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AQUACULTURE IN JAPAN:
POTENTIAL RELEVANCE TO CANADIANS

by

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PREFACE

In a report "Aquaculture: A Development Plan for Canada", the Science Council of Canada stated "Canada must quickly adopt, adapt, and develop the necessary techniques for a viable aquaculture industry before the window on market opportunities closes". The Council further emphasized that "at both the levels of governmental policy and industrial application, a great deal can be learned from other countries". This statement is based on the final report of the Industry Task Force on Aquaculture created on the recommendation of the Council at the first National Aquaculture Conference held in St. Andrews, N.B., in 1983, under the co-sponsorship of the Department of Fisheries and Oceans and the Council.

I undertook a survey of aquaculture in Japan as a part of my Professional Development Leave projects between November 7, 1984 and April 30, 1985. The objective was to gather first-hand information on research and development of fisheries with an emphasis on aquaculture in Japan. This report presents a summary of my inspection visit to major aquaculture sites and research establishments as well as a synthesis of information gathered on the present state and new trends in fisheries in general. Topical research activities of potential relevance to Canada have also been reviewed, however, no attempt has been made to give a detailed description of practical application of the aquaculture currently in use in Japan.

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TABLE OF CONTENTS

	Page
PREFACE	ii
ABSTRACT/RÉSUMÉ	iv
1. INTRODUCTION	1
2. PRESENT STATE OF FISHERIES IN JAPAN	1
2.1 Supply and demand for fishery products	1
2.2 Trade of fishery products	1
2.3 Marketing	2
2.4 International cooperation and aid	2
2.5 Current issues and problems in fisheries	2
3. FISHERIES MANAGEMENT AND SYSTEMS	3
3.1 Fishing right and licensing system	3
3.2 Fisheries cooperatives	4
3.3 Fisheries financing	5
3.4 Organization of government agencies	5
4. FISHERIES RESEARCH AND EDUCATION	5
4.1 Prefectural fisheries experimental stations	5
4.2 National fisheries research institutions	5
4.3 The role of the Agriculture, Forestry and Fisheries Research Council	5
4.4 Management and philosophy orienting the conduct of research	7
4.5 Technology transfer from laboratories to industry	7
4.6 Education and training	7
4.7 International cooperation	7
5. AQUACULTURE AND SEA FARMING	8
5.1 Present state of aquaculture	8
5.2 Concept and prospects of sea-farming	9
5.3 Salmon ranching	9
6. TOPICAL RESEARCH ACTIVITIES OF POTENTIAL RELEVANCE TO CANADA	10
6.1 Marinopolis plan	10
6.2 Biotechnology - research and development	10
6.3 Fish health program	11
7. CONCLUSIONS	11
8. RECOMMENDATIONS	12
9. REFERENCES	13

LIST OF TABLES

Table		Page
1	Comparison of seasonal variations in the climate of Sapporo, Tokyo, Kagoshima, and Winnipeg	14
2	Organization of fisheries cooperatives and their prefectural and national associations	15
3	Organizational structure of Fisheries Agency, Ministry of Agriculture, Forestry and Fisheries	16
4	National fisheries research institutes and laboratories.	17
5	Structural organization of the National Research Institute of Aquaculture	18
6	Number of aquaculture firms in Japan	19

LIST OF FIGURES

Figure		Page
1	Major ocean currents influencing the climate in Japan	20
2	The total fish catch by the world's major fishing countries	20
3	Major exporting countries of fisheries products to Japan	21
4	Major landing ports of fishing products and wholesale markets in Japan	22
5	Trends in fishery production by sectors	23
6	Kumamoto Prefectural Inland Water Fisheries Experimental Station	24
7	Allocation of research personnel by research field among the national fisheries research laboratories.	25
8	The National Research Institute of Aquaculture	26
9	Culturing of a variety of shellfish in a bay off northern Japan	27
10	Yearly increases in the total fisheries production and aquaculture production	27
11	The total marine and inland water fisheries productions in Japan	28
12	Coho salmon cage culture in the Shizugawa Bay, Miyagi Prefecture	29
13	Increase in the survival rate by optimizing the timing of fingerling release by intermediate rearing operations	30
14	Location of National Sea Farming Centres with their head office in Tokyo and the list of species currently under large-scale stocking operations.	30
15	Kagoshima Prefecture Sea Farming Centre, Tarumi, Kagoshima.	31
16	The total number of yearly return of chum salmon	32
17	An artist's view of the marine ranching operation of sea bream at the Saeki Bay, Oita and a buoy (27 m high) generating echoes for feeding fish and transmitting various data to the control centre.	33

LIST OF APPENDICES

Appendix		Page
1	National fisheries research laboratories and institutes	34
2	Universities and colleges with fisheries faculty or department	35
3	Biotechnology research currently underway at prefectural fisheries experimental stations under the Regional Biotechnology Research and Development Program	36

ABSTRACT

Hara, T.J. 1988. Aquaculture in Japan: potential relevance to Canadians. Can. Tech. Rep. Fish. Aquat. Sci. 1574: iv + 36 p.

This is a summary report on fisheries, particularly aquaculture research and development in Japan, based on on-site visits and a literature review between November, 1984 and April, 1985. Current trends and problems in Japanese fisheries' organization, management, and operations are evaluated. However, no attempt is made to give technical details on fisheries practices.

In Japanese fisheries the emphasis now is given to development of free ranging fish farming and marine ranching supported by basic and applied research rather than intensive aquaculture. Topical research activities including biotechnological development of potential relevance to Canada are described. Areas in need of research and development are recommended to ensure long-term stability in resource management, exploitation, and product marketing in Canadian fisheries.

Key words: fisheries; sea farming; marine ranching; biotechnology; fish health.

RÉSUMÉ

Hara, T.J. 1988. Aquaculture in Japan: potential relevance to Canadians. Can. Tech. Rep. Fish. Aquat. Sci. 1574: iv + 36 p.

Il s'agit d'un rapport sommaire sur les pêches au Japon, en particulier sur la recherche-développement dans le domaine de l'aquaculture, établi comme suite à des visites d'installations dans ce pays et à un recensement des publications sur le sujet entre novembre 1984 et avril 1985. Les tendances et les problèmes actuels inhérents à la structure, à la gestion et aux opérations des pêches au Japon sont évalués, mais on ne donne aucun détail technique sur les procédés de pêche.

Dans le milieu des pêches au Japon, on met actuellement l'accent sur le développement de l'élevage en liberté, en pisciculture et en pacage marin - des travaux de recherche fondamentale et appliquée viennent d'ailleurs soutenir cet effort -, plutôt que sur l'aquaculture intensive. On y décrit les activités de recherche spécialisée, notamment les travaux dans le domaine biotechnologique qui peuvent être appliqués au Canada. Les secteurs où des recherches ainsi que des travaux de développement s'imposent sont mis en lumière afin que soit assurée la stabilité à long terme de la ressource quant à l'exploitation, la gestion et la commercialisation des produits des pêches canadiennes.

Mots-clés: pêches; aquaculture; élevage en pacage marin; biotechnologie; santé des poissons.

1. INTRODUCTION

The Japanese archipelago, situated off the east coast of the Asian continent, consists of the four principal islands of Hokkaido, Honshu, Shikoku, and Kyushu, plus thousands of smaller islands. It stretches over 3000 km from the north-east to south-west, between latitudes 45°33' and 20°25' north. In area, Japan is 377 728 km^2, roughly one-twenty-seventh the size of Canada. It lies in the temperate zone, and has abundant vegetation. Japan is 74% mountainous with an extremely irregular coastline of about 33 000 km. It abounds in good natural harbours, aiding greatly in industry, transportation, trade, and fisheries.

Japan enjoys four regular and distinct seasons, and their climatic changes are much greater than in other countries in the temperate zone, particularly in temperature and amount of precipitation (Table 1). The climate of Japan is much influenced by two oceanic currents (Fig. 1). The warm Japan Current, or Kuroshio, originates in the Northern Equatorial Current north of the Philippines. It flows along the eastern coast of Taiwan and the Nansei Islands where it divides into two streams. One stream flows along the eastern side of Shikoku and Honshu before turning east toward the Aleutian Islands, while the other flows west of Kyushu and into the Sea of Japan (Tsushima Current). The fertile cold Kurile Current, or Oyashio, begins in the Sea of Okhotsk and the Bering Sea and passes along the eastern shores of Hokkaido and Honshu until it meets the Japan Current.

The surrounding seas are a major economic asset for Japan. Relative scarcity of cattle, together with the Buddhist prejudice against the taking of animal life, have made the Japanese fish eaters for most of their history. Thus fishing in both inland and sea waters has traditionally been of major importance to the Japanese. The total annual fisheries production has steadily increased since modernization of the country began in the middle of the last century. However, with the implementation of the 200 mile zone of extended jurisdiction by the world nations, and a changing national economy pattern, fisheries in Japan are confronted with new problems. To cope with these difficulties Japanese fisheries are examining various measures such as promotion of sea farming and restructuring of fisheries management systems.

Aquaculture, the cultivation and harvesting farming) of aquatic plants and animals, is an established, profitable industry in many countries. Aquaculture production increased so rapidly in the last decade that it accounts for more than 10% of the world's total catches of fishery products. Japan is the acknowledged world leader of aquaculture when the entire range of species and culture environments is considered. Some of the most advanced and variable aquaculture enterprises are carried out with strong support by all levels of government. Prefectural governments designate the areas to be used for aquaculture, and the local fishermen's cooperative associations, unique and highly effective organizations, allocate subareas to individual aquaculturists at no charge. In Canada, aquaculture is still a developing industry. The purpose of this report is to describe the Japanese model for fisheries resource husbandry for Canadian fisheries managers interested in pursuing a comprehensive aquaculture industry.

2. PRESENT STATE OF FISHERIES IN JAPAN

2.1 SUPPLY AND DEMAND FOR FISHERY PRODUCTS

Japan is the largest consumer of fish products in the world. The total demand in 1982 was estimated at 12 million metric tons, of which 11.3 million tons were for domestic consumption. Nearly 8 million tons were for direct human consumption, and the rest for livestock and fish feeds. Although the total demand for domestic consumption is increasing annually, the demand for feeds has stabilized in recent years. With the estimated Japanese population at 120 million, the per-capita consumption of fishery products is about 65 kg per annum. Of the total animal protein taken daily per person 45% is derived from fishery products compared to 4% in Canada and the United States, where major sources of animal protein are livestock and poultry products.

The total fishery production of the world is estimated at 70 million tons, of which 10 million tons are produced by Japan (Fig. 2). Despite a continuing decrease in far sea fisheries production, the total catches show a yearly increase, due primarily to increased sardine and mackerel fishing. Sardine alone accounts for 40% of the total catches, 85% of which are processed for livestock and fish feeds. There have been varying demands for different fishery products, reflecting changed life styles among Japanese people; the six most popular products are squid, salmon, shrimp and crab, tuna, and jack mackerel.

2.2 TRADE OF FISHERY PRODUCTS

In order to meet demand, Japan imports various fishery products from other countries. The majority of imports are from the United States, Korea, Taiwan, India, Indonesia, and Canada (Fig. 3). In 1984, Canada exported various fishery products totalling 233 million dollars, representing 4% of the total Canadian exports to Japan. Herring roe is highest at 106 million dollars, followed by capelin, salmon, and crab, amounting to 32, 29, and 25 million dollars, respectively. Japan exports processed products such as canned mackerel, sardine, tuna, and fish oil to the United States, Taiwan, Hong Kong, and other countries. Thus, Japan imports fishery products totalling 5.5 billion dollars annually accounting for 23% of the world's trade values, and exports products worth 1.5 billion dollars. Canada, the leading exporter, exports fishery products amounting 1.3 billion dollars, or 8.8% of the total world's fishery products, and imports 300 million dollars worth of products yearly.

2.3 MARKETING

Effective marketing systems have been developed reflecting demands for quality, freshness and diversity. Two major marketing areas are identified, landing or production and consumer districts. Fish and shellfish landed at fishing ports are sold to wholesalers and processors through auction or open tender at wholesale markets. Species to be marketed fresh are immediately sent out to major national wholesale markets (Fig. 4). Technological advancement in cold-storage networks (cold chain) and processing has created tremendous changes in the distribution pattern. The frozen and processed products have replaced traditionally preferred fresh products. One notable commodity is the minced meat products of Alaskan pollack, widely known as "Kamaboko". Its production has increased by almost 20 times during the past 10 years.

In the consumer districts, the products from the producing district markets are dealt by wholesalers and brokers, through auction or tender to central wholesale markets of major cities. The central wholesale markets established in 53 major cities under the permit of the Ministry of Agriculture, Forestry and Fisheries, handle approximately 4 million metric tons of vegetable and fishery products, or 20 billion dollars annually. The total annual value of the fishery products amounts to 8.5 billion dollars. More than 400 local wholesale markets licensed by prefectural governments finally distribute the products to retailers. Reflecting consumer's demand, the total volume of processed products handled in the markets has increased dramatically, with little or no change in the proportions for fresh and frozen products in recent years. Fish retail stores had enjoyed a 70% share of the total retail markets until the early 1960s. The dramatic increase in the number of supermarkets and convenience stores reduced this to 40%. To cope with the competition, traditional fish retail stores are trying to attract consumers by introducing new management ideas, such as stocking fresher, high quality products.

2.4 INTERNATIONAL COOPERATION AND AID

Japan is actively involved in international cooperative aid programs to promote development of fisheries in developing countries. During the 1983-1984 fiscal year, a total of 36 countries received financial and technical aid through either governmental or private sectors. Capital grants totalled 50 million dollars. The following are the major overseas fisheries cooperation and aid programs.

i) Capital grants (governmental) were established in 1973 to contribute to improving the socio-economic infrastructure of developing countries. The non-repayable grants may be used for projects including the construction of training facilities, training and research vessels and fishing ports. During the period from 1973 to 1983, a total of 290 million dollars were distributed to 93 projects among 44 countries (33% African, 26% Oceania, and 24% Asian countries).

ii) Technical aid (governmental) is supplied by providing instructors and advisors and training fisheries personnel from developing countries through the Japan International Cooperation Agency. Technical assistance was also provided to specific projects such as fish culture in Chile, seawater aquaculture in Indonesia, coastal aquaculture in Thailand, fishery processing in Peru, fisheries education in Argentina. One of the unique programs is the Overseas Cooperation Volunteers. The agency provides teams of young fishery personnel who live together with native people to participate in fish farming, processing, and the development of fisheries cooperatives.

iii) Overseas Fishery Cooperation Foundation Projects is a non-profit organization to aid private-sector fisheries development in various countries throughout the world. The program covers broad areas including loans through Japanese fishing firms to promote joint ventures, technical aid expertise advice, training , supply of fishing equipment, and invitation of key fisheries personnel to visit industries and exchange views.

iv) Joint ventures were initiated by major Japanese fishing companies in 1953 to direct investments to oversea fishing industries. Nearly 200 joint-venture companies have been established in the areas of fishing, aquaculture, cold storage, and fish processing in over 44 countries.

v) Joint research and survey of fishery resources by the Japan Marine Fishery Resource Research Centre was established in 1971 to aid the development of fishery resources in other fishing countries. With the support and guidance by the central government, the Centre conducts comprehensive surveys of fishery resources jointly with other coastal nations. Recent projects include distribution and ecology of sablefish and cod off the Aleutian Islands, stock assessment of squid and bottom fishes off New Zealand, and stock assessment of krill in the Antarctic waters.

2.5 CURRENT ISSUES AND PROBLEMS IN FISHERIES

Despite continuing increases in the annual production of fishery products, there is not always a favourable national and international environment surrounding the Japanese fishery industry. Major problems and remedies include:

i) Stagnant demand for fishery products--Per-capita consumption of fishery products (65 kg) has been relatively steady for the last 10 years. Because annual consumption of livestock products has increased considerably over the same period (from 10 to 15 kg), consumers are becoming less dependent on fishery products for protein. Consumers, especially the younger generations, eat less fish products, and avoid traditional fresh fish preferring newer processed products. To promote consumption of fishery products the government has initiated special measures including stabilization of the price and supply, and promotion of public awareness of scientific information on nutritional characteristics of fisheries products. For example, there is convincing evidence that cardiovascular disease, the leading cause of death in the western world, is diet related. People are now learning that fish and shellfish meats contain high levels of polyunsaturated fatty acids such as arachidonic acid, eicosapentanoic acid (EPA), and docosahexanoic acid, which are potent in lowering blood cholesterol. EPA is predominant in red fish meat of marine species (sardines, mackerels, and sauries) and freshwater species (eels, carps, and rainbow trout). The average Japanese eat four to six times as much seafoods than westerners, which is implicated in their substantially lower risks of heart disease. EPA also helps prevent blood clots, a major cause of heart attacks. Taurine, an amino acid, also abundant in fish and shellfish, and its conjugates particularly with arginine (taurocyamine), are potent agents for lowering serum cholesterol levels.

ii) Shifting emphasis from oceanic fishing to coastal fishing---Japanese fishing boats once sailed all seven oceans of the world chasing huge schools of fishes. However, such ocean fishing operations have been severely hampered as a result of adoption of the 200-mile exclusive fishing zones by coastal nations. Nearly all major fishing grounds in the world fall within this limit. The central government is trying to secure fishing agreements with these countries through diplomatic channels. There is, however, an obvious need to develop alternative sources of marine protein, large enough to meet the nation's demand. The total fishery product shows an increase of offshore catches of sardines, but overall the far-sea fisheries are declining (Fig. 5). Japan's marine product industry is now in transition from the traditional ocean "catching" to a new "cultivating" system in coastal waters.

iii) Unstable fisheries operations -- Continuing price increases of oil, movement of the youth labour force away from fishing communities, and sluggish national economy contribute to current unstable fishery operations. In 1982, 437 000 fishermen from 212 000 fishery enterprises engaged in Japan's marine fishing operations. This represents 2.6% decrease from that of previous years. In contrast, small scale household industries accounting for 96% of the total coastal fishery showed a slight increase. A marked decrease was registered in the number of young males in the fishing work force while the proportion in the middle-aged group increased. To stabilize fishery industries, measures have been taken to rationalize fishery operations through energy conservation, cost-cutting, and through structural reorganization.

3. FISHERIES MANAGEMENT AND SYSTEMS

All fisheries operations are regulated under two pieces of legislation, the Fisheries Act and the Fisheries Resource Conservation Act. Under these acts, the Minister of Agriculture, Forestry, and Fisheries and the Prefectural Governors exercise a wide range of regulations to maintain fishery resources, fishing grounds, and management. The minister is primarily responsible for licensing off-shore and far-sea fishing. The governors grant fishing rights and issue fishing licences and regulations within the prefectural waters.

This contrasts with the more complicated legal framework of Canadian fisheries. Canada is a federal state with divided legislative jurisdictions and frequent delegation of administrative responsibilities. The general principles of the Federal mandate for fisheries are written into Constitution Acts (British North America Act . The Federal government has the power to legislate in relation to sea coast and inland fisheries and to enact measures to protect and preserve both marine and freshwater fisheries as a public resource. Yet, the subaquatic lands underlying freshwaters and tidal areas, and perhaps some distance into the offshore, are part of the provincially controlled property base.

The Japanese Fisheries Act currently in force was enacted in 1948 as a part of "land reform" granting exclusive fishing rights to working fishermen who control fishing grounds. To achieve the objective, the "National Fishery Coordination Board" and the "Fishery Cooperative Associations" were established. The principal board members are elected by fishermen.

3.1 FISHING RIGHTS AND THE LICENSING SYSTEM

A fishing right is required to do any fishing in specific areas on coastal waters.

This right is granted by prefectural governors under licence to local fisheries cooperatives. Fishing rights are regarded as property rights to which provision of land are applied mutatis mutandis. Each member of a fishery cooperative has an equal right to operate fishing within the fishing right areas (a common fishing right), except for collecting seaweed or shellfish, and cage culture (a demarcated or specific fishing right). The licensed fisheries cooperative of a region is thus authorized to set up all the fishing regulations within the area including the type of fishing operations, numbers of fishermen, fishing gear and boats, and length of the fishing season. Essentially the same fishing right system applies to all riverine fisheries. However, riverine fisheries cooperatives have an obligation to replenish streams by releasing fingerlings, and the cooperatives in return are authorized to collect fishing fees from non-members, such as sport fishermen. In case of disputes between licensed fishermen and sport fishermen over the use of fishing grounds, the prefectural governors, under a new regulation are authorized to conciliate an agreement.

All the fisheries operations on the offshore and in distant waters are under the regulation of a licensing system. Those fisheries which are registered nationally are licensed directly by the minister, and those under prefectural management are licensed by the governors. The licence limits the number and size of fishing boats, fish species, fishing season, and areas. The term of the licence is normally five years, but only one year when the operation is of an international nature.

3.2 FISHERIES COOPERATIVES

Because the right to operate fisheries in coastal waters is granted to local fishing cooperatives, and not to individual fishermen, fisheries cooperatives are the functional unit for all fisheries activities. The law of Fisheries Cooperative Associations' states that the purpose of the Association is to contribute to the national economy by increasing fisheries productivity and improving the socio-economic state of fishermen and fish processors. Fishermen may not be engaged in fishing unless they are members of a cooperative. Almost all owner fishermen and fishing enterprises belong to at least one cooperative. The fisheries cooperatives are non-profit organizations operating primarily on Rochdale's cooperative principles. They have to accumulate their own capital and modernize facilities and management to be economically viable. One of the major functions of the cooperatives is to market products. On behalf of member fishermen, cooperatives market all fishery products through wholesalers. Member fishermen also purchase fuel, fishing gear, feeds and other goods essential for fishing operations through the cooperative. Four types of fishery cooperatives are identified:

i) Regional or area fishery cooperatives-- The most important primary cooperative may consist of 20 or more fishermen in one particular region. The region may vary in size, but does not normally exceed municipality limits city, town, or village). Fisheries enterprises and fish production cooperative associations (see below) are also eligible for the full membership. In cases where there are several regional cooperatives formed along the same coastal areas (such as a bay), they can form a federation of cooperatives to which fishing rights may be granted. Besides marketing and purchasing, the cooperatives also engage in education and training of members to improve fisheries management and techniques. Involvement in this latter area is gradually increasing as aquaculture and fish farming advance.

ii) Fishery production cooperatives-- Seven or more fishermen can jointly form fish production cooperatives, two-thirds of whom must be engaged in cooperative fishing. This scheme was originally introduced to aid small scale fishermen and assist in granting fishing rights and licences by the government. They are qualified for full membership in regional and specialized fishermen's cooperatives (see below).

iii) Specialized fishermen's cooperative-- Fishermen and enterprises engaged in one particular type of fishing (by species or by fishing methods) usually form their own cooperatives. Because they are not formed by geographic areas, they often span several prefectural fishing grounds. There are more than 300 cooperatives of this type. Aquaculture fishermen form their own cooperatives under this association.

iv) Fish processors' cooperatives-- Nearly 200 cooperatives have been established among fish processors. Unlike the other types of cooperatives, members have very little in common with each other and they do not deal with serious matters such as fishing rights and licensing. Therefore members are loosely cohesive maintaining a modest profile. Recent advancement in fish processing and upsurge in demands for processed products have renewed interest in collaboration between fishing and fish processing industries.

Altogether 4 400 fisheries cooperatives serve 550 000 members throughout the country. Regional cooperatives and other cooperative groups from Prefectural Federations of Fishery Cooperatives are pyramided into a comprehensive and effective National Federation of Fisheries Cooperatives Association (Table 2). The National Federation headquartered in Tokyo has 40 executives and 400 employees. Besides financing business (see below), it operates eight fuel stations, six cold storage and processing factories, and two seaweed distribution centres along the national coastlines. As in other

business enterprises, associations of fishery cooperatives are more widespread and important features of the Japanese fishery than in Canada. Japanese are more group oriented than most North Americans and have developed greater skills in cooperative group living.

3.3 FISHERIES FINANCING

In association with the regional fishery cooperatives described above, Credit Federations of Fishery Cooperative Associations have been established in each prefecture. They deal exclusively with financial matters of fishermen and fish producers and provide general banking services for cooperative members. The credit federations are further integrated into the Central Cooperative Bank for Agriculture and Forestry. The bank, although established with 50% of the capital contributed by the government, is a non-governmental organization supported totally by the cooperative members. Certain limitations are imposed on its services. For example, loans can be extended only to cooperative organizations, local public bodies, and private enterprises engaged in agriculture, forestry, and fisheries.

In order to facilitate long-term financing for construction of fishing boats and operations, the government created the Agriculture, Forestry, and Fisheries Financing Corporation. Under a governmental interest-subsidy program, fishermen can apply through the corporation for long-term, low interest loans for specially defined projects. These include fishery modernization, natural disaster restoration, stabilization of fishery operations, and economic stabilization of fishing management units related to North Pacific fisheries. Similar plans are also provided for damages due to oil spills and accidental discharges of chemicals.

3.4 ORGANIZATION OF GOVERNMENT AGENCIES

The Fisheries Agency, Ministry of Agriculture, Forestry, and Fisheries and the prefectural governments administer all fishery operations and research in Japan. Aid is provided by the National Fisheries Regulation Board composed primarily of fishermen. Generally, the Ministry regulates the fishery licensing system for major or designated fisheries under Cabinet or Ministerial ordinances, and the prefectural governments exercise granting of fishing rights and licences and regulate fishing operations within the prefectural waters. However, the fishermen themselves play significant roles in maintaining fishery operations and developing resources. To address diversified fisheries interests, national and international, the Fisheries Agency is consolidated into five management units (administration, promotion, oceanic fishery, fishing ports, and research; Table 3). This contrasts with the Canadian counterpart, the Department of Fisheries and Oceans, which is administered under six regional units (Newfoundland, Scotia-Fundy, Gulf, Quebec, Central and Arctic, and Pacific) each with multiple reporting relationships.

4. FISHERIES RESEARCH AND EDUCATION

Fisheries research in Japan is conducted at prefectural and national fisheries research laboratories and stations as well as at universities.

4.1 PREFECTURAL FISHERIES EXPERIMENTAL STATIONS

In each prefecture throughout the country 57 marine fisheries experimental stations, 19 inland fisheries experimental stations, and one seaweed research station carry out research and surveys on closely related fisheries problems in their regions under the general guidance and aid of the Fisheries Agency (Fig. 6).

4.2 NATIONAL FISHERIES RESEARCH INSTITUTIONS

Seven regional fisheries research laboratories and two institutes are administered by the Fisheries Agency (Table 4, Appendix 1). Reflecting the Agency's emphasis in fisheries research, 131 out of the total 412 research personnel from the national institutes examine fisheries resources, 106 conduct aquaculture studies and others work in various fields (Fig. 7).

Under the Agency's Fisheries Research Promotion Program started in 1979, the Freshwater Fisheries Research Laboratory, National Pearl Research Laboratory, and Aquaculture Division of the Tokai Regional Fisheries Research Laboratory were consolidated into the new National Research Institute of Aquaculture. Basic research is conducted on aquaculture to provide technical information and advice to the rapidly expanding fish farming industries and to intensify fishery production within the 200-mile economic zone. The Institute consists of the coastal station (head office) in Nansei, the inland station in Tamaki (Mie Prefecture) and two branch stations in Nikko and Ohmura (Fig. 8). Having a total floor area of 9 450 m^2, the Institute is excellently equipped. Fish holding and experimental facilities with temperature controlled water supply systems (six different temperatures within the range 5-30°C) for both marine and freshwater species are included. Also, the Institute is involved in biotechnological research on hybridization by cell fusion and nuclear transplant with a newly established (April, 1986) Cell Engineering Section. At the Institute, 66 of the total 89 staff members participate in research in five divisions and two branches (Table 5). The ratio of research to support (management services) staff is high throughout the national fisheries laboratories (national average 3.3:1); the same figure for a Canadian laboratory, Winnipeg's Freshwater Institute, is 2.3:1.

4.3 THE ROLE OF THE AGRICULTURE, FORESTRY, AND FISHERIES RESEARCH COUNCIL

To promote comprehensive, effective research relating to agriculture, forestry, and fisheries activities and the livelihood of the

rural communities and fishermen, the Agriculture, Forestry, and Fisheries Research Council was established within the Ministry. The Council acts in an advisory capacity to the Minister, who appoints a chairman and six members from scholars and experts in the field. The Council is responsible for:

1) Planning and coordination of research activities,
2) Administration and supervision of the national research institutes,
3) Assistance to the research activities administered by prefectures and other organizations, and
4) Liaison and coordination between research institutes and administrative bodies.

To accomplish its objectives, the Research Council established a Secretariat, and may appoint additional experts to the Council. The Director General heads the Secretariat which consists of two research councillors, nine advisors, and 18 research coordinators. There are seven Divisions and Offices, with 252 staff members. All research projects administered by the Ministry are categorized into five groups, depending upon degree of importance, scope, and urgency:

1) Ordinary (Operating) research projects form the nucleus of research activities within the national research institutes, promoting seed research to meet a wide range of demands. Each institute decides on research projects in line with the research objectives defined by the Research Council. An average of twelve thousand dollars per researcher, or the total amount of 72.3 million dollars were allocated nationally in 1984.

2) Special research projects are large-scale projects, generally not covered by ordinary research funds. Four million dollars were allocated to 28 projects (3-4 year) in 1984.

3) Major research projects are similar to the special research projects, but larger in scale and expected to have greater influences. Three million dollars were allocated to three projects (five-year) in 1984.

4) Multi-disciplinary research projects represent long-term research projects on important issues such as new technological development of natural resources and energy for the future. Twelve and a half million dollars were allocated to three projects (10-year) in 1984.

5) Comprehensive research projects are research subjects of administrative importance and urgency requiring long-term, comprehensive solutions. These are collaborative research between national and prefectural laboratories. Eight million dollars were allocated on three projects (10-year) in 1984. In addition, a new project on advanced biotechnology research started in 1984, with initial research funds of 4 million dollars.

Most notable is that the final decision on the selection of research projects, except for operating funds, is made by the Research Council after a lengthy process of general and subcommittee discussions, adjustments, and budget negotiations with the Finance Ministry. However, the process starts by an individual institute's submission of specific proposals. Normally, they are submitted in October, final budgetary assessments made by the Ministry of Finance in December of the next year. The budgets finally come into force after being passed by parliament in July of the following year. Major research programs currently in operation include:

1. Development of methodology to standardize nutritional index for cultured fish (Special; $120 K).

2. Short term forecasting by satellite of fishing grounds in warm currents (Special; $130 K).

3. Development of new fish breeding methods by nuclear transplant (Major; $200 K).

4. Green energy plan to encourage effective utilization of solar energy in agriculture, forestry, and fisheries. It includes physiological studies on growth of seaweeds; distribution of solar energy in coastal waters; geographical distribution of primary production in the hydrosphere; seasonal and geographical changes in solar energy in inland waters (Multidisciplinary; $5.6 million).

5. Marine ranching plan (Multidisciplinary; 3.8 million).

6. Biomass plan to promote efficient use of biological resources (Multidisciplinary; $400 K).

7. Technological development to forecast outbreak of red tide (Multidisciplinary; $300 K).

The projects are periodically reviewed and evaluated. An interim report meeting led by the Research Council is held in July or October to review the progress of the research projects. Some adjustments in the projects are made at this stage. Normally, a particular project leader, (i.e. division head of the laboratories) chairs the meeting. A progress-report meeting takes place in Tokyo in February. Although attended by research administrators from the Council, this meeting is generally an annual meeting in nature to report the progress of projects but no evaluation is made. All projects are evaluated at a Special Study Meeting by specialists and administrators. Major changes and adjustments are made here.

Based on the results from this meeting, an evaluation of each project is made once every three years.

4.4 MANAGEMENT AND PHILOSOPHY ORIENTING THE CONDUCT OF RESEARCH

Fisheries research places emphasis on technological innovation to solve problems confronting fisheries in Japan. Through collaborative efforts among the government, industries, and universities on a long-term basis, the Research Council defines objectives to promote effective research pertaining to agriculture, forestry, and fisheries. By establishing basic guidelines for the formulation of fisheries policies, the Council promotes studies on the ecosystem and rational applications of technology to conserve the natural resources and to preserve aquatic environment, while studying improvement of productivity and output through the enhancement of the genetic potential of fish and shellfish. Promotion of technological innovation through the development of advanced technology including biotechnology is emphasized to meet the future needs.

The Research Council coordinates the operation of research activities in the laboratories. A system called "Coordination Units" is set up to cover each specialized field or region. The directors general of the respective institutes are given responsibility to coordinate all research activities in cooperation with the Research Council. For efficient management and performance of research institutes, the Research Council Secretariat establishes research review teams which periodically evaluate the use of funds and facilities, supervisory roles, and cooperation with other research organizations, etc.

The national fisheries institutes cooperate with universities and private institutes by:

1) Providing financial assistance to university and private laboratories to support research activities closely linked to national fisheries interests.

2) Undertaking collaborative research and exchanging technical information; e.g., in obtaining a patent on account of collaborative works, priority is given to researchers from private sectors.

3) Contracting research from non-governmental organizations to conduct studies, surveys, analyses, the training of workers, or requests for expert opinions.

4) Exchanging researchers.

4.5 TECHNOLOGY TRANSFER FROM LABORATORIES TO INDUSTRY

To rapidly convey the experimental results to the administration and extension services, and eventually to each fisherman, central and regional Research and Administration Liaison Committees were established. "Fisheries Extension Workers", stationed at prefectural fisheries departments (approximately one for every 500 fishermen), effectively disseminate the results of investigations and surveys to regional fishermen. In close cooperation with laboratories, the administration, and fisheries cooperatives, the workers not only give instruction and guidance on technical matters to fishermen, but also advise fishermen thereby promoting group activities and improving fisheries management.

4.6 EDUCATION AND TRAINING

Technological change associated with new development in fisheries involve extensive skills and knowledge pertaining to production, utilization, and operational management. These skills and knowledge are normally acquired through formal training at high schools, colleges, and universities. There are 53 high schools with a fisheries curriculum. Some of these schools are exclusively devoted to secondary education in fisheries (fisheries high school). All are administered by prefectures. The number of students enrolled in fisheries high schools is about 17 000. In addition, 19 colleges and universities with fisheries faculties or departments provide post-secondary education in fisheries (Appendix 2 . Most have post-graduate study programs and grant graduate degrees in fisheries sciences. The number of students enrolled in fisheries college and university faculties is over 6 000.

A variety of training programs in specialized fields are available for researchers, research administrators, and others for refreshing, re-training and orientation. Researchers within the Ministry are seconded to universities and other institutions, and sent abroad. The national institutes offer intensive training courses for research personnel affiliated with prefectural laboratories.

4.7 INTERNATIONAL COOPERATION

International cooperation in research is administered under cooperative agreements in science and technology with other countries. Also, the "Conference for the Promotion of International Research Cooperation in Agriculture, Forestry, and Fisheries" was established in the Research Council Secretariat. For Canada, the agreement on scientific cooperation between the Natural Sciences and Engineering Research Council of Canada (NSERC) and the Japan Society for the Promotion of Science operates in the fields of exact, natural, and applied sciences. It offers funds for the exchange of scientists, collaborative research projects, and scientific seminars.

Starting in 1988, a new long-term Japanese international cooperative research program is to be introduced under the administration of the Science and Technology Agency. This program

deals specifically with basic, fundamental, and creative research on man's interactions with environment. Subjects related to fisheries sciences are:

1. Communication among animals and plants and mechanisms of recognition, identification, and orientation (pheromones, migration, biological clocks, and related areas).

2. Physiological and ecological mechanisms of animal functions and their application (insect and nematode pheromones, immune mechanisms, homeostasis, biosensors, recombinant DNA, and related areas).

5. AQUACULTURE AND SEA FARMING CENTRE

Japan has a long history of aquaculture. Non-fish marine culture has been practised since the 17th century when oyster cultivation started. Traditionally, aquaculture in Japan has aimed at culturing those aquatic organisms which command high prices in the market. Some of the most advanced and the greatest variety of aquaculture enterprises are carried out with strong support by all levels of government (Fig. 9; Table 6). The prefectural governments designate the areas to be used for aquaculture, and the cooperative associations allocate subareas to individual aquaculturists. This contrasts with the Canadian situation, where legislative powers are divided between the federal government and ten provinces. Whether aquaculture is a federal or a provincial concern is not defined. Consequently, the aquaculture industry has developed more slowly.

5.1 PRESENT STATE OF AQUACULTURE

Aquaculture in Japan has been developing steadily in response to the increasing demand for medium to high-grade fish and shellfish (Fig. 10). The total aquaculture production in 1984 reached 1.2 million metric tons, 5% increase over the previous year (Fig. 11). Its share in the total fisheries production is 8.7%. However, for inland fisheries, aquaculture accounted for 48% of the total production in 1984. The production of non-fish species, oyster, pearls, and lavers, is entirely dependent on culture, and the production of yellowtail, sea bream, and kuruma shrimp is also highly dependent on culture (approximately 70%, 45%, and 40% respectively). The total number of management units (over 95% of which are of the household size) engaged in mariculture fishery was 44 189 in 1984. For inland waters, 12 046 units were involved in some form of aquaculture in that year and the total of all fishery management units was 219 485.

Culture of yellowtail, a traditional delicacy for sushi and sashimi, started in the 1930's in Kagawa (Shikoku) and rapidly spread to neighbouring prefectures along the coast of the Seto Inland Sea, with the development of the floating net-cage culturing method around 1965. Yellowtail culture begins by collecting naturally-spawned fry called "mojako", living under seaweeds drifting with the current. They are caught by specially-licenced fishermen and sold to fish farmers. Artificial seeding has not been established on commercial scale. The total culture production of yellowtail has levelled off in the last few years, primarily because of its unstable market, and damage due to outbreaks of red tides in principal producing prefectures (Ehime, Kagoshima, Kagawa, and Nagasaki). This red tide results from the massive bloom of planktonic dinoflagellates which produces paralytic shellfish toxins.

Mariculture of coho salmon started in Shizugawa Bay (Miyagi) in 1975 and is a growing industry in the generally non-expanding aquaculture enterprise. Although small, relative to the nation's total fishery production, total production of coho in 1984 doubled compared to the previous year (5 000 from 2 700 metric tons). The number of producers increased from 120 to 170. In coho salmon mariculture, eyed eggs are imported from the west coast of the United States in December. The eggs are raised in fresh water for about 10 months to the smolt stage. In October or November of the following year, these young fish are transferred after a short period of acclimatization to sea water and raised on moist pellets, which are 90% frozen sardine and mackerel (Fig. 12). The fish grow to 2-3 kg by the end of the next July, when they are harvested for marketing. The mariculture of coho salmon is designed to fill the market void during spring-summer months with high quality, red coloured fish meat. The greatest advantage of mariculture over ordinary fishing is that the time and the volume of production and shipment can be controlled according to market requirements.

Aquaculture production for inland waters, though steady over the last few years, reached a peak of 1 million metric tons in 1984 (Fig. 10). This increase is primarily due to increased production of eels and Tilapia. The eel is the most favoured freshwater fish in Japan. Technical innovation combined with the introduction of ready-to-eat or precooked eel products into the fish markets and supermarkets has considerably increased the production in recent years. The eel culture is centred in southern prefectures in Shikoku and Kyushu as well as Shizuoka, Aichi, and Mie Prefectures.

Spawning activity and early larval development of the Japanese eel are not yet well understood. Years of effort have failed to produce a consistent method of spawning eels in captivity. Therefore, eel culture still depends on wild elvers migrating to the Japanese coasts in spring time. Elvers are caught at night on the incoming tide in river mouths. As many as 25% of the elvers, however, may die during the 2-3 days between capture and delivery to the farm. Thus, because of their fragility, large demand, and limited supply, a kilogram of elvers (1 100 to 1 200) can cost anywhere from $32 to $320. The elvers are kept in small concrete tanks darkened with black screens and are fed mashed Tubifex worms. After the first week,

a high-protein artificial diet made from dried fish and soybean meals mixed into the Tubifex mash. Over a period of days, the ratio of worms to artificial diet is changed until the pellets consist entirely of artificial diet. At the same time, the feeding area is gradually narrowed until food is given to the elvers only from one fixed feeding place along the tank wall. Elvers are thus trained to feed on a certain feed at a certain time of the day reducing water fouling and related diseases.

Due to the extraodinarily high value of both land and elvers, more and more intensive culture methods have been developed. Once common, outdoor still-water ponds have been replaced by indoor tanks with flow-through or circulating heated water systems. The availability of warm water all year round eliminates the eel's hibernation period. The farm can grow eels to market size (about 250 g in eight months rather than the two years required by seasonal cultivation. The indoor tanks produce 80 000 kg of eels per hectare. However, eel farming in Japan faces stiff competition from neighboring Taiwan.

Development of artificial foods for elvers is critical for future eel culture industry. Elvers during the first week of captivity depend entirely on live or mashed Tubifex worms. Feeding Tubifex is costly (as much as $15 per kilogram), and increases the risk of bacterial infection. No formulated food has been successfully produced at the commercial level. Recently, a food pellet composed mostly of crude proteins flavoured with chemical attractants based on the chemical analysis of Tubifex extract has been introduced into the market.

5.2 CONCEPT AND PROSPECTS OF SEA-FARMING

The availability of favourable areas characterized by calm surface waters with appropriate current is prerequisite in aquaculture. However, because the availability of such areas is limited, over-utilization can result in harmful effects. Coupled with the implementation of its own 200-mile offshore economic zone, a re-examination of fisheries within the limit becomes vital to the future of Japan's marine products industry. The government allocated 3.7 billion dollars to promote sea farming along the coastal fishing waters under a five-year plan for comprehensive coastal development (1982-1987). Emphasis now is placed on development of extensive systems for free ranging of fish farming and marine ranching supported by basic and applied research projects. The concept of sea farming is to expand a production base for coastal fisheries by stocking seedlings and fingerlings, supplemented by construction of artificial reefs and nurseries, and environmental protection and improvement. In salmon ranching, artificially bred fingerlings are raised to an optimal size, released, and the adults harvested. Alternatively, in scallop culture, a large volume of naturally bred seedlings are collected, raised under semi-artificial conditions, released, and harvested. Optimizing the timing of release increases the survival rate in both cases (Fig. 13).

In 1962, the Seto Inland Sea-Farming Centres were established in Yashima and Hakatajima to develop techniques for large-scale production and stocking of seedlings. At the request of the government, they were placed under the management of the Seto Inland Sea-Farming Association the following year. With the increase in the number of fish-farming centres, the Association was reorganized into the Japan Sea Farming Association. Presently, there are 13 national fish-farming centres (another is under construction) throughout the country (Fig. 14 and 15). The national centres, in cooperation with 37 newly built prefectural fish farming centres, have established a network to collect information and analyze data for efficient research and operation. The Association is fully financed by the central government and has 32 prefectures and 27 prefectural fisheries cooperatives associations as members. With a total operating budget of $36 million for sea-farming projects in 1985, the total seedling production and stocking reached 2.7 billion and 2.0 billion, respectively. Major species include sea bream, prawn, abalone, and scallop. There are however, a number of problems which the association faces. Because the principle of sea-farming is "free ranging", fingerlings released at one association's expense may move beyond their fishing ground limit. At present, who can fish those targeted species in an overall area is controversial.

5.3 SALMON RANCHING

Industrial-scale salmon ranching has become important throughout the North Pacific Rim. Release of juvenile salmon from hatcheries has doubled in recent decades, and this trend is expected to continue. In some geographic areas, more than 90% of harvested salmon originate in hatcheries.

The Japanese have a progressive, well-established salmon-ranching industry. They presently harvest over 30 million ranched chum salmon annually (Fig. 16). Although three species of salmon (chum, pink, and masou) are fished commercially in Japan, more than 90% of the total are chum salmon. This is due to the chum salmon enhancement program, a five year effort which ended in 1983. Despite the great success of the program, the Japanese salmon industry faces a number of problems:

1) Apportionment of expenses--All three levels of government are involved in salmon fisheries in Japan. Hatcheries are operated by a mixture of private organizations, prefectural governments, and the central government. The central government owns and allocates eggs for hatchery propagation and thereby exercises control over all production. Presently, 37 central government hatcheries, four local government hatcheries, and 62 private hatcheries are in operation in Hokkaido and have the capacity to rear

a total of 1.3 billion salmon eggs. In Honshu, 124 hatcheries are all privately owned and have the capacity for 500 million salmon eggs. In 1983 alone, 83 million dollars were spent in salmon artificial spawning/stocking operations, and over 34 million dollars or 40% of the total were defrayed by the fishermen themselves. At the same time, however, the investment of more resources by the private sector is required to further stabilize financial standing in the salmon fishery. There is a need to re-examine the overall operational system, including governmental aid and cost apportionment by the private sector.

2) Market demand--It is anticipated that the supply of chum salmon will soon exceed the national demand, resulting in a price decrease. People prefer high quality salmon meat such as those of masou and sockeye salmon. To this end, while maintaining the present level of the chum salmon production, propagation of masou and sockeye salmon is promoted by developing new techniques to advance smoltification, optimize the timing of smolt release and control diseases. In the long-term, a new strain of salmon which has characteristics to meet consumers' demand is being developed by preserving the genetic character through selective breeding, and by biotechnological gene manipulation.

6. TOPICAL RESEARCH ACTIVITIES OF POTENTIAL RELEVANCE TO CANADA

Based on Japanese experience, there are a number of components which could be considered in planning a future aquaculture development strategy for Canada.

6.1 MARINOPOLIS PLAN

The world's first fenceless "marine ranch" experiment has been conducted in Saeki Bay, Oita Prefecture, to rear fish by an audio conditioning technique. This experiment was to improve sea bream farming. Baseline studies were conducted by the national and prefectural fisheries laboratories as a part of a comprehensive research project on the development of fishing grounds in coastal areas during 1974-1979. Marine ranching is a core project under the prefectural government's "Marinopolis" plan and is attracting attention as a milestone in coastal fisheries. The red sea bream fry are reared at the local fisheries experimental station by feeding several times a day following 300 Hz pulses through an underwater loudspeaker for 90 days until a conditioned response is established. The conditioned fry are released into the bay where there are two sound-generating and feeding buoys. The fry are fed several times a day when called by generating pulses. The experiments show that the trained fry within a radius of about 2 km from the buoy respond to the sounds for up to 90 days. Fish radar, underwater cameras, and various sensors collect data on water temperatures, salinity, water currents as well as fish movement and automatically transmit them to the control station (Fig. 17). More than 20% of the fry released are expected to be harvested when they grow to more than 20 cm. The advantage of marine ranching is that the fish are free swimming, but restrained by "fenceless" cages. Therefore environmental derangement and normally unavoidable consequences of intensive aquaculture due to over-feeding are minimized. Although the operation is still at the experiment stage, local fish production could be considerably enhanced if fry are released into "protected" nursery grounds and national fishery management introduced.

6.2 BIOTECHNOLOGY - RESEARCH AND DEVELOPMENT

High technology research and development in Japanese fisheries are advancing rapidly. To coordinate planning, development, and application of high technology in fisheries, the Fisheries Agency established in 1985, a High Technology Research and Development Division within the Research and Development Department (cf. Table 3). The new Division is responsible for collection and evaluation of information, planning, and promotion of high technology research and development in fisheries in universities, industry, and fisheries research laboratories. Application of high technology in fisheries includes biotechnology, electronics, and the use of new materials. The Agency is to coordinate nationally high technology research, which has been carried out separately, under prefectural administration. Under the promotion of Regional Biotechnology Research and Development Program, the whole country is divided into seven blocks, each with a national fisheries research laboratory as their nucleus. Research subjects unique to each block will be systematically investigated (Appendix 3). A new breeding technique incorporating parthenogenic, gynogenetic, and chromosome multiplication procedures has already been established in rainbow trout. Production of pure strain, short-term fixation of desirable genetic characters, and mass production of seedlings will be possible. It is now possible to produce all-male or all-female stocks or progeny and its application to masou salmon propagation is underway. For example, in pond culture, an all-female fingerling population enhances egg production and smoltification. The all-male group would enhance the culture of YAMABE, the land-locked masou salmon.

The areas of application for hormone production by genetic engineering are enormous, ranging from the production of hormones to a broader understanding of cellular regulation and the adaptability of organisms. Recently, a method for mass production of salmon growth hormone by using gene cloning techniques has been developed. Salmon growth hormone thus synthesized in Escherichia coli has been shown to be equipotent to the natural hormone in

promoting increases in weight and length of rainbow trout. The same technique has been established in eels and yellowtails. Hybridization by cell fusion has been used in breeding of seaweeds.

The Biotechnology Division of the Agency allocated an initial operation budget of $600 000, in 1986, to undertake research on "Genetic Assessment Project for Aquatic Resources (GAP)". This is a three-year project carried out by universities and sea farming centres as well as fisheries research laboratories. The objective of the project is to assess the genetic factors characteristic of each member of the aquatic fauna and flora by using isozyme techniques. Genetic assessment of marine resources by isozyme heterogeneity is considered essential for future development and management.

The Agency is currently planning a "new" biotechnology project on the "Efficient Utilization of Genetic Resources by Genetic Engineering", to start in 1987. The objective of the project is to produce new breeds and biochemicals (hormones, pheromones, antibodies, etc.) by recombinant DNA techniques. As the cloning of salmon growth hormone gene has been established, isolated promotor genes (genes controlling gene activation) are linked to salmon growth hormone genes and transplanted into eggs, thereby a hybrid with a gene capable of producing growth hormone in the tissues other than the pituitary is produced. Administration of chemicals which activate or switch these genes could produce a "super" fish. In addition, the Ministry is to establish a special organization for promotion of high technology research in agriculture, forestry, and fisheries. According to the plan, the Ministry promotes high technology research and development in private sectors by financing and facilitating cooperative research between fisheries and industry laboratories.

6.3 FISH HEALTH PROGRAM

Aquaculture is subject to a wide range of unpredictable and potentially damaging pathogenic organisms including bacteria, viruses, fungi, and various parasites. Fish cultured under intensive conditions are in danger of being infected by diseases. In 1982, the total loss due to diseases in aquaculture amounted to $220 million (7.4% of the total production). The most immediate need in treating fish diseases is adequate training in identification and prevention. Although widely available veterinary drugs are effective against some fish pathogens, uncontrolled use of these drugs may create resistant bacteria, requiring the development of new formulations.

To promote preventive measures against fish diseases, the Fisheries Agency has established the Fish Diseases Centre within the Japan Fisheries Resource Conservation Association. The Centre is responsible for:

1) Coordination of operations of fish disease prevention by prefectures--This includes collection and dissemination of information on fish diseases, examination of diseases, providing consultants, and extension of preventive technology. Prefectural fish disease centres have been established in 18 prefectures as of 1986.

2) Promotion of research and development--Cooperative studies with universities, fisheries research laboratories, and private research institutes are conducted on techniques for prevention of fish diseases.

3) Training of fish disease technologists--Three types of courses are offered primarily for prefectural fisheries technical personnel. The major one is the Fish Health Officer course, which is a three-year, 156 credit hour course. The curriculum includes pathology, bacteriology, immunology, parasitology, pharmacology, public health, pharmaceutical law as well as fish diseases, and associated exercises. A qualification test is taken upon completion of the course. A refresher course is available to expose certified health officers to new information and technical development.

4) Prevention of foreign pathogens --To prevent communicable diseases from foreign countries entering Japan, all imported fish eggs and seedlings are subjected to inspections for viruses, bacteria, and parasites according to the notices issued by the Director General. The Centre is responsible for production, preservation, storage, and distribution of antisera required for diagnosis of major diseases in cooperation with other organizations involved.

5) Acquisition of information on research of fish diseases and prevention--The Centre also produces films and tapes on fish diseases and their prevention.

7. CONCLUSIONS

Japan, as the world's leading producer of fishery products, has long enjoyed extensive far-sea, offshore, and coastal fisheries operations. With the implementation of the 200 mile zone of extended jurisdiction by the world nations and a changing national economy pattern, fisheries in Japan is now confronted with a number of problems. Yet, the total fisheries production exhibits a steady improvement both in quantity and quality. Support is provided by strong government incentives, well organized fisheries cooperatives, and innovative high technology research. Important measures taken by the Japanese government are:

1) Traditionally, the Japanese have engaged in intensive aquaculture (pond culture of eels and carps, cage culture of yellowtails, net culture of seaweed, hanging culture of scallop, etc.). Recently development of free ranging sea farming and marine ranching supported by basic and applied research by universities, industry, and fisheries research laboratories is emphasized. Under a five-year comprehensive coastal development plan (1982-1987), the Japanese government allocated 2.5 billion dollars to develop coastal fishing grounds by construction of artificial reefs, propagation grounds, and embankments and breakwaters.

2) Fourteen National Sea Farming Centres have been established to promote development of aquaculture and sea farming technologies suitable for regional diversity and species diversity. These centres, in cooperation with 37 prefectural fish farming centres, have formed a network to collect information and analyze data for efficient research and operation under the coordination of the Japan Sea Farming Association. The main function of the centres is to produce and stock seedlings for farming and their technological development. The centres currently produce and stock 3 billion seedlings from more than 40 different species including abalone, scallop, sea bream, and yellowtail.

3) With the successful completion of the chum salmon enhancement program annual return of ranched chum salmon reached 30 million), the national salmon propagation operation is shifting to the masou salmon project, to maintain a steady supply of high quality fishes. The project aims at replenishing seriously depleted masou salmon stocks in northern Japan. Methods for maintaining brood stocks, facilitation of smoltification, shortening of freshwater life, and rehabilitation of natural spawning grounds are investigated with the aid of new biotechnology. The project is a part of the "Marine Ranching" program.

4) By establishing a High Technology Research and Development Division within the Fisheries Agency, fisheries research in Japan has entered a new era. This is marked by the production of new breeds by sex control and gene cloning mass production of hormones, pheromones, and antibodies by recombinant DNA; and production of "super" fish by growth hormone produced in tissues other than pituitary. The concern of the fisherman to develop new fishing technologies and species is well-symbolized by the fact that the prefectures rather than the central government are the driving force of recent trends in research and development in new high technology.

5) Veterinary and diagnostic services are vital components of the fish production industry. A network of fish health services and educational and training programs is installed in a new Fish Disease Centre, again fully supported by the government.

8. RECOMMENDATIONS

Canadian fisheries have changed since the extension of fisheries jurisdiction to 200 miles. However, this 200-mile zone is not a limitless reservoir; sound policies and programs in resource management, exploitation and product marketing will be needed to ensure long-term stability. Intensive aquaculture, though viable in Canada, is not a single solution to remedies for all economic ailments. A long-term futuristic plan for resource development and exploitation in coastal and offshore fishing grounds is required. Japanese aquaculture is already changing from its traditional patterns and as Canadian aquaculture develops, there is much that can be learned from the Japanese experience. Based on my own inspection and review of the research and development in Japanese fisheries described above, I recommend that:

1) The federal Department of Fisheries and Oceans develop a long-term development strategy for aquaculture and sea farming for Canada. A model is available in the Japanese comprehensive development for fisheries resource husbandry.

2) The regulatory and control powers of salmon ranching be decentralized, and a principle "fisheries by fishermen" be established. The structures of institutions engaged in salmon ranching vary considerably among governments. The participation of all levels, federal and provincial governments and particularly the fishermen themselves, is essential for ever-increasing sophistication of the industry.

3) An "eat more fish" campaign be initiated. All the scientific evidence indicate that the omega-3 polyunsaturated fatty acid present in highest concentration in marine fish, has a role in reducing risk of heart disease by reducing the levels of blood cholesterol, increasing the time for blood clotting, and by producing potent anti-clotting agent. Thus, substituting fish for other animal flesh that is higher in calories and where the fat is more saturated is desirable from a health point of view.

4) Quality control procedures be enhanced throughout fishery processes. This will eventually lead to an expansion of the domestic fishery markets. Canada exports more than 40% of fisheries' products to the United States and other countries. Although, growth is occurring in aquaculture, its industrial potential is difficult to assess. The advantages of aquaculture should be that fish are harvested only upon demand and shipped directly to the wholesalers throughout the year.

5) High technology research, biotechnology in particular, be promoted at all laboratories relevant to fisheries research throughout Canada. Biotechnology research and development in Japanese fisheries has expanded at a phenomenal rate during the last several years. Genetic engineering will now result in biological organisms that produce hormones, pheromones, and other biological materials as well as the production of "super" offsprings.

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Table 1. Comparison of seasonal variations in the climate in Sapporo, Tokyo, Kagoshima, and Winnipeg.

	Sapporo				Tokyo				Kagoshima				Winnipeg			
	Jan	Apr	Jul	Oct	Jan	Apr	Jul	Oct	Jan	Apr	Jul	Oct	Jan	Apr	Jul	Oct
Temperature (C°)																
Average	-5.1	6.1	20.2	10.4	4.1	13.5	25.2	16.9	6.7	15.6	26.9	19.1	-18.3	3.4	19.7	6.1
Maximum	-2.1	11.3	25.1	16.0	9.4	18.4	29.2	21.1	12.0	20.9	31.0	24.2	-12.8	8.9	26.7	11.1
Minimum	-9.5	1.3	16.2	5.4	-0.4	9.1	22.1	13.5	2.0	10.7	23.6	14.1	-22.2	2.2	13.9	1.1
Relative humidity (%)	75	68	80	74	57	66	79	74	75	76	82	75	79	69	68	70
Precipitation (mm)	118	64	90	104	49	122	140	203	91	235	347	107	21	39	76	31
Days of rain or snow	16	9	9	13	5	10	10	11	11	12	13	8	12	8	11	8

Table 2. Organization of fisheries cooperatives and their prefectural and national associations. Approximate numbers of cooperatives and associations in parentheses.

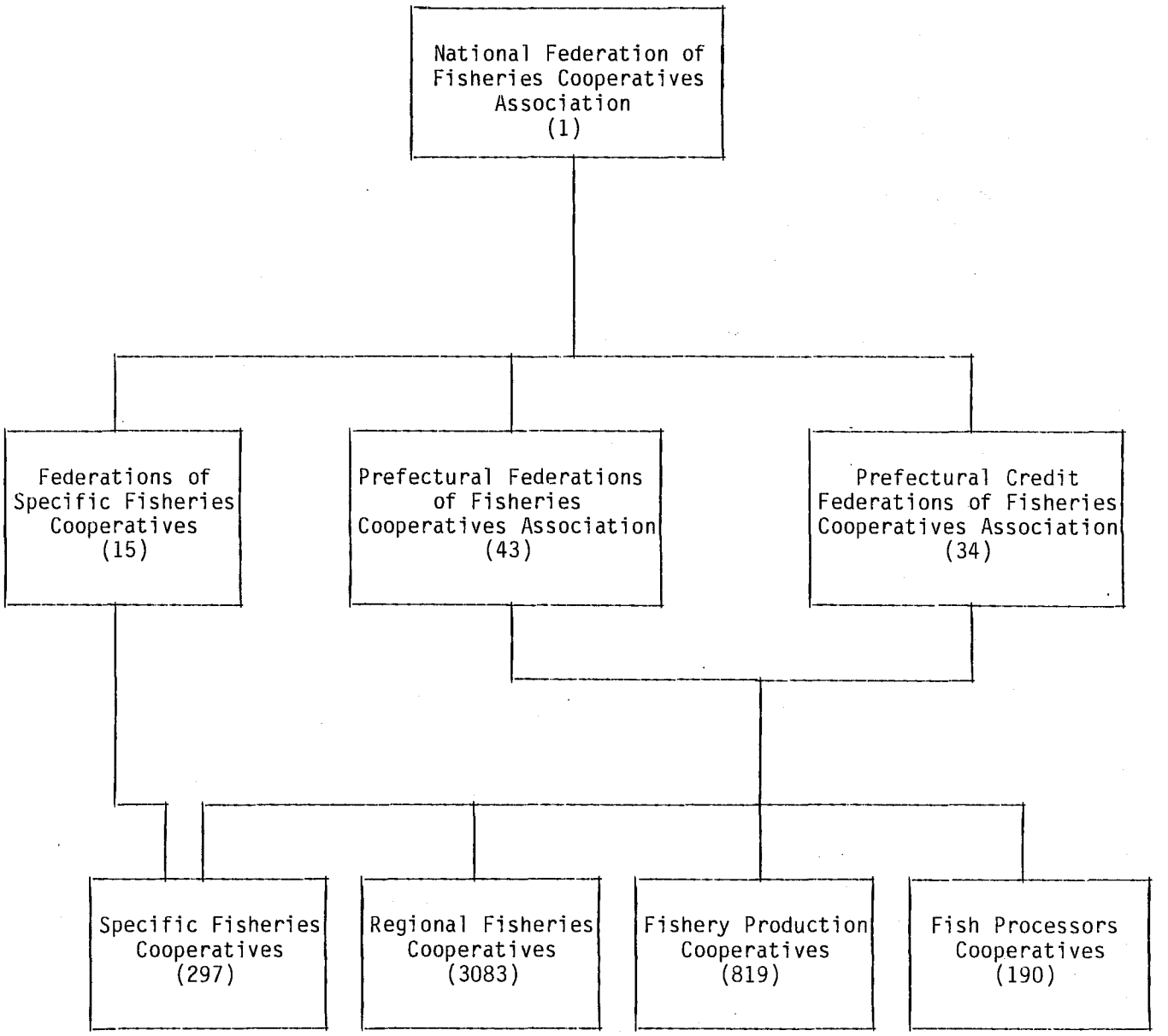


Table 3. Organizational structure of the Fisheries Agency, Ministry of Agriculture, Forestry, and Fisheries.

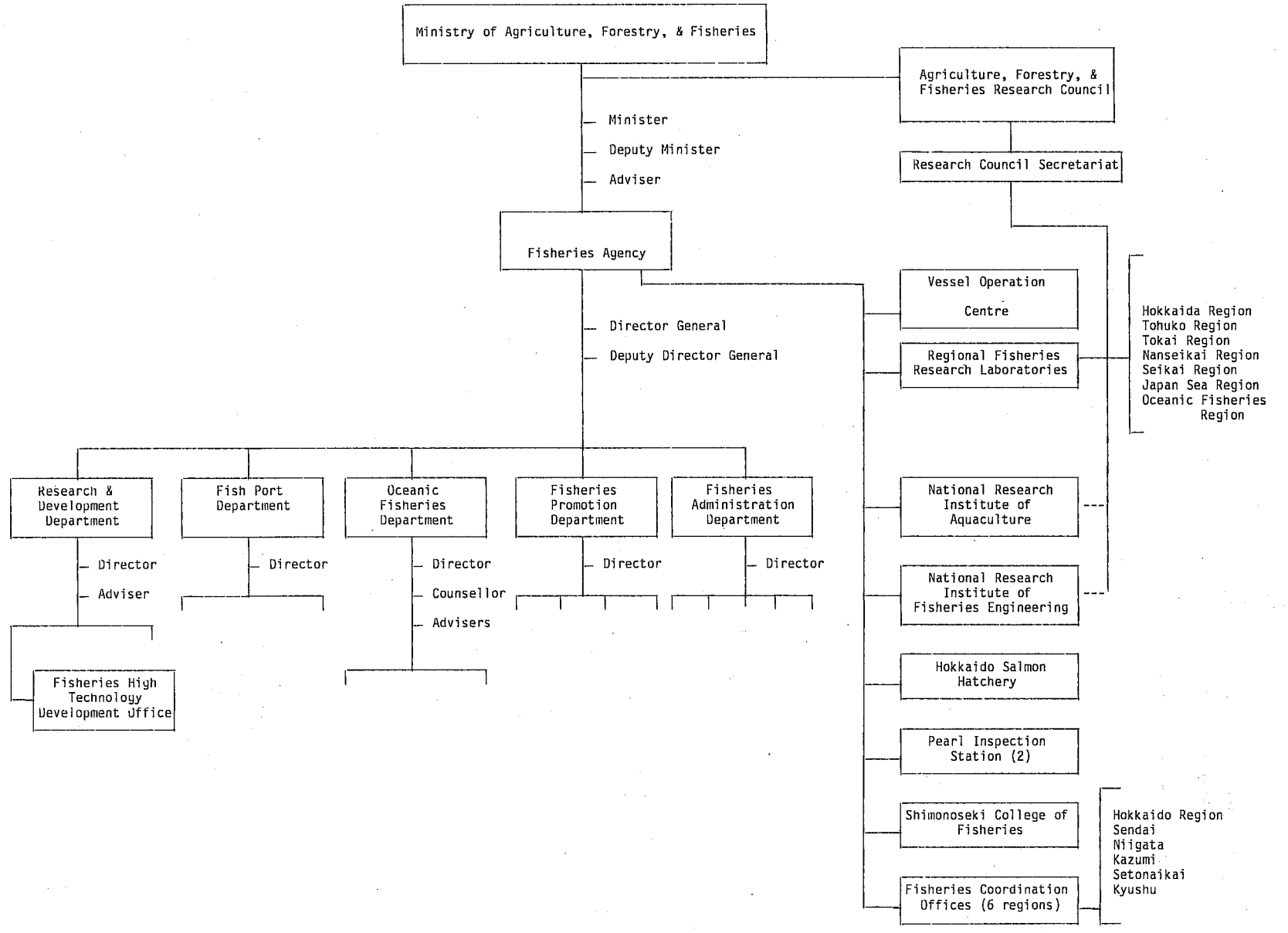


Table 4. National fisheries research institutes and laboratories.

Laboratories & Institutes	Location	Major Research Areas (Research Sections)	No. of Personnel* (Research/ Administration)	Operating Budgets ** (Million dollars)
Hokkaido Regional Fisheries Research Laboratory	Kushiro, Hokkaido	Fisheries resources, Oceanography, Aquaculture	34/9	5.8
Tohoku Regional Fisheries Research Laboratory	Shiogama, Miyagi	Fisheries resources, Oceanography, Aquaculture	40/11	5.0
Tokai Regional Fisheries Research Laboratory	Tokyo	Fisheries Resources, Statistics, Oceanography, Inland fisheries, Marine products, Fish preservation, Biological chemistry, Water pollution, Marine environmental radioactivity.	112/37	13.2
Nansei Regional Fisheries Research Laboratory	Ono, Hiroshima	Inland sea fisheries resources, Offshore fisheries resources, Oceanography, Red tide research, Aquaculture.	48/11	5.4
Seikai Regional Fisheries Research Laboratory	Nagasaki	Fisheries resources, Oceanography, Coastal fisheries development	45/12	5.5
Japan Sea Regional Fisheries Research Laboratory	Niigata	Fisheries resources, Coastal fisheries development.	32/12	3.9
Far Seas Fisheries Research Laboratory	Shimizu, Shizuoka	North Pacific fisheries, Pelagic fish resources, Groundfish resources, Oceanography, South oceans resources.	57/20	5.8
National Research Institute of Aquaculture	Nansei, Mie	Fish genetics, Fish reproduction, Fish nutrition, Environmental management, Fish pathology.	65/23	5.7
National Research Institute of Fisheries Engineering	Hasaki, Ibaraki	Aquaculture and fishing port engineering, Fishing boat and instruments, Fishing gears and methods.	47/10	5.5

* Research vessel crews excluded
** Fiscal year 1983; estimated in Canadian dollars.

Table 5. Structural organization of the National Research Institute of Aquaculture. Numbers of personnel in parentheses.

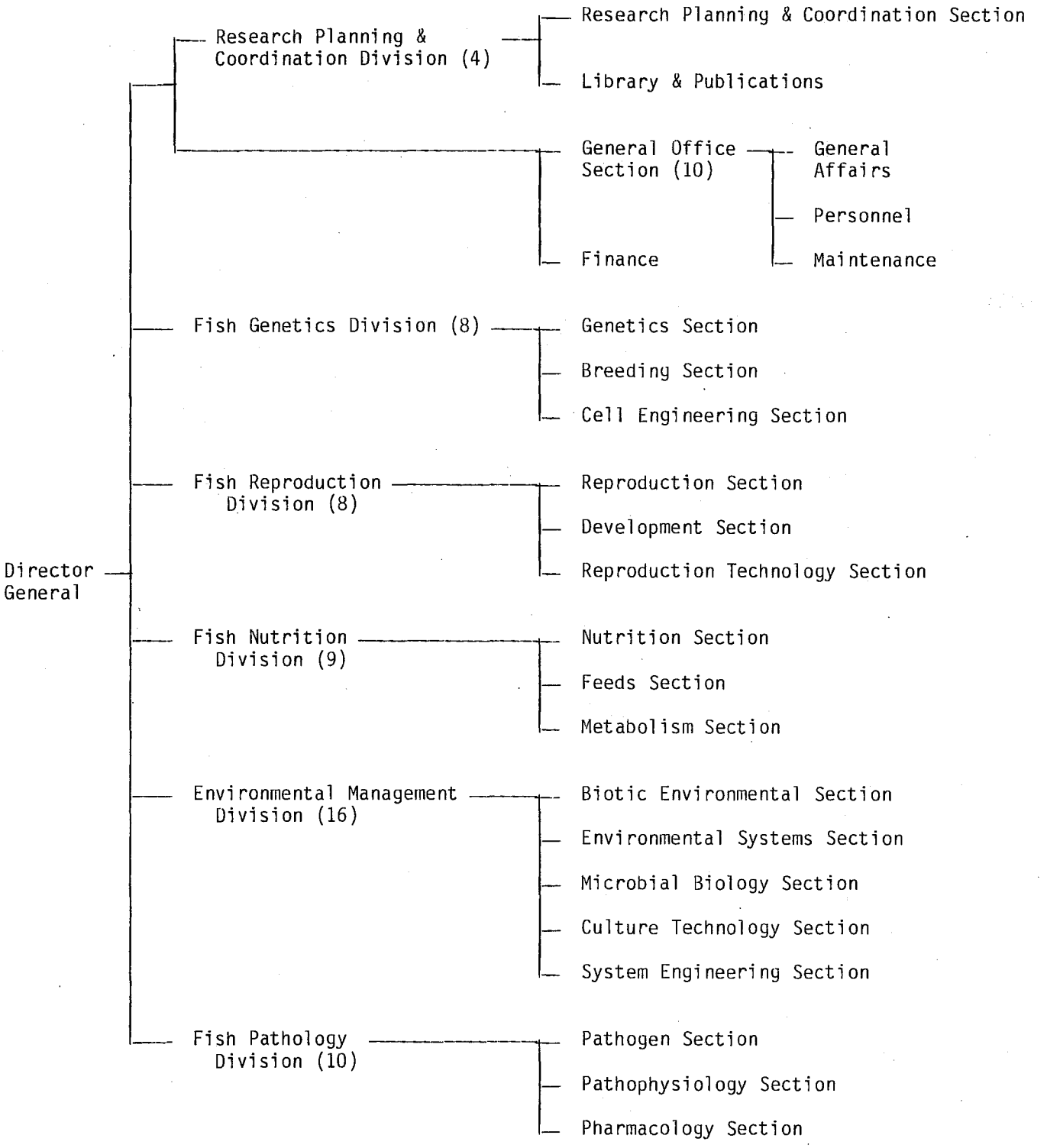


Table 6. Number of aquaculture firms in Japan. Based on the Fisheries Census - 1984.

Sea Waters		Inland Waters	
Fishes		Fishes	
Yellowtail	3 411	Carp	1 712
Sea bream	2 894	Eel	1 569
Saurel			
0			
		Others	252
Shellfishes			
Oyster	5 781		
Scallop	5 564		
Others	622		
Seaweeds			
Laver	21 297		
Undaria	13 027		
Kelp	4 352		
Others	1 876		

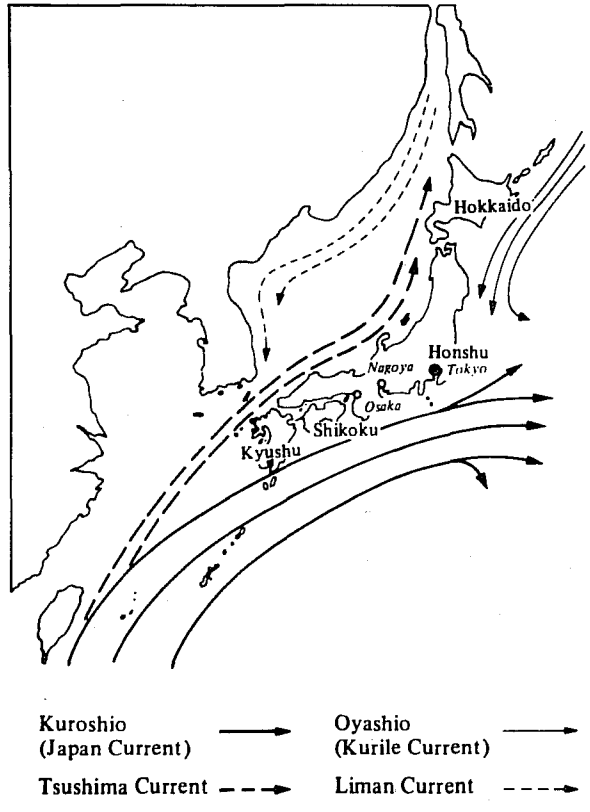


Fig. 1 Major ocean currents influencing the climate in Japan.

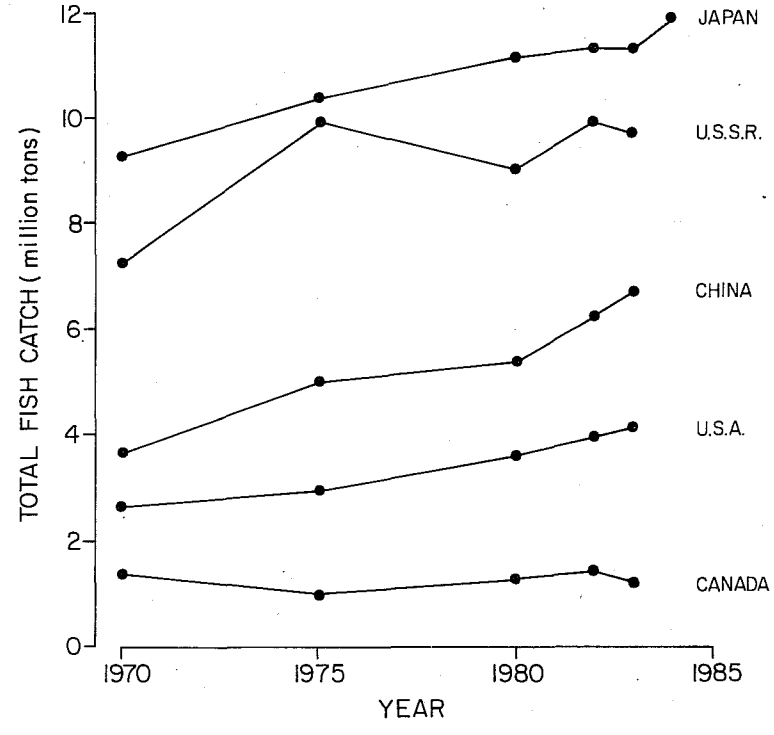


Fig. 2 The total fish catch by the world's major fishing countries.

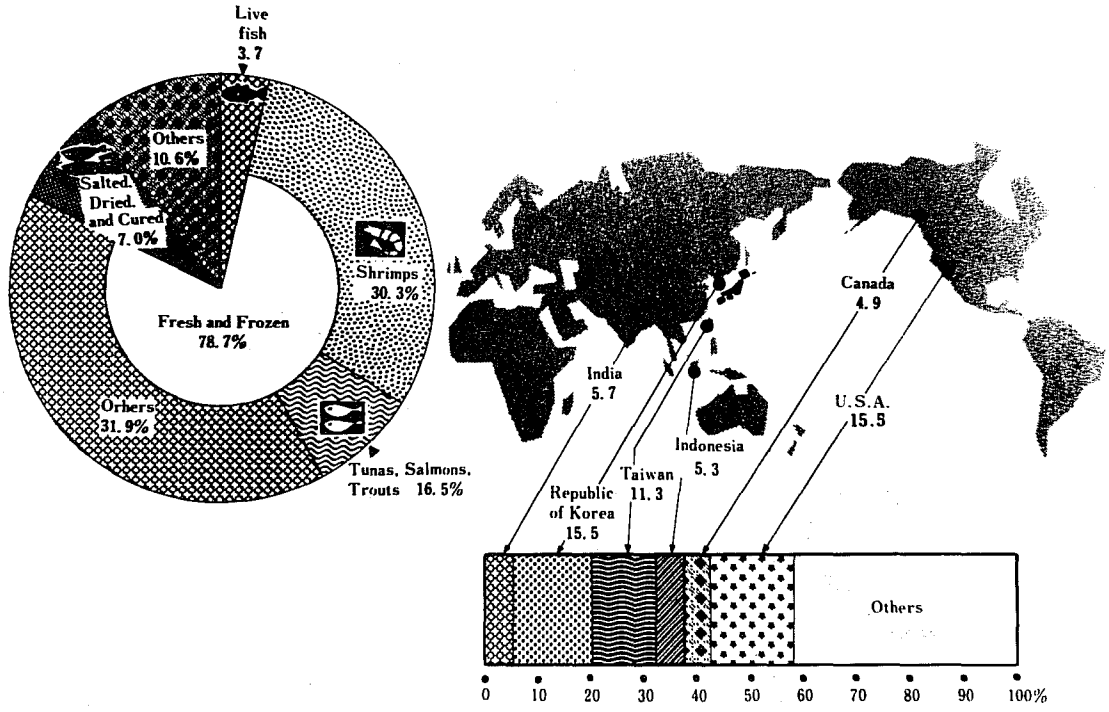


Fig. 3 Major exporting countries of fisheries products to Japan.

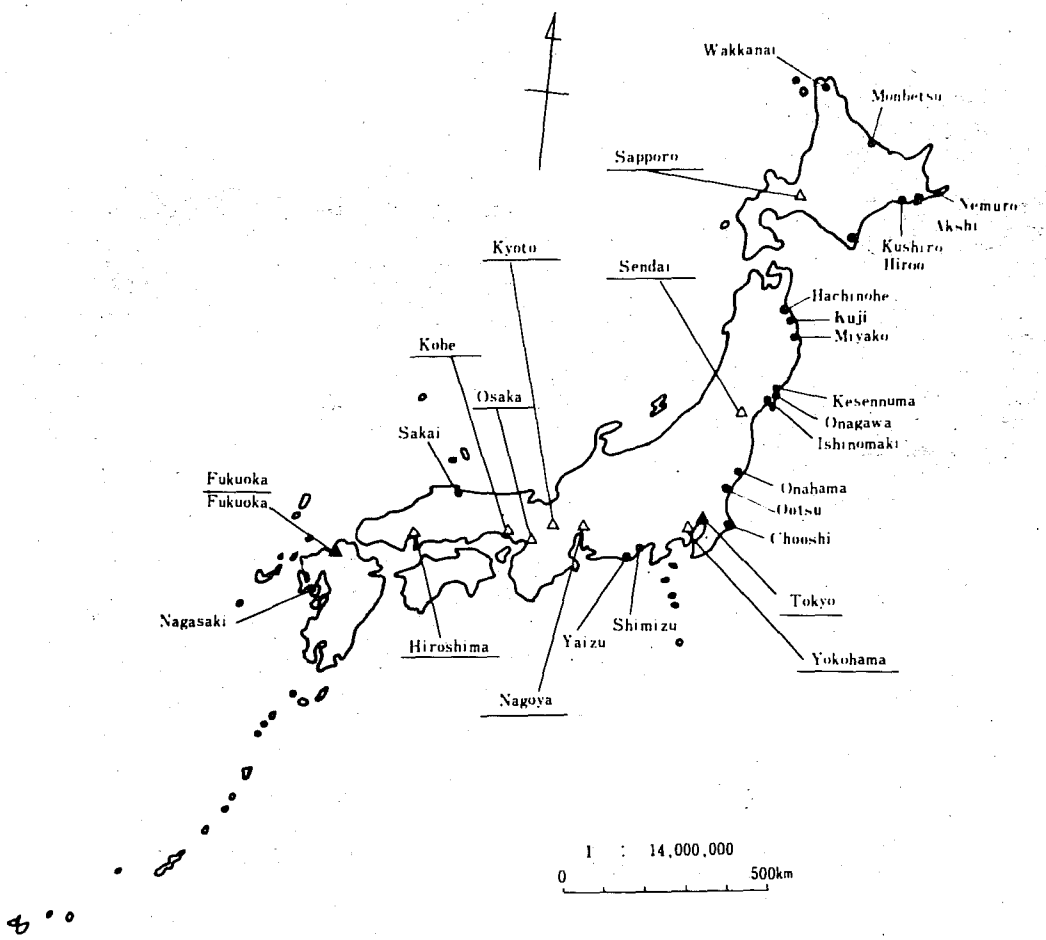


Fig. 4 Major landing ports of fishing products and wholesale markets in Japan.

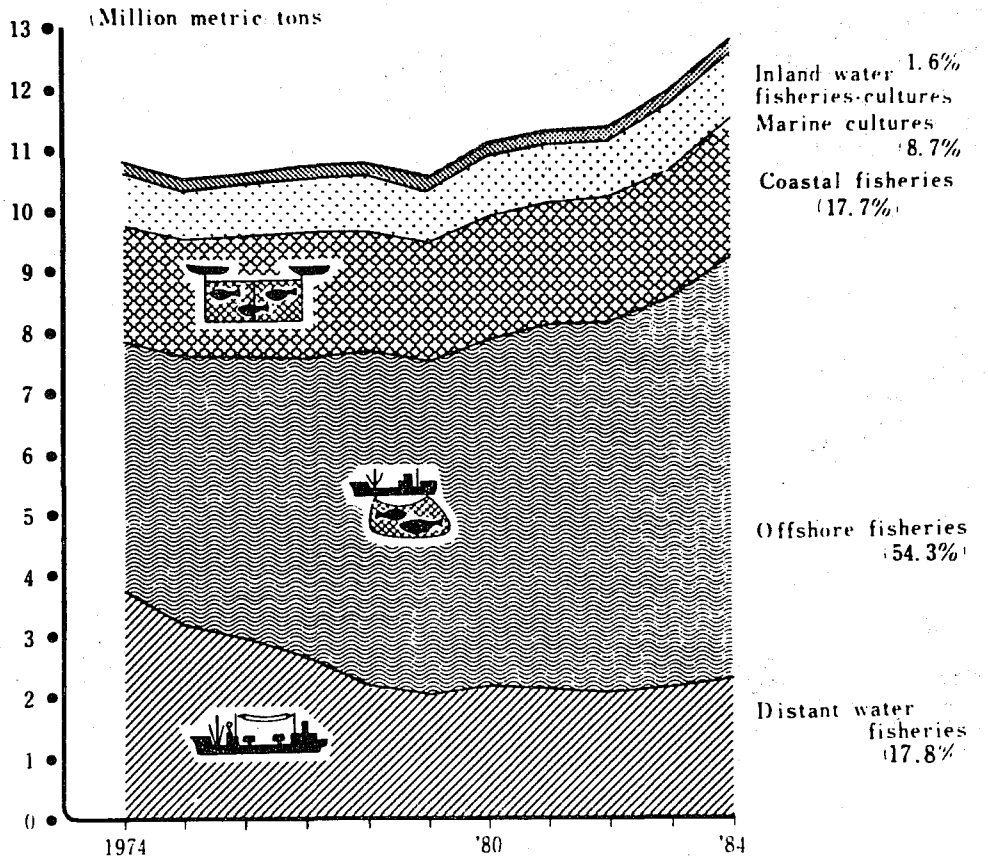


Fig. 5 Trends in fishery production by sectors. Coastal fisheries include aquaculture.

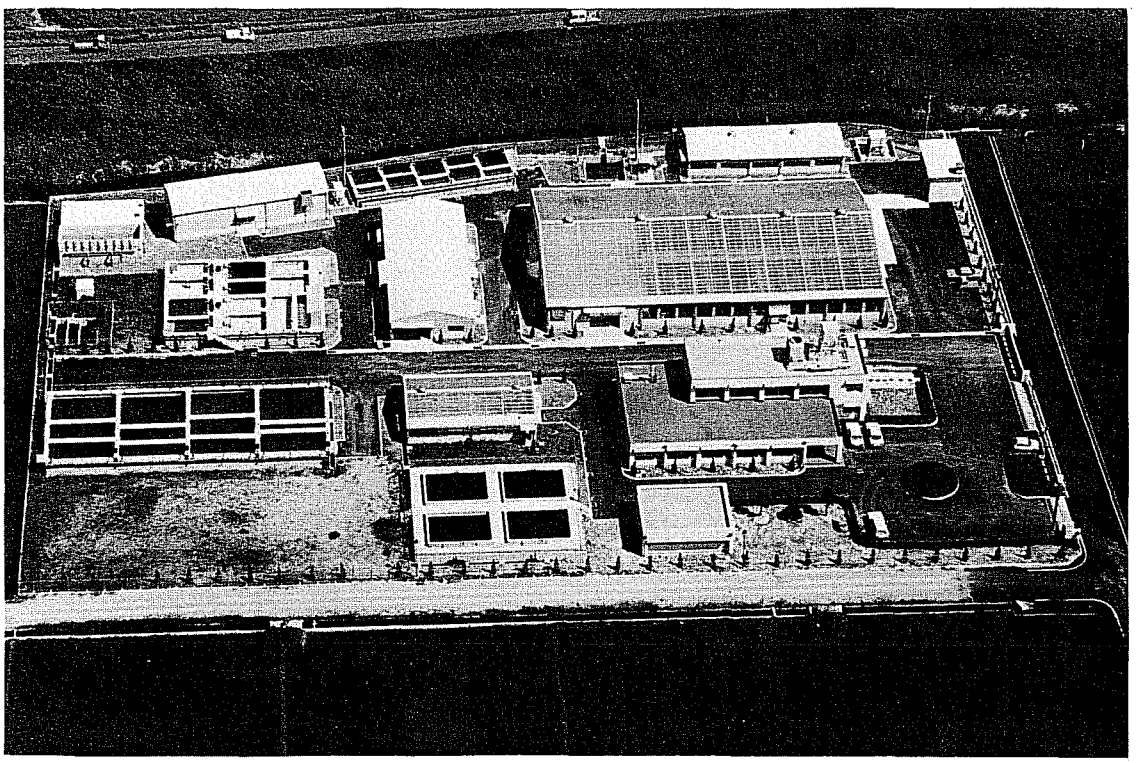


Fig. 6 Kumamoto Prefectural Inland Water Fisheries Experimental Station. With the total floor area of 2 215 m , breeding and stocking of Ayu (Plecoglossus altivelis) are emphasized.

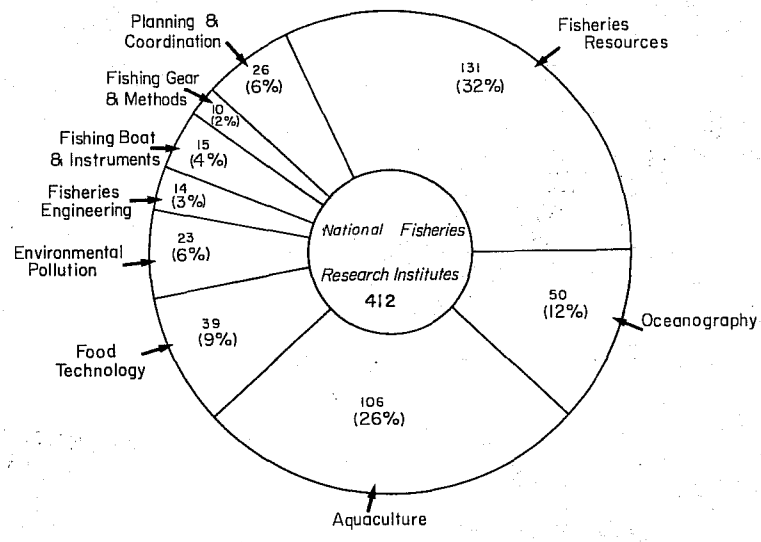


Fig. 7 Allocation of research personnel by research field among the national fisheries research laboratories.

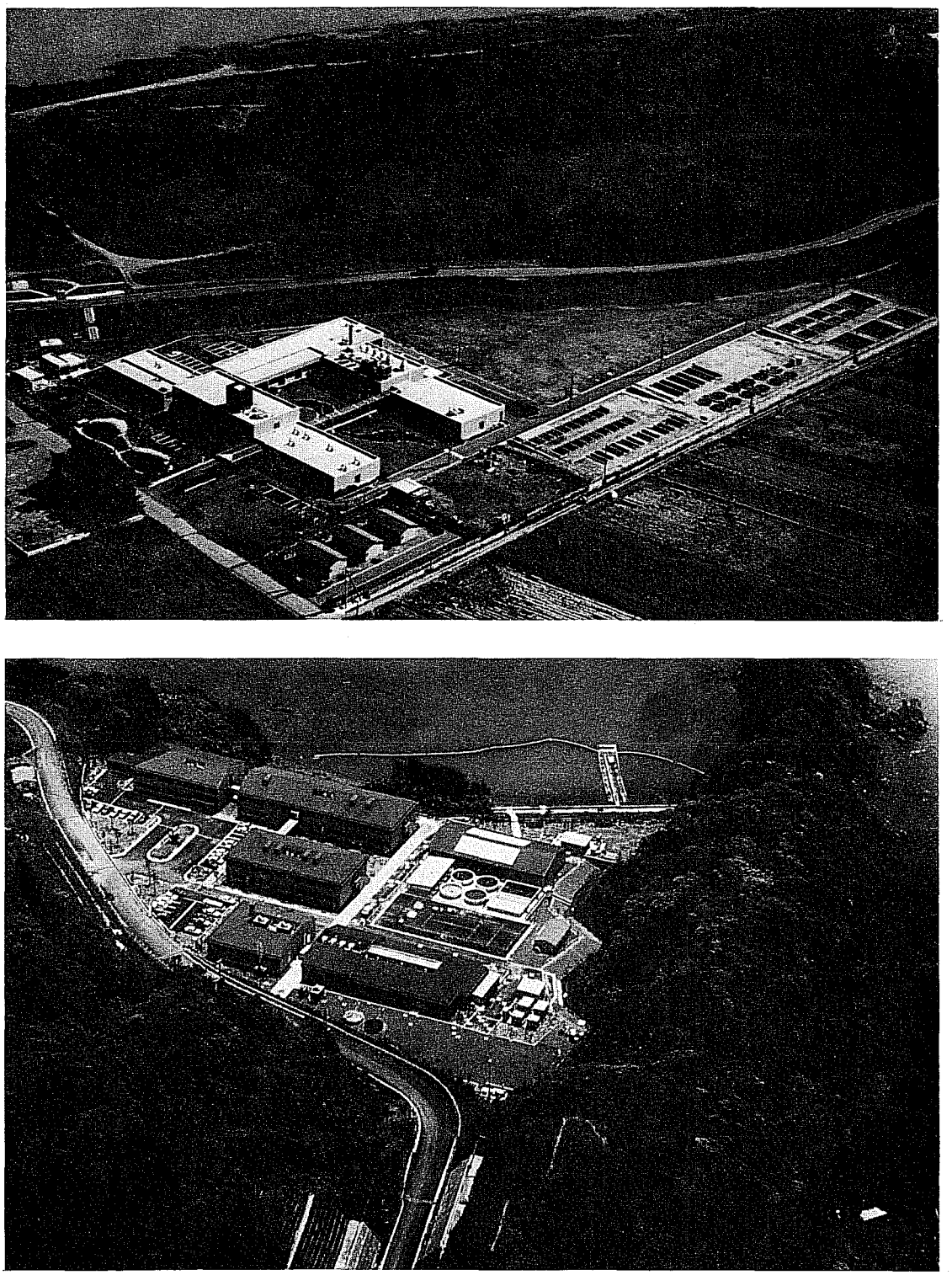


Fig. 8 The National Research Institute of Aquaculture. Inland station (top) and coastal station, headquarters (bottom).

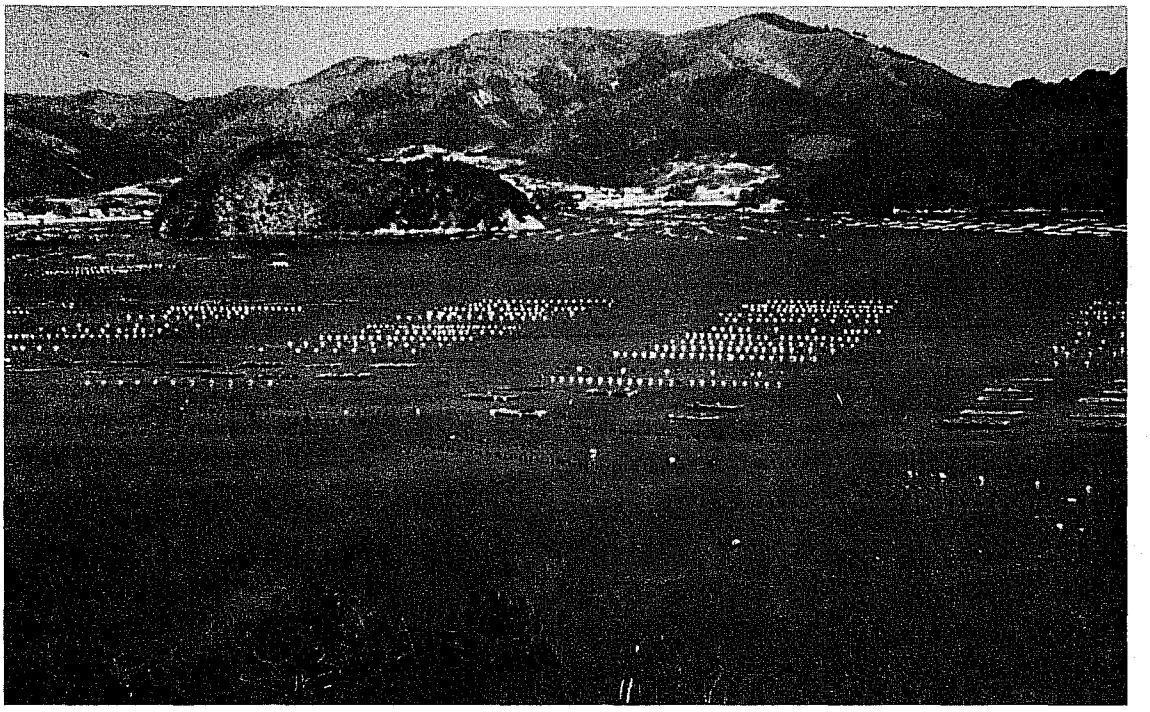


Fig. 9 Culture of a variety of shellfish in a bay off northern Japan.

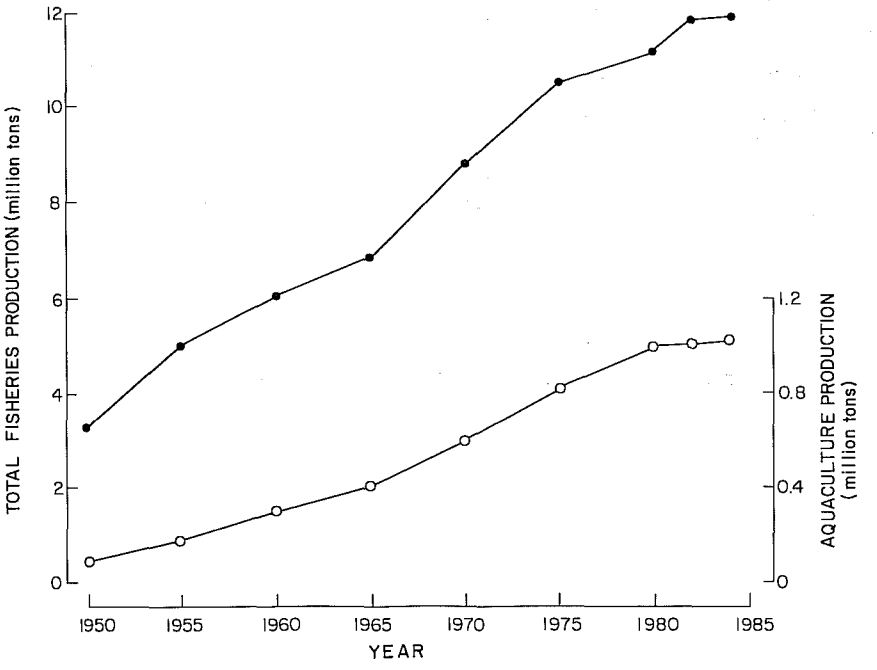


Fig. 10 Yearly increases in total fisheries production (solid circle) and aquaculture production (open circle).

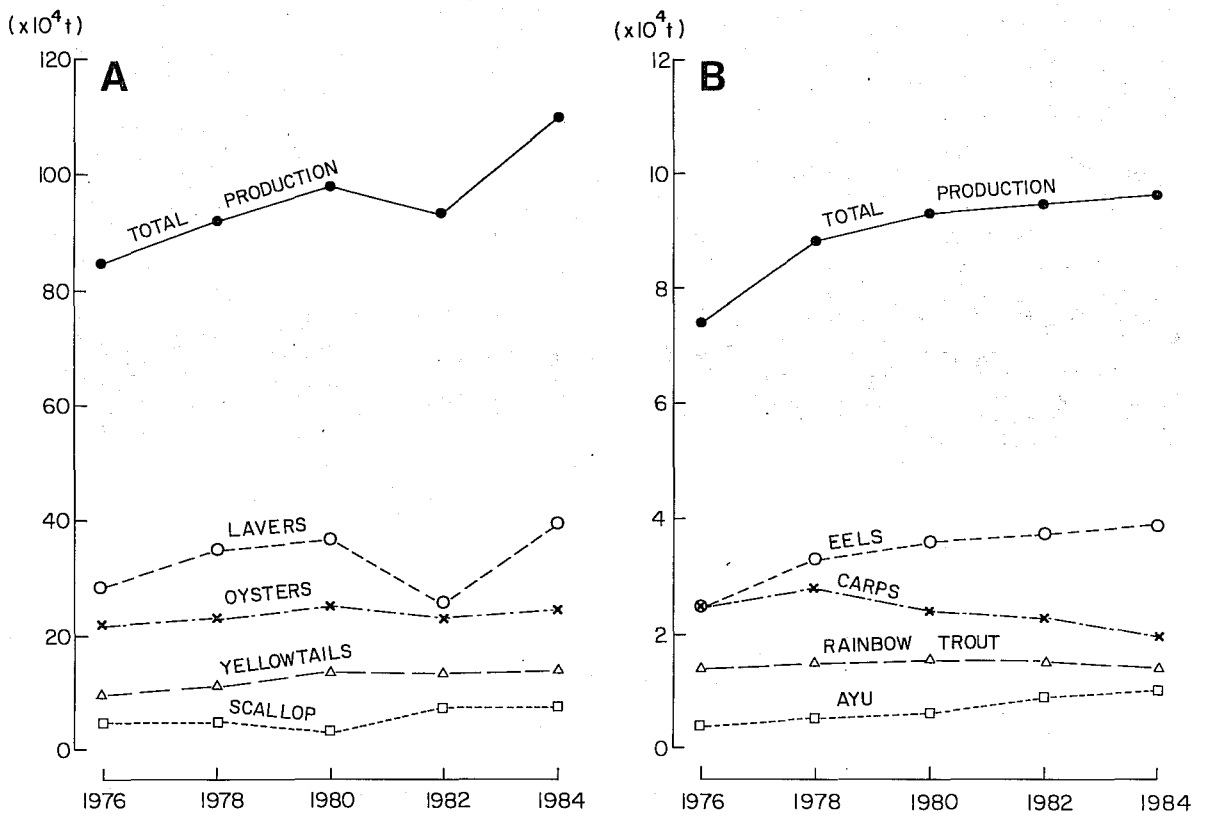


Fig. 11 The total marine (A) and inland water (B) fisheries productions in Japan.

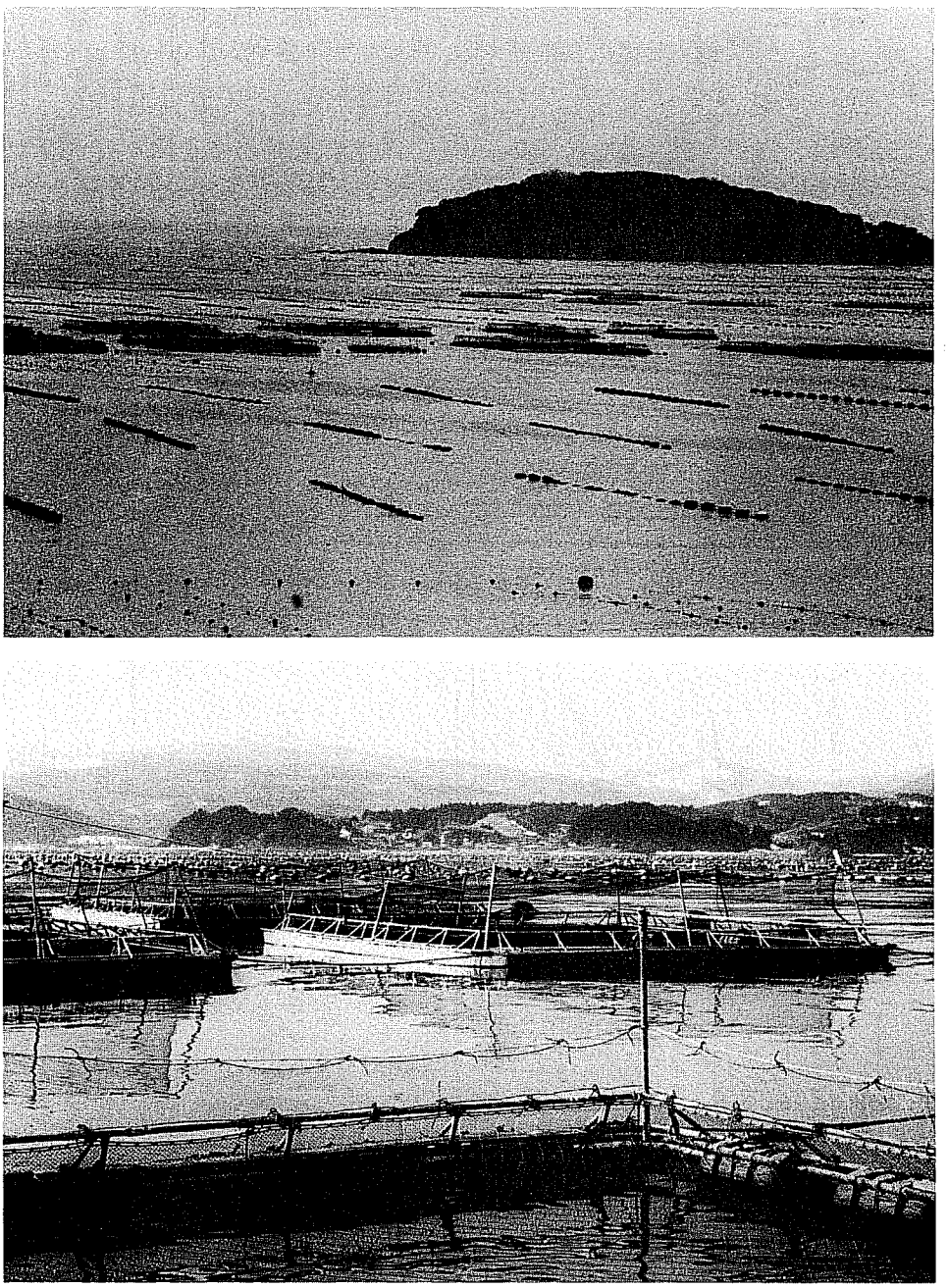


Fig. 12 Coho salmon cage culture in the Shizugawa Bay, Miyagi Prefecture.

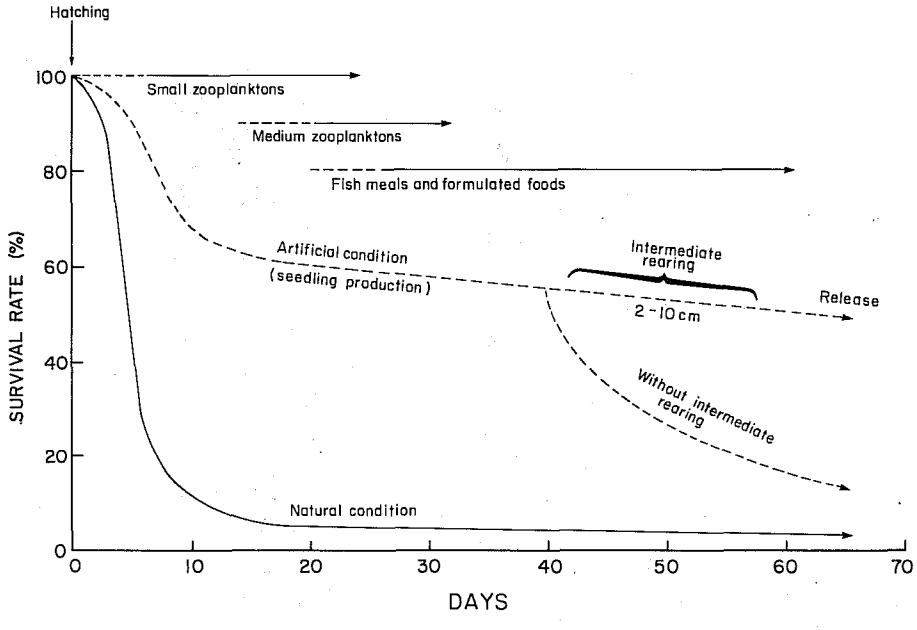
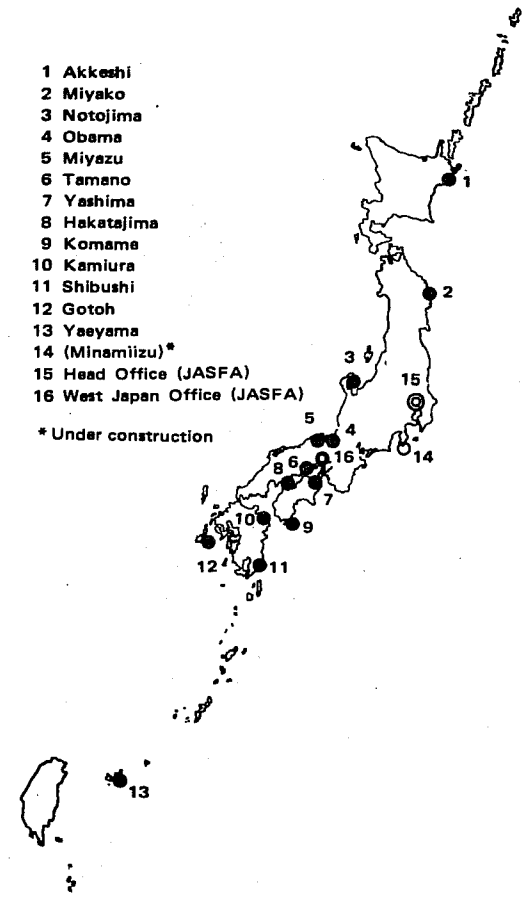


Fig. 13 Increase in the survival rate by optimizing the timing of fingerling release by intermediate rearing operations.

Fig. 14 Location of National Sea Farming Centres with their head office in Tokyo, and the list of species currently under large-scale operations. →



Center	Species
Akkeshi	Herring, Kingcrab, Flatfish
Miyako	Flounder, Jacopever, Herring, Horsehair crab
Notojima	Flatfish, Cod, Sandfish, Pandalid shrimp
Obama	Snow crab, Flatfish, Pandalid shrimp
Miyazu	Red tilefish, Flatfish, Arrow squid, Crago shrimp
Tamano	Blue crab, Grouper, Octpus
Yashima	Yellow tail, Spanish mackerel, Octpus
Hakatajima	Red seabream, Flounder, Grouper, Octpus
Komame	Red seabream, Yellow tail, Striped jack
Kamiura	Red seabream, Yellow tail, Striped jack, Japanese horse mackerel
Shibushi	Kuruma prawn, Horseshoe crab, Yellowsea prawn, Flog crab
Gotoh	Yellow tail, Striped jack, Grouper
Yaeyama	Tunas, Amberjack, Cuttlefish, Grouber, Blue fusilier, Mud crab

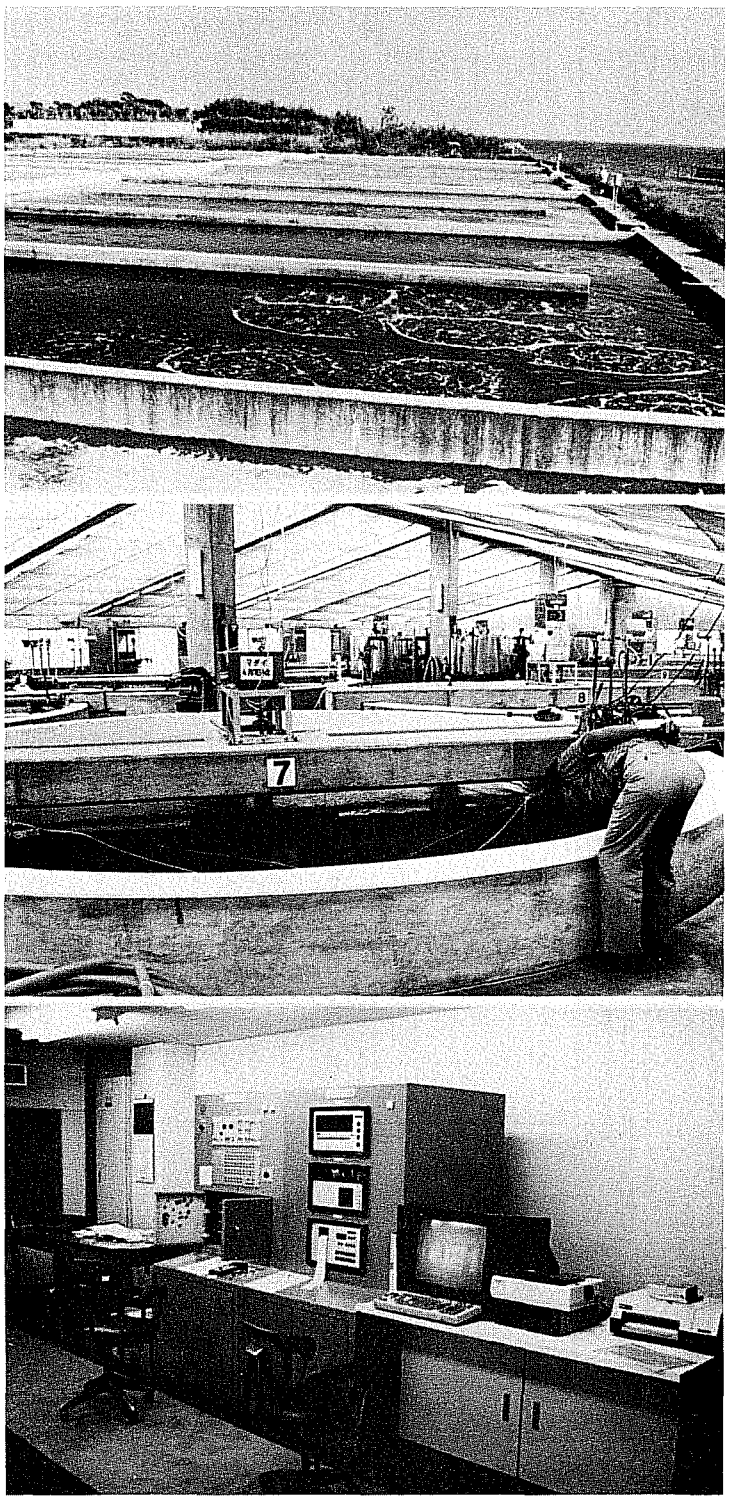


Fig. 15 Kagoshima Prefecture Sea Farming Centre, Tarumi, Kagoshima. Indoor and outdoor rearing of sea bream fingerlings and control centre.

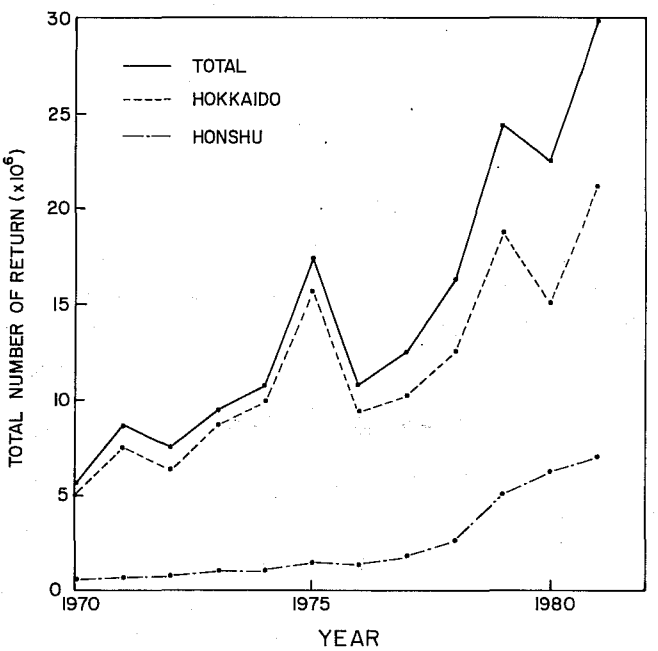


Fig. 16 The total number of yearly return of chum salmon.

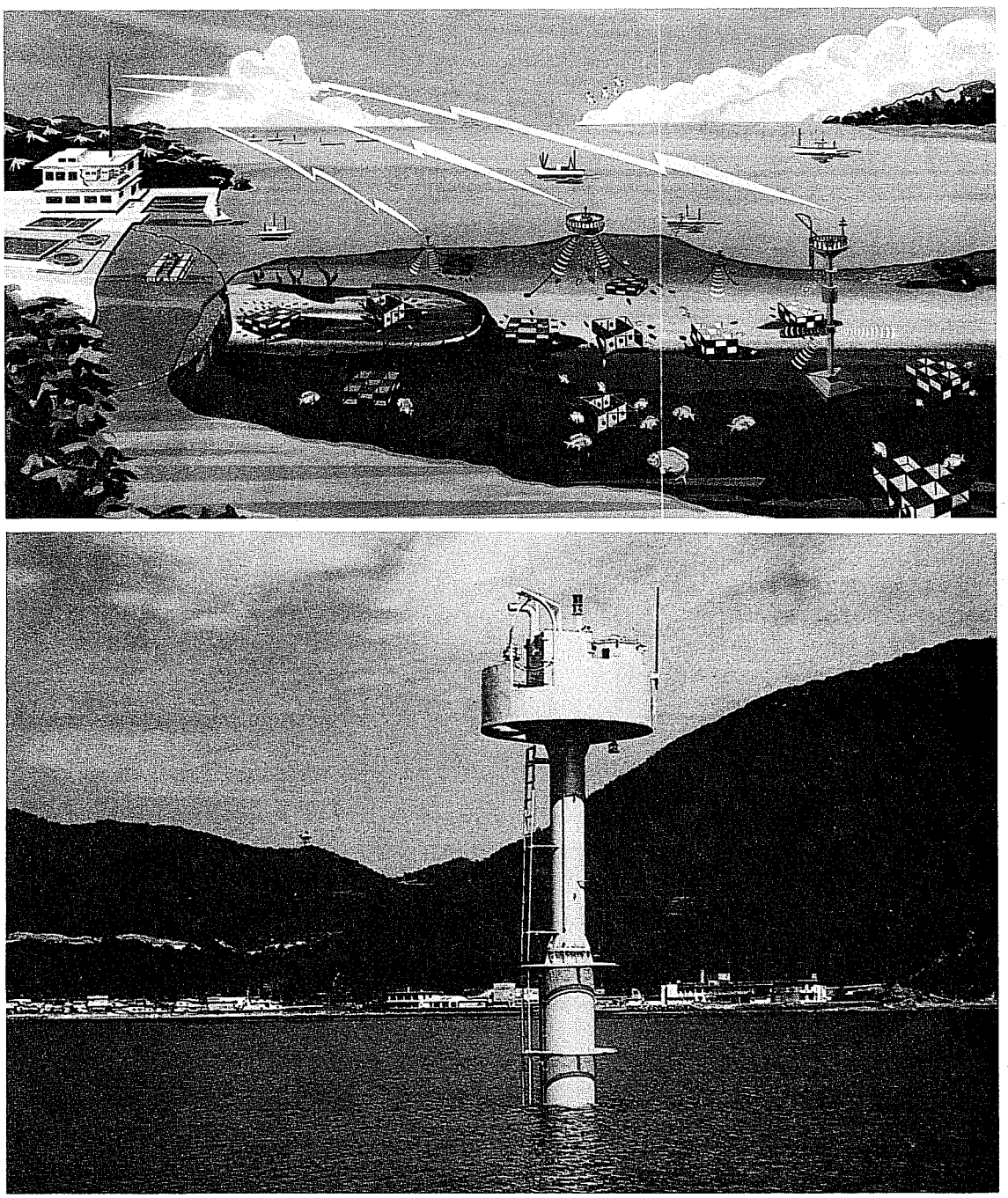


Fig. 17 An artist's view of the marine ranching operation of sea bream at the Saeki Bay, Oita (Top) and a buoy (27m high) generating pulses for feeding fish and transmitting various data to the control centre.

Appendix 1. National fisheries research laboratories and institutes.

Hokkaido Regional Fisheries Research Laboratory	116 Katsurakoi Kushiro, Hokkaido 085 TEL 0154-91-9136
Tohoku Regional Fisheries Research Laboratory	3-27-5 Shinhama-cho Shiogama, Miyagi 985 TEL 02236-5-1191
Tokai Regional Fisheries Research Laboratory	5-5-1 Kachidoki Chuo-ku, Tokyo 104 TEL 03-531-1221
Nansei Regional Fisheries Research Laboratory	7782-9 Maruishi Ono, Hiroshima 739-04 TEL 0829-55-0666
Seikai Regional Fisheries Research Laboratory	49 Kokubu-cho Nagasaki, Nagasaki 850 TEL 0958-22-8158
Japan Sea Regional Fisheries Research Laboratory	1-5939-22 Suido-cho Niigata, Niigata 951 TEL 0252-28-0451
Far Seas Fisheries Research Laboratory	5-7-1 Orido Shimizu, Shizuoka 424 TEL 0543-34-0715
National Research Institute of Aquaculture	422-1 Nakatsuhamaura Nansei, Mie 516-01 TEL 05996-6-1830
National Research Institute of Fisheries Engineering	7620-1 Ebidai Hasaki, Ibaraki 314-04 TEL 04794-4-4961

Appendix 2. Universities and colleges with fisheries faculty or department.

Hokkaido University Faculty of Fisheries	3-1-1 Minato-machi Hakodate, Hokkaido 041 TEL 0138-41-0131
Tohoku University Faculty of Agriculture	1-1 Tsutsumidori Amemiya Sendai, Miyagi 980 TEL 0222-72-4321
Kitasato University School of Fisheries Sciences	160-4 Okkirai Sanriku, Iwate 022-01 TEL 01924-4-2121
Tokyo University of Fisheries	4-5-7 Konan Minato-ku, Tokyo 108 TEL 03-471-1251
University of Tokyo Faculty of Agriculture	1-1-1 Yayoi Bunkyo-ku, Tokyo 113 TEL 03-812-2111
Nihon University College of Agriculture & Veterinary Medicine	3-34-1 Shimouma Setagaya-ku, Tokyo 154 TEL 03-421-8121
Tokai University College of Oceanography	3-20-1 Orido Shimizu, Shizuoka 424 TEL 0543-34-0411
Nagoya University Faculty of Agriculture	Furo-cho Chikusa-ku, Nagoya 464 TEL 052-781-5111
Mie University Faculty of Fisheries	2-80 Edobashi Tsu, Mie 514 TEL 0592-32-1211
Kyoto University Faculty of Agriculture	Kitashirakawa Oiwake-cho Sakyo-ku, Kyota 606 TEL 075-751-2111
Kinki University Faculty of Agriculture	3-4-1 Kowakae Higashiosaka, Osaka 577 TEL 06-721-2332
Hiroshima University Faculty of Applied Biological Science	2-17 Midori-machi Fukuyama, Hiroshima 720 TEL 0849-24-6211
Kochi University Faculty of Agriculture	200 Monobe otsu Nangoku, Kochi 783 TEL 08886-3-4141
Kagawa University Faculty of Agriculture	2366 Miki-cho Kida-gun, Kagawa 761-07 TEL 08789-8-1411
Shimonoseki College of Fisheries	1944 Yoshimi Nagatahon-cho Shimonoseki, Yamaguchi 759-65 TEL 0832-86-5111
Kyushu University Faculty of Agriculture	6-10-1 Hakozaki Fukuoka, Fukuoka 812 TEL 092-641-1101
Nagasaki University Faculty of Fisheries	1-14 Bunkyo-cho Nagasaki, Nagasaki 852 TEL 0958-47-1111
Miyazaki University Faculty of Agriculture	3-210 Funatsuka Miyazaki, Miyazaki 880 TEL 0985-27-0214
Kagoshima University Faculty of Fisheries	4-50-20 Shimo-arata-cho Kagoshima, Kagoshima 890 TEL 0992-54-2181

Appendix 3. Biotechnology research currently underway at prefectural fisheries experimental stations under the Regional Biotechnology Research and Development Program. Estimated budget for 1986, $0.7 million.

1. Production of "super-sized" salmonid fishes by sterilization techniques. Aomori Pref.
2. Technical development of sex control. Miyagi.
3. Production of "all-female" land-locked masu salmon by sex control. Yamagata.
4. Mass production of sterile triploid masu salmon by chromosome manipulation. Toyama.
5. Production of sterile land-locked sockeye salmon by chromosome manipulation. Ishikawa.
6. Technological development for production of female, sterile "super" rainbow trout by sex control and polyploidy. Nagano.
7. Hybridization of ayu and amago salmon by polyploidy. Gifu.
8. Breeding of polyploid rainbow trout and charr. Shiga.
9. Production of "superior" hybrid seedlings of flounders by genetic engineering. Tottori.
10. Mass production of flounder seedlings by sex control and sterilization. Yamaguchi.
11. Technical development of triploid production of pearl oysters. Ehime and Kochi.
12. Isolation of laver protoplast and production of hybrids by cloning. Fukuoka and Saga.
13. Hybridization of sea bream and flounders for aquaculture by gene cloning. Nagasaki and Kumamoto.