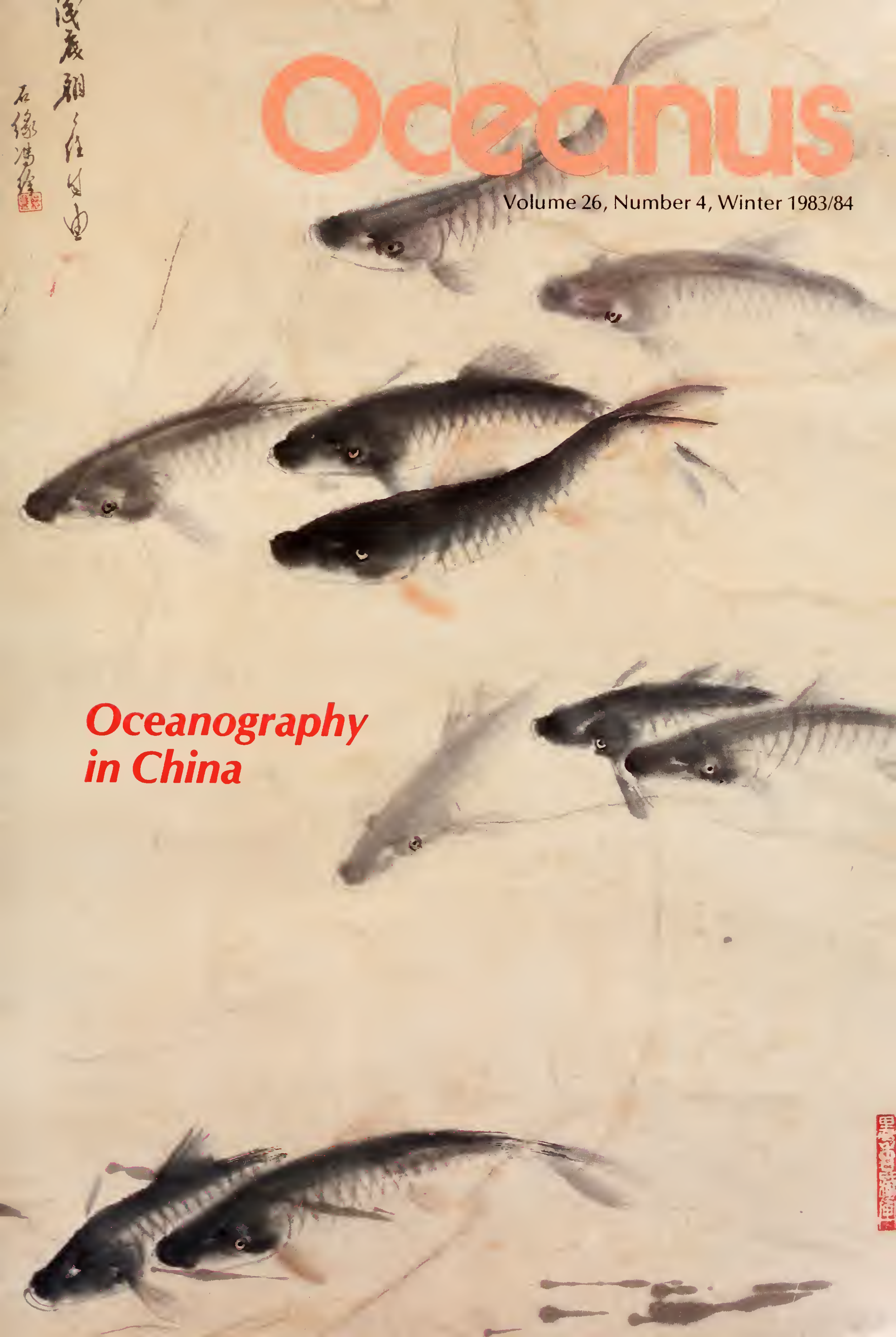
Oceanus

Volume 26, Number 4, Winter 1983/84

Oceanography in China



Oceanus®

The Magazine of Marine Science and Policy
Volume 26, Number 4, Winter 1983/84

Paul R. Ryan, *Editor*
Michael B. Downing, *Assistant Editor*
Elizabeth Miller, *Editorial Assistant*
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Cover:
Fluttering in shallow water as they please – carp by Shi Yuan Feng. Courtesy of Ronald D. Zweig.

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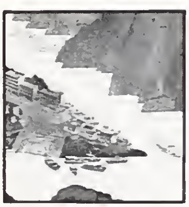

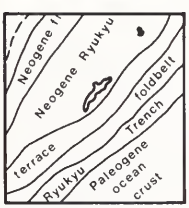

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comment

In October of 1983, the nation's oldest and largest academic institution devoted to oceanography, the Scripps Institution of Oceanography, held special ceremonies to celebrate its 80th anniversary. In 1980, the Woods Hole Oceanographic Institution (WHOI), the nation's largest independent institution devoted to oceanography, took pride in celebrating its 50th year of marine research. We think it only fitting at this time to point out some of the history and achievements of our worthy rival sister in faraway, sunny southern California.

