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Fisheries technology cooperation for the 21st century

Paul Kilho Park*

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Abstract: Shifting paradigms from capturing to nurturing living marine resources require continuing cooperation among industry, commerce, academia, and government. Both management and technological competence must be tapped. In conjunction with the UJNR Aquaculture Panel's activities, the UJNR Marine Facilities Panel can play a pivotal role to enhance this cooperation. Oceanic acoustics and optics; remote sensing of temperature and color; platform and buoy innovation; coastal and civil engineering; genetic engineering and pathobiology in reference to sea-farming and sea-ranching are some of the needed matrices that 21st century fisheries engineering requires.

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I . Introduction

A unique opportunity to streamline cooperation among industry and commerce, academia, and the government with budgetary preparedness and a pooling of human talent, wisdom, and intellectual property are looming in the field of fisheries engineering in the 21st century. As such, I solicit an active participation of the UJNR(U. S.-Japan Natural Resources) Marine Facilities Panel to initiate a continuous dialogue on the 21st Century fisheries engineering cooperation as part of the panel's future undertaking.

Unlike the present fossil-fuel industrialization, fisheries in principle are sustainable for many generations to come. Furthermore, the enhancement of fisheries engineering is economically important to both the United States and Japan in the field of international trade. For instance, the U. S. fishery trade deficit in 1994 was \$4.6 billion(National Marine Fisheries Service, 1995). Japan, too, imports much: it was \$1.7 billion in 1992, the second largest import item after crude oil and natural gas of \$3.8 billion in that year(Japan Fisheries Agency, 1993). About one-third of Japanese seafood is imported.

My vision of 21st century fisheries engineering is similar to that of agricultural engineering that has been enabling people to establish a stable human community for over a century. Agriculture, forestry, and fisheries are producers for humanity, and they are sustainable, supporting the welfare of future generations, adding fresh energy into the populace, and keeping the global ecosystem alive

II. The World Biomass

In his thought-provoking book entitled "A History of Knowledge", Van Doren(1992) offers a table of "The World Biomass" on page 393(Table 1). His first-order estimate shows that human beings at 5 billion weigh 250 million tons. Plants, primary producers, are estimated at 70 billion tons, and animals, including humans, at 2 billion tons. Van Doren's(1992) estimate can be augmented by adding phytoplankton biomass, standing crop, when we quantify the oceanic primary productivity in time and space.

People already occupy over 10% of the total animal weight. Over 90% of land animals are people-controlled, which in turn impact the current issue of maintaining a healthful biodiversity on earth. Furthermore, our global ecosystem changes on, and Van Doren's estimate will be modified as we quantify the various components of the global biomass and their dynamics in time and space.

The sun's energy reaching the surface of the earth begets primary production. Pauly and Christensen(1995) give a synopsis of what we know and deduce. According to them, global primary productivity generates about 200 billion tons dry weight of biomass a year. This is an input vector. Of this, 59% is produced in terrestrial ecosystems, agriculture included, and the rest in aquatic systems. About 35 to 40% of the terrestrial productivity is used as food, fiber, animal feed, *etc.* by man. Some will enter the ocean as organic matter, which, too, is an energy vector the ocean receives. In 1972, the late Professor Robert M. Garrels asked me a profound question: "Is the ocean oxidizing or reducing?" I then and still even today could not and cannot answer it quantitatively. Simply stated: "Is the ocean a net producer or a net consumer?"

III. Primary Production Required by Fisheries

The United Nations Food and Agriculture Organization (FAO), Roma, Italy, issues the FAO Year Book annually. Utilizing its 1993 Year Book information, Pauly and Christensen (1995) give the following summary:

Table 1. The world biomass, from "A History of Knowledge" by Charles Van Doren, Ballantine Books, April 1992 (from page 393)

Biomass	Million tons
<u>Human beings</u> (five billion persons)	250
<u>Animals</u>	
Livestock : cattle	520
sheep, goats, etc.	75
hogs	100
chickens, ducks, geese, etc.	10
Pets	5
Large wild animals (lions, eagles, whales, ardvarks, mustangs, elephants, etc.)	10
Small wild animals (rats, mice, frogs, toads worms, etc.)	15
Insects, bacteria, etc.	15
Fish and crustaceans	1,000
<u>Plant*</u>	
Crops	2,000
Other land plants	8,000
Trees	39,000
Seaweed and other aquatic plants	24,000
Total biomass of earth	75,000

* Phytoplankton may modify the table considerably.

