins in these markets as well. Finally, imports from developing countries may displace much of U.S. production [8]. On this basis, we would expect developing premium markets overseas to be the major trade concern of emerging productive units, while cost competition would be the preoccupation of these which were highly developed. Similarly, products or processes having export potential would have a more lasting and important positive effect on balance of trade than would import substitution.

In sum, productive units at the emerging stage of evolution in their product and process technology are expected to have frequent and novel product change stimulated by users and market factors, to have flexible but inefficient production processes with general purpose equipment and skilled labor, and to have small scale capacity in an entrepreneurially based organization. On the other hand, productive units at the developed stage of evolution are expected to have predominantly incremental change stimulated by cost, to have highly standardized products with few major variations and to have large scale integrated facilities specialized to particular products and to be vertically integrated.

In effect, the stages of evolution represent extreme cases. It is apparent in several industrial sectors that productive units currently at the mature stage were at the emerging stage earlier. In other words, productive units evolve from the emerging stage in transition to the developed stage. The predominant mode of innovation during this transition shifts from radical product innovation to incremental innovation, and process innovation increases in relative importance to product innovation. Sources of stimuli for innovation, production pattern and segment structure all change as the segment develops from the emerging stage to the developed stage. For example, businesses raising catfish and trout have moved and changed in the manner described. Aquaculture of marine animals appears to be at an earlier point in the pattern and may be expected to evolve in a similar way.

In other words, productive units at different-stages in the evolution of their product and process technology are expected to undertake different types of innovation and to have different production capacities and processes in response to differing stimuli. This contingent relationship between technological innovation and the evolving structure of the productive unit present various implications for decision makers as to when and what actions are likely to be effective in a particular situation. Then, how do the findings of the sector studies relate to the model above and what are the implications?

VI.2 Patterns of Innovation in the Sectors Studied

While it is always risky to discuss complex issues in terms of simplified and preconceived categories, we think it is helpful in discussing needs for research and technology to view parts of the four sectors as being earlier or later in the spectrum of change from emerging to highly developed. Firms in marine aquaculture and bio-medicals have many aspects characteristics of emerging productive units. Conversely, tuna and menhaden firms and secondary fish processors have many of the characteristics of highly developed productive units. Other parts of the sectors studied appear to fall between these extremes.

Two sectors, Marine Aquaculture and Bio-chemicals are:

- dominated by small, new entrepreneurial firms for the most part with very little vertical integration
- focused heavily on developing a product of quality and appeal
- focused on skilled labor as the critical production resource
- emphasizing initial system design and have a crudely developed technology
- normally showing high growth, high profit margins and are expanding from an initial specialty or regional market
- in a position of high export potential based on newness and appeal in their products.

The more highly developed and mechanized segments of the Fishing and Fish Processing industries, in particular tuna, menhaden and secondary fish processing, appear to have the following characteristics:

- operate near source of supply
- usually larger, established firms with considerable integration
- changes are focused on improvements in the process of production to reduce costs and strengthen competitive position
- productive use of capital is critical in these operations
- changes tend to be incremental improvements

- equipment is highly specialized
- growth in the industry is relatively low, with standardized products and low unit profit margins
- variations in supply are critical to health of the industry
- high degree of competition with imports based mainly on price.

Technical developments being attempted by firms and current needs for research and technology which were encountered during our study of these sectors also appear to match prior expectations. These are covered in detail below.

Emerging Sectors

Aquaculture and biochemicals are characterized by a small number of individual entrepreneurs, (as in the case mainly of aquaculture) or by large firms exploring a new area of business. The market offers a potential opportunity for new products but market pay-off relies heavily on the successful development of the product and production process. Research and development are expensive because of the many unknowns in the technology and market.

Research and development activities in the industry are on a small scale due mainly to the reluctance of both the top management and investors to commit a large investment to a high risk venture. For example, the few large firms involved in the development of intensive shrimp salt-water aquaculture technology are unwilling to invest any more funds until basic technological unknowns on maturation, nutrition, containment and disease control are solved. On the other hand, it was observed that these firms are closely monitoring the development of research efforts undertaken by university and NMFS extension stations in hopes of seeing technological barriers to large-scale market development overcome.