Institutionally, Scripps is a graduate school of the University of California, San Diego. Its affiliation with the University of California goes back to 1912, some five decades before the undergraduate campus was established in La Jolla.

At the turn of the century, University of California zoology professor William E. Ritter was leading summer excursions along the California coast, conducting the first biological surveys of that state's shoreline. He came to San Diego in 1903 at the urging of physician Fred Baker, an amateur conchologist, who had raised $1,200 from the local business community to sponsor Ritter's group and had arranged for the use of a boathouse at the Hotel del Coronado.

The success of that summer's work and the enthusiasm of Baker, Ellen Browning Scripps, her brother E. W. Scripps, and other prominent San Diegans, led to the establishment of the Marine Biological Association of San Diego on 26 September 1903, which officially marks the start of Scripps. The summer field studies continued in a small wooden building in La Jolla Cove park until 1910 when the first laboratory/classroom building was completed at the institution's present location in La Jolla Shores. The Ritters made this their full-time residence.

In 1912, the marine station was transferred to the University of California and renamed Scripps Institution for Biological Research, which by then had become a year-round facility.

Research studies during the institution's early years concentrated on nearshore marine animals and plants, with emphasis on classification, distribution, and the ocean environment. Short cruises were taken on rented or borrowed ships, including yachts owned by E. W. Scripps, and from 1907 to 1916 on the *Alexander Agassiz*, an 85-foot research ship built with funds provided by Ellen Scripps. The first doctoral degree was awarded in 1919.

Ritter, a writer, naturalist, and biological philosopher, directed the institution for 20 years, until his retirement in 1923.

T. Wayland Vaughan became director in early 1924, at a time when the focus of the institution's research was broadening to aspects of the oceans other than biology. Its name was changed to reflect this in 1925 to Scripps Institution of Oceanography.

Vaughan retired in 1936, and his successor as director was Harald U. Sverdrup, a Norwegian physical oceanographer. The boat *Scripps* burned in San Diego in late 1936, and Sverdrup convinced Robert P. Scripps to purchase a luxurious 104-foot sailing schooner for the institution. Renamed *E. W. Scripps,* it began taking monthly voyages to gather data along the California coast.

The war changed Scripps, and with the infusion of funds from the federal government, especially the Navy, oceanography became a richer and larger branch of American science. Scripps's staff increased, new buildings were added, new research ships acquired, and a great variety of equipment was developed. The vast experience gained during World War II caused Scripps administrators to expand the scientific investigations beyond California's coast to all the world's oceans with emphasis on the Pacific.

Sverdrup left Scripps Institution in 1948, and for two years Carl Eckart, who had been with the Division of War Research and later director of its successor, the Marine Physical Laboratory, served as director of Scripps. Eckart considered the post temporary, and yielded it readily to Roger Revelle, a 1936 Scripps graduate who had been a prominent figure in the Navy's oceanographic research efforts.

Revelle left Scripps in 1964, and for one year, geophysicist Fred N. Spiess served as director while continuing as the director of the Marine Physical Laboratory. In 1965, William A. Nierenberg became the seventh director of the institution.

A physicist, Nierenberg has urged the use of sophisticated equipment and instrumentation for oceanographic studies, increasing computer capabilities and the use of satellite remote sensing data.

It would require considerably more space than we have available here to list the many contributions of Scripps to the development of oceanography over the last 80 years. One of its greatest contributions, however, is its progeny. Several are world leaders in research and directors of institutions. Others have major roles in the development of such organizations. C. K. Tseng, who has written the preface to this issue, is a case in point. Director of the Institute of Oceanology, Academic Sinica, in China, he worked as a Research Associate at Scripps from 1943 to 1946 following studies at the University of Michigan.

Today, Scripps is comprised of about 1,200 people, including 84 faculty members (14 emeritus) and nearly 200 graduate students. The annual institutional budget is about $68 million, with approximately 75 percent derived from federal contracts and grants. Among many anniversary congratulatory letters, including one from President Reagan, was one from Rear Admiral L. S. Kollmorgen, Chief of Naval Research: "Your 80th . . . is one that clearly shows Scripps to be looking forward, broaching frontiers throughout the ocean, never for a moment permitting a hint of complacency from well-deserved laurels."

Oceanus salutes this fine research center on its 80th anniversary. We hope that the relations between our two great institutions will continue in a spirit of friendly rivalry and genuine cooperation in the exploration and understanding of our oceans.

Paul R. Ryan

PREFACE

by C. K. Tseng
Director, Institute of Oceanology, Academia Sinica,
People's Republic of China

The devotion of this issue of *Oceanus* to Chinese oceanography is, indeed, a great honor rendered to the oceanographers of China. I greatly appreciate the invitation of John Steele, Director of the Woods Hole Oceanographic Institution, to write the preface for this special issue.