"The mean of reported annual world fisheries catches for 1988-1991 (94.3 million tons) was split into 39 species groups, to which fractional trophic levels, ranging from 1.0(edible algae) to 4.2(tunas), were assigned, based on 48 published trophic models, providing a global coverage of six major aquatic ecosystem types. The primary production required to sustain each group of species was then computed based on a mean energy transfer efficiency between trophic levels of 10%, a value that was re-estimated rather than assumed. The primary production required to sustain the reported catches, plus 27 million tons of discarded bycatch, amounted to 8.0% of global aquatic primary production, nearly four times the previous estimate. By ecosystem type, the requirements were only 2% for open ocean systems, but ranged from 24 to 35% in fresh water, upwelling and shelf systems, justifying current concerns for sustainability and biodiversity."

As given in the previous section and above, since 35 to 40% of the terrestrial primary productivity is used by man, and since the reported catches from inshore and nearshore waters require 24 to 35% of the primary production, our inshore fisheries are rapidly approaching the upper limit of what the sun can provide for humanity. Conversely, only 2% of the open ocean's primary productivity is utilized by fisheries(Pauly and Christensen, 1995). Judicious sea-ranching, such as Japanese sardine ranching in waters between the Japanese island chain and the Kuroshio axis, considered by the Mitsubishi Heavy Industry, Nagasaki, is a plausible and laudable undertaking in theory(personal communication, Professor Takashige Sugimoto¹⁾, University of Tokyo). Satellite remote sensing, such as by the new Japanese patches of phyto-and zooplankton blooms and introduction of the oceanic Japanese sardine ichthyoplankton, into the plankton patches, will ensure the integrity of the sardine year class, which is a needed first step.

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Twenty-first century fisheries technology requires sophisticated remote sensing capability as well as real-time information dissemination to realize its goals. Offshore structures, too, will enhance future technology. Already available structures, such as unused oil rigs, can be recycled for innovative fisheries endeavors.

IV. The U. S. Effort

In the United States, the National Marine Fisheries Service (NMFS) is mandated by the Magnuson Fishery Conservation and Management Act to carry out specific fisheries research activities (Table 2). The act also spells out that national standards on the fishery conservation and management measures must be based upon the best scientific information available. Therefore, NMFS is mandated to carry out research activities and to provide the best scientific information for the national fishery management program (Title III of the act). This requires a continuing effort to timely innovate, operate, synthesize, and deliver scientific findings. Concomitant and cost-effective technological improvement is essential to carry out the intent of the act. The technological improvement requirement covers gathering of emerging, novel technological information worldwide; its effective application to the act' and finding a way to engage in the needed technology development via the most effective way, be it outsourcing or in-house research and development. The challenges NMFS faces are formidable, requiring a new paradigm to establish a functioning network with industry, academia, and the military via timely application of declassified technological information, nationally and internationally (especially in the fields of oceanic acoustics and optics), and continuous and vigilant surveillance on emerging domestic and foreign intellectual properties. High-speed computing

and application of satellite-generated information are equally essential.

The fisheries research activities mandated by the act are specific and expansive. The four areas in the act that require sophisticated technology, including ships and other platforms, are as follows:

- (1) Abundance and availability of fish, including the study of fish behavior;
- (2) Biological research on the interdependence of fish stocks;
- (3) Pollution impacts on fish populations; and
- (4) Wetland and estuarine degradation.

