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Fishery science teaching at the university level

Report of a Unesco/FAO workshop on university curricula in fishery science

Paris, May 1980

Unesco, 1981

UNESCO REPORTS IN MARINE SCIENCE

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6	Organization of marine biological reference collections in the Mediterranean Arab countries *Available in Arabic, English and French*	1979
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Report of a workshop on university
curricula in fishery science
Unesco, Paris, 5 - 8 May 1980
organized by the
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Unesco, 1981

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PREFACE

Unesco Reports in Marine Science are issued by the Unesco Division of Marine Sciences. The series includes papers designed to serve specific programme needs and to report on project development. Collaborative activities of the Division and the Intergovernmental Oceanographic Commission, particularly in the field of training and education, are also represented in the series.

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SUMMARY

The current challenges and opportunities facing fisheries are immence and multifaceted. The lack of consistent success in the past management of important fisheries and the current scarcity of professional expertise in many developing countries clearly suggest some future needs.

Fishery practices and management in a particular area are usually complicated, and differences between fisheries of different areas may be pronounced. Such complexity and variety preclude any simplistic approach to the content of fishery education. Fishery education should be adaptive to circumstances with a consequence that it should be multidisciplinary, multi-level and multi-purpose.

One of the consequences of recent international developments with respect to the Law of the Sea is that the demand for well-educated fishery workers will grow. Many developing countries will expand their marine fisheries competence, and some developed countries may reorient their fishery interests in part toward more intensive coastal and maricultural fisheries. The need for competence in fishery workers - in research, administration and industry - will expand. Expertise with a background in biological and physical sciences will continue to be important, but additional expertise related to social sciences and communication skills will be required as well.

Though various structural aspects of fisheries educational programs and institutions differ markedly among some countries, the overall contents of integrated educational sequences do not differ so greatly (in comparison to the structural features). In general, structures are less important than contents. Both the nature of the contents and of the structures are currently evolving rapidly in several countries, and may do so in the near future in other countries. In such a period of creative turmoil, the potential for useful interactions between fishery educators of different countries is high.

A variety of informal mechanisms routinely operate to tend to ensure the general comparability in the standard of excellence of the educational offerings of various colleges and universities the world over. No formal mechanisms are needed, but the evidence that develops from the working of the informal mechanisms should periodically be examined by the administrators responsible for the educational institutions, and appropriate upgrading undertaken, if necessary.

Fish culture and exploitation of fishes are generally "sensitive uses" of aquatic systems, in that environmental quality must be carefully managed for them to be productive. These fishery uses are usually diminished through less sensitive uses of many kinds. Professional workers that serve the most sensitive uses must play leading roles in the overall planning and management of these systems if the sensitive uses are to be safeguarded or expanded. Fishery science educators should recognize that their students will increasingly become "leaders" in aquatic management and their educational offerings should help their students to realize this role.

More and better literature, texts and related materials suitable for use in fishery education are needed in most regions and countries of the world, especially in tropical countries.

A fisheries-related education is at best only half an education when it is not complemented by practical fisheries, field, and/or laboratory experience. Good results for acquiring such experience can be achieved by a close working relationship between universities and government research institutions. Considerable benefit can accrue from such a working relationship, and a large part of the research by faculty and students should flow from real-world problems.

INTRODUCTION

Wise use and management of living aquatic resources and environment are most important tasks for humanity. Recent social and economic changes in the world are causing increased demands for marine and freshwater living resources. However, various problems caused by human impacts upon aquatic resources and environments give warning of the need for improved management and monitoring strategies. It is necessary to reconsider how to train and educate people at the university level in order to produce fishery science experts who can effectively contribute to the complex management, planning and research problems of today and of the future. Fishery science education is needed in many countries to produce leaders for the fishery and food processing industries, fishery management agencies, and environmental planning offices, as well as to produce research scientists and educators. However, until very recently, fishery science has not been effectively taught in the university curricula except for a few countries which have highly developed fishing industries. In many countries, fishing methods and gear engineering are taught at technical schools. Administrators in government fishery agencies may often lack fishery science education in their background, and this may limit their effectiveness.

The development of a strategy aimed at enhancing the understanding and management of the fishery and aquatic environments has been discussed in several meetings that FAO, Unesco and IOC (Intergovernmental Oceanographic Commission) have held during the past few years, within the context of the Inter-secretariat Committee on Scientific Programmes relating to Oceanography - (ICSPRO). A key factor often absent in developing countries is the existence of trained scientists and management specialists. This workshop, jointly sponsored by FAO and Unesco, was organized in response to the recommendations adoped by ICSPRO. The purpose of the workshop was to examine the present status and problems in fisheries science teaching in various countries and to develop curricula in fishery science at a university level.

The Workshop concluded that no one fisheries science curriculum is appropriate to all universities. Instead the curriculum should be adapted to the specific needs of the country and of the students. To this end, the Workshop examined various case studies of curricula in the present global context. Specific reference was made to Japanese curricula as a highly specialized example in a country with a highly developed fishery industry. The Workshop then developed criteria for preparing fisheries science curricula. It agreed upon basic curricula which can serve as a basis for the preparation of specific curricula by educational authorities according to their identified needs and through application of the relevant criteria.

For ease of use, this report first presents the criteria and recommended curricula (Part I), and then presents the analysis of the global situation and the national case studies (Part II). The report concludes with Annexes giving selected references, a minimum list of relevant journals and the detailed case study curricula of the Tokyo University of Fisheries.

For additional information on the development of curricula in the marine sciences, the reader may wish to consult the following Unesco reports :

Syllabus for training marine technicians, Unesco report in marine science 4, 50p., 1979

Marine science syllabus for secondary schools, Unesco report in marine science 5, 45p., 1979

Marine science teaching at the university level, Unesco technical paper in marine science 19, 45p., 1974.

The members of the workshop, which met at Unesco Headquarters in Paris, 5 to 8 May 1980 were :

Dr. S. Dutt	Professor and Head Department of Marine Sciences Andhra University Visakhapatnam 530003 INDIA
Dr. J. A. Gulland	Chief, Marine Resources Service Food and Agriculture Organization Rome ITALY
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DEFINITION OF FISHERY SCIENCE

The phrase "fishery science" does not have a consistent meaning or usage throughout the world. Indeed the term ichthyology is broadly used to describe all aspects of fishery science in the Union of Soviet Socialist Republics, and in Japan the definition is somewhat more specialized. A working definition is provided here in order to minimize misunderstanding by the readers of this report. For the purposes at hand, fishery science will be defined to include not only scientific knowledge of the biology and state of fish stocks and effects of exploitation upon them, but also advice and research on the short and long term probable effects on the fish and fishery of various management measures and decisions concerning the aquatic environment. Thus, fishery science concerns itself with the scientific analysis of the structure and dynamics of stocks, as well as the interactions of biota, habitat and man, with the objective of providing advice on the achievement of human goals related to fisheries. Some direct knowledge of and experience with the technology of commercial fish capture and preservation seems highly desirable for most fishery scientists.

The above definition arbitrarily excludes vocational technical training for the fishing industry, which involves such materials as fishing gear design and fabrication, ship operations, seamanship, navigation, etc. leading to competence in fish harvesting operations and related matters. It is clearly recognized that training programmes leading to certificates and diplomas in the catching sector are a very important part of the requirements of the fishing industry, and the practical training programmes related to them are considered to be a candidate subject for another report related to training requirements for the fishing industry. Some prior studies have already dealt with aspects of vocational education and training requirements for the fishing industry. Such studies include the Guide to Fishery Education and Training, United Nations, Food and Agriculture Organization, Fisheries Technical Paper No. 128, 1973, by R. C. Cole and D. N. F. Hall.

Similarly, it is recognized that the science and technology related to post-harvest operations of the fishing industry are very important, due to the significant post-harvest losses of fish encountered at present on a global basis. However, the training and educational requirements for fish processing and preservation technology applied to reducing post-harvest losses and maintaining the quality of the product during storage and transport are not considered in detail as being outside the terms of reference of this report. Other post-harvest problem areas not included in detail are development of food products from fish now used for reduction, development of products which use a larger proportion of the raw food fish than is used at present, and development of analytical techniques for problems of public health significance involving fish products. Again, a separate report outlining the educational and training requirements in the area of fish processing technology and related matters would be highly desirable.

This report also excludes education in subjects such as biochemistry or engineering which are essential for those who will undertake research aimed at improving methods of fish processing or catching. However, these should certainly be included among the fishery sciences in the wider sense.

In the adopted definition of fishery science, an attempt is also made to maintain some distinction between the provision of scientific information and advice, and the management decision-making process. For an effective management role, there is a clearly recognized need for professional management personnel well educated in business management and administration, political science, economics, law and other social sciences, and in communication skills. How this management area fits into the definition of educational requirements for a fishery scientist and manager is considered in this report, but the educational requirements for these two types of fishery personnel are somewhat different.

Intensive fishery management, which includes propagation under partial human control, may approximate aquaculture. This report addresses some aspects of aquaculture, because it overlaps with the adopted definition of fishery science and because of its perceived potential importance. There are unique biological and engineering educational requirements for specialization in aquaculture, and some suggestions for these are made in this report.

Educational institutions in some countries have put considerable emphasis on freshwater fisheries (and others on pond culture) in the organization of educational programmes at both the undergraduate and the graduate levels. Some of this has been related to the recreational (sport) fishery. Freshwater fishery scientists have often been more concerned with the aquatic habitat and the whole network of user groups interested in that ecosystem than have their marine counterparts. The reason is that many freshwater habitats and ecosystems can be relatively easily perturbed by many different user groups and manipulated as part of a management strategy. The growing importance of freshwater fisheries is recognized, as is the background of relevant research dealing with recreational fisheries. There are also some parallels in the allocation problem, where there is already a historical precedent in dealing with the allocation of water and living resources among diverse users (commercial, recreational, etc.). A well-conceived curriculum in fishery science will permit the fishery scientist to adequately deal with the diverse problems mentioned above. Well-defined and rigorous educational requirements would help fishery scientists provide useful information and good advice to formulate sound policies, to translate policies into effective management measures, and to make management decisions which maintain the resources at adequate levels and which minimize adverse social and economic effects. To this end, this report divides fishery science into the following specialized (albeit arbitrary divisions:

(i) Fishery resource science

(ii) Aquaculture (including mariculture)

(iii) Aquatic environmental science (including fishery related oceanographic studies)

(iv) Fishery management, economics and policy.

CHOICES OF STRUCTURES AND COURSES

General Statement

Later sections describe the pattern of fishery education in a few individual countries which all have important fisheries and fishery education programmes. These serve as case studies. They reveal significant differences, even among the countries considered. If the smaller developing countries were included, the variety would have been very much greater. In many of these smaller developing countries, virtually all the fishing is done by untrained artisanal fishermen. The demand for university trained people may be at most for one or two people a year to enter the national fishery administration, or a small research group attached to government or university. The numbers involved may be too small to justify a specialized fishery course at any level, and training in fisheries will have to be done abroad, usually at the post-graduate level.

No one pattern of fishery education can be proposed as suitable for all countries. The pattern chosen will depend on the importance of the national fisheries, the demand for trained people in different sections of these fisheries, the total number of those attending universities at undergraduate and graduate levels, etc. The choice of the appropriate pattern, e.g. whether to include specialized fisheries training at the first degree level, is one that has to be made by each country and to some extent by each university individually in the light of its specific requirements.

The purpose of this section is to examine the choices that have to be made in respect of each level of education. In doing this it is recognized that, except at the most senior level, each step of the educational ladder must serve two purposes - either as a preparation for moving to a higher step, or as the final educational stage prior to entering outside employment in industry, administration or research.

Pre-university Training
(secondary school or technical school, ages usually 15 - 18 years)

It is not useful for those proceeding to universities, even for entering specialized university courses in fisheries, to receive specialized training in fisheries at this level. Instead, those intending to enter a university will require training in the conventional subjects, biology and zoology, mathematics (probably including some statistics) and probably at least one foreign language.

Specialized training at this level is useful for many of those who will enter the industry directly. In several nations, fishery training is available at a secondary level, and even to some extent at a lower level. A number of high schools offer fishery training, and their course offerings include fishing methods, fish processing, engineering, radio communications, aquaculture and management.

Beyond the secondary level of specialized training are various non-degree programmes of varying duration and requirements. Most are premised on successful completion of a secondary education or equivalent and they lead to certificates, diplomas, licenses or associate degrees. Such training institutions can generally be classed as post-secondary vocational schools or community colleges. The graduates of post-secondary specialized training schools are expected to eventually become captains, navigators, deck officers, etc. for either high seas or coastal fishing fleets, although many may start as deck hands. In addition to the training required for the fish capture operations, some specialized training in fish processing and preservation, marine engineering, fish culture, fishery management and electronics is offered in these institutions, and some graduates become employed in these areas. The secondary and post-secondary training described above is considered to be outside the terms of reference of this report.

However the decisions as to whether to set up such training institutions, and of what type, and where to locate them are important elements of an overall plan for fishery education. They can have influence on the university level, since the existence of secondary or post-secondary training institutions can sometimes make students aware of opportunities and stimulate interest in fisheries and fishery science.

These training institutes are commonly located within the structure of the department of fisheries (or department of agriculture or other unit in the government directly concerned with fisheries) rather than the department of education. This administrative arrangement is desirable to ensure that the institute best serves the perceived needs of the country's fisheries. However, close links should be maintained with the general education system of the country in order to maintain the quality of instruction.

Undergraduate level
(ages typically 18 - 22 years)

This is the first level at which serious consideration should be given to the instruction in specialized courses for those who might be proceeding to higher degrees, and ultimately enter the higher levels of fishery science. Though a case can be made for a specialized Bachelor of Science level course in fisheries for these people (provided that the total demand for fishery graduates is sufficient to justify it), undergraduates desiring to become fishery scientists should be encouraged to concentrate on the conventional sciences (mathematics, physics, chemistry, biology, economics, etc.) at this level. They should delay most formal instruction in fishery science until they are enrolled as graduate students at either the Master of Science or Doctor of Philosophy level.

The introduction of specialized courses at the B.Sc. level is more easily justified for those likely to leave the university with a bachelor's degree in order to enter fisheries in jobs such as fishery development officers, production officers, advisors to government or industry, processing and marketing specialists, or gear experts. The decision will depend to a large extent on the number of students who would want to take such courses, and the balance of skills required. As noted in the reviews of national systems later in this report, several countries with large fisheries have established successful B.Sc. courses in fisheries. These could be used as models for other countries and universities considering establishing such a course. This is discussed in detail in the following section.

There will remain many countries for which the total demand within fisheries for graduates at the B.Sc. level is not sufficient to support a specialized fishery course. Nevertheless there still will be a small but regular flow of graduates entering the fishing industries, or fishery administration. It is important that these graduates receive as good an education for their future work as is practicable. The importance of a multi-disciplinary approach has already been stressed as a general principle in all fishery education, but this is even more important in the smaller countries where the individual in government administration (and often in industry) is likely to have wider responsibilities than in larger administrations. Often the needs of fisheries can be served by a course in natural resources and resource management in which fisheries is treated together with for example, forestry or wildlife.

Advanced degree courses
(Master of Science, Doctor of Philosophy, typical ages 21 - 25+ years)

The person expected to move into fishery science employment (most often in fishery research of one type or another) will normally expect to specialize in fisheries at this level, although many scientists have made significant contributions to fishery research after transferring into fisheries at later stages in their careers. This latter transfer often appears to be a random or accidental process, and while it should be encouraged, it is not something that can be readily built into an organized educational structure. While the advanced degrees are generally used as a stage towards a career in fishery science and are virtually essential for this, they are also sometimes considered as a necessary stage towards a career in fishery administration. This can represent a waste, both of the time of the individual and of university facilities, and it would be preferable to ensure that the curriculum at the B.Sc. (or at most at the M.Sc. level) provides training in the scientific aspects of fisheries that is adequate for future administration. If further training is considered desirable, it would be more effective if it dealt with administration and management.

The question facing countries at this level is not whether to offer specialized courses, but whether there exists in the country the means to provide the specialized training and supervision required. It has to be recognized that many countries cannot expect to command high-level expertise in all fields, and some subjects must be neglected. This is expecially true for the smaller developing countries, for reasons of numbers in the population if no other. There has therefore been a long history of potential fishery scientists going abroad to study for higher degrees. This is in many cases inevitable, and indeed welcome, but more attention needs to be given to the location and nature of this post-graduate training.