China is an old country and for the last 1,000 or more years there have been distinguished naturalists who have collected and described marine plants and animals, investigating their functions, and observing, explaining, and predicting tidal phenomena. There also were expert navigators who investigated oceanographic conditions in the seas they visited. For instance, in the years 1405 to 1433, the Chinese minister Zheng He (Cheng Ho) commanded a fleet of some 200 ships — the largest about 3,000 tons displacement — and conducted seven expeditions to the South China Sea and Indian Ocean as far as Madagascar and East Africa. Data on the depth of different parts of the seas and the nature of the seafloor were collected *en route* and the sea routes were mapped.

The invention of the compass, and later, the application of the compass to navigation (approximately 1,000 years ago) undoubtedly reflected necessity, considering the thriving navigational activities in China at that time.

In terms of modern oceanography, however, China is a very young partner in the world of this science. Chinese marine scientists had a very late start in their marine research activities. Perhaps a very brief sketch of the development of oceanography in China will not be out of place here, especially its early stages, which are not well known even in China today.

Oceanography in Old China

In the early 1920s, two of China's first-generation biologists joined the staff of the University of Amoy (now spelled Xiamen), the first university situated in a coastal city. They painstakingly built up a large collection of Chinese animal and plant specimens, including marine forms, and trained a few young scientists in marine biology, thus laying the foundation for further development in the field. In 1929, an experimental biologist came to the University and used the abundant marine plants and animals for experimental studies. A few other biologists in China shared the same idea, and in 1931, the Marine Biological Association of China, based at the University of Amoy, was inaugurated. During the next three years, summer workshops for marine biological studies were conducted in Amoy. Three annual reports were published by the Association from 1932 to 1934, and the Marine Biological Station of the University published two volumes of the Amoy Marine Biological Bulletin from 1936 to 1937. In 1933, the marine biologists of Amoy University undertook a brief survey of the marine plants and animals of the Dongsha Island (better known in the West as Pratas Island). Thus, Xiamen became the first center of marine biology in China.

In another coastal city, Qingdao (formerly spelled Tsingtao), another university was established, the National Shandong (formerly spelled Shantung) University. With an experimental biologist and two marine biologists joining the Department of Biology in 1934 and 1935, respectively, Qingdao soon became a rival center of marine biological studies. In 1936, after the suspension of the activities of the Marine Biological Association, a meeting of the representatives of some natural-science societies, such as the Chinese Zoological

Above, workers evaluate ovulation and spermatogenesis of abalone and scallops in breeding tanks at Qingdao. (Xinhua News Agency [XNA])

Society and the Chinese Botanical Society, was called. A decision was made to establish a Chinese Institute of Marine Sciences and to use left-over funds from the Marine Biological Association to construct a building in 1937 for the Institute. The building was completed after the occupation of Qingdao by Japanese invaders who used the building to house a museum.

In 1935, the first oceanographic survey of any part of the China Sea involving hydrography and marine biological investigation by Chinese scientists was conducted by the National Central Academy of Sciences in the Bohai Sea. In 1936, a similar survey was conducted by the National Peiping Academy of Sciences in the Jiaozhou Bay of Qingdao. Reports on these surveys were later published by these two organizations.

Besides the previously mentioned works, all primarily concerned with marine biology, there also were some studies in the late 1920s and 1930s devoted to delta geology, such as the Changjiang (Yangtze River) and the Zhujiang (Pearl River) deltas, coral reefs along the China coast, and the influence of southeast monsoons on the rainfall of China. In the 1930s, the Qingdao Bureau of Meteorology also established a marine department to study tides and water-temperature changes in the local area. Thus, in 1937, it seemed that China was ready to enter a new stage in the development of oceanography. In fact, in July, 1937, my assistant and I were on Hainan Island making the necessary preparations for carrying on an investigation of the marine flora of the Xisha Islands (better known in the West as the Paracel Islands). With the outbreak of the Sino-Japanese War in July, 1937, all efforts by Chinese scientists to develop oceanography were in vain. The two coastal universities moved inland. Practically all activities in the marine sciences were suspended.

In the Fall of 1946, after the cessation of hostilities, Amoy University and Shandong University moved back to their original sites. Both were actively engaged in the establishment of an Institute of Oceanography. Owing to a lack of adequate support by the government, very little research activity was conducted from 1947 to 1949, and this was concerned with the investigation of coastal plants and animals, phytoplankton, and experimental embryology of marine animals. However, in both universities, we successfully offered a course in oceanography, and at the Shandong University, courses on marine phycology and economic phycology also were offered. During the same period, a new institute — the Central Fisheries Research Institute — was established in Shanghai, primarily for marine fisheries research. Generally speaking, during the first three post-war years government support was very inadequate and the recovery process very slow.

Oceanography in New China

With the founding of the People's Republic of China in October, 1949, new social orders were soon established, normal economics recovered, and the importance of science and technology was recognized by the new government. Since then, funds have been more adequately allocated to the cause of scientific research. Four periods in the development of oceanography in new China may be distinguished.

The first period, 1950 to 1956, may be regarded as the founding stage in the development of China's oceanography. In old China, most of the marine scientists were biologists. When it was decided to establish a marine research organization in the newly organized Chinese Academy of Sciences (Academia Sinica) in 1950, only a small number of marine biologists could be found on the mainland. Therefore, in 1950, a marine biological laboratory was organized in Qingdao, first as a department in the Institute of Hydrobiology and later, beginning in 1954, as an independent organization in Academia Sinica.