The U. S. Exclusive Economic Zone (EEZ) areas covered by the act are expansive and almost semi-global, from American Samoa near New Zealand in the southern hemisphere of the Pacific to Guam south of Japan to the Arctic Ocean north of Alaska and to the Virgin Islands in the Atlantic (Fig.1). Fundamental, synoptic survey of all the areas alone will require years of effort, even taking into consideration the available information generated by the global fishing community. In addition, the physical dynamics of the oceans must be elucidated to intelligently decipher the fishery stock assessment information. The oceanic wind, current, temperature, primary and secondary productivity, oceanic ecosystem dynamics that include the predator-prey relationships, pollution condition, long-term climatic changes, and El Niño and La Niña events all contribute to the needed information synthesis. Fisheries scientists in NMFS thus must be conversant in the physical sciences, such as physical oceanography and meteorology, to understand why fishery stock assessment information varies in time and space. Overfishing also comes into the total picture. Unfortunate habitat and nursery destructions in the nation's wetland and estuarine regions also fundamentally affect the fisheries. For instance, the recent demise of American shad is attributed to the loss of spawning grounds due to the damming of rivers.

Table 2. Fisheries research, mandated by the Magnuson Fishery Conservation and Management Act as amended through 28 November 1990.

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- (1) Within one year after the date of enactment of the fishery Conservation Amendments of 1990, and at least every three years thereafter, the Secretary* shall develop and publish in the Federal Register a strategic plan for fisheries research for the five years immediately following such publication. The plan shall --
 - (A) Identify and describe a comprehensive program with a limited number of priority objectives for research in each of the areas specified in paragraph (2);
 - (B) Indicate the goals and timetables for the program described in subparagraph (A); and
 - (C) Provide a role for affected commercial fishermen in such research, including involvement in field testing.
 - (2) The areas of research referred to in paragraph (1) are as follows :
 - (A) Research to support fishery conservation and management, including research on the economics of fisheries and biological research concerning the interdependence of fisheries or stocks of fish, the impact of pollution on fish populations, the impact of wetland and estuarine degradation, and other matters bearing upon the abundance and availability of fish.
 - (B) Conservation engineering research, including the study of fish behavior and the development and testing of new gear technology and fishing techniques, to minimize the harvest of nontarget species and promote efficient harvest of target species.
 - (C) Information management research, including the development of a fishery information base and an information management system that will permit the full use of data in the support of effective fishery conservation and management.
 - (3) In developing the plan required under paragraph (1), the Secretary* shall consult with relevant Federal agencies, scientific and technical experts, and other interested persons, public and private, and shall publish a proposed plan in the Federal Register for the purpose of receiving public comment on the plan. The Secretary* shall ensure that affected commercial fishermen are actively involved in the development of the portion of the plan pertaining to conservation engineering research. Upon final publication in the Federal Register, the plan shall be submitted by the Secretary* to the Committee on Commerce, Science, and Transportation of the Senate and the Committee on Merchant Marine and Fisheries of the House of Representatives.
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* Secretary, U. S. Department of Commerce.

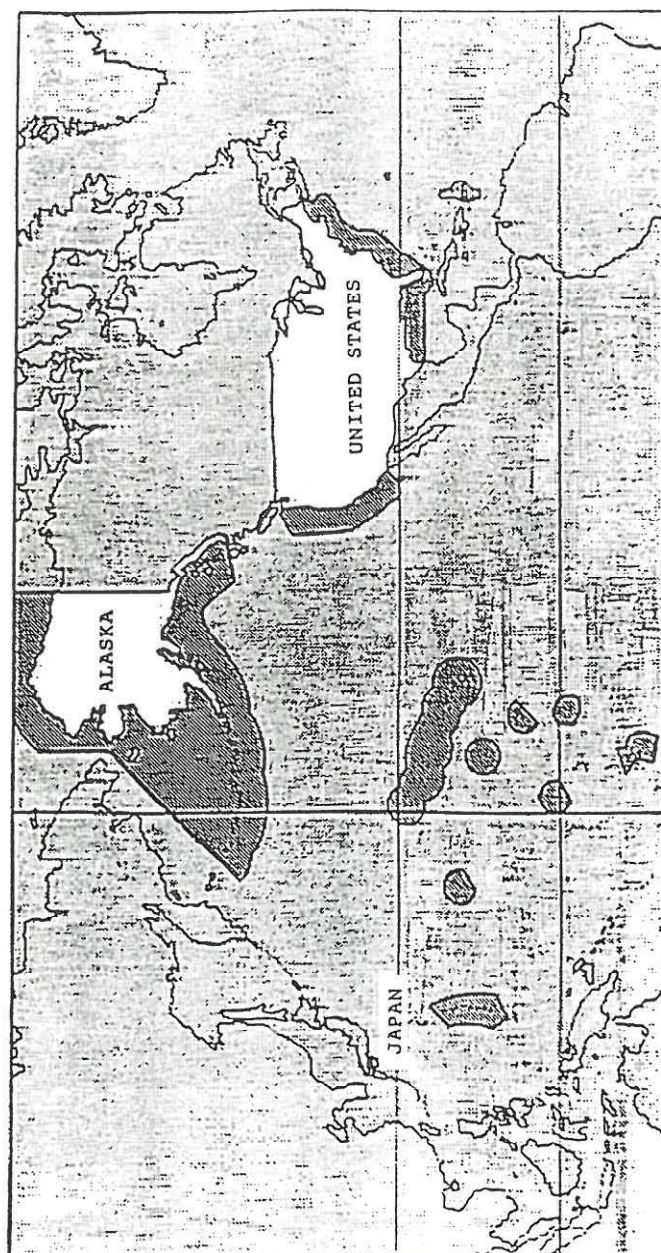


Figure 1. Expansiveness of U.S. Exclusive Economic Zone(shaded areas)

It is time to reexamine economically the ongoing NMFS fisheries stock assessment efforts that require emerging technology, research ships and other platforms. Nevertheless, the ongoing effort cannot be abandoned abruptly with untested, and yet undeveloped, techniques and methods. For instance, ships are needed in the foreseeable future, and the life span of ships is not long(20 years in Japan, and 30 years in the United States). We are now in the throes of transition. Furthermore, the research fund appropriation is not plentiful, thus requiring the most innovative and cost-effective ways to carry out the intent of the act.

In aquaculture, in comparison with Japan, the U. S. sea-farming and sea-ranching technology is in its infancy and expected to accelerate in the coming years. In the United States, strict EPA water quality standards must be adhered to in order to have aquaculture permits. Some novel approaches have been tested. For instance, Willinsky and Champ(1993) report their experiments on a submersible fish cage.

In addition, much classified information exists in the fields of oceanic acoustics and optics. They were used heretofore for the military, such as for antisubmarine warfare(ASW), and satellite sensor development. As these data become declassified, their fisheries application will stimulate considerably the growth of fisheries engineering.

V. The Japanese Effort

Japan's fisheries problems are many. Both far-seas and offshore fisheries are waning, partly on account of the restrictions imposed on them by 200 nautical mile(370km) EEZ of many countries. Another concern is that the fishery community in Japan is dwindling, from 320,000 in 1988 to 280,000 in 1992, and aging

(one-third of the fishermen were 60 years old or older in 1992). In addition, Japan imports one-third of its seafood from abroad. There is a joke in Japan that when the fishery import becomes greater than 50% of the total in-Japan consumption, the present Japan Fisheries Agency will become a part of MITI (Ministry of International Trade and Industry) as a Department or Division. In the United States, NMFS already has been a part of the U. S. Department of Commerce for the past 25 years.

On the other hand, Japan's nearshore, sea-farming, and inland fisheries are vigorously attended and improved with much patience. Harvest has grown from 2 million tons per annum in 1956 to 3 million tons in 1992, after numerous trials and errors, as given in the 30th year report issued by the Japan Sea-Farming Association (1993).

In order to enhance their EEZ fisheries, the savants of Japanese fisheries established the Association for Fishery Development on 200 Nautical Miles Waters in Japan, Marine-Forum 21, in 1985 to develop innovative fisheries engineering to enhance their 200-mile EEZ fisheries. I visited the Association on 26 May 1994 and was received graciously by Professor Dr. Akihiko Shiota, Technical Advisor to Marine-Forum 21, who kindly briefed me on the overall activities of the Association. I immediately recognized the Japanese' ability to thoroughly streamline the best of academia, industry, and government (both local and national) in developing the needed fisheries engineering know-how to enhance their EEZ fisheries. Unfortunately, Professor Shiota requested my understanding in realizing that most of the Association's activities are proprietary. He was not allowed to disclose them to me, for their development funding comes from both industry (\$9 million per annum) and government (\$6 million per annum) for Japan to build its intellectual property rights, a sellable commodity. Many industrial patents are actively developed, obtained, and held by the Association (neither

industry nor government have them), especially that of high-technology and multi-purpose inventions. I personally was much impressed by Japan's new concerted effort to sea-ranch Kuro Maguro(kuro means black, and maguro means tuna in Japanese), bluefin tuna, in the Pacific Ocean off Okinawa. Sea-ranching tuna is a formidable task, but Japan now has begun undertaking it.

VI. Sea-Farming Strategy of Japan

Japan approaches sea-farming by a matrix system, graded by the degree of difficulty and complexity, and by job division among fisheries co-ops, non-profit fishery foundations, Japan Sea-Farming Association, prefectural governments(state governments), and the national government.

The Marino-Forum 21 is one of the non-profit fishery foundations that does not have any government red tape, though partly funded by the national government. Other non-profit foundations include the Oversea Fishery Cooperations Foundation and the Japan Sea-Farming Association.

Sea-farmed fishery species are divided into three groups. They are (1) highly migratory species, such as tuna, (2) migratory species, such as sea bream(a delicacy in Japan), flatfish, shrimp, and crabs, and (3) stationary species, such as abalone and sea urchins. All of them are expensive seafood items in Japan. The tasks to be carried out are also divided into three parts. They are (1) basic and applied technology development, (2) industrialization, and (3) commercial operation.

The majority of technological development is carried out by the local and national government entities, supported by the Japan Sea-Farming Association. On sedentary species, local government entities, not national, engage in technological development. On

industrialization, it is interesting to note that the national government is presently earmarked to work on the difficult tuna sea-ranching. On migratory species, local governments, non-profit fishery foundations, and fisheries co-ops all work together to industrialize it. On sedentary species, only fisheries co-ops industrialize it. For commercial operation, no entity is assigned for tuna sea-ranching yet. For migratory species, both non-profit foundations and fisheries co-ops are charged to carry it out. Finally, for sedentary species, only the local fisheries co-ops operate it.

The Japan Sea-Farming Association plays a pivotal coordinating role for the entirety of Japan, connecting the government, academia, fisheries laboratories, and various fisheries co-ops through local governments. The fisheries co-ops, fishing community, are the recipients of the economic benefits of this focused, coordinated networking. The Japan Sea-Farming Association also operates all 15 national fish-farming centers on behalf of the Japan Fisheries Agency. An additional tuna-farming center recently has been constructed near Okinawa.

The National Research Institute of Fisheries Engineering is located by the mouth of Tone River at Hasaki. It was established in March 1979, and its construction completed in March 1993. Its main research programs are in the fields of (1) aquaculture ground engineering, (2) fishing port engineering, (3) fishing boat engineering, (4) development of instruments for fisheries survey, and (5) fishing gear and methods. The institute had an annual operating budget of \$9 million and staff of 63 in 1992. This expansive institute occupies 81,500 square meters. Many students come to work on their graduation theses (the Japanese school year ends the latter part of March; undergraduate students are required to produce a graduation thesis during the fourth year), thus to ensure the nurturing of a new cadre of workers for years to come.

The institute's focused effort on the enhancement of aquaculture ground and of the amenity of fishing villages is noteworthy. Improvement of fish reefs goes on. Some water tanks are capable of varying waves, water flow, light and sound intensity, and hydrostatic pressure for simulation studies. Some fish are now trained to associate being fed with artificially emitted sound. The use of old cars to build fish reefs is not preferred due to the unpredictable movement of the cars, thus damaging nets and other aquaculture structures. A Report to the Diet Assembly(Congress) from the Japan Fisheries Agency in 1993 speaks of the importance of the enhancement of fishing village amenity, which requires a new kind of coastal engineering and civil engineering(the Japanese Society of Civil Engineering is now discussing to replace "civil engineering" to "civil cosmos", reflecting peoples's cultural values be enhanced in engineering endeavor).

Artificial fertilization improvement for sea-farming goes on in Japan. It is on the cutting edge in genetic engineering. Similar to agriculture, sea-farming must ensure superb seed-stock hatching en masse; raise them away from predators when they are young and vulnerable, especially during the first two months or so; release them at suitable sites; continue to offer protection and enhancement in nature; and eventually harvest them.

In 1963, assisted by both the local government and the fishery community, the Seto Inland Sea was first used as a pilot sea-farming site for a national government project. In 1979, the non-profit Japan Sea-Farming Association was officially established. In 1994, a national tuna sea-ranching center was built south of Kyushu.

Ensuring a strong disease-resistant gene pool has been a formidable task, especially against detrimental vira. Therefore, in sea-farming, marine pathology and fish genetics are two important fields to ensure profitable sea-farming. Many pairs of parent

organisms, 25 to 250 pairs, are considered to sustain a continuing, healthful gene pool.

Reducing the mortality of fingerlings too is an important consideration. Without protection, the survival rate for new fingerlings is very low; often, less than 10% of the original population survives 10 days. The Sea-Farming Association's target is to maintain a greater than 50% survival at the end of two months by the progression of feeds suitable for optimal growth, from small to medium size zooplankton, and later minced seafood. Feed technology, too, is a significant effort that Japan pursues.

The Association for Fishery Development on 200 Nautical Miles Waters in Japan, Marino-Forum 21, is to develop Japan's 21st century fisheries. It was established in October 1985 and became a non-profit association under the Ministry of Agriculture, Forestry and Fisheries(MAFF) in July 1986. The goal of Marino-Forum 21 is to establish effective networks to enhance the technical capability of the fishery community, and to foster the willingness of local governments and non-profit cooperations to further develop the fishery industry. It will focus its activities within the 200 nautical mile EEZ of Japan by developing suitable fishery grounds, and by developing new technology needed to sea-farm and sea-ranch, thus offering stable and continuing seafood supply to Japan. New technological development, 200-mile EEZ fishery potential survey and research, and its concordant information-gathering are some of its activities.

Acoustic feeding is developed by Marino-forum 21. Flatfish, rockfish, and sea bream(similar to red snapper) ranching is being carried out at depths of 5, 10 and 57m, respectively. All of them use automatic acoustic feeding devices attached to offshore platforms or buoys. The sound source is at 30W, 150dB, 300Hz, discontinuous. The platforms and buoys are powered by both solar (200W or six 46.3W) and ordinary batteries. Thermal and fish-

school sensors are attached to the platforms and buoys. They are telemetered to the onshore command posts. Training fish to associate a certain sound with feeding requires 40, 60, and 80 days for flatfish, rockfish, and sea bream, respectively. An interesting sideline is that wild fish too are concurrently being trained to associate sound with feeding. Attitudinal change among the local fishing community to recognize that sea-ranching is beneficial to the local economy, such as by concurrent eco-tourism and sport fishing, is an important dividend in addition to actual enhanced fishery yield.

VII. Discussion

Japan and the United States have been sharing a common heritage starting in 1868, when a group of Japanese farmers immigrated to Hawaii. Our combined intellectual pool is second to none in the world. Unlike the short-lived epoch of fossil-fuel exploitation in human history(Hubbert, 1973), technologically enhanced sea-farming and sea-ranching, in addition to well-regulated high-sea fisheries, both commercial and sport fisheries, can become a legacy our generation can leave behind for its progeny. Economic competition goes on between Japan and the United States, sometimes furiously. At the same time, our two countries are the leaders in maintaining global health. We assist many countries in education and in mitigating natural disasters. My view of unselfish cooperation in fisheries engineering in the 21st century by these two countries is to believe in the future benefit for humanity, thus for the future of our progeny. One day, I would like to see that sellable intellectual property developed by us be shared between us when necessary. That "when" may come sooner than we expect.

Acknowledgments

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