In the fresh-water aquaculture segment, by contrast, production systems and methods have been under constant improvement. Innovations have occurred mainly in process technology rather than new products. Cost and price pressure stemming from competition not only with domestic natural stocks but also with foreign supplies, plus the demand for continuous high quality supplies, have been major factors stimulating technological innovation. Specific needs for technology in the aquaculture sector are:

- Experimental or pilot stage R&D for species with strong demand potential.
- Basic research on disease control, environmental requirements, behavior patterns, food conversion, etc. of certain aquaculture species.
- Site identification and testing for aquaculture installations.
- Equipment testing for marine and fresh-water environment control systems.
- Engineering models for different culture intensities.
- Technical manpower training in marine and fresh water aquaculture.
- Communication and diffusion of aquaculture techniques to commercial interests.

The biochemical segment, like the marine aquaculture segment, consists mainly of a few small firms led by entrepreneurs with technical backgrounds who recognized new business opportunities in the fields of their expertise. Their production processes are in a crude or experimental stage with low productivity. On the other hand, the marine polymer segment is represented by several medium-sized firms and small divisions of large firms, which are often integrated vertically. Production processes are relatively labor intensive but are also heavily dependent on capital equipment.

The market for biochemicals is still in the formative stage. However, market opportunities for new products such as vaccines for the control of disease in the husbandry of aquatic organisms are promising since disease control is regarded as an essential requirement for the successful commercial rearing of aquatic animals. Seaweed colloids have been used in foods as thickeners or stabilizers and have recently found their way into industrial use. In short, sizeable markets appear to exist in these segments, and growth prospects are promising. Technology must solve basic problems in order to establish these segments as competitive or profitable.

Technological innovation observed in the biochemical segment has been concerned with developing satisfactory products of high quality. Any substantial progress in these segments is expected to have major impact. The pattern of innovation here appears to be based on firms research and development to a greater extent than in aquaculture. Yet, the lack of basic knowledge, the high degree of uncertainty and risk in these business ventures, the limited size of research funds relative to the size of the research tasks to be undertaken, and the under-developed marketing capability of the firms involved, appear to be the major barriers to technological development.

In the sector of pharmaceuticals and biochemicals, the following areas of applied research are positive candidates:

- Detection, extraction and identification of marine substances of high potential value.
- Development of broad spectrum indicators for useful physiological activity.
- Product and application development for non-drug chemicals and special substances.
- Preliminary testing of new products seeking FDA and USDA approval.
- Development of methods for resource management of source species.
- Research and development of biologicals of economic value for disease control and other functions in aquaculture systems.

Sectors in Transition

Certain segments investigated in the sector studies exhibit general characteristics which seem to be in transition from the emerging to the highly developed stage. Both the fresh-water aquaculture and marine polymer segments show basic characteristics which are similar to those of the emerging stage, as in marine aquaculture and biochemicals, but the former are more developed than the latter in terms of production technology, market conditions, and innovation pattern. Production technology is moderately advanced in degree of mechanization. For fresh-water aquaculture, the regional market has already been exploited, with a slow attempt to seek wider national distribution. Marine polymer products have been used in food processing, but they have also found their way into industrial use. That is, the products of these segments are moving slowly from an established small market to a wider national distribution or application. While the incremental improvement of production processes is the established pattern of technological innovation, an avenue of new product applications opening up in the marine polymer segment provides a new stimulus for future innovation.

Recent technological innovation observed in the marine polymer segment has been mainly concerned with improvement of the production process. In light of the fact that marine polymer products are exceptionally versatile, they have many new applications. Market opportunities stemming from the rapid development of food processing, and new avenues opening up in industrial non-food uses of the products are major factors that might facilitate technological innovation. Constraints to new uses of marine polymers in foods, drugs and cosmetics are imposed by FDA requirements, and technical assistance could be helpful in successfully meeting test requirements.

Needs and opportunities for innovation in the marine polymer segment are found in both production and use. Demand is already straining the availability of marine colloids. Research that might lead to an increase in the supply of gelidium in American waters or to an introduction of methods for obtaining a similarly high quality polymer from abundant local species such as gracilaria, would reduce U.S. dependence on imports.

<u>Highly Developed Sectors</u>

While aquaculture and biochemicals offer several clear examples of the emerging stage of industrial and technological development, certain segments of <u>fishing</u> and <u>fish processing</u> are by contrast highly developed, particularly the large sub-sectors of tuna and menhaden. These segments are comprised of a few large firms with highly mechanized and often continuous automated operations, which are in most cases vertically integrated from fishing through processing to marketing. In the fishing segment, purse seining, power blocks, fish pumps and spotter planes together with modern electronic equipment, constitute the most sophisticated fishing technology in the country. Tuna processing uses more automated processes as the product enters the canning phase. Menhaden processing is an automated, continuous operation through the cooking, pressing and drying processes.