Most of this training has been done in large temperate countries (Europe, USSR, Japan and North America). The ecological, economic and social conditions in these countries differ very greatly from those in most developing countries. The experience and training acquired may therefore not be at all relevant to the problems that the scientist will meet when he returns home. To some extent this difficulty can be reduced by a careful choice of institution. For example a Ph.D. student from Thailand studying in North America is unlikely to gain much insight to Thai problems from studying salmon, but might well find useful parallels between the multi-species trawl fisheries in the Gulf of Thailand and those on the Bering Sea or on Georges Bank. Nonetheless, more emphasis needs to be given to the possibilities of post-graduate training in countries with similar conditions. This will require action by several different groups in order to strengthen existing institutions in developing countries which already have some facilities for post-graduate training, to encourage other developing countries to send their students there rather than to the developed world, and to encourage aid agencies to support this type of training, e.g. through fellowships.

Practical work and other facilities

At whatever level, education in or for fisheries must contain adequate practical field work. However well trained in classroom or laboratory techniques a scientist may be, he is most unlikely to perform well, whether in research administration or industry, unless he has practical experience at sea or on rivers or lakes. So far as possible this experience should cover not only the practical aspects in working in difficult and often uncomfortable environments (e.g. experience in SCUBA diving), but should also include experience in commercial fisheries, and with commercial fishing vessels and gears. For example, it is very difficult to understand how a given type of gear interacts with the entire biological community in the field, unless the scientists are familiar with its practical operation and with how any type of gear takes a very biased sample of the community.

Universities offering fisheries training must therefore have access to facilities which can offer this field experience. This is not always easy, particularly as regards sea-going experience. Ships are expensive to operate. Because of larger number of students involved, the technical institutes at the pre-university level concerned with the training of ship officers and others often can better justify a special training vessel and the high proportion of the syllabus that is involved in practical sea-going work. Access to a vessel by such institutes is also helped by two factors : (i) the close links that often exist with the fisheries administration, and (ii) by the fact that because most of the training is in the operation of fishery vessels and the use of commercial types of fishing gear, there will often be appreciable catches of fish that can be sold to reduce the operational costs of the vessel. These considerations do not apply to the university level courses, and it is an exceptional and fortunate fishery group in a university that has immediate access to a vessel for the purpose of practical training.

This problem of gaining practical experience of conditions at sea, or in freshwater fisheries, has been tackled in some countries (e.g. Canada) by establishing close links between universities and government research institutes. Students taking fishery-oriented courses are given part-time employment as field staff by the government research institutes during the university vacations, particularly in summer, which is in temperate areas usually the time of greatest field activity.

This practice could be more widely followed particularly in developing countries, where the working links between universities and government research institutes are often weak. Both sides stand to gain considerably. The student gains invaluable practical experience of fishery conditions - even occasionally finding that he is not suited to go to sea in small ships, in which case he can transfer to some other subject without waste of time. The research institute gets the use of young and usually enthusiastic workers, and more particularly, early contact with potential recruits who may enter the staff in two or three years time. There are also great advantages in other forms of interaction between research institutions; apart from employment during the relatively short vacations, students might be encouraged to take a full position for a year at the completion of their first degree (B.Sc. or equivalent). They would during this period take up temporary employment, e.g. as technicians or assistants, in the research institute. In addition to general practical experience, this would give them insight into how fishery research operates which would be valuable in arranging their future studies, as well as deciding whether they wished to get into fishery research at all.

The links between research institutions and universities should also be carefully strengthened in relation to the actual process of acquiring a post-graduate degree. It is recognized that some of the outstanding work in fishery research has been carried out by scientists whose formal university training had proceeded no further than the B.Sc. (or equivalent) degree. Given the somewhat individual characteristics of fisheries, this is probably desirable. In certain individual cases, there may be little advantage in a promising scientist proceeding through the formal academic machinery rather than starting work in a fishery research institute while he still has youth and enthusiasm. This is particularly the case when the staff of the research institute can provide the younger scientist with at least as good guidance and supervision as he might receive in an average university. Nevertheless, it is also recognized that the customs in many countries demand that progress up the professional ladder research (and to some extent also in administration) is dependent on obtaining higher degrees. In such cases there could be very great advantages if part of the work towards the higher degree, especially that concerned with the preparation of a thesis or other original study, can be carried out at a fishery research institute as part of a general research programme. Arrangements of this kind are already in existence in some developed countries in which the supervision of Ph.D. students is shared between the laboratory and the university, for example in England between the Fisheries Laboratory, Lowestoft, and the University of East Anglia. With due adjustments to local conditions, similar arrangements between governmental research institutions and universities can be most fruitful.

Education in fishery science need not be confined, even in part, to university training. Many fisheries scientists in the developing world would have received training from one source or another after leaving university and starting research work at national institutes. Much of such training has been carried out by FAO and SEAFDEC (Southeast Asian Fisheries Development Center) with the support of various bi-lateral and multi-lateral aid agencies in such fields as fish stock assessment, surveys of fishery resources with acoustic methods, aquaculture, or general fishery biology. This training has been effective in providing training to small groups - often from a number of countries in the same region - which would otherwise find difficulty in receiving comparable training from any other source, largely because of the small members involved. By providing short-term and intensive training (usually over a period of two to six weeks) to small groups (usually those who have already more experience of research in governmental institutions) such training enables universities to concentrate their efforts on more general and more widely based instruction of relevance to a larger number of students.

The ready availability of both basic textbooks and journals and other material is essential for enabling staff and students to keep aware of current research and thinking. This importance of a good library has been stressed by other reports concerned with university training. It is at least equally important with respect to fisheries, and the existence of a good library is essential for good education.

Selected references and a suggested minimum list of journals concerning fisheries science and related subjects are given in Annexes I, II and III. It is recognized that the costs of books have been rapidly increasing, and the purchase of all the books that are desirable presents a serious problem, particularly for smaller institutions or those with foreign exchange difficulties. Ways should be examined in which textbooks and other material can be made more easily available to universities and other institutions in developing countries. Most textbooks are based on experience in temperate waters which is not always relevant to conditions in tropical latitudes. It is hoped that progress would be made towards a more balanced presentation particularly in respect of examples from tropical conditions.

RECOMMENDED UNDERGRADUATE LEVEL PROGRAMME

General Statement

Fishery-related training and education at the bachelor's level and higher is provided in higher technical and engineering institutions (which are equivalent to universities) and in universities, following secondary level programmes. Some institutions offer only curricula for a bachelor's degree programme in some aspect of the fishing industry which leads to job opportunities as fishery development officers, operations managers, advisors to government, processing and marketing experts or gear experts, etc. Other institutions may also provide degrees in fishery science. On the other hand, some large universities offer specialized degrees in fishery science at the Bachelor of Science level to the exclusion of the other elements of the fishing industry.

Some members of the Working Group considered that the establishment of a full fishery science department, institute, or other recognized sub-division of a university appears to be the most effective way to promote the development of a diverse and effective educational curriculum in fishery science. However, the Working Group recognized that successful and effective fishery science courses and programmes operate through affiliation with other science departments in universities as well. The reasons for preferring a departmental or organizational status for fishery science in the university is the opportunity to gather an adequate nucleus of faculty, as well as adequate library and laboratory facilities. No specific recommendations for the minimum number of faculty seems possible due to the variety of organizational structures and the difficulties in classifying faculty from related disciplines who actively contribute to fishery research and educational programmes at some universities. Several alternatives for the organization of fishery science education are acceptable, and these structures are considered a logistic rather than conceptual or educational problem.

The recommendations of the undergraduate level curricula in this section are summarized as follows. The background requirements for an advanced degree in fishery science include a considerable emphasis on the basic sciences. Historically, it has been demonstrated that a well-educated scientist in any of the basic disciplines may become a capable fishery scientist with some additional education and/or experience. Although a specialized undergraduate degree in fishery science may lead to the ability to apply some of the methods of fishery science, this degree alone is considered inadequate to provide background for new conceptual developments in most cases, and further study is desirable.

Bachelor of Science Degree without Specialization in Fishery Science-General Requirements

This section refers to undergraduate degrees in the natural or physical sciences without specialization in fishery science. Such a degree is recommended as the preferred prerequisite for advanced graduate training in fishery science. This report does not address the general education requirements for all undergraduate students in such areas as health and physical education, foreign languages, and humanities subject areas. Some social sciences will be specifically indicated if deemed applicable to fishery science however.

The nominal degree requirements for a B.Sc. in one of the natural sciences is considered to about 750 lecture hours in a basic subject, such as biology, physics, chemistry, geology or mathematics. It has been the experience of faculty involved in graduate education in fishery science that candidates who have completed degree programmes in the basic sciences, especially the physical sciences, seem to do extremely well in later work with a fishery science orientation. The background of all students preparing for an advanced degree in fishery science should involve an understanding of certain basic disciplines up to the levels indicated below:

Mathematics -

Introductory and Intermediate Calculus with Analytic Geometry - To include application of the derivative in determining maxima and minima of rates of change, applications related to trigonometric, logarithmic and exponential functions, including polar coordinates and vector algebra.

Introduction to Linear Algebra - To include studies of finite dimensional vector spaces, linear transformation, matrices, determinants, and systems of linear equations.

Biology -

General Zoology - To include physiology, development, genetics, ecology and studies of types of animals with emphasis on evolution.

Introductory Ecology - To include structure and function of ecosystems, limiting factors, population dynamics, population interactions and community relationships at an introductory level.

Physiology - To include fundamental physiological processes of animals with emphasis on homeostatic mechanisms.

Physics -

General Physics - To include mechanics, heat and sound, optics, electricity, magnetism and modern physical principles such as atomic structure and atomic spectra.

Chemistry -

General Chemistry - To include descriptive inorganic chemistry, qualitative analysis and an introduction to quantitative analysis with some attention to solution of stoichiometric problems.

Organic Chemistry - To include principles of organic chemistry with emphasis on aliphatic compounds, especially those of physiological significance, such as amino-acids, proteins, carbohydrates, fats and waxes.

Other Course Work -

Other course work in subject areas considered important for strengthening the basis for fishery science includes:

- Statistics
- Computer Science
- Geology
- Meteorology
- Oceanography
- Economics
- Management Science
- Communication Skills
- Limnology
- Botany

Bachelor of Science Degree with Specialization in Fishery Science

Usually, the requirements for a specialized degree at a baccalaureate level include completion of a core curriculum which includes some of the above-mentioned background courses considered important for advanced study. Most universities list a minimum number of lecture hours (or equivalents) in mathematics and statistics, environmental science, and social sciences required for the B.Sc. degree in the core curriculum. In addition to the core curriculum, the candidate selects prescribed courses from certain areas of emphasis. These areas of emphasis are variable, but include such subject specializations as : aquaculture (fish culture) or mariculture[1] resource management, and environmental quality. Other university programmes offer a B.Sc. in fishery science but do not list options within this area. Such degree programmes involve a list of courses which must be completed to meet degree requirements. Included in these curriculum requirements are the following: ichthyology, invertebrate zoology, fishery biology, limnology, commercial fisheries, and introduction to population dynamics. Ichthyology is here defined as a study of the systematics, evolution and zoogeography of marine and freshwater fishes.

Specialized Undergraduate Degree in Fishery Science or Equivalent

These curricula are very specialized. Local needs and capabilities should be carefully evaluated, and such curricula adopted only after it is determined that they are preferred to the general approach recommended in this report. The suitability of these curricula to Japan reflects the special conditions present there.

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1 Note that the terms "aquaculture", "mariculture" and "fish culture" do not have consistent meanings from country to country. Thus in this report, there is some variability in their usage.

The curriculum requirements in terms of undergraduate courses and options offered by the Tokyo University of Fisheries are considered as an example of a highly structured and specialized course sequence leading to the Bachelor of Fisheries degree with some specialization. Of a total 135 or more credits required for graduation, 52 credits are required in the general education programme, and the balance is from selected specialized courses in the following areas: fishing science and technology, fishing technology and engineering, food science and technology, food technology and engineering, mariculture, aquaculture, marine environmental science and technology, fisheries economics and management, and training for high school teachers. The credits listed above can be converted to other units by recognizing that one credit consists of approximately 15 lecture hours in a subject or approximately 30 laboratory hours in the case of laboratory or field experience.

Appendix II of the 1978 English edition of information concerning the "Offered Subjects and Credits in the Courses" is reproduced in its entirety as Annex IV of this report, with the kind permission of the President, Tokyo University of Fisheries, Dr. Keishi Amano. This material is used as an example to demonstrate the nature of an extremely specialized series of course sequences leading to the B.Sc. and to provide a basis for selection and comparison with other curricula.

With respect to the general education group of subjects in Annex IV, it is evident that specific language requirements, humanities and social science requirements will vary considerably among countries. However, the basic natural science requirements in the general education group are considered an acceptable minimum standard.

With respect to the specialized education programmes in the various specializations, it is evident from examination of Annex IV that some of the subjects listed are routinely offered in various departments in the larger universities. Other subjects which have descriptive terms relating to fisheries, such as fish ethology, fisheries economics, fish nutrition, pharmacology of fish, fish physiology, etc. are also taught in the more conventional sense, without special reference to fisheries. These are considered to be completely acceptable substitutes in many instances.

If an oceanographic institute or an oceanography programme is already available at the university level, then an additional list of courses related to ocean science, such as chemical oceanography, meteorology, general oceanography, coastal oceanography, biological oceanography, marine geology, dynamical oceanography and perhaps others, may already be available for incorporation into a fishery science related curriculum.

Without going into further detail, the point is emphasized that frequently at universities, in which specialized fishery science curricula are being developed, already have in place a large number of course offerings which are relevant to the fishery-related curriculum.

Full advantage should be taken of interdepartmental and interdisciplinary offerings in such departments. At some places such an approach as described above has met with resistance in the past for various reasons. The potential benefits which can assure from such an arrangement, in terms of minimizing costs and redundancy, and still broadening quality education are many. The institutional and administrative barriers preventing such multi-disciplinary interaction should be removed.

RECOMMENDED GRADUATE LEVEL PROGRAMME IN FISHERY SCIENCE

General Statement

The real core of the educational requirements in fishery science is believed to properly reside in the graduate level curriculum (post bachelor degree level). The changing and multidisciplinary nature of modern fishery science must be emphasized. Modern fishery science will require specialists in various areas of fishery science who are thoroughly familiar with the principles of basic science and trends in other disciplines. It is expected that there will be increasingly more transitions from one area of fishery specialization to some other. This will be much easier with a good scientific background prior to specialization.

In some countries as has been noted earlier, a strong liaison has been established between governmental institutions of various kinds and the university providing graduate level education in fishery science. This liaison is considered to be useful in several ways. It can result in the efficient use of facilities, the funding of relevant research projects, and effective communication between the scientists in the various institutions. Some types of facilities and equipment (such as ships and specialized laboratory facilities) are extremely expensive, and sharing is of mutual benefit.

General Degree Requirements

Master of Science (M.Sc.) Degree

The general requirements for the M.Sc. are roughly comparable among the universities and educational institutions of the industrialized countries. These usually include qualifications consisting of a B.Sc or equivalent from an accredited academic institution in a suitable subject area, and often certain minimum grade or entrance examination requirements. Competency in the language of the admitting institution is also often requested. The minimum science requirements for entrance to graduate education in fishery science have already been suggested in the report.

The Master of Science degree is usually conferred upon candidates who have successfully completed from two to four years of study beyond the bachelor's degree, and who acquire during this period a specified minimum number of credits (about 450 lecture hours) in specialized subject areas and research, and who complete a thesis and a final examination based primarily on the thesis. There are sometimes added special requirements, such as one foreign language reading competency or a comprehensive examination.

Sometimes a Master of Arts or some specialized Master's degree is offered in subject areas related to fishery science. These specialized degrees usually do not involve a thesis, and often they may be granted upon completion of a specified amount of course work and/or research.

Doctor of Philosophy (Ph.D) or Doctor of Science (D.Sc.) Degree

This degree may be earned in the area of specialization listed for the M.Sc. degree. However, the exact description of the area specialization varies by institution. Most universities, although offering subject area specialization, do not confer degrees which explicitly indicate the area specialization. However, the transcript is a reflection of the course work and research. The overall requirements for the Ph.D or D.Sc. degree include:

a) Completion of a specified minimum amount of graduate level course work or study (including dissertation credit) beyond the bachelor's degree, with some minimum grade-point or other measure of academic standards. This usually involves more than 1000 lecture hours or their equivalents.

b) A period of concentrated graduate study beyond the Master's degree level, usually involving two to four years.

c) Successful completion of a comprehensive examination (oral and/or written) usually after completion of formal study, at about the mid-point through the programme.

d) Presentation (and sometimes formal publication) of an acceptable dissertation embodying the results of an original investigation.

e) Variable foreign language requirements, ranging from one to two.

f) Successful completion of a final oral examination on the dissertation and the immediate field of investigation.