In 1952, the Department of Oceanography of Amoy University was merged with the small group of oceanographers at Shandong University with the aim of training students of physical oceanography and creating a Department of Oceanography. This department eventually became the nucleus for the founding of the Shandong College of Oceanology in 1959.

In 1950, the Central Fisheries Research Institute also was moved from Shanghai to Qingdao. Therefore, in the founding stage of China's oceanography, marine-research activities were centered around marine biology. Achievements were made in the studies of marine fauna and flora, on basic studies in mariculture, especially in the solution of some crucial problems relating to *Laminaria* mariculture — devising methods of summer sporeling cultivation, open-sea fertilizer application, and extending commercial cultivation southward — on basic biological studies in experimental embryology of Branchiostroma and ascidians and in the life history of *Porphyra*, and on investigations of the mackerel fishing ground in the North Huanghai (Yellow) Sea, including hydrography, plankton ecology, and mackerel biology.

The second period, 1956 to 1964, the growing stage of China's oceanography, is marked by the drafting and execution of the national 12-year plan for the development of science and technology, in which oceanography is one of the important items. Several important events occurred. The Academia Sinica Marine Biological Laboratory was to serve as the nucleus for the establishment of an oceanological institute. A few dozen new college graduates with various training — such as in physical oceanography, marine biology, geology, chemistry, and geography — were assigned to this laboratory in 1956. The institute was allocated a ship to be remodeled into a research vessel. In 1957, remodeling of the ship was completed, giving birth to China's first oceanographic research vessel, the *R/V Venus,* which took part in a survey of the North Huanghai Sea and Bohai Sea in the latter part of the year. In the same year, the Marine Biological Laboratory was expanded into the Academia Sinica Institute of Marine Biology, which was further

Right, evidence of flourishing fisheries in Chanchiang, a southern port city. (Hsinhua News Agency [HNA])

View of Shanghai from Whangpoo River. (Photo by Joan Cohen)

expanded into the Academia Sinica Institute of Oceanology in January, 1959 — at the time, the only oceanological research institution in China with various training departments, including biology, chemistry, geology, and physical oceanography.

Another measure taken was to establish, under the management of the National Bureau of Meteorology, a series of coastal stations of various sizes to keep records of local oceanographic conditions and to organize a special survey group with a vessel to take regular transectional records of some parts of the sea between selected points. In 1963, the latter survey group, with the vessel, was transferred to the Academia Sinica Institute of Oceanology.

In the 1960s, the Academia Sinica Institute of Acoustics set up a few marine stations for marine acoustics research. By this time, the need for a large group of marine scientists for the future development of China's oceanography was apparent, and therefore the Shandong College of Oceanology was founded in the Spring of 1959, based in the Department of Oceanography and supported by the marine scientists from the other departments of Shandong University. At the time, it was the only educational institution for the training of marine scientists. In the early 1960s, within the framework of the Academia Sinica, four more units concerning oceanographic research were established, mostly affiliated to some degree with the Institute of Oceanology. Thus, in this and the previous period, Academia Sinica was the principal agency involved in oceanographic research.

In accordance with the 12-year plan, it was decided that a general oceanographic survey of the China Sea — including the Bohai Sea, the Huanghai Sea, and the East China Sea west of 124 degrees North, and the South China Sea west of 17 degrees North — would be undertaken. A national committee was organized to mobilize teachers and students in universities and colleges in the coastal provinces, and ships belonging to research institutes, including fisheries ships and the Navy, to participate in the China Sea oceanographic survey, which started in 1958 and took about three years to finish. As a result of the survey, we have a better idea of the general oceanographic conditions in these areas, including hydrography, currents, tides, chemistry, geology, plankton, benthos, nekton, and fisheries resources.

After the general oceanographic survey, a series of multidisciplinary oceanographic investigations (especially surveys of fishing grounds) was conducted and studies made on the biology and population sizes of the food fish yellow croakers *Pseudosciaena*, the hair-tail *Trichiurus*, and the Japanese mackerel *Pneumatophorus* and the food crustaceans *Penaeus* and *Acetes*; suggestions for the management of these fisheries resources were submitted. In mariculture, studies on *Laminaria* genetics and breeding, and further studies on fertilizing *Laminaria* farms and on enhancing production, were successfully conducted. Methods were devised utilizing modified floating rafts for the commercial cultivation of *Porphyra* at the conchocelis and conchospores stages. Success was achieved, in 1960, in the laboratory culture of the Chinese shrimp *Penaeus orientalis* and its different larval stages under controlled conditions, forming a basis for later development of commercial cultivation. A method of preventing growth of ship-bottom fouling organisms, especially barnacles and mussels, was devised.

The third period, 1965 to 1978, may be regarded as the partial expanding stage in the development of China's oceanography, characterized by the establishment of the National Bureau of Oceanography and the participation of the governmental ministries of Geology and Petroleum Industry. By 1963, the 12-year plan drafted in 1956 was nearly accomplished, and a new 10-year plan for the Development of Science and Technology was proposed. While discussing the new plan, it became evident that a governmental agency for oceanography, similar to that for meteorology, was needed. A concrete proposal by a group of senior marine scientists was forwarded to the national government.

Accordingly, the National Bureau of Oceanography was set up in late 1964 as a governmental agency and started to function in 1965. In order to support the National Bureau of Oceanography so that it could carry on its function, the Academia Sinica decided to transfer to it three of the five units engaged in oceanographic research; the Institute of Oceanology also decided to transfer the marine acoustics group and the transectional survey group together with its research vessel to the National Bureau of Oceanography. The National Bureau of Meteorology rendered support by transferring its coastal oceanographic stations to the National Bureau of Oceanography. Other governmental agencies, especially the Navy, also rendered generous help. Thus, soon after its setup, the National Bureau of Oceanography had under its organization five research units and one

Coastal city, Xiamen, in Fujian Province. (Photo by Joan Cohen)

Ongoing industrialization at the port of Dalian. (Photo by Joan Cohen)

Shima Fishing Production Brigade at work in the East China Sea. (HNA)

transectional survey group as well as a number of ships.

From the preliminary tectonic studies of the China Sea by the young marine geologists of Academia Sinica in the early 1960s, the prospect of undersea petroleum resources was considered quite good. The Ministry of Geology organized two groups to conduct series of tectonic surveys of both the South China Sea and the East China Sea. The Ministry of Petroleum Industry also started similar work. In addition, the Ministry of Communication conducted studies in connection with harbor construction, and the Ministry of Metallurgy conducted studies in metal corrosion in the sea. The three fisheries research institutes continued their studies on marine fisheries resources and mariculture.

During the 10 years of turmoil caused by the Cultural Revolution, oceanographic studies not concerned with production, especially basic research, were all suspended. It was not until 1978, after the National Science Conference, that oceanography, as well as other sciences, returned to normal.

The fourth period, 1978 to present, may be regarded as the elevation stage. For the last few years, oceanographic investigations have extended far beyond the 124 degrees East line to the Okinawa Trench and even to the eastern Pacific, and south of the 17 degrees North line to the southern Pacific and the southern part of the South China Sea. Sedimentary and structural geological studies have been conducted more intensively. Theoretical and practical investigations of oceanographic phenomena — such as waves, currents, and tides, pollution studies, biological studies of mariculture, oceanographic studies of China's continental shelf, dynamic studies of coastal geomorphology, biological studies of fouling and fouling organisms, chemical studies of metal corrosion and seaweed polysaccharide, basic studies in developmental biology and comparative photosynthesis, and investigations of marine flora and fauna — are among the numerous projects already carried out and still underway.

As I mentioned earlier, China's oceanography is still very young and, generally speaking, our academic level is still low in comparison with that of our oceanographic colleagues in the more advanced countries. We still have difficulties successfully coping with some of the important problems to be solved, despite the adequate material support of our government, which is in full realization of the importance of oceanography to the welfare of our people. The more we work, the more we realize the importance of elevating our general academic level. This is the principal problem facing us in the present stage of development. We are therefore using elevation (of the academic level) as the mark of the present stage.

Under the open-door policy, we have been carrying on cooperative research projects with foreign marine scientists, especially those of the Woods Hole Oceanographic Institution. As I mentioned previously, in modern oceanography in the broad sense, China is a very young partner in the world of marine science and has much to learn from the oceanographers of various countries. Oceanography is still a developing science. We have to date only meager knowledge of the oceans and seas, of the multiple life in them, and of the precious water that makes living on Earth possible and our little planet Earth unique in the universe.

We still have lots to learn. Chinese oceanographers would like to cooperate more closely with oceanographers throughout the world for the common cause of human welfare.

About 71 percent of the earth's surface is covered with water, and with the increasing population of the world, man has naturally to look to the seas and oceans for resources that are being continually depleted on land — especially for food to feed the ever-increasing population of the human race.

We firmly believe that by converting the seas and oceans into marine farms and pastures, as our forefathers did with the land, we should be able to procure much more food from the seas and oceans. This must be one of the important aims of oceanography and one of the important missions for oceanographers. It is a realm for cooperation among the oceanographers of the world. The Chinese oceanographers will be more than willing to cooperate in this and other fields of oceanography for the common welfare of the *Homo sapiens.*

Signing of collaboration Protocol at the third meeting of the Joint United States–China Working Group for Marine and Fishery, Scientific, and Technological Cooperation, held in Washington, D.C., on 31 March 1982. Standing, left to right: James Churgin, Robert Junghans, Ferris Webster, Qian Ho, Wu Yikang, Wang Jinkang, Liu Tianjing, Qin Zhang, Cao Peifu, Mei Jinsheng. Seated, left to right: M. Grant Gross, Ned Ostenso (co-chairman), Luo Yuru (co-chairman), Wu Chaoyuan. (Photo courtesy of NOAA)

Introduction:
U.S. — China Collaboration in Oceanography

by Ned A. Ostenso

A nation composing a quarter of the world's population, China obviously has many interests that extend beyond its domestic boundaries. Such interests range from strategic concerns, through economic, political, scientific, and technological interests. The United States, in turn, has a fundamental national interest in preserving and advancing its strategic and political relations with China. Such relations did not exist during the decades of the 1950s and 1960s, to our mutual disadvantage. In the early 1970s, the leadership of both countries realized that their respective interests would be better served by a cooperative and productive relationship. A reconciliation movement of historic importance was launched, and by January, 1979, a normalization agreement was negotiated which established diplomatic relations between the United States and the People's Republic of China. A U.S.-China Joint Communiqué on the Establishment of Diplomatic Relations was issued on 1 January 1979, by the two Governments.

As stated by President Reagan in August, 1982:

> *Building a strong and lasting relationship with China has been an important foreign policy goal of four consecutive administrations. Such a relationship is vital to our long-term national security interests and contributes to stability in East Asia. It is in the national interest of the United States that this important strategic relationship be advanced.*

As is frequently the case, research was made the "cutting edge" of foreign-policy implementation. Early among the actions taken in the normalization process was the negotiation of specific science and technology protocols. In May, 1979, a bilateral agreement on Cooperation in the Field of Marine and Fishery Science and Technology was signed in Beijing (formerly Peking) by the Administrator of the National Oceanic and Atmospheric Administration for the U.S. side and by the Director of China's National Bureau of Oceanography. Although lead agencies were signators to the formal agreement, it was intended that there be truly national participation from both sides. This Marine and Fishery bilateral agreement was but one facet of cooperative research in areas of mutual interest that served as a basis for developing broader national accords. It provided an outlet to satisfy the desires of people to work together in the interest of science and for the development of mutual understanding among people living, studying, and working a broad ocean apart.

The terms of the bilateral agreement on Marine and Fishery Science and Technology

Cooperation provides for a policy-level group, with three members designated by each side, to meet periodically to agree on areas of activity and subsequently to review the progress achieved and problems that have arisen. As viewed by the United States, scientific initiatives would be undertaken by experts and scientists from both academic institutions outside the government and from government laboratories and related facilities. Initial exploratory meetings disclosed a range of interests in marine sciences that were addressed in three categories: 1) those that were ready for implementation; 2) those where details needed further development and negotiation; and, 3) those for possible future consideration. Reciprocal exploratory visits by small groups of experts in specific fields are made to establish personal relationships and to develop the scientific strategy for cooperative projects.

Program Initiatives

An immediate need was to establish protocols for the exchange of marine data. China requested, and the United States agreed to, cooperation in establishing a National Oceanographic Data Center in China. Accordingly, the development of an Ocean Services program in China has begun with U.S. collaboration, initially in ocean-temperature monitoring and reporting. Storm surge and Tsunami predictions also are identified for collaboration but have yet to be implemented.

Collaboration in aquaculture has been discussed, exchanges of scientists have been completed, and project proposals are pending, but no specific projects are underway as yet.

Exchange visits of scientists involved in marine-pollution research and monitoring have been completed and project proposals are being formulated. Chinese experts in marine instrumentation and engineering visited the United States, and a reciprocal visit to China by U.S. experts is being planned in the area of instrumentation standards and methodology and in buoy-technology applications. It also is hoped that the Chinese will participate in a major research project on ocean heat transport in the western Pacific Ocean and

Contemporary map of the People's Republic of China with provincial boundaries. Coastal cities identified are sites of major oceanographic research centers; stars denote most promising areas for petroleum exploration.

Transport along the Whangpoo River outside Shanghai. (Photo by Joan Cohen)

international studies of the interannual variability of the tropical ocean and the global atmosphere.

To date, the major collaborative research project has been a three-year study of the sedimentation processes in the East China Sea with special emphasis on discharge from the Yangtze River. This study, begun in 1980, is described in an article in this issue (p. 20) by John Milliman, the lead U.S. scientist for the multidisciplinary study. His counterpart was Jin Qingming from the NBO Second Institute of Oceanography. The first cruises in the field phase of the study included the NOAA ship *Oceanographer* along with the Chinese research vessels *Xiangyanghong* 09, *Shuguang* 06, and *Shijian*. The second field phase involved the Chinese ships *Shuguang* 06 and *Shijian*. U.S. participants in the research cruises came from the Woods Hole Oceanographic Institution, NOAA's Pacific Marine Environmental Laboratory, the University of Washington, Oregon State University, Yale University, Massachusetts Institute of Technology, North Carolina State, Florida State, University of Chicago, Louisiana University Marine Consortium, U.S. Geological Survey, and from the industrial sector, including Klein Associates, EPC Laboratories, and Neil Brown Instrumentation. The Chinese scientists were from the First and Second Institutes of China's National Bureau of Oceanography, Shanghai Normal University, and the CAS Institute of Oceanology.

Considering the complex scope of the project, the fact that American and Chinese scientists had not worked together for several decades, and the logistical problems of installing and operating U.S. oceanographic equipment on Chinese research vessels, the program went quite smoothly. The program culminated in an international symposium, jointly sponsored by NOAA and the National Bureau of Oceanography, held in Hangzhou, China, in April, 1983. Many of the papers read at the symposium were authored jointly by Chinese and U.S. scientists.

Benefits — Problems

Communication among scientists from two vastly different societies resulted in improved understanding of cultures, in addition to respective scientific achievements. Collaboration provides the Chinese access to contemporary technology not available previously, and China has since become a market for U.S.-produced oceanographic equipment. Much scientific data collected over the years by the Chinese should become available for various research initiatives once the data are translated into computer-compatible formats for exchanging and processing such data.

The bilateral policy group provides a means for exploring areas of mutual interest and for arranging cooperative scientific ventures employing the combined resources of the two nations. Exchanges of research results are facilitated by these bilateral relations. Opportunities have been provided for Chinese students to study at U.S. marine-science institutions and to participate in U.S. oceanographic research cruises. In the long term, additional benefits should be available from joint research projects of broadened scope and participation.

Throughout the brief history of renewed collaboration in marine sciences between the People's Republic of China and the United States there has been a series of problems as well as accomplishments. None of the problems has proved insurmountable, but some have been rather frustrating.

The pace of negotiation has been quite slow for several reasons. Different languages are an obvious problem. A seemingly complex bureaucracy in China contributes to slow and ponderous decision-making during the various phases of negotiation. The objective of most U.S. scientists is to organize and conduct research, while the Chinese seem to focus more on the acquisition of technology.

Chinese and American roustabouts at work on the Java Sea, *a drill ship that works the South China Sea. (Huang Jianqiu/HNA)*

There also seems to be a preoccupation with tactics to draw U.S. dollars into China as part of technical activities under the bilateral agreement. The degrees of flexibility in program planning vary widely. Once the details of a plan have been agreed upon, it is usually not possible to obtain undelayed agreement on modifications when changing circumstances require a change in project plans. All modifications seem to require the same lengthy review and approval process used to arrive at basic program decisions. Rapid judgments at the program-management level do not appear to be permissible nor are they forthcoming at the policy level.

Organizational rigidities in China have hindered broad participation at Academia Sinica, Shandong College of Oceanology, and at the fisheries institutes. But these problems seem to be working themselves out. United States scientists tend to build research alliances largely on personal bases, whereas in China cooperation tends to be organizationally determined. Meanwhile, in the United States, multi-agency collaboration has been arranged from the start with relative ease, and the National Science Foundation is a major leader and sponsor of the bilateral agreements along with numerous universities and governmental organizations.

A substantial learning process has been and continues to be required concerning the way each side does business. Budgeting processes, program planning, and resource allocations seem to be handled quite differently by the two governments. There appears to be much more centralized control for all those functions in China. The inverse seems to apply with respect to scientific data and information storage; however, this situation may be corrected when China's National Oceanographic Data Center is fully established and operational.

While there have been problems, we have, for the most part, found solutions. Given the positive progress made with research activities thus far and the benefits or promise of benefits to both sides, a turning back is not anticipated. Where problems remain, and if new ones arise, we will continue to deal with them fairly and openly. With goodwill, appreciation of the value of the relationship, adherence to our basic principles, and Chinese reciprocity, the prospects for further progress remain good.

As Dr. C. K. Tseng points out in his preface to this special issue of *Oceanus* (page 3), China is both an old and a new country. The United States is just a new country. Advantages we may enjoy in modern technology are often more than balanced by centuries of cultural, technological, and infrastructural developments, as in the cases of plant and animal aquaculture illustrated in the articles by Tseng (page 48) and Ronald Zweig (page 33). We have much to learn. The article by Douglas Wolfe and his associates (page 40) shows that we have permitted unbridled industrial development to pollute our marine environment to a degree unparalleled in the People's Republic. From our mistakes, we have much to teach China. But most importantly, as K. O. Emery points out in the introduction to his article (page 26), we inhabit but one planet and share a common lithosphere, hydrosphere, and atmosphere. With this common heritage and goodwill, we will continue to work together to decipher the mysteries of the oceans for our mutual benefit and the benefit of all mankind.

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The Structure of Oceanography in China

by James Churgin

Representing the National Oceanographic Data Center (NODC), I led a delegation of American marine scientists on a 24-day tour of the People's Republic of China in November, 1979. [Since Churgin's visit, several delegations of marine scientists have toured China. This account, updated with more recently acquired data, remains the most cogent description of the structure of marine science in China — Ed.] Under the terms of a Protocol on Cooperation in the Field of Marine and Fishery Science and Technology between the United States' National Oceanic and Atmospheric Administration (NOAA) and China's National Bureau of Oceanography (NBO), the delegation's objectives were threefold:

1) To gain an understanding of the nature of marine programs in China. Before any proposals for exchange of data-management assistance could be made, an understanding of how the marine programs are organized, the scope of these activities, the nature and objectives of research, the types of instruments being used, and the data-processing, storage, and dissemination capabilities had to be secured.
2) To make a preliminary assessment of exchange and assistance that might be implemented. Since this was a first step, it was planned to explore possible areas of agreement and discuss these with officials of the NBO.
3) Plan for a reciprocal visit by Chinese marine-data specialists. It was thought that it would be profitable to explore the nature of such a visit so that plans and invitations could be issued well in advance.

Understanding all the players in the marine-sciences picture in China is about as simple as understanding marine sciences in the United States. I would classify the organizations involved as: government bureaus and ministries, Academia Sinica (Academy of Sciences), universities, and provincial institutes. One should keep in mind that, in China's political system, all organizations are under government control; therefore, there is some overlap among these four categories. For example, the Ministry of Education may oversee the universities or a provincial institute may conduct research sponsored by a bureau or ministry. For a history of marine-science programs in China, see C. K. Tseng's preface to this issue, page 3.

Chinese government ministries and bureaus are roughly equivalent to U.S. departments and independent agencies reporting directly to the Executive Office. Following are descriptions of the primary marine agencies in China.

National Bureau of Oceanography (NBO)

The NBO was established in 1964-65; it is responsible for programs in all disciplines of oceanography. There are three regional subbureaus (South China, East China, and North China or Yellow seas), three institutes of oceanography (First, Second, and Third), an Institute for Information, and an Institute for Environmental Protection. In addition, the NBO has a General Station for Prediction in Beijing.

The subbureaus and institutes regularly conduct observational programs at sea and other research projects, and have coastal research stations. They also have special programs, such as an East China Sea Shelf study, prediction research, a current measurements network, and coastal environmental protection studies. NBO sites visited are outlined below.

The First Institute of Oceanography, National Bureau of Oceanography, Qingdao (Tsingtao), Shandong Province: This is a comprehensive oceanographic institution; its main tasks are to investigate the natural environment of the Yellow and Bohai seas and neighboring ocean areas. The First Institute conducts investigations of the marine environment and emphasizes applied research. It provides various organizations with data, charts, methods of forecasting, and practical technologies to help with the understanding, development, and exploitation of the sea.

Established at the end of 1964, the Institute employs more than 300 in four divisions: Marine Hydrometeorology, Marine Geology, Marine Biochemistry, and Marine Physics. There also is a Marine Book Data Service. Some of the tasks of the First Institute are part of the national plan for the development of science and technology, while others are carried out at the request of local organizations undertaking offshore development.

Second Institute of Oceanography, National Bureau of Oceanography, Hangzhou: This is a comprehensive institute of oceanography. The main research objective is to study the natural environment of the East China Sea and its adjacent areas. Thus, the principal tasks are to investigate and study the characteristics of the natural environment, including the coastal zone and marine resources, and to apply aerial remote-sensing techniques to marine science. Workers at the Second Institute also do marine environmental forecasting, seawater desalination techniques, and conduct theoretical research.

To do all this, the Second Institute is divided into nine departments: Marine Geology; Coastal Zone; Marine Hydrology and Meteorology; Marine Remote Sensing Techniques; Marine Chemistry; Marine Biology; Marine Geophysics; Desalination; and Information and Data.

In addition to the above-mentioned departments, the Second Institute was, at the time of our visit, establishing a Department of Comprehensive Techniques. The management of all the scientific research programs and coordination with other institutes is performed by the government's Scientific Research Division. In touring this 400-person facility, we noted that an atomic absorption spectrophotometer and other laboratory instruments had recently been purchased from the United States. Again, the 30 people in the Information and Data Department are primarily involved in library collecting and translation. Data processing and storage consists of copying and archiving data. Most of what we would consider data processing is done in the research departments. Although all NBO Research Institutes are comprehensive (that is, they include all disciplines), the Second Institute seems to be particularly interested in marine geology and geophysics.

Third Institute of Oceanography, National Bureau of Oceanography, Xiamen (Amoy): The predecessor of this Institute was the East China Institute of Oceanography of Academia Sinica. Their Xiamen facilities were built in 1959, and in 1965 transferred to the NBO. The Third Institute has a professional staff of 200, organized into six laboratories and a Division of Information and Data. The laboratories are: Marine Biology; Marine Chemistry; Marine Geology; Marine Radioisotopes; Marine Instruments; and Marine Hydrometeorology. The Division of Information and Data collects, processes, and disseminates information, data, and library materials; the data was all in hard-copy form when we were there, and as far as I could establish, no automated processing was done. The library collection contained about 25,000 documents. The Third Institute seemed to concentrate on marine biology and chemistry. Because it had not been visited by Westerners, researchers there seemed especially anxious to receive publications and other documents dealing with marine-science subjects.

Xiamen General Ocean Station, National Bureau of Oceanography, Xiamen (Amoy): This is one of three such stations under the NBO East China Sea subbureau — apparently each of the subbureaus operates three "stations." These stations are responsible for the operational (or routine) acquisition, analysis, and dissemination of marine data and information. Their responsibilities include maintenance of ships, buoys, and coastal facilities.

The station we visited was on the Island of Kulangsu, near the city of Xiamen. It operates nine "substations" or data-collection sites. Five are on land and are primarily for the collection of sea-level data; the other four are offshore buoys and collect similar data as well as recordings of wave height. The Kulangsu main station also is responsible for the operation of three research vessels.