Productive units in these segments are usually divisions of food processing firms or of multi-division conglomerates. The production process is efficient, capital intensive and special purpose. The products are fairly standardized, and price is a major competitive factor in the market. Supply of raw material is generally available either from local or foreign sources. Innovations that made major impacts on product and process development took place two or three decades ago. Since then, the processes have been gradually and incrementally improved in order to increase productivity. Product standardization and scant research for product and market development are major barriers to the use of new technology in these segments.

The market and technology for existing standardized products have reached maturity. Incremental changes necessary to improve productivity have been taken care of by the firms themselves or the equipment manufacturers. However, successful development of a new product and market, especially for minced fishflesh, might make a major impact on the development of the U.S. fisheries. For example, if a new market is developed for minced fishflesh products, an existing deboner could increase the recovery rate of fish from 30% to 50%. The 20% increase would mean as much as 200 million pounds more fishflesh available for human consumption, worth more than $100 million at 1975 prices. This suggests that market development is as important as product or process development for these segments.

In the fishing sector, several areas of applied research are suggested by the sector analysis:

- Research into resource management--seeding, migratory patterns, spawning, husbandry, etc.
- Experimental research on new species for human and industrial consumption.
- Experiments with standardized fishing equipment and vessel design to reduce equipment costs to fishermen and increase efficiency.
- Development of new techniques for fish finding and harvesting.
- Investigation of transport cost reduction.
- Investigation of product and market development for new species for food or industrial consumption.
- Study of species, fishing practices and other factors affecting economic feasibility of a domestic frozen block industry.
- Programs designed to encourage training and recruitment of skilled people for the sector.

In the fish processing area, several areas of effective support appear to be:

- Development of waste disposal or elimination technology
- Development of standardized quality control testing procedures where needed--e.g., tuna spoilage factors, thaw and re-freeze indicators for packaged foods, etc.
- Development of uses for products and by-products which are now wasted or under-utilized.
- Product innovation, market assessment and pre-marketing assistance for potential new seafood forms, (minced flesh, species blends, new species, etc.).
- Improvements in preservation technology, especially where most needed, e.g., whole tuna, blue crab, etc. Improvements in control of moisture transfer in frozen products.

VI.3 Summary

In general, the needs of emerging sectors appear to be centered on reducing technical uncertainty by providing basic data, helping in design and adapting production systems, and on reducing target uncertainty through assistance with early commercial trials and production runs and through market development. The high levels of risk involved limit incentives for firms to grapple with technical uncertainties until markets are better developed. Firms are probably best equipped to deal with target uncertainties.

Firms in highly developed sectors appear to be able to develop or adopt most needed technology, but need assistance with resource and technical problems they share in common. Solutions offer benefits for the sector as a whole but individual firms have few incentives or capabilities to deal with such problems.

Sectors in transition appear to be dealing well with most technical problems and needs, while problems shared in common are growing in importance but not yet critical. Here a more focused, case-by-case selection of areas for Sea Grant support would be the recommended course.

Understanding how a line of business will emerge and develop, how competitive factors and needs for technology will evolve, and knowing the factors that will probably shape and constrain product and process innovation may give us a powerful and consequential tool for analyzing the potential of new program areas and areas which may benefit from expanded support.

FOOTNOTES FOR CHAPTER VI.

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VII. SUMMARY AND CONCLUSIONS

VII.1 The Study and its Objectives

The specific aims of the study were to establish the extent and conditions under which Sea Grant-supported research projects showed commercial potential and foreign trade impact. Recognition of the circumstances under which these conditions occurred or failed to occur would be useful in the on-going management of the Sea Grant program.

In order to achieve these objectives, a structured sample of 77 R&D projects funded by Sea Grant at 26 university locations was examined and over 50 industrial firms engaged in related commercial activities were visited. The analysis and interpretation of this primary information has been developed in the preceding chapters against a background of published information on the status of technology in the impacted industrial sectors and extensive experience with the innovation process. Numerous observations and conclusions were included within the context of the preceding chapters. The more significant ones are brought together here for convenience and form the basis for some additional second-order conclusions.

VII.2 Potential Commercial and Foreign Trade Impacts

- Comparative estimates of potential economic impact are fraught with conceptual and analytical problems but a method of expressing anticipated sales in 1980 proved reasonable.

- Sea Grant-supported projects have produced significant commercial potential but with the bulk concentrated in a few projects.

- One half of the projects analyzed did have sales potential estimated in total to be about $122 million annually by 1980.

- Potential trade impact estimates are more complex and tenuous than sales estimates.

- About one third of the projects had either import substitution or export potential for a total value of $93 million per year by 1980.

- To our knowledge, a similar analysis has not been attempted for other research support programs making comparisons difficult, but it is highly likely that Sea Grant support leads to more rapid and extensive commercial application of research results than most other programs.

VII.3 Characteristics of Projects with Commercial Potential

- The principal investigator was encouraged by strong user interest and by their direct support of his efforts often in applications to his field of investigation.
- Most commercially successful projects were directed toward a market or production need rather than a scientific or technical opportunity.
- The project had reached the developmental stage and the technical uncertainties were low.
- The principal investigator was active in communicating the results to technical and user groups.
- There was early and continuous involvement of users as well as extensive communication and participation of other scientific and technical colleagues.
- The promise of high profitability often led to new enterprises being formed frequently with the involvement of the investigator or his associates.
- Barriers to commercial success of technological innovations such as capital, industry structure, risk, etc., were not considered to be as significant as other "softer" issues such as environmental regulation, legal or institutional problems and market development.
- Chances of success were enhanced when the university environment was highly supportive and had a strong experiment station or advisory service orientation.

VII.4 Industry Sector Relationships

Since Sea Grant R&D support is heavily concentrated towards the interests of renewable marine resources, the study focused on the aquaculture, fishing, sea food processing and biochemicals sectors. These can be subdivided on the basis of species, product or location into ten industrial segments. It is then possible to recognize different stages of technological development and corresponding innovation needs.

- The Marine Aquaculture and Biochemical segments are good examples of the emerging stage of technological development. Their technological needs are considerable, not yet clearly defined and rapidly changing. Hence there are high technical and commercial risks involved. Basic research information is often lacking and much novel engineering is required. Experienced, technically trained personnel are in demand and resources of all kinds must be drawn or adapted from a variety of external sources.

- Tuna, Menhaden, and Secondary Sea Food Processors are in a relatively mature stage of technological development. Their technological needs are oriented to incremental improvements leading to cost reductions that improve their competitive position in well-established markets. These firms are generally capable of making their own innovations. External support, such as Sea Grant, is likely to be better applied to investigating the complex scientific, technical, institutional and legal aspects of the management of the natural resources upon which they depend..

- Fresh Water Aquaculture and Marine Polymers are examples of segments in a transition stage of technological development somewhere between the emerging and mature examples noted above. It is in such a stage that the conventional type of Sea Grant support is likely to be most useful providing the success-related characteristics noted above are recognized and the innovation status of the industrial segment or productive unit are clearly recognized. This could be enhanced by an overall "portfolio" approach wherein research support was viewed in a matrix of technical excellence and economic potential but dependent on subject matter priorities and sustained support over time.

- North Atlantic Groundfish, Gulf Finfish, and Shrimp and Shellfish segments are not so easily characterized because of the unique conditions they face. The essential problem facing these segments is overall resource management. It is doubtful whether support of further technological development of capture techniques is warranted until some progress is made in controlling access to and improving the management of these declining resources. Technological developments are likely to be adopted and benefit foreign fishing activities more quickly than those of the U.S.

VII.5 Some General Conclusions Regarding Government Involvement

- Except for the more intensive types of aquaculture, existing technology does not appear a major limitation to economic development in view of current renewable resource levels and the many insitutional, legal and environmental issues that impact the related industries.

- A major challenge exists to provide, through reasonably integrated R&D support programs, the baseline biological data and resource management guidelines needed for both existing and potential commercial species.

- The development and testing of a "system" extending from harvest to market for all marketable finfish in U.S. waters is clearly needed. Extended jurisdiction is more a prerequisite than a solution to this dilemma.

- Comprehensive market studies by government and industry are necessary to identify the commercial potential and to increase the consumption of presently accepted as well as other readily available aquafoods. Considerable sophisticated innovation and concerted effort will be required to overcome the minor contribution to the national diet and the indifference of entreprenuers, investors and consumers.

- The introduction of foreign technology should be facilitated as should be the profitable export of U.S. technology.

- Recognizing that major progress towards utilization of products from the sea ultimately depends on social and institutional changes concerning the utilization of common resources and areas, the following issues should be addressed in the management of the Sea Grant program:

  - How can national, regional and local interests be balanced in the encouragement and selection of projects for support?

  - What relative importance should be attached to food supply and nutritional standards versus luxury and specialty foods?

  - What is required to establish the theoretical and practical feasibility of "enhancement" methods for increasing U.S. supplies of seafood products?

  - When does economic potential and risk dictate the need for government support for commercial-scale trials?