Recommended Graduate Level Curriculum

It has already been emphasized that modern fishery science requires a strong foundation in the basic sciences. Graduate studies in fishery science are best initiated after a strong academic preparation in basic sciences without undue emphasis on specialization in fishery related subjects.

Examination of the curricula of various universities offering graduate level education in fisheries and related subjects indicates a great deal of variability in the definitions of subjects and the course descriptions by subject as well as in overall educational philosophy. It is not possible to resolve these discrepancies in this report. However, an effort will be made to include brief definitions or subject descriptions when these are considered important for understanding.

Fishery research at a graduate level generally focuses on quantitative analyses of marine and freshwater fish populations, water quality, fish systematics, invertebrate fisheries, fish and invertebrate physiology, ecosystem modeling, and aquaculture (mariculture).

Advanced study (course work) in fishery science at a graduate level may be pursued in population dynamics, water pollution biology, ecology of marine fishes and freshwater fishes, taxonomy and systematics, genetics, pathology, and aquaculture (mariculture).

There are many combinations of the above at various educational institutions throughout the world. Indeed, formal course work in fishery science may not be offered at all in some universities. Yet, graduate level research and individual study under the direction of outstanding scientists is common in these institutions.

Sub-divisions of fisheries science exist, and specialized graduate level education and research in these areas is considered desirable. How many of these areas should be considered and how they should be defined depends upon the purpose of the classification. In a somewhat arbitrary manner, the following sub-divisions or graduate level options have been selected for the purposes of this report:

(i) fishery resource dynamics and assessment

(ii) mariculture - aquaculture

(iii) fishery environmental studies (including fishery-related ocean studies)

(iv) fishery management, economic and policy studies.

The definition of fishery science in this report embraces all of the above subsets of the discipline. However the subject areas of food science and technology and engineering, and fishing technology and engineering are excluded from further consideration herein.

There are obviously no clearly defined boundaries among these sub-divisions of fishery science. Some background knowledge of aquatic flora and fauna, aquatic communities, life histories of major groups, and basic principles of conservation are considered absolute pre-requisites for specialization in any of the above-mentioned areas. It is also evident that portions of several of these divisions might be combined in the graduate career of an individual. The minimum levels of competence in background subjects and in the four fishery resource options listed above are suggested as follows for an advanced degree in fishery science.

Fishery resource dynamics and assessment is defined as including statistical analysis of population data; methods of stock assessment; mathematical representation of basic population processes such as growth, mortality, and natality; application of optimization techniques to yield models; applications of parent-progeny models; analysis and design of mark-recapture experiments; and related theory and methods.

Fishery Resource Dynamics and Assessment Option:

A. Related background subjects

1) Mathematics - to include the theory of ordinary and functional differential equations, series and numerical methods, and selected topics from periodic solutions and boundary value problems. Advanced calculus and applications and partial differential equations are suggested. 45 to 90 hours beyond the baccaleureate level are suggested.

2) Statistics - to include fundamental probability and statistics, sampling and applications, and experimental design. Multivariate statistical methods are suggested. 90 to 120 hours are suggested.

3) Computer science to include algorithms, techniques and practical procedures for computers emphasizing linear computations and statistical applications. 45 hours are suggested.

B. Fishery science-related subjects

1) Fishery biology - to include principles and methods used in the study of fish populations, abundance and distribution of fishes, estimation of stocks, aging, mortality estimation, fish production estimation, and theory of fishery regulation. 45 hours are recommended.

2) Fish resource dynamics - to include analytical models for population management, mathematical implementations of basic population processes, modeling and analyses of dynamic systems, statistical properties of the estimation procedures. 60 hours are recommended.

3) Ecology of fishes - to include spawning, growth, survival, distribution in relation to environmental factors, and a study of the fisheries resources of the world oceans and freshwater environments. 45 to 60 hours are recommended.

4) Special problems in fisheries - to include classroom, laboratory or field studies on problems of current interest. Variable number of hours.

Aquaculture. This term includes culture (intensive and extensive) of aquatic organisms, which includes invertebrates and vertebrates in freshwater, brackish and marine environments. This also includes the use of hatcheries and ponds to produce fish for sport and commercial purposes; genetics, pathology, and nutrition as related to this type of husbandry. Included also are reclamation and improvement of fishing grounds, and artificial reef development and analysis.

Mariculture (Aquaculture) Option:

A. Related background subjects -

1) Biology - to include population genetics, and principles of development in addition to the minimum biology requirements for the undergraduate curriculum stated previously. 90 hours.

2) Nutrition - to include principles of animal nutrition, metabolism of carbohydrates, fats, proteins, vitamin requirements, etc. 45 hours.

3) Statistics - to include principles of experimental design. 45 hours.

4) Ecological principles - as listed in B.3 above - to include spawning, growth, survival, distribution in relation to environmental factors, and a study of the fisheries resources of the world oceans and freshwater environments. 45 to 60 hours.

B. Fishery science related subjects -

1) Mariculture-aquaculture - to include methods of production, environmental and ecological considerations, cultural practices employed for selected species, selective breeding, feeding, disease, processing and marketing. 90 hours.

2) Fishery biology - as listed - to include principles and methods used in the study of fish populations, abundance and distribution of fishes, estimation of stocks, aging, mortality estimation, fish production estimation, and theory of fishery regulation. 45 hours.

3) Special problems in mariculture-aquaculture. To include chemoreception, culturing, spawning, incubation, feed formulation, disease control, systems management, harvesting, transport or problems of current interest. Variable time requirements.

Fishery environmental studies. This is composed of two further subcourses. The first subcourse includes fisheries oceanography which involves marine weather forecasting, oceanography and ecology of fishing grounds, oceanographic and resource abundance preduction, and the relationships between fish and the environment. The other subcourse includes the broad study and application of biological and engineering principles to the solution of water pollution problems; studies of pollution sources and abatement procedures especially as related to fisheries; nutrient cycles; assessing effects of environmental perturbations; and studies of the physiological and toxicological effects of pollutants on aquatic organisms.

Fishery Environmental Studies Option:

A. Background requirements are considered similar to those listed under the fishery population dynamics and assessment option. An undergraduate degree in engineering or physical sciences is considered very helpful for this graduate level option. Specific background studies suggested are:

1) Coastal and ocean engineering - to include wave theory and forecasting, beach erosion, relevant transport, wave forces, effects of pollution on water quality, materials for ocean construction. 90 hours.

2) Environmental engineering and monitoring - to include treatment of industrial waste waters, stream and estuarine pollution, ocean waste disposal, effects of dredging and marine construction, design of monitoring plans and data analysis. 45 hours.

3) Marine meteorology, oceanography, limnology and fisheries forecasting. 45 to 90 hours.

4) Ecological principles - as listed in Mariculture A.4 - to include spawning, growth, survival, distribution in relation to environmental factors, and a study of the fisheries resources of the world oceans and freshwater environments.

B. Fishery related studies include:

1) Fishery biology - as listed - to include principles and methods used in the study of fish populations, abundance and distribution of fishes, estimation of stocks, aging, mortality estimation, fish production estimation, and theory of fishery regulation. 45 hours.

2) Water pollution biology - to include application of biological principles to the solution of water pollution problems, and physiological and biochemical effects of industrial, urban and agricultural chemicals on aquatic biota, metabolic effects of poisons on aquatic organisms and environmental monitoring. 90 hours.

Fishery management and economic and policy studies. This area includes studies of resource economics and economic theories with application to fisheries, fisheries management methodologies, sociology as related to fisheries, administrative methods, laws related to fisheries, and various research techniques with application to management.

Fishery Management and Economic Studies and Policy Option:

Background requirements are considered similar to those listed under the Fishery Population Dynamics and Assessment Option.

Relevant study areas for this option include:

1) Fishery biology - as listed previously. To include principles and methods used in the study of fish populations, abundance and distribution of fishes, estimation of stocks, aging, mortality estimation, fish production estimation, and theory of fishery regulation. 45 hours.

2) Production and operations management - to include concepts and problems associated with the design and development of systems for the creation of products and services. 45 hours.

3) Business decision theory - to include statistical analysis of managerial decision making under uncertainty using Bayesian inference and subjective probability. 45 hours.

4) Macroeconomic theory - to include static and dynamic models of aggregate economic behavior. 45 hours.

5) Microeconomic theory - to include the analytic tools of optimization, linear programming and production theory. 45 hours.

6) Other subjects of possible value for this option include: econometrics, operations research, anthropology, sociology, and fisheries law. (Hours for these are considered variable).

PART II - NEED FOR FISHERY SCIENCE GRADUATES AND CASE STUDIES

NEED FOR FISHERY SCIENCE GRADUATES

Historical Trends in Fisheries

A brief review of some aspects of the history of fishing and some indication of its future prospects in relation to man's needs may be useful in gaining an appreciation of the extent of current aquatic production and in assessing the role of fishery science education in future and related activities.

In 1850 the world catch of fish and shellfish (excluding whales) was about 1.5-2.0 million tons. By 1900 it had increased to about 4 million tons; in 1930 to 10 million tons; in 1950 to 20.2 million tons; in 1960 to 38.2 million tons, and in 1970 it was 70 million tons. Since that time the catch has not increased substantially, and fluctuations have become more apparent.

The industrialization of major fishing activities through technical innovations introduced toward the end of the 19th century set the stage for rapid expansion of the yields from traditional fisheries. Elements of this industrialization included otter trawls, steel hulled vessels equipped with steam engines, as well as better preservation, marketing and distribution. Up to about 1945, the expansion in fishing activity was limited to industrialized countries in the northern hemisphere. Shortly after that, two important developments occurred which resulted in further increases in yield. The first was the extension of industrialized fishing to include all areas of the globe through the use of long-range fishing vessels and a much greater number of nations participating in this fishery. The second major development involved the significant intensification of the fishery for pelagic species in both coastal and oceanic areas. This was due to technical developments in the methods of capture, acoustic detection, as well as the development of new market outlets, such as the use of fish-meal for livestock feeds. By 1970 the catches of pelagic species were double those of demersal fishes, and about 90 percent of the pelagic fish catch was being processed into fish-meal.

The sharp upsurge in world fish catches from 1945 to about 1970 did not include increased catches from all stocks of fish. On the contrary, for many stocks, especially those supporting the demersal fisheries, the catches were rising very slowly, if at all, indicating these have been intensively exploited for some time. Since the early 1970's the total catch of fish has fluctuated around 70 million tons. An increased exploitation of some stocks has compensated somewhat for the decline in the catch of an important single species stock, the Peruvian anchoveta.

In general, the large-scale ocean fishery development took place in areas outside national jurisdiction, then usually extending no more than 3 miles from the coast, under conditions of open access and with minimum restraint or control. This led to intense exploitation and over-exploitation of certain species. However, within the past few years, very many coastal nations have extended their jurisdiction over fisheries out to distances of up to 200 nautical miles offshore, and negotiations are proceeding in the Third UN Conference on Law of the Sea to make such action universal. The consequences of this extended jurisdiction are profound. The one of interest in the present context is that much of the world's fish catch is taken within the areas which are now or soon may come under national jurisdiction. As a result of this extension of control, coastal states now have both the opportunity and the responsibility to manage resources in ways which were not possible in the past. The challenges and opportunities which are expected to result from potential worldwide implementation of the Exclusive Economic Zone (EEZ) principle are great. Any discussion of educational requirements in fishery science must clearly recognize the educational needs for formulating sound policies and programmes within this zone.

The history of development of the modern theory related to freshwater fishery evaluation and allocation dates back to about 1950. Since that time, governments have become confronted with increasing and often conflicting demands for aquatic resource use and development. The economic and biological consequences of alternative uses of freshwater resources are serious, and the need for continued attention and further studies are appreciated. The International Symposium on "Fishery Resources Allocation" (Vichy, May 1980) of the European Inland Fisheries Advisory Commission (EIFAC) is a specific example of the importance of and attention given to this subject area at present.

Future Challenges in Fishery Management

There are still some possibilities for expansion of fisheries by traditional methods. For example, there appear to be opportunities for further exploitation in the temperate and cool parts of the southern hemisphere as well as in several tropical areas.

However, there are other approaches to increase food from the sea. One of these is the development of technology to harvest the large amounts of mesopelagic fishes of several species found throughout the world ocean and to process them in a form acceptable on world markets. The present low values of the harvested product, small size, and the unpalatable appearance seem to be limiting factors to further development of this fishery, which will partly take place outside the proposed national exclusive economic zones.

Expansion of the fishery for the antarctic pelagic crustacean *Euphausia superba* (krill) seems a possibility for the future, though it is likely that there will not be an immediate and rapid expansion need beyond the present pilot-scale catches. Again it appears that current processing technology is the major limiting factor for further development. In addition there are some problems of developing improved methods of capture. More basic research on the biology and behavior of krill, as well as ecosystems of the antarctic waters, is strongly required; an effort on this is being made internationally with a cooperational programme: Biological Investigations of Marine Antarctic Systems and Stocks (BIOMASS). Harvesting small mesopelagic fish or krill are the best examples of the superficially appealing strategy of harvesting organisms lower down the food chain than is done at present. It is generally recognized that there is a very significant energy loss at each step as calories pass through the sequence: sunlight - phytoplankton - zooplankton - small fish - large fish.

In principle it is possible to estimate the amount of food available each year in the form of fish from the world oceans. It has been estimated that the net plant production of the world oceans is about 13 thousand million metric tons of carbon fixed per year, or about 130 thousand million tons of organic matter. Due to energy transfer inefficiencies at each step in the trophic web, this amount is quickly reduced somewhat as follows:

Trophic Level	Organic Matter Production (millions of metric tons per year)
Green plants	130,000
Primary consumers (zooplankton, including krill, and anchoveta)	13,000
Secondary consumers (small fish, e.g. herrings, sardines)	2,000
Tertiary consumers (e.g. cod, croakers)	300
Quaternary consumers (e.g., tuna, sharks)	45

However, this is an over-simplified description of how the aquatic ecosystem works, and it may not be as easy as this theory suggests to increase production by changing exploitation to earlier stages in the food web. In practice it may be very difficult to harvest sufficient quantities of small low-priced animals to pay for the costs of the operation.

For the immediate future, it is clear that the bulk of the world's fish catches will continue to come from the well-known types of fish, and that the weight taken from wild stocks in the seas or freshwaters cannot be greatly increased. However, this does not mean that the supply of protein to mankind from these stocks cannot be increased. Millions of tons of fish are dumped at sea, especially by shrimp trawlers, because the fishermen cannot get an adequate price for them. Other millions of tons are landed, but are lost because of poor processing before they reach the consumer. The large part of the catch of pelagic fish which is used for fish meal is not wasted, but could supply more protein to the human consumer if the processing and marketing problems of its large scale use, other than for fish meal, could be solved.

The catch from new wild stocks could increase the total world catch perhaps 10 to 20 million tons annually under good management. If, in addition, the above problems could be dealt with, then there could be supplied about 20% of the estimated world requirements of 36 grams of protein per person per day: a good achievement for an often neglected industry, and one that fully justifies attention within the university curriculum.

Production of fish can also be increased from culture in both marine and freshwaters. Aquaculture can take many forms, from intensive culture based almost entirely on artificial feeding, through extensive culture, to stocking and enhancement of wild stocks. In the latter form, it merges into the more active forms of management of natural stocks. Though the difficulties of successful aquaculture are sometimes underestimated, and though some forms of aquaculture of valuable species (e.g. yellowtail) add little to the net supply of protein, aquaculture is an important supplement (but not an alternative) to harvesting of wild stocks. Present production from aquaculture is not well documented, but is probably around 5 million tons per year, much of it from East and South Asia, where local food preferences are biased toward fish and where alternative supplies of protein are often scarce.

Technical improvements to reduce waste, development of economically viable exploitation schemes for currently underutilized stocks, and increased aquacultural research and development are important for the future success of world fisheries, but action to manage successfully the existing fisheries is probably more important. This last aspect will require many different skills.

The first skills needed are essentially biological - to predict the effect on the stocks of proposed actions. If properly trained, the resource scientist has available to him techniques that are adequate for predicting what will happen in the traditional single species fishery of temperate waters, assuming that natural environmental conditions do not change. Few present day fisheries are of this type: most exploit a range of species, many are in tropical waters, and the natural environment does change, sometimes spectacularly (e.g. the El Niño phenomenon off Peru). The young fishery biologist must therefore be able to develop new techniques of resource assessment, as well as learn the old ones.

Fishery management is not concerned only with biology. A stock may be maintained in a productive state while the fishery based on it is in severe economic and social difficulties. The FAO ACMRR (Advisory Committee on Marine Resources Research) Working Party on the Scientific Basis for Determining Management Measures in its interim and final reports (1979, 1980) has stressed (i) the wide range of interests involved in management, which include fishermen, industry, consumers and taxpayers; (ii) the variety of interests and groups whose decisions affect the way in which fisheries are managed, which include investors, tax authorities, as well as "managers" in the narrow sense; and (iii) the number of disciplines that are required in the provision of advice to the decision makers, which include biology, economics, law. Even though in the past many fisheries were carried out partially or wholly outside the national jurisdiction, it was necessary that management decisions be made on the basis of consensus between all interested countries. This generally resulted in a least-common-denominator approach to maintaining biological protection, and economic and social considerations tended to be neglected. This has been changed by the establishment of national equivalents of the Exclusive Economic Zone (EEZ) and the negotiations concerning the EEZ in the Third UN Conference on the Law of the Sea. These developments have made it possible, indeed essential, for these aspects to be dealt with to a much greater extent in managing fisheries.

There is another aspect of managing fisheries that is requiring increasing attention, especially, but not exclusively, in freshwaters. That aspect is the use of these waters by other interests. Such use can and often does result in the alteration of the habitat in which the fish live, usually to the disadvantage of the fish and of the fishermen. This alteration is caused from various land use practices, which result in lake and stream eutrophication, thermal pollution, oil spills and siltation, and which cause the introduction of pesticides, radio-nuclides, and other non-point sources of contaminants, etc. It is vital for the future success of fisheries that, first, the nature of the impact of these non-fishery activities on fisheries is properly understood; and second, that all groups concerned with fisheries are effectively involved at a suitable stage in the relevant decision-making process, which usually means very early. For example, it is little use if it is shown that the construction of a large dam has subsequently caused ruin of the fisheries downstream; this all too often happens. The time to look at the potential impact on the fisheries was when small changes in the location or design of the dam might have reduced the adverse effects.

In summary, world fisheries are entering a challenging period. With sufficient skills in a number of disciplines, production can be maintained or even increased, more of this production can be used where it is needed, and the economic and social benefits will be increased. Moreover many of these benefits can accrue to the coastal and rural populations of the poorer countries of the world. The following section discusses in more detail how these skills will be needed, particularly with reference to future employment of those emerging from the university training programmes such as discussed in this report.

Societal Roles of Education in Fishery Science

The overall societal role, or the set of users or user groups, of science-based university education is not a simple unique role or set. In the course of society's evolution, university education inter-relates more or less closely to a number of other forms of training and education. Each form of training and education in turn contributes a number of somewhat different roles.

Table 1 illustrates one way of relating different kinds of training/education to different societal roles. As it stands, the table does not correspond exactly to what now exists in any country of the world. It approximates recent history in Japan and in the Socialist countries. It is somewhat less realistic for other developed countries, most of which are now missing the training/education component identified as "technical high school". Almost all developing countries are missing at least one of the training/education components and at least one of the societal role components shown in Table 1.

Table 1. Assessment of relative distribution of graduates according to employment and background during 1970 to 1980.

Top level of training/education achieved by individual person	SOCIETAL ROLES SERVED BY PERSONS TRAINED/EDUCATED IN DIFFERENT WAYS					
	Fishery Industry		Government Agency		College and University	
	small, non-integrated	large, integrated[a]	management, planning	research, transfer[a]	technology, teaching	scientific research[a]
On-the-job training, indefinite time	many[b]	some	few	negligible	neglibible	negligible
Technical high school,[c] e.g. 3-yr. curriculum	some	many	few	negligible	negligible	negligible
Technical college, e.g. 2-yr. curriculum	few	many	some	few	negligible	negligible
University bachelor's degree, e.g. 4-yr. curriculum	few	many	many	some	some	few
University science masters and/or doctoral degree	negligible	few	some	many	many	many[b]

a. These columns are not well developed in many developing countries

b. The absolute number of individuals characterized as"many" is much greater at the left edge of the table than at the right edge.

c. This row now well developed only in Japan, Norway, and Socialist countries; teachers are often graduates of universities with speciality in fisheries.

The more complex the interrelationship between fisheries and other industries, particularly between fisheries and other direct and indirect users of aquatic systems, the greater will be the role of advanced education and research.

With regard to Table 1, the transition or progression from one kind of training/education and societal role to another is not always easy. For example, the recipient of a highly specialized bachelor's degree may not have an adequate conventional science subject background so as to make easily the transition to a higher post-graduate degree programme which is research-oriented.

It is considered desirable for the various educational/training institutions to clearly indicate the requirements for, and the expected roles which can be satisfied at, various levels in the educational succession.

It is also considered necessary to challenge from time to time the assumption that universities and training institutions are providing their graduates with the requisite skills and background to cope with contemporaneous and future fishery science problems, and if shown necessary, to revise the curricula accordingly.

CASE STUDIES ON THE ORGANIZATION OF FISHERY SCIENCE EDUCATION

National Patterns

The working group prepared case studies of fishery science education and training in several countries where fisheries are important. These case studies served as a basis for the general recommendations given in Part I. The case studies in this section present a review of the situation in the following countries: Japan, India, Norway, Canada, U.S.A., U.S.S.R. The case of Japan is given in more detail than the others because of both the highly specialized nature of her fishery education and the highly developed character of her fishing industry.

The case studies were chosen to represent a range of national approaches and to illustrate their differences. None is recommended specifically for adoption by any user of this report. Rather the user should carefully examine the recommendations and the case studies to determine an approach that is best adapted to his own needs.

The material which follows illustrates that, in general, the industrialized nations with the greatest interest in fisheries have the most structured programmes. In a few highly industrialized nations fishery training is available at a secondary school level, and even to some extent at a lower school level. Some high schools offer fishery training, and their course offerings include fishing methods, fish processing, engineering, radio communications, aquaculture, and management. Shipboard training aboard special training vessels often is an important part of these programmes.

Beyond the secondary level of specialized training are various non-degree programmes of varying duration and requirements. Most are premised on successful completion of a secondary education or equivalent, and they lead to certificates, diplomas, licenses or associate degrees. Such training institutions can generally be classed as post-secondary vocational schools or community colleges. The graduates of specialized post-secondary specialized training schools are expected to eventually become captains, navigators, deck officers, etc. for either high seas or coastal fishing fleets, although many may start as deck-hands. In addition to the training required for the fish capture operations, some specialized training in fish processing and preservation, marine engineering, fish culture, fishery management and electronics is offered in these institutions, and some graduates become employed in these areas.

The secondary and post-secondary training described above are considered to be outside the terms of reference of this report. However, it is recognized that fishery-related training curricula in secondary and post-secondary training institutions sometimes make students aware of opportunities and stimulate general interest in later university studies in fishery science.

Case Study: Japan

The Japanese system of fishery education is illustrated in the flow chart (Table 2). In Japan, nine years of school is compulsory and high school is defined as grades Ten through Twelve. Fishery education can start from the high school level. There are 37 fisheries high schools and 15 high schools with a course in fisheries. These schools are all under the education department of the prefecture. Course content is defined by the prefectures under legal and administrative guidelines set by the Minister of Education of Japan. Each fishery high school has its own training vessel. During fishing classes, training on board is one of the most important parts of the course. Without having this practice, students cannot obtain a technical marine license and cannot become the head of the fishing crew. A fishery high school course is expected to be a terminal degree and most of the graduates go to the industry. Only a few students continue study in a university.

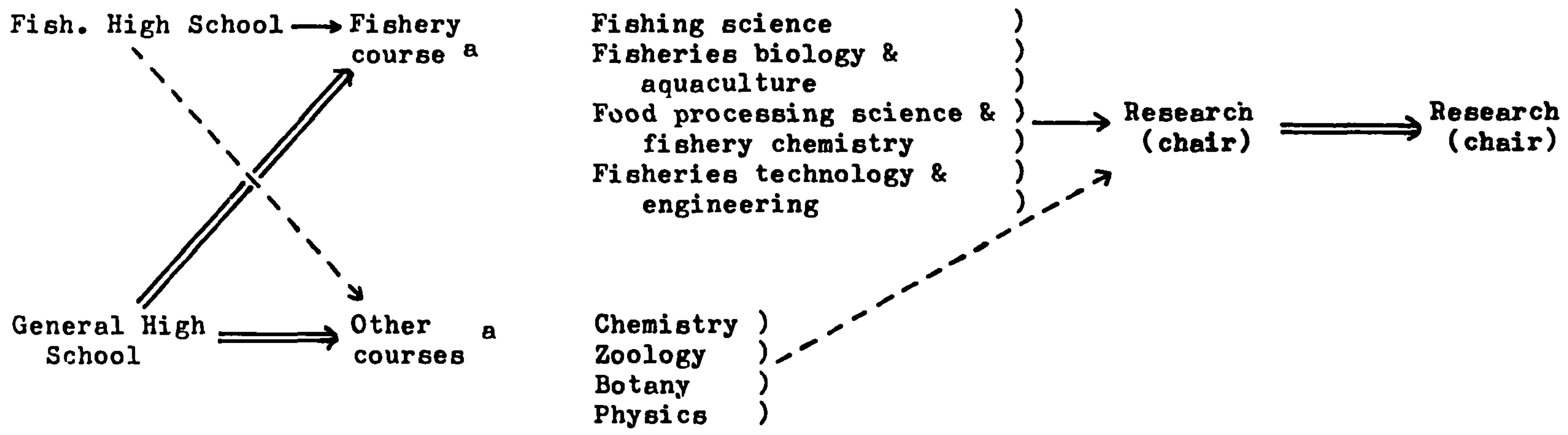
The universities provide the central basis for fisheries education and development in Japan. They provide the technical and professional personnel that do the research and education, management of the resources, administration in the governmental offices and operation of the larger fishing vessels. Most of the candidates to a university (faculty or department of fisheries) are from general high schools. There are 18 universities that have fisheries faculties (colleges) or fisheries departments within faculties of agriculture or marine science. Among them two are universities of fisheries, five are faculties of fisheries and others are departments of fisheries. Most of the departments give a general fishery programme but some are specialized in a narrow field of work such as food processing or aquaculture. Of 18 universities, four are private universities, one is under the Ministry of Agriculture, Forestry and Fisheries, and the remainder are national universities under the Ministry of Education. About 1900 students are being accepted every year in the fishery courses.

In the university, the first two years are for junior courses and students get a general education in humanities, social sciences, two foreign languages and natural sciences including mathematics, physics, chemistry and biology. Most of the education in fisheries is given in the last two years. Fishery education may be divided into the following four fields (though actual division is different depending upon the universities): (i) fishing science (fishing ground environmental study), (ii) fisheries biology and aquaculture, (iii) food processing science and fishery chemistry, and (iv) fisheries technology and engineering (or navigation). The fourth field is provided only in a small number of universities which have a large fishery education system. The curriculum for specialized fishery education is more or less similar in different universities. In departments of fisheries which have only few professors and laboratories, such as in the University of Tokyo, fishery science is not divided into further small divisions. Thus the educational system lays greater stress on the fundamental science than on the technical aspects of the subject, and the students in the third year receive various lectures and practical exercises in a broad range of general and basic fishery science subjects such as fishing methods and gears, aquatic zoology, aquatic botany, physiology, physical oceanography, statistics, aquaculture, biochemistry and food science. Besides these, general concepts of fishery economics, laws of fisheries, navigation and seamanship,

Table 2. Flow chart showing fishery-related education in Japan

The arrows indicate relative importance of the transition as follows: - - -> = little; ——> = some; ==> = major

High School (age 15 and above)	B.Sc. Degree (age 18 and above)	M.Sc. Degree (age 22 and above)	D.Sc. Degree (age 24 and above)



[a] These are terminal courses leading to employment

microbiology, and meteorology are studied. In large fishery universities or faculties of fisheries such as the Tokyo University of Fisheries and Hokkaido University, different curricula are given for each of four fields of fishery science. In both university systems, research is an important function, as it is required that the student be trained in the scientific method regardless if he is to be a captain of a fishing boat or a university professor. Thus, all students are allocated to a laboratory(chair) in the fourth year, and under the guidance of a professor they begin research on a subject to complete a graduation thesis. Besides the study in classroom and laboratory, students also carry out various types of field work for a total period of three to four weeks at marine and freshwater biological/fishery stations and training ships. Furthermore, those students who so desire can make use of their summer vacations to undergo practical training in fishing industries and research institutions.

Generally speaking at the undergraduate level education in fishery science, there is a traditional trend in Japan to put more emphasis on biology and chemistry than on mathematics and physics. Subjects related to computer science and statistics are not adequately provided within the curricula of fishery science, although students can take lessons at other faculties or departments. Fishery biology and population dynamics are often given under the category of either fishing science or aquaculture. Fishery oceanography is taught as a part of either fishing science or environmental science.

Education in graduate courses is strongly oriented toward a research purpose. Students conduct research projects under the guidance of a certain professor of the laboratory. Course work receives rather minor emphasis. Most of the work is for preparation of a thesis for the M.Sc. or Ph.D degree. Most graduate students in fishery science come from a fishery course of a university (faculty or department of fisheries). Only a few students come from other subject courses such as given in departments of zoology or chemistry.

As examples of alternate approaches, the fisheries curricula of three Japanese universities are given below:

1) The Department of Fisheries, University of Tokyo, consists of the following six laboratories (chairs): Fisheries Biology, Aquaculture, Technology of Marine Products, Fish Physiology, Fisheries Oceanography, and Marine Biochemistry. Teaching of a variety of subjects to students who are interested in a particular field of fishery science, is often provided by specialists from other departments of the university or from outside the university.

2) The Faculty of Fisheries, Hokkaido University, has four departments with 28 laboratories. Each laboratory consists of two to four teaching staff. Two training ships, one research vessel, three field stations, and a practice factory on campus belong to the faculty. The following subjects are taught in the four departments:

Department of Fishing Science and Technology : applied ecology of fishing grounds, biology of fish population, oceanography and meteorology, fishing navigation, operation technology of fishing, fishing gear engineering, mechanical engineering for fishing, instrument engineering for fishing, engineering of fishing boats, fishing boat seamanship, fisheries business economics.

Department of Food Science and Technology: food chemistry I, food chemistry II (food hygiene), biochemistry, microbiology, food technology.

Department of Chemistry: biopolymer chemistry, chemistry of fish oil, marine chemistry, analytical chemistry, chemical engineering.

Department of Biology and Aquaculture : marine botany, embryology and genetics, marine zoology, physiology and ecology, planktonology, freshwater aquaculture, marine aquaculture.

The Department of Fishing Science and Technology includes such courses as fishing ground environmental study, fishery navigation and fishery engineering. In the latter course, emphasis is put on engineering of fishing gears, fishery boats and other fishing equipment. The students in the fishing navigation course can obtain a ship officer's licence after one additional year of training with training ships of the Faculty.

3) The Tokyo University of Fisheries is an example of a well-established University organization which offers specialized education at both the undergraduate as well as the graduate levels. Qualified candidates for advanced degrees may be admitted with a specialized or a more general background of undergraduate work.

Graduate level specialization may be obtained in most of the following departments or divisions.

Fishing Science and Technology - This area specialization includes the theoretical and practical aspects of fishery production, fishery forecasting, conservation and management of fishery resources, and population dynamics. These subjects as well as certain basic marine science subjects are emphasized.

Fishing Technology and Engineering - This relates to theory and application of such subjects as fishery instrumentation, navigation, seamanship, and boat handling, for the purpose of improving fish production and the productivity of labor involved in the fishing operation.

Food Science and Technology - This area specialization includes research and education in the theoretical and practical aspects of food science related to fisheries. Curriculum offerings include biochemistry, food chemistry, physical chemistry of foodstuffs, food microbiology, food preservation and processing, as well as food hygienic chemistry.

Food Technology and Engineering - This involves education and research in subjects such as thermal process engineering, food refrigeration engineering, marine industrial chemistry, and food conversion engineering.

Mariculture - This includes biological principles and their application to the exploitation and conservation of living natural resources in the sea, with special regard to restocking and environmental improvement, as well as biological approaches to fishery exploitation. Special subjects included in this are phycology, aquatic zoology, fishery biology, animal ecology, and algae cultivation.

Aquaculture - This area involves primarily fish culture with special regard to the knowledge of reproduction and growth in relation to seed (eggs, larvae and juveniles) and rearing in intensive culture. Subjects offered in this area include ichthyology, fish physiology, fish pathology, fish nutrition and fish culture.

Marine Environmental Sciences and Technology - This relates to protection of the marine environment and pollution abatement. Subjects included in this specialization are environmental physics, fisheries oceanography, environmental instrumentation, environmental chemistry, environmental protection engineering and environmental hydraulic engineering.

It should be noted that the graduate school of the Tokyo University of Fisheries is composed of five divisions. Mariculture as well as Fishing Technology and Engineering listed above are not taught in separate divisions.

Case Study: India

In India and in many other countries of South Asia and in Africa, there has been no provision for education in fishery science below the undergraduate level. Until recently, systematic ichthyology, fish biology and fishery science have been taught along with marine biology and ecology at the graduate level for a Master's degree in Zoology, and in more recent years, in Marine Biology or Marine Sciences. There is considerable variation in the scope and level of the curricula in the various universities. In the last ten years, fishery science has been offered at the undergraduate level for a Bachelor of Fishery Science degree, at the College of Fisheries at Mangalore of the University of Agricultural Sciences. Another College of Fisheries is developing at Tuticorin in Tamil Nadu. It is felt that with relevant curricula such as contained in this report, these institutions could, for some time to come, meet the needs of the country and perhaps the needs of some of the neighbouring Asian and African countries.

There is limited scope in India for teaching fishery science at the pre-degree level. However, curricula can be developed in fishery biology and aquaculture (especially freshwater and brackish water fish-farming) for the undergraduate level, as courses to be taken along with other courses in zoology, botany and chemistry that the students are expected to take in order to fulfill the requirements for a Bachelor's degree.

The following factors bear mention in formulating curricula in fishery science at the undergraduate and graduate levels:

1) There is need for the publishing of textbooks providing information on the biology, behavior and ecology of the fishes and other exploited living resources represented in the tropical and sub-tropical waters. The warm water living resources and environment possess some distinctive features which need to be brought out for their rational exploitation and effective management. Theories and concepts evolved from studies at higher latitudes are not necessarily applicable to warm water fishes. Literature on warm water environments and their resources is widely scattered and hence not easily accessible to institutions involved in the teaching of fishery science.

2) The national universities and colleges do not maintain seaworthy boats, equipped with essential equipment and gear required to provide adequate and meaningful ship-board experience, because of their expense. Institutes and organizations run by the Government (Ministry of Agriculture) or by some of the national institutes do have well equipped research vessels. These vessels could also be utilized for providing the necessary practical training for both undergraduate and graduate students of fishery science.

3) There are institutions like the Central Institute of Fisheries Education at Bombay which could also provide training in planning and management to junior-level officers of various governmental fishery agencies from India as well as neighbouring countries, to meet the needs of the coming decades.

Table 3 provides an idea of the stages in education at which fishery science is taught at present.

There is need to organize regional workshops for the effective implementation of curricula developed by the present workshop.

Training of fishermen, other crew, engineers and technicians is done by institutions under the Ministry of Agriculture or by institutions run by the Departments of Fisheries of concerned States. It could be useful for universities involved in teaching and research in fishery science to assist in developing curricula for such institutions.

In-service and on-the-job training and refresher courses in fishery science as well as in research, planning and management in government agencies need to be stressed.

Table 3. Fishery-related education in India

Level of Education	Nature of Education
Primary and Secondary School (approx. age 15)	General
Pre-university or Intermediate (approx. age 17)	General, Physics, Chemistry, Biology
B.Sc. Degree (approx. age 20)	1. General 2. Fishery Science in agricultural universities (recent)
M.Sc./Ph.D. Degree (approx. age 22 and 25 or above, resp.)	Marine Biology/ Ecology including Fishery Science

Case Study: Norway

The material which follows concerning the Norwegian experience in fishery training/education relies almost completely on the work described by Dr. P. O. Heggelund, of the Marine Advisory Programme, University of Alaska.

Norwegian fishery training education can be categorized as follows:

(i) Fishery related education in primary and secondary schools

(ii) Special vocational schools

(iii) Universities and technical schools

(iv) Continuous (adult) education programmes

See Table 4 for a diagrammatic representation of the perceived educational sequence in Norway.

1) Primary and Secondary Schools

On the primary level, fishery and marine subjects are part of the elective courses the students may choose. On the secondary level, the students may elect two separate majors in fishery education: fishery technology and seafood processing.

2) Vocational Schools

a) Fishing Technology: This is a one-year course following nine years of primary and secondary schooling and prepares the students for the "Second Class Coast Shipper"exams. If the students (17 to 18 years old) pass the exams, the certificate is not written out until the students have 26 months of vessel experience and have passed the age of 21 years. This particular course is now given at four schools in Norway. It was first given in 1973-1974 and has been well received.

If the students want to further pursue their education in fishing technology, the traditional course for fishing skippers at the fishery vocational school is still available. This one-year course prepares the students for "First Class Fishing Skipper" certificates. At present there are five vocational schools with this curriculum in Norway. The course itself may be used as a prerequisite for students who will pursue a general maritime education.

In addition to the one-year course in fishing technology, these vocational schools also offer courses in engineering (engine) and galley cooking.

Table 4. Fishery-related Education in Norway; abstracted from a document by P. O. Heggelund (1978)

Level of Education	Nature of Education
Primary and Secondary School (age approx. 16)	Fishery and marine courses as electives in a general curriculum.
Vocational School (age approx. 17 to 18)	Fishing technology, navigation, mechanical training etc. Seafood processing
Community College (duration 1 to 2.5 years)	Fishery biology, resource science, industry, economics, co-operatives, politics, teaching
Undergraduate, B.Sc. (duration usually 4 years)	Norwegian Fishery University (consortium of four universities) fishery biology, economics, food technology, political organizations
Graduate, M.Sc., Ph.D (duration up to several years)	Norwegian Fishery University - fishery biology, economics, food technology, political organizations

b) Seafood Processing: Education in this area is also offered at two schools as a 10th year in addition to the compulsory primary and secondary education. An attempt is presently being made to solicite support from the processing industry in providing the students with employment seniority based on their education.

In addition to this one year, vocational training and additional courses are offered at the seafood processing school in Vard. There is only one of these processing schools in Norway.

Other vocational schools for the fishing industry train students at the Norwegian Canners' School, and the Federal School for Food Science.

3) Universities and Technical Schools

The Norwegian Fishery University was established in 1972 as an umbrella institution for fishery education at the Universities of Tromso, Bergen, Oslo, and Trondheim. The University of Tromso has a broad spectrum of fishery related studies including: fishery biology, fishery economics, seafood technology and political organization. The graduates receive the title of Fishery Candidates.

The Universities of Bergen and Oslo, the Norwegian Technical University (at Trondheim) and the Norwegian School of Business Administration (at Bergen) provide graduate programmes for their students in fishery biology and nutrition, seafood processing and fishery economics.

Bergen's Technical College provides, depending on student demand, a one-year course in seafood processing.

With an education from the Norwegian Fishery University, the student may obtain employment in educational and research institutions, private and public sector, extension service and numerous political and cooperative fishery organizations.

Norland Community College at Bodo offers the following courses related to fisheries :

1. The two and one half-year programme emphasizes fishery economy, marine biology and seafood processing. Upon graduation, the students qualify for employment in the private and public sector of the fishing industry, fishery cooperatives, political organizations and extension service.

2. The one-year programme emphasizes fishery resource biology and the utilization of these resources.

3. Two courses of a half year each emphasize fishery biology and marine resources and are offered for teachers in secondary schools.

The commonality of the fishery programme at Nordland Community College is its vocational emphasis directed toward educational institutions and the fishing industry in general.

4) Continuing (Adult) Education

Continuing education is offered by the Directorate of Fishery in fishing gear, electronics and navigation. Universities and other educational institutions are now also beginning to offer similar short courses, particularly within the framework of the secondary school system. This redirection, which has occurred over the last four to five years, will elevate the educational standard of the employees in the fishing industry.

Fisheries educational opportunities in other parts of Canada are not much different from those of Ontario, which are described as the case study in the rest of this section. A practically-oriented technical college related to marine fisheries has long existed in St. John's, Newfoundland. A facility for training frewshwater commercial fishermen exists at Gimli, Manitoba, but has not been very active recently. Numerous other universities have educational programmes similar to those of Ontario's universities.

Very little is taught in Ontario's primary and secondary schools that is directly relevant to fisheries matters. The opportunity to do so exists, and it would not be difficult to infuse fisheries-related material into curricula at these levels. It has apparently never been attempted, though it is likely that something will be done during the 1980s. The new strategy plan for Ontario fisheries calls for better education on fisheries matters, implicitly at all age groups.

Other than occasional short courses to a few aquaculturists, there is no opportunity for training in subject matter of direct practical interest to the fishermen and fishery industry. Almost everything is learned by them through on-the-job training, often within a family group. Ontario's Department of Education has proposed short courses to upgrade various practical capabilities, but the people in industry have not yet shown great interest in those proposals.

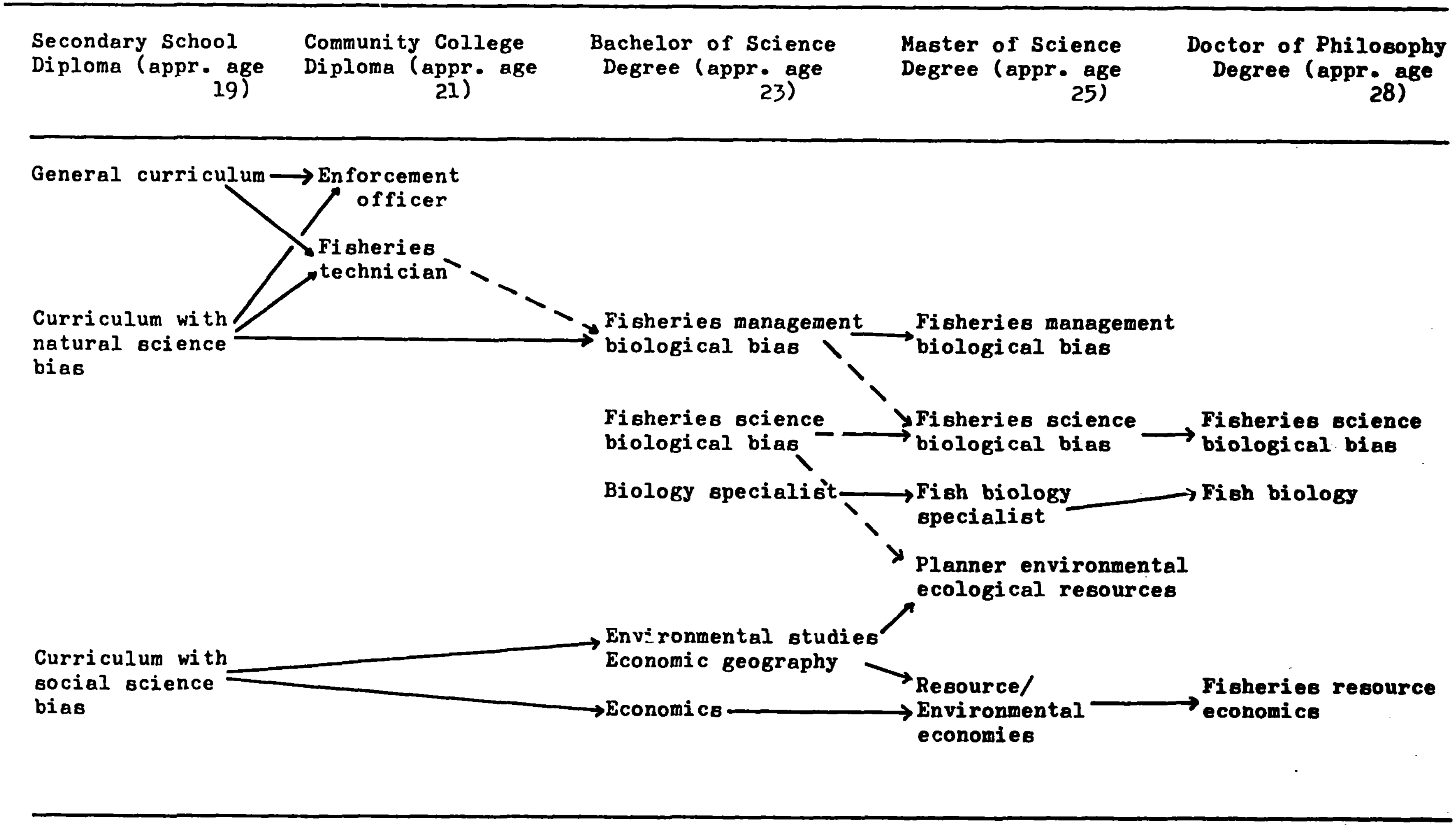
With respect to formal education, various options are sketched in Table 5. This social science sequence began to emerge in the preceding decade. The full set of options is not available within any one institution, but the opportunities are scattered among two or more community colleges and some twelve or more of Ontario's universities. Of the universities only three offer most of the university-level options shown: Guelph, Toronto and Waterloo.

The terms used in the body of Table 5 are descriptive and were chosen to facilitate understanding. They are not standard terms and are not usually entered into a particular degree document. They describe instead the nature of the curricula which are selected and aggregated by students who eventually become employed in fisheries-related fields. Only one university, Guelph, has organized and named course sequences specially for fisheries managers and researchers.

Students enrolled in fisheries-related university course sequences are generally expected to make private arrangements for the practical experience that is usually considered essential by prospective employers. Government agencies, university professors, and occasionally fishing industry and consulting firms hire students during extended holidays for field, laboratory and office experience. Operating small boats, maintaining sampling equipment and fishing gear, data collecting and processing data etc. are usually learned in this way. Most students interested in careers related to fisheries now master self-contained underwater breathing apparatus (SCUBA) techniques at their own initiative.

Table 5. Sequences of Fishery-related education in Ontario, Canada, in 1980

Dashed lines imply that the corresponding transitions are possible but occur only seldom



As undergraduates, fisheries-oriented students generally take short field courses of several weeks long at a field station in Ontario or at a marine station on Canada's east coast.

Either after the bachelor's or master's degree, or both, individuals may work for a fishery management or research agency for one or more years before continuing for an additional advanced degree. Thus for example, Ph.D. candidates nowadays will likely have published scientific papers or will have participated in practical work in Canada or abroad.

Senior researchers in government agencies are in some cases cross-appointed to graduate schools at universities. They assist in supervising graduate research and in teaching courses, usually through a voluntary partnership with a regular university faculty member. This arrangement facilitates the graduate student's use of the logistic capabilities available in a government agency; furthermore it facilitates the agency researcher's access to such university resources as libraries, and computors as well as to relatively inexpensive graduate student assistance on scientific matters of common interest. By and large such arrangements are kept relatively informal so as to avoid possible bureaucratic complications.

Fishery-oriented university students in Ontario are directly involved mostly with freshwater subjects. Upon completion of their studies at whatever level, they may seek employment or further education related to marine fisheries and have characteristically not encountered discrimination nor encountered serious difficulties in addressing marine problems.

Case Study: United States of America

There are a small number of institutions which provide training directly related to the fishing industry. These institutions offer a two year post-secondary programme leading to an Associate in Science Degree. This Degree is considered terminal and degree recipients are almost entirely employed by some segment of the fishing industry. A B.Sc. degree in fishery technology is not currently available in any college or university, although a B.Sc. degree in maritime studies is available. Most entrants into the associate degree programme come from general or vocational curricula in secondary schools and become directly involved in fishing operations when finished. A recent study by W. E. Yasso entitled "Educational Needs of the U.S. Commercial Fishing Industry, A Report to the United States Senate by the National Sea Grant Programme, NOAA" relates to perceived needs of the commercial fishing industry in the United States as a result of extended jurisdiction. The report recommends new or upgraded programmes at several educational levels including the university level, which if implemented, would provide B.Sc. and higher level commercial fishery-related curricula in U.S.A. institutions.

There are several colleges and universities in the U.S.A. which offer the B.Sc. degree with specialization in fishery biology. The degree is not necessarily terminal, although many graduates from such institutions are trained to become managers of commercial or recreational fishery resources and are employed in this capacity upon completion of degree requirements.

It is generally agreed that adequate preparation for a professional career as a fishery scientist involves further education and training to either a M.Sc. or Ph.D. level. A M.Sc. degree is considered a minimum requirement for a fishery research position, generally.

Among the features of the U.S.A. fishery education system which are considered to be somewhat unique are:

(i) There is an increasing trend for employees of State and Government agencies to take advanced professional degrees on a part-time basis after being employed by that agency for variable periods, usually several years.

(ii) There is some tendency for persons employed in the fishing industry and in fisheries agencies to take specialized degrees, such as Master of Marine Affairs, M.A. in Marine Extension, and policy and planning degrees.

(iii) There is an unusually high formal course requirement at the graduate level in U.S.A. universities, compared with West European and Canadian institutions.

(iv) There are few national standards, and thus a high degree of variability exists in the quality of curricula and degree programmes among institutions. There is a large number of universities and colleges (more than 100) offering fishery science-related courses, which range considerably in size and quality.

See Table 6 for some of the educational sequences leading to an advanced degree in fishery sciences.

Table 6 : Some sequences of fishery-related education in the United States of America

Secondary School (age approx. 18)	Post Secondary (age approx. 20)	B.Sc. Degree (age approx. 22)	M.Sc. Degree[a] (age approx. 24 and above)	Ph.D/D.Sc. Degree (age approx. 25 and above)
General or vocational curriculum (no fisheries-related specialization)	Fishing technology (Associate in Science; employment in industry)	Fishery technology (proposed; employment in industry)	Fishery technology (proposed)	Fishery science (employment in research, teaching, administration)
		Fishery management (State/Federal employment and managers)	Fishery biology (State/Federal employment or private research and development)	
		General Science (zool., chem., math.)	Science	
		Social science engineering, etc.	Master of Marine Affairs (planning)	

[a] Also specialized Master's level degrees.

Case Study: Union of Soviet Socialist Republics

General structure of fishery-related science education and training in the U.S.S.R.

Training of specialists for the fisheries industry in this country is being accomplished at different levels (see Table 7). The lowest level is the system of technical schools of the fisheries industry preparing technical personnel for fishing vessels, for fish processing and preservation factories, fisheries stations and for other related enterprises.

The next level is preparation of qualified technical personnel at the Institutes of Fisheries. There are three such institutes under the Ministry of Fisheries Industry in the U.S.S.R., which are located in Kaliningrad, Astrakhan and Vladivostok. Their structure is quite alike and there is no reason to consider them separately. These institutes include such faculties as technological, marine engineering, fishery, fishing industry, fishing navigation, economics and ichthyology. In addition in each institute, there are evening and extramural study facilities giving the opportunity to obtain an education while having a job. The graduates from these institutes are specialized respectively in marine food technology, maintenance of ship power plants, fishing industry, marine navigation, economics and food industry accounting, automatic control systems, ichthyology and fish breeding.

The need for specialists to carry out successfully the future strategy of fishery science in the U.S.S.R. is fully met. But to improve this strategy and to work out new principles and methods, specialists of a new kind and level are needed. This level is available in the universities. There are more than 60 universities in the U.S.S.R. Many of them prepare specialists in ichthyology, aquatic ecology, oceanology and oceanography, economics and planning. In addition, the universities offer post-graduate courses in the related chairs. After completing dissertations, these specialists are qualified either to lead research teams or teach related subjects in the universities and institutes as well. A discussion follows on the university level education and training.

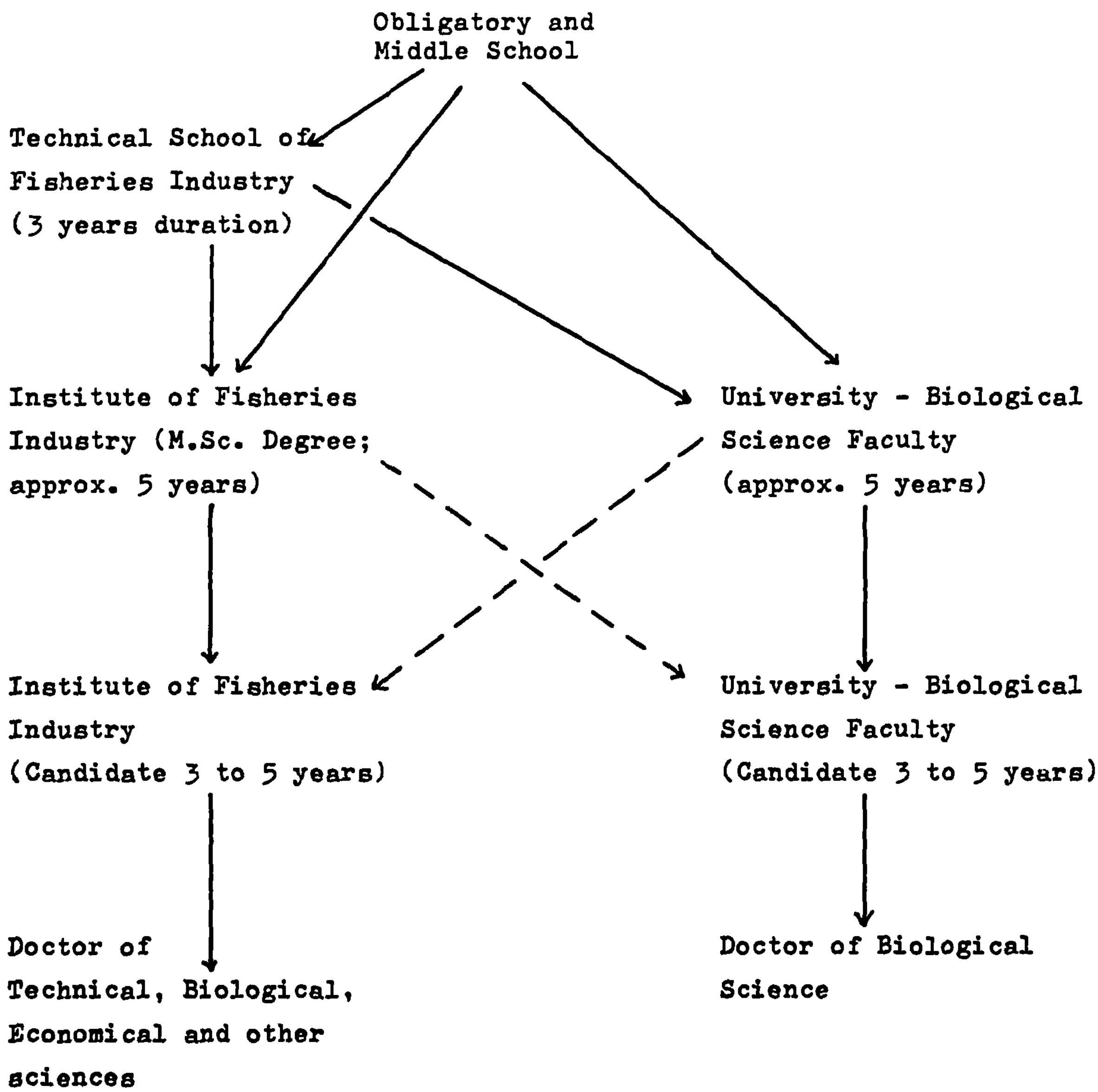
Fisheries education and training programme at the university level in the U.S.S.R.

It is not feasible to consider all universities in the U.S.S.R. Two typical universities will serve as examples: Moscow University as the leading one in the Soviet Union, and Irkutsk University, as a regional one.

Moscow University

In the Moscow University, three of the twenty departments are directly concerned with the problems of fisheries and fish breeding. The department of ichthyology trains specialists in ecology, embryology and fish behaviour and in paleoichthyology. The department of general ecology and hydrobiology deals with the problems of the role of fish

Table 7: Flow chart showing fishery-related education in the Union of Soviet Socialist Republics



in aquatic ecosystems. In addition this department offers programmes in aquatic ecology, aquatic toxicology and biological productivity of water basins. And lastly, the department of invertebrate zoology prepares marine and freshwater zoologists as well as specialists in other areas.

The curriculum of the biology faculty involves five years of study. General biology science education includes zoology, botany, ecology, physiology of animals and plants. Basic science background is ensured by a large amount of mathematics, physics, inorganic and organic chemistry, programming, physical and chemical methods of analysis. All theoretical education involves the first three years. During the fourth and fifth years, the students specialize in different areas at the departments.

Course offerings of the department of ichthyology include general ichthyology, hydrobiology, embryology, fish physiology, comparative anatomy of fishes, methods of ichthyological research, biological foundations of fish breeding and zoogeography of fishes. This involves 500 lecture hours. The other two departments offer specific courses closely related to ichthyological subjects. The department of general ecology and hydrobiology offers courses on ecological physiology of aquatic organisms, biological productivity of water basins, planktology, aquatic toxicology and mathematical planning of biological experiments. The department of invertebrate zoology offers courses on freshwater fauna, sea fauna, sea and freshwater zoogeography, and economic value of aquatic invertebrates. Practical work in systematics, anatomy, embryology, physiology, biochemistry, fish morphometry, the study of fish growth and feeding,and hydrochemistry are obtained through practical studies in the department of ichthyology (350 hours are suggested).

The students carry out summer field work at sea and in freshwater basins where they master the techniques of collecting data and making observations under natural conditions. Bases for field work are biological stations of the University in Zvenigorod near Moscow and in the White Sea. In the fourth year a student prepares a course paper, and in the fifth year a diploma paper. During all periods of education, students actively participate in research at the departments. University graduates specialized in ichthyology obtain employment in the universities, research institutes of the Academy of Sciences and in the research institutions under the Ministry of Fisheries of the U.S.S.R.

Irkutsk University

There is no special department of ichthyology in Irkutsk University. The preparation of students is ensured by the department of vertebrate zoology of the faculty of biology. Besides, aquatic ecology specialists are prepared at the department of invertebrate zoology and hydrobiology. The interfaculty department of physico-chemical biology provides specialists in mathematical methods of estimating water communities. Beyond general courses analogous to those in Moscow University, the students of Irkutsk University are offered specialization courses in general and practical ichthyology, biological foundations of fish breeding, fisheries and ichthyopathology. This involves 200 lecture hours. Practical studies in ichthyology involving 100 hours are part of the education in vertebrate zoology. Summer field work is carried out at the Baikal biological station of the University, at the Institute of Biology attached to the University and during research expeditions. Since specialization begins in the third year in Irkutsk University, each student prepares two course papers in the third and fourth years, in addition to a diploma paper.

University graduates specialized in ichthyology obtain employment as research associates, teachers, fisheries engineers in fisheries enterprises of Siberia and the Far East of this country, in laboratories of research institutes under the East Siberian Branch of the Academy of Sciences, in higher establishments, as fisheries protection inspectors, and in systems of the hydrometeorological service of the U.S.S.R.

Graduate education and training of highly qualified specialists

The best diploma graduates having an aptitude for research after some years of practical work, are recommended to continue their education through graduate courses. Graduate courses on a full-time basis involve three years, while extramural graduate courses require four years. During the education, a graduate attends seminars in philosophy and foreign language and takes examinations in a speciality, philosophy and foreign language. But the major part of this time a graduate devotes to work on the dissertation (thesis) under the guidance of one of the professors of the chosen department. By graduation and completion of the dissertation, a graduate is to have at least two to three published scientific papers. Defense of the dissertation is the final requirement of the graduate education. After successful defense a graduate is awarded the degree of Candidate of Biological Sciences. Education at the graduate level provides not only scientific workers but also highly qualified educators. A further advance in qualification can be made through the execution of practical research as assistants to leading professors. Besides, each educator of the regional universities is expected once in five years to take up three to five months of refresher courses in one of the leading universities of the U.S.S.R.

The highest degree of Doctor of Biological Sciences is granted after successful defense of the doctoral dissertation, embodying the results of a long-term original investigation and laying the foundations of new scientific trends.

In addition to their scientific and training activity, Doctors and Candidates of Sciences give instruction to young specialists who are carrying out practical work in the field of fishery and fish breeding. Much work is being done by the Doctors and Candidates of Sciences on propaganda of the latest scientific achievements among the workers of the fishery industry, through lectures directly in fish-breeding and fish-processing enterprises and on board fishing vessels.

ANNEX I

FAO PUBLICATIONS ON LIVING MARINE RESOURCES APPRAISAL[1]

Fishery

Holden, M.J., and D.F.S. Raitt, eds. 1974. Manual of fishery science. Part 2. Methods of resource investigations and their application. FAO Fish. Tech. Pap. 115 Rev. 1. 214 p. (E,F.S)[2]

Kesteven, G.L. 1973. Manual of fishery science. Part 1. An introduction to fish science. FAO Fish. Tech. Pap. 118. 43 p. (E,F,S)

Laevastu, T. 1967. Manual of methods in fisheries biology. FAO Man. Fish. Sci. 1. 10 fasc. (E,F,S)

Tomczak, G.H. 1973. Environmental analyses in marine fisheries research. FAO Fish. Tech. Pap. 170. 141 p.

Stock Assessment and Fishery Management

Beverton, R.J.H., and S.J. Holt. 1966. Manual of methods for fish stock assessment. Tables of yield functions. FAO Fish. Tech. Pap. 38 Rev.1. 67 p. (E,F,S)

Csirke, J. 1980. Introducción a la dinámica de población de pesca. FAO Fish. Tech. Pap. 192. 82 p.

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FAO. 1978. Some scientific problems of multispecies fisheries. Report of the expert consultation and management of multispecies fisheries, Rome, Italy, 20-23 September 1977. FAO Fish. Tech. Pap. 181. 42 p.

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1. FAO publications on fisheries research are issued in three main series: (a) FAO Manuals in Fisheries Science - used for major publications (b) FAO Fisheries Technical Papers - the main series for technical studies, (c) Fisheries Circulars - for preliminary studies that may be revised and then issued as Technical Papers. Other series that occasionally have papers of research interest are: (d) Fisheries Reports series - reporting on meetings of FAO Fishery Councils and Commissions and other bodies, (e) technical publications of FAO regional projects. All FAO publications are available from the Distribution and Sales Section, FAO Via delle Terme di Caracalla, Rome 00100, or from the agent for UN publications in each country.

2. Letters indicate language availability as follows : E-English, F-French, J-Japanese, P-Portuguese, R-Russian, S-Spanish.

FAO. 1978. Models for fish stock assessment. FAO Fish. Circ. 701. 122 p. (E,F)

Garcia, S., and L. Le Reste. 1980. Cycles vitaux, dynamique, exploitation et aménagement des stocks de crevettes penaeides côtières. FAO Fish. Tech. Pap. (E in prep.)

Gulland, J.A. 1969. Manual of methods for fish assessment. 1. Fish population analysis. FAO Man. Fish. Sci. 4. 154 p. (E,F,S)

Gulland, J.A. 1974 Guidelines for fishery management. Indian Ocean Programme. IOFC/DEV/74/36. 84 p. (E)

Gulland, J.A. 1977. Goals and objectives of fishery management. FAO Fish. Tech. Pap. 166. 14 p.

Gulland, J.A. 1972. Some introductory guidelines to management of shrimp fisheries. IOP/DEV/72/24. 12 p.

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Jones, R. 1976. Mesh regulation in the demersal fisheries of the South China Sea area. South China Sea Fisheries Development and Coordinating Programme. SCS/76/WP/34.

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Pope, J.A., A. R. Margetts, J.M. Hamley, and E. F. Akyüz. 1975. Manual of methods of fish stock assessment. 3. Selectivity of fishing gear. FAO Fish. Tech. Pap. 41 Rev. 1. 46 p.

Resource Surveys

Alverson, D.L. 1971. Field surveys and the survey and charting of resources. IOFC/DEV/71/6.

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Forbes, S.T., and O. Nakken, eds. 1972. Manual of methods for fisheries resource survey and appraisal. 2. The use of acoustic instruments for fish detection and abundance estimation. FAO Man. Fish. Sci. 75. 138 p. (E,F,S)

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Saville, A., ed. 1977. Survey methods of appraising fishery resources. FAO Fish Tech. Pap. 171. 76 p. (E)

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Banerji, S.K. 1974. Frame surveys and associated sample survey designs for the assessment of marine fish landings. IOFC/DEV/74/39. 15 p.

Banerji, S.K. 1975. Improvement of national fishery statistics. IOFC/DEV/75/41. 15 p.

Banerji, S.K. 1975. Applied fishery statistics: vectors and matrices. FAO Fish. Tech. Pap. 135 Suppl. 1. 34 p. (E) (F,S in prep.)

Bazigos, G.P. 1974. The design of fisheries statistical surveys - inland waters. FAO Fish. Tech. Pap. 133. 122 p. (E,F,S)

Bazigos, G.P. 1974. Applied fishery statistics. FAO Fish. Tech. Pap. 135. 164 p. (E,F,S)

Bazigos, G.P. 1976. The design of fisheries statistical surveys - inland waters. FAO Fish. Tech. Pap. 133 Suppl. 1. 46 p. (E)

Bazigos, G.P. 1977. Mathematics for fishery statisticians. FAO Fish. Tech. Pap. 169. 183 p. (E)

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Brander, K. 1975. Guidelines for collection and compilation of fishery statistics. FAO Fish. Tech. Pap. 148. 46 p. (E)

Gulland, J.A. 1966. Manual of sampling and statistical methods for fisheries biology. 1. Sampling methods. FAO Man. Fish. Sci. 3. 87 p. (E,F,S,P)

Moller, F. 1979. Manual of methods in aquatic environmental research. Part 5. Statistical tests. FAO Fish. Tech. Pap. 182. 131 p. (E)

Inland Fisheries

Welcomme, R.L., and H.F. Henderson. 1976. Aspects of the management of inland waters for fisheries. FAO Fish. Tech. Pap. 161. 40 p. (E,F,S)

Welcomme, R.L., and H.F. Henderson. 1978. Fishery management in large rivers. FAO Fish. Tech. Pap. 194. 60 p. (E)

ANNEX II

SELECTED ADDITIONAL REFERENCES CONCERNING FISHERY SCIENCE AND RELATED SUBJECTS

Fishery Science

Arrignon, J. 1976. Aménagement écologique et pisciculture des eaux douces. Gauthier-Villars, Paris. 320 p.

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Cushing, D.H. 1975. Fisheries resources of the sea and their management. Oxford University Press, London. 87 p.

Everhart, W.H., A.W. Eipper, and W.D. Young. 1975. Principles of fishery science, Rev. ed. Comstock Publishing Associates, Cornell Univ. Press, Ithaca. 288 p.

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Gulland, J.A., ed. 1971. The fish resources of the ocean, Rev. ed. Fishing News (Books), West Byfleet, Surrey. 255 p. (First published in 1970 as FAO Fish. Tech. Pap. 97. 425 p.)

Gulland, J.A. 1974. The management of marine fisheries. Scientechnica, Bristol. 198 p.

Gulland, J.A., ed. 1977. Fish population dynamics. John Wiley, London. 372 p.

Hickling, C.F. 1961. Tropical inland fisheries. Longmans, Green and Co., London. 287 p.

Hirano, T., ed. 1975. Fisheries oceanography (in Japanese). Studies in Oceanography 15. Univ. Tokyo Press, Tokyo. 214 p.

Japan International Cooperation Agency. 1974. Fisheries biology and population dynamics of marine resources. Textbook for Marine Fisheries Research Course in Tokai Regional Fisheries Research Laboratory. Japan International Cooperation Agency, Tokyo. 210 p.

Laglar, K.F., J.E. Bardach,and R.R. Miller. 1962. Ichthyology: the study of fishes. John Wiley, New York. 545 p.

Nikolsky, G.V. 1965. Fish population dynamics. (Transl. from Russian.) Oliver and Boyd, Edinburgh. xiv + 323 p.

Nikolsky, G.V. 1963. Ecology of fishes. Academic Press, London and New York. 352 p.

Nose, Y. 1979. Principles of Fisheries (in Japanese). Fishery Science Series 2. Univ. Tokyo Press, Tokyo. 280 p.

Regier, H.A. 1978. A balanced science of renewable resources, with particular reference to fisheries. Div. Marine Resources, University of Washington, Seattle. 108 p.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can. 191. 382 p.

Ricker, W.E., ed. 1971. Methods for assessment of fish production in fresh waters. IBP Handbook 3. Blackwell Scientific Publications, Oxford. 348 p.

Rothschild, B.J., ed. 1972. World fishery policy: multidisciplinary views. Univ. of Washington Press, Seattle.

Royce, W.F. 1972. Introduction to the fishery sciences. Academic Press, New York and London. 351 p.

Steele, J.H., ed. 1977. Fisheries mathematics. Academic Press, London. 198 p.

Tanaka, S., ed. 1973. Population dynamics of fisheries resources (in Japanese). Studies in Oceanography. Univ. of Tokyo Press, Tokyo. 191 p.

Welcomme, R.L. 1979. Fisheries ecology of floodplain rivers. Longman, London. viii + 317 p.

Aquaculture/Mariculture

Bard, J. 1976. Handbook of tropical fish culture. Centre Technique Forestier Tropical, Nogent-sur-Marne. 165 p.

Bardach, J.E., J.H. Ryther, and W.O. McLarney. 1972. Aquaculture: the farming and husbandry of freshwater and marine organisms. John Wiley & Sons, New York. 868 p.

Chen, T.P. 1976. Aquaculture practices in Taiwan. Fishery News (Books), Farnham, Surrey. 161 p.

Egusa S., S. Kubota, and T. Miyazaki. 1979. Pathological histology of fishes (in Japanese). Fishery Science Series 1. Univ. Tokyo Press, Tokyo. 176 p.

Forrest, D.M. 1976. Eel capture, culture, processing and marketing. Fishing News (Books), Farnham, Surrey. 203 p.

Hickling, C.F. 1971. Fish Culture. Faber & Faber, London. 317 p.

Huet, M. 1973. Textbook of fish culture, breeding and cultivation of fish. Fishing News (Books), West Byfleet, Surrey. 436 p.

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Iverson, E.S. 1976. Farming the edge of the sea. Fishing News (Books), Farnham, Surrey. 434p.

Japan Fisheries Association. 1976. Fish farming in Japan, 1975. Japan Fisheries Association, Tokyo. 44 p.

Japan International Cooperation Agency. 1975. Culture of marine life. Textbook for Marine Fisheries Research Course in Tokai Regional Fisheries Research Laboratory. Japan International Cooperation Agency, Tokyo. 164 p.

Kato, J. 1975. Guide to design and construction of coastal aquaculture pond. Japan International Cooperation Agency, Tokyo. 76 p.

Korringa, P. 1976. Developments in aquaculture and fisheries science. Vol. 1. Farming marine organisms low in the food chain. A multi-disciplinary approach to edible seaweed, mussel and clam production. Elsevier, Amsterdam. 264 p.

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Marr, A., A.E. Mortimer, and I. van der Lingen. 1974. Fish culture in central East Africa. Rome, FAO, 160 p.

Miller, J.W. 1977. Simon raises fish: a guide to fish culture extension in Africa. Rome, FAO, 47 p.

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Pillay, T.V.R., and W.A. Dill, eds. 1979. Advances in aquaculture. Fishing News (Books), London.

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Sedgwick, S.D. 1976. Trout farming handbook. Seeley, Service & Co., London. 157 p.

Shigueno, K. 1974. Shrimp culture in Japan. Japan Publications Trading Co., Tokyo. 153 p.

Spotte, S.H. 1970. Fish and invertebrate culture; water management in closed systems. Wiley-Interscience, London. 145 p.

Usui, A. 1974. Eel culture. (Transl. from Japanese.) Fishing News (Books), West Byfleet, Surrey. 186 p.

General

Anderson, L.G. 1977. The economics of fisheries management. John Hopkins Univ. Press, Baltimore.

Bogozov, V.G. 1969. The life of the ocean (in Russian). Moscow.

Bond, C.E. 1979. Biology of fishes. W.B. Saunders, Philadelphia.

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Gerking, S.D., ed. 1978. Ecology of freshwater fish production. Blackwell Sci. Publ., London.

Heggelund, P.C. 1978. Appendix D in W.E. Yasso, Educational needs of the U.S. Commercial Fishing Industry. Report by the National Sea Grant Program to the U.S. Senate.

Hoar, W.S., and Randall, D.J. Fish physiology. 8 Vols. Academic Press, London & New York.

Johnston, D.M., ed. 1976. Marine policy and the coastal community, the impact of the Law of the Sea. St. Martin Press, New York. 338 p.

Ruivo, M., ed. 1973. Marine pollution and sea life. Fishing News (Books), London. xxiv + 624 p.

Uda, M. 1960. Oceanography of Fishing Grounds (in Japanese). Fisheries Science, Tokyo. 347 p.

ANNEX III

SUGGESTED MINIMUM LIST OF JOURNALS

Advances in Marine Biology, London and New York

Aquaculture, Elsevier, Amsterdam

Aquiculture, Tokyo (in Japanese)

Archiv für Fischereiwissenschaft, Hamburg

Australian Journal of Marine and Freshwater Research, Melbourne

Bulletin, Far Seas Fisheries Research Laboratory, Shimizu

Bulletin of the Japanese Society of Scientific Fisheries, Tokyo

Bulletin, Tokai Regional Fisheries Research Laboratory, Tokyo

Copeia, New York

Fishery Bulletin, Seattle, Washington

Investigación Pesquera, Barcelona

Indian Journal of Fisheries, Ernakulam

JCRR Fisheries Series, Taipei (in Chinese)

Journal of Fish Biology, London and New York

Canadian Journal of Fisheries and Aquatic Sciences (formerly Journal of the Fisheries Research Board of Canada), Ottawa, Ontario

Journal of the Tokyo University of Fisheries, Tokyo

Marine Policy, Guildford

Meddelelser fra Danmarks fiskeriog havundersoegelser, Ny serie, Copenhagen

Kieler Meeresforschungen, Kiel

Netherlands Journal of Sea Research, Texel

New Zealand Journal of Marine and Freshwater Research, Wellington

Rapports et procès-verbaux des réunions. Commission internationale pour l'exploration scientifique de la mer Mediterranée, Monaco

Journal du Conseil, International Council for the Exploration of the Sea (ICES), Charlottenlund. (Also ICES Reports.)

Transactions of the American Fisheries Society, Washington

ANNEX IV

CASE STUDY: TOKYO UNIVERSITY OF FISHERIES, OFFERED SUBJECTS AND CREDITS IN THE UNDERGRADUATE COURSES (as of APRIL 1, 1978)

Note: In the following tables are shown the subjects offered in the academic years concerned: Freshmen (I), Sophomore (II), Junior (III) and Senior (IV) years, together with the number of credits available in each subject. A 4-credit subject means usually a one year subject: a subject repeated during two years is usually one that is begun in the second semester of one year and continued in the first semester of the next year.

I UNDERGRADUATE CURRICULA

I GENERAL EDUCATION PROGRAM

A GENERAL EDUCATION GROUP

Subjects	I	II	III	IV	Total
Humanities					
Philosophy	4				4
Ethics	4				4
Literature (Classical Japanese)	4				4
Psychology	4				4
Logic	4				4
Cultural History	4				4
Social Sciences					
Sociology	4				4
Human Geography	4				4
Law	4				4
Economics	4				4
Social History	4				4
Political Science	4				4
Natural Sciences					
Mathematics (Calculus I)	4				4
Physics I+					
Chemistry+	4				4
Biology+	4				4
Sum	60				60

+ Two of these three subjects may be offered in this group depending on undergraduate courses.

B. FOREIGN LANGUAGE GROUP

Subjects	I	II	III	IV	Total
Languages I					
English I	4				4
English II	4				4
English III		4			4
Seminar in the English Language			2		2
Languages II					
German I	4				4
German II	4				4
German III		4			4
French I	4				4
French II	4				4
French III		4			4
Russian I	4				4
Russian II	4				4
Russian III		4			4
Seminar in the German Language			2		2
Seminar in the French Language			2		2
Seminar in the Russian Language			2		2
Sum	32	16	8		56

C HEALTH AND PHYSICAL EDUCATION GROUP

Subjects	I	II	III	IV	Total
Individual and Public Hygiene	1				1

Introduction to Physical Education	1			1
Athletics	1			2
Sum	4			4
Total	96	16	8	120

2. SPECIALIZED EDUCATION PROGRAM

A FISHING SCIENCE AND TECHNOLOGY

Subjects	I	II	III	IV	Total
Group I					
Mathematics (Linear Algebra)	4				4
Mathematics (Calculus II and Exercise)		3			3
Exercise in Mathematics	2				2
Advanced Calculus			4		4
Statistics		4			4
Mathematical Statistics			4		4
Seminar in Mathematical Statistics		1			1
Physics I	4				4
Physics II		4			4
Laboratory Physics		2			2
Classical Mechanics	2				2
Exercise in Classical Mechanics	1				1
Hydraulics		4			4
Exercise in Computer Programing		1			1
Introduction to Electronic Data Processing System		2			2
Data Processing			2		2
Geology	4				4
Laboratory Geology	1				1
Meteorology		2			2
Maritime Meteorology			2		2
Introduction to Oceanography		2			2
Methodology of Oceanographic Observation and Practice		1			1
Chemical Oceanography		2			2
Environmental Chemistry			2		2
Laboratory Environmental Chemistry			1		1
Organic Chemistry		4			4
Laboratory Biology				1	1
Ichthyology		2	2		4
Laboratory Ichthyology		1			1
Aquatic Biology	4				4
Fishery Biology			4		4
Physiology of Fish		2	2		4
Introduction to Fisheries	4				4
Maritime Schooling	1				1
Training in Fishing		1			1
Training on Board I			3		3
Sum	27	33	31	1	92
Group II-A					
Fishing Methodology		2	2		4
Seminar in Fishing Methodology			1		1
Fish Ethology		2			2
Laboratory Fish Ethology			1		1
Fishing Technology I			2		2
Fishing Technology II			2		2
Science of Fishing Operation				2	2
Seminar in Science Fishing Operation				1	1
Fishing Gear		2	2		4
Laboratory Techniques in Fishing Gear		2	2		4
Fishing Gear Materials			2		2
Polymeric Materials for Fishing Gear		2			2
Laboratory Techniques in Fishing Gear Materials			1		1
Fishing Gear Designing				2	2
Seminar in Fishing Gear Designing				1	1
Population Dynamics			2	2	4
Seminar in Population Dynamics				1	1
Fisheries Oceanography			2		2
Information Science of Fisheries				2	2

Subjects	I	II	III	IV	Total
Fishing Instrumentation			2		2
Navigation I		2			2
Fishing Boat Operation		2	2		4
Fishery Mechanics			2		2
Fishing Boat Designing			2	2	4
Maritime Electric Engineering		4			4
Food Refrigeration II			2		2
Fisheries Economics			4		4
International Maritime Law				2	2
Field Trip on Fisheries			1		1
Seminar in Fishing Science and Technology				1	1
Thesis Research				4	4
Sum		16	33	20	69
Total in groups I and II-A	27	49	64	21	161
Group II-B (preparatory subjects for advanced course)					
Seminar in Navigation I			1		1
Practics in Fishing Boat Operation		1	1		2
Navigation II			2		2
Seminar in Navigation II				1	1
Capabilities of Fishing Boats			2	2	4
Fishing Boat Instruments			2		2
Laboratory Techniques in Fishing Boat Instruments			1		1
Navigational Instruments				2	2
Laboratory Techniques in Navigational Instruments				1	1
Mechanical Engineering I		2			2
Mechanical Engineering II		2			2
Maritime Legislation			2		2
Training on Board II				3	3
Training on Board III				9	9
Sum		5	11	18	34

B FISHING TECHNOLOGY AND ENGINEERING

Subjects	I	II	III	IV	Total
Group I					
Mathematics (Linear Algebra)	4				4
Mathematics (Calculus II and Exercise)		3			3
Exercise in Mathematics	2				2
Advanced Calculus			4		4
Statistics		4			4
Physics I	4				4
Physics II		4			4
Laboratory Physics		2			2
Classical Mechanics	2				2
Exercise in Classical Mechanics	1				1
Hydraulics		4			4
Mechanical Engineering I		2			2
Mechanical Engineering II		2			2
Practice in Design for Mechanical Engineering		2			2
Electronics		2			2
Seminar in Electronics		1			1
Automatic Controlling	2				2
Exercise in Computer Programing		1			1
Introduction to Electronic Data Processing System			2		2
Data Processing			2		2
Geology	4				4
Laboratory Geology	1				1
Meteorology		2			2
Introduction to Oceanography		2			2
Methodology of Oceanographic Observation and Practice		1			1
Chemical Oceanography			2		2
Environmental Chemistry			2		2
Laboratory Environmental Chemistry			1		1

Subjects	I	II	III	IV	Total
Organic Chemistry		4			4
Laboratory Biology				1	1
Ichthyology		2	2		4
Laboratory Ichthyology		1			1
Aquatic Biology		4			4
Fishery Biology			4		4
Introduction to Fisheries	4				4
Maritime Schooling	1				4
Training in Fishing		1			1
Training on Board I			3		3
Training on Board II				3	3
Sum	29	40	20	4	95
Group II					
Fishing Boat Operation		2	2		4
Practice in Fishing Boat Operation		1	1		2
Capabilities of Fishing Boats			2	2	4
Navigation I		2			2
Seminar in Navigation I			1		1
Navigation II			2		2
Seminar in Navigation II				1	1
Fishing Boat Instruments			2		2
Laboratory Technique in Fishing Boat Instruments		1			1
Navigational Instruments				2	2
Laboratory Technique in Navigational Instruments				1	1
Fishing Instrumentation		2			2
Laboratory Fishing Instrumentation		1			1
Maritime Electric Engineering		4			4
Fishing Boat Designing			2	2	4
Fishery Mechanics			2		2
Food Refrigeration II			2		2
Air Conditioning Engineering				2	2
Fishing Methodology		2	2		4
Information Science of Fisheries				2	2
Fishing Technology I			2		2
Fishing Technology II			2		2
Fishing Gear		2	2		4
Fishing Gear Designing				2	2
Population Dynamics			2	2	4
Seminar in Population Dynamics				1	1
Fisheries Oceanography			2		2
Maritime Meteorology			2		2
Legislation related to Marine Pollution				2	2
International Maritime Law				2	2
Maritime Legislation		2			2
Seminar in Fishing Technology and Engineering				1	1
Thesis Research				4	4
Training on Board III				9	9
Sum		13	36	35	84
Total	29	53	58	39	179

D FOOD SCIENCE AND TECHNOLOGY

Subjects	I	II	III	IV	Total
Group I					
Mathematics (Linear Algebra)	4				4
Mathematics (Calculus II and Exercise)		3			3
Exercise in Mathematics	2				2
Advanced Calculus			4		4
Statistics		4			4
Advanced Statistics			4		4
Introduction to Electronic Data Processing System			2		2
Physics II		4			4
Laboratory Physics		2			2
Classical Mechanics	1	1			2
Exercise in Classical Mechanics	1				1
Aquatic Biology		4			4
Laboratory Biology				1	1
Introduction to Fisheries	4				4

Subjects	I	II	III	IV	Total
Laboratory Geology		1			1
Maritime Schooling		1			1
Chemistry		4			4
Analytical Chemistry		4			4
Organic Chemistry		4			4
Biochemistry I			4		4
Physical Chemistry			4		4
Therman Engineering			4		4
Food Refrigeration II				[illegible]	2
Food Closure Science				4	4
Mechanical Engineering I			2		2
Mechanical Engineering II			2		2
Marine Industrial Chemistry I				2	2
Waste Water Treatment				2	2
Basic Laboratory Technique in Food Technology and Engineering I			1		1
Food Conversion Engineering			2		2
Thermal Engineering for Processing			2		2
Sum	31	34	23	3	91
Group II					
Microbiology		2			2
Laboratory Microbiology			1		1
Biochemistry II			2		2
Basic Food Chemistry		2			2
Food Chemistry I			2		2
Chemistry of Nutrition			2		2
Physical Properties of High Polymers			2		2
Food Hygiene		2			2
Marine Food Preservation			2		2
Laboratory Food Chemistry I		1			1
Laboratory Food Chemistry II		1			1
Applied Microbiology			2		2
Food Microbiology I			2		2
Physical Chemistry of Food Stuffs			2		2
Food Processing			2		2
Enzymology			2		2
Food Chemistry II			2		2
Chemical Thermotics			2		2
Food Microbiology II			2		2
Meat and Agricultural Food Processing			2		2
Science of Public Health			2		2
Food Packaging				2	2
Food Hygienic Chemistry			4		4
Laboratory Technique in Food Production Chemistry I			1		1
Laboratory Technique in Food Production Chemistry II			1		1
Seminar in Food Production Chemistry				1	1
Practice in Food Production			3		3
Industrial Visit			1		1
Seminar in Food Science and Technology				1	1
Thesis Research				4	4
Sum		8	41	8	57
Total	31	42	64	11	148

E FOOD TECHNOLOGY AND ENGINEERING

Subjects	I	II	III	IV	Total
Group I					
Mathematics (Linear Algebra)	4				4
Mathematics (Calculus II and Exercise)		3			3
Exercise in Mathematics	2				2
Advanced Calculus			4		4
Statistics		4			4
Advanced Statistics			4		4
Introduction to Electronic Data Processing System			2		2
Physics I	4				4

Subjects	I	II	III	IV	Total
Physics II			4		4
Laboratory Physics			2		2
Classical Mechanics		2			2
Exercise in Classical Mechanics		1			1
Aquatic Biology			4		4
Laboratory Biology				1	1
Introduction to Fisheries		4			4
Maritime Schooling		1			1
Geology		4			4
Laboratory Geology		1			1
Analytical Chemistry		4			4
Organic Chemistry		4			4
Physical Chemistry			4		4
Basic Food Chemistry			2		2
Food Chemistry I			2		2
Industrial Chemistry			4		4
Physical Chemistry of Food Stuffs			2		2
Microbiology		2			2
Marine Food Preservation			2		2
Food Processing			2		2
Food Hygiene		2			2
Laboratory Food Chemistry I		1			1
Laboratory Food Chemistry II			1		1
Sum	31	32	19	1	83
Group II					
Thermal Engineering		4			4
Fluid Mechanics		4			4
Food Processing Operation and Machinery			2		2
Thermal Installation for Processing			2		2
Practice in Designing for Mechanical Engineering		2			2
Automatic Controlling	2				2
Process Controlling			2		2
Energy Conversion		4			4
Mechanical Engineering I		2			2
Mechanical " II		2			2
Laboratory Technique in Food					
Processing Installations			2		2
Industrial Materials			2		2
Mechanical Technology			2		2
Basic Laboratory Technique in Food Technology and Engineering I		1			1
Transport Phenomena			2		2
Thermal Engineering for Processing			2		2
Food Conversion Engineering			2		2
Food Closure Science			4		4
Corrosion Science			2		2
Food Refrigeration I			2		2
Food Refrigeration II			2		2
Air Conditioning Engineering				2	2
Marine Industrial Chemistry I			2		2
Marine Industrial Chemistry II			2		2
Chemical Utilization of Sea Water			2		2
Waste Water Treatment				2	2
Laboratory Technique in Food Technology and Engineering I			1		1
Laboratory Technique in Food Technology and Engineering II			1		1
Exercise in Food Technology and Engineering				1	1
Practice in Food Production			3		3
Industrial Visits			1		1
Seminar in Food Technology and Engineering				1	1
Thesis Research				4	4
Sum	2	20	40	10	72
Total	33	52	59	11	155

F MARICULTURE

Subjects	I	II	III	IV	Total
Group I					
Mathematics (Lingear Algebra)	4				4

Mathematics (Calculus II and Exercise)			3		3
Exercise in Mathematics		2			2
Physics II			4		4
Biology		4			4
Maritime Schooling		1			1
Statistics			4		4
Introduction to Oceanography			2		2
Phycology			4		4
Laboratory Phycology			1		1
Invertebrate Zoology			4		4
Laboratory Zoology of Invertebrates			1		1
Ichthyology			2	2	4
Laboratory Ichthyology			1		1
Fundamental Ecology			2		2
Algal Ecology				2	2
Aquatic Animal Ecology				3	3
Planktology		2			2
Fishery Biology				4	4
Seminar in Fishery Biology				2	2
Ecology of Aquaculture				2	2
Seminar in Ecology of Aquaculture				2	2
Algal Cultivation and Propagation				2	2
Mariculture Technology				2	2
Sum	11	30	17	4	62
Group II					
Geology	4				4
Laboratory Geology	1				1
Introduction to Fisheries	4				4
Analytical Chemistry	4				4
Organic Chemistry	4				4
Laboratory Physics		2			2
Limnology		2			2
Meteorology		2			2
Field Study of Rocky Organisms			1		1
Laboratory Planktology			1		1
Animal Embryology			2		2
Laboratory Technique in Animal Embryology			1		1
Physiology of Algae				2	2
Laboratory Physiology of Algae			1		1
Field Study of Algal Ecology			1		1
Practice in Ecology of Aquaculture				1	1
Training in Diving Technique			1		1
Field Research in Fishery Biology			1		1
Algal Cultivation			2		2
Field Trip on Algal Cultivation and Propagation			1		1
Fish Culture				2	2
Pollution Biology			2		2
Introduction to Electronic Data Processing System			2		2
Civil Engineering in Aquaculture			4		4
Practice in Civil Engineering in Aquaculture			1		1
Coastal Oceanography				2	2
Chemical Oceanography			2		2
Training in Oceanographic Observation II			1		1
Biological Oceanography			2		2
Environmental Chemistry			2		2
Fisheries Economics			4		4
Technical Tour			1		1
Seminar in Mariculture				1	1
Thesis Research				4	4
Sum	17	11	30	10	68
Total	28	41	47	14	130

G AQUACULTURE

Subjects	I	II	III	IV	Total
Group I					
Mathematics (Linear Algebra)	4				4
Mathematics (Calculus II and Exercise)		3			3
Exercise in Mathematics	2				2
Physics II		4			4
Biology	4				4
Maritime Schooling	1				1
Phycology		4			4
Laboratory Phycology		1			1
Physiology of Algae			2		2
Invertebrate Zoology			4		4
Laboratory Zoology of Invertebrates			1		1
Ichthyology		2	2		4
Laboratory Ichthyology	1				1
Physiology of Fish		2	2		4
Laboratory Physiology of Fish		1			1
Pathology of Fish		4			4
Laboratory Pathology of Fish				1	1
Pathology of Fish		4			4
Laboratory Pathology of Fish				1	1
Fish Nutrition		4			4
Laboratory Technique in Fish Nutrition		2	1		3
Fish Culture I		2			2
Fish Culture II				2	2
Practice in Fish Culture			1	1	2
Sum	11	22	20	5	58
Group II					
Statistics		4			4
Geology	4				4
Laboratory Geology	1				1
Introduction to Fisheries	4				4
Analytical Chemistry	4				4
Organic Chemistry	4				4
Laboratory Physics		2			3
Field Study of Rocky Organisms		1			1
Limnology		2			2
Animal Histology		2			2
Laboratory Technique in Animal Histology		1			1
Animal Embryology		2			2
Laboratory Technique in Animal Embryology		1			1
Biochemistry I		4			4
Microbiology		2			2
Laboratory Physiology of Algae			1		1
Introduction to Electronic Data Processing System			2		2
Environmental Chemistry			2		2
Training in Diving Technique			1		1
Pharmacology of Fish			2		2
Practice in Pathology of Fish				1	1
Algal Cultivation			2		2
Field Trip on Algal Cultivation and Propagation			1		1
Fish Breeding			2		2
Civil Engineering in Aquaculture			4		4
Practice in Civil Engineering in Aquaculture			1		1
Coastal Oceanography				2	2
Chemistry of Nutrition			2		2
Fisheries Economics			4		4
Technical Tour			1		1
Seminar in Aquaculture				1	1
Thesis Research				4	4
Sum	17	21	25	8	71
Total	28	43	45	13	129

H MARINE ENVIRONMENTAL SCIENCE AND TECHNOLOGY

Subjects	I	II	III	IV	Total
Group I					
Mathematics (Linear Algebra)	4				4

Mathematics (Calculus II and Exercise)		3			3
Exercise in Mathematics	2				2
Physics I	4				4
Physics II		4			4
Statistics		4			4
Laboratory Physics		2			2
Advanced Calculus			4		4
Mathematical Statistics		2	2		4
Seminar in Mathematical Statistics			1		1
Classical Mechanics	2				2
Wave and Oscillation Theory		2			2
Seminar in Wave and Oscillation Theory		1			1
Electronics		2			2
Seminar in Electronics		1			1
Hydraulics		2			2
Exercise in Hydraulics		1			1
Automatic Controlling	2				2
Mechanical Engineering		2			2
Introduction to Electronic Data Processing System			2		2
Data Processing Theory			2		2
Marine Soil Mechanics			2		2
Surveying			2		2
Practice in Surveying			1		1
Marine Construction Materials		2			2
Strength of Materials		2			2
Structural Mechanics for Marine Environment			2		2
Industrial Technology			2		2
Analytical Chemistry	4				4
Organic Chemistry	4				4
Physical Chemistry		4			4
Introduction to Oceanography		2			2
Meteorology		2			2
Marine Geology		2			2
Geology	4				4
Laboratory Geology	1				1
Methodology of Oceanographic Oberservation and Practice	1				1
Training in Oceanographic Observation I	1				1
Training in Oceanographic Oberservation II		1			1
Introduction to Fisheries	4				4
Laboratory Biology				1	1
Fishery Biology			4		4
Fundamental Ecology		2			2
Algal Ecology			2		2
Aquatic Animal Ecology			3		3
Pollution Biology			2		2
Aquatic Biology		4			4
Maritime Schooling	1				1
Sum	33	46	34	1	114
Group II					
Dynamical Oceanography I			2		2
Dynamical Oceanography II			2		2
Dynamical Oceanography III				2	2
Coastal Oceanography				2	2
Seminar in Marine Environmental Physics				1	1
Marine Meteorology			2		2
Descriptive Oceanography			2		2
Fisheries Oceanography			2		2
Seminar in Fisheries Oceanography			1		1
Ocean Environment Metrology I			2		2
Ocean Environment Metrology II			2		2
Instrumentation for Ocean Environments Studies			2		2
Laboratory Technique in Instrumentation for Ocean Environment Studies			1		1
Chemical Oceanography			2		2
Material Cycle			2		2
Environmental Chemistry			2		2
Laboratory Technique in Environmental Chemistry			1		1
Chemical Engineering for Water Treatment			2		2

Bio-Engineering for Water Treatment				2	2
Practice in Environmental Protection Engineering				1	1
Hydraulic Model Test			2		2
Environmental Hydraulic Engineering I			2		2
Environmental Hydraulic Engineering II				2	2
Laboratory Technique in Environmental Hydraulic Engineering				1	1
Simulation for Hydraulic Engineering				2	2
System Dynamics of Environmental Protection			2		2
Design and Drafting of the Ocean Structures			1	1	2
Working Methodology in Marine Construction				2	2
Waste Water Treatment				2	2
Legislation related to Marine Pollution				2	2
International Maritime Law				2	2
Seminar in Marine Environmental Science and Technology				1	1
Thesis Research				4	4
Sum			34	27	61
Total	33	46	68	28	175

I FISHERIES ECONOMICS AND MANAGEMENT

Subjects	I	II	III	IV	Total
Group II					
Fisheries Management I			2		2
Fisheries Management II				2	2
Business Administration		4			4
Accounting			4		4
Economic History of Fisheries			2		2
Industrial Policy in Fisheries				4	4
Resource Economics			4		4
International Marine Administration				2	2
Civil Law and Commercial Law		4			4
Industrial Technology			2		2
Structure of Industry				2	2
International Economics			2		2
International Relations in Fisheries			2		2
Fisheries Sociology			2		2
Fisheries Laws and Regulations			2		2
Financial Theory of Fisheries			4		4
Fisheries Marketing				2	2
International Maritime Law				2	2
Co-operative Societies				2	2
Business English				2	2
Exercise I			2		2
Exercise II				2	2
Field Survey			1		1
Seminar in Fisheries Economics and Management				1	1
Thesis Research				4	4
Group II Total		8	33	25	66

J TRAINING FOR HIGH SCHOOL TEACHERS

Subjects	I	II	III	IV	Total
Principles of Education I	2				2
Principles of Education II	1				1
History of Education		2			2
Seminar in Education			2		1
Educational Psychology I		2			2
Education Psychology II		1			1
Exercise in Educational Psychology			2		2
Methodology in Teaching of Fisheries I			2		2

Methodology in Teaching of Fisheries II			1		1
Methodology in Teaching of Science I			2		2
Methodology in Teaching of Science II			1		1
Methodology in Vocational Education			3		3
Methodology in Industrial Education			3		3
Moral Education				2	2
Educational Technology			2		2
Exercise in Teaching in High School I				1	1
Exercise in Teaching in High School II				1	1
Industrial Psychology			2		2
Vocational Guidance			2	2	4
Total	3	11	18	4	36

II CURRICULUM OF ADVANCED COURSE FOR SEAMANSHIP

Subjects	Credits
Navigation	
Advanced Instrumentation in Navigation	2
Radio Wave Engineering	2
Advanced Navigation	4
Seamanship	
Advanced Boat Operation	4
Hygience in Ship	2
Marine Engineering	2
Law	
Maritime Traffic Rules	2
Sum	18
Training on Board	21
Total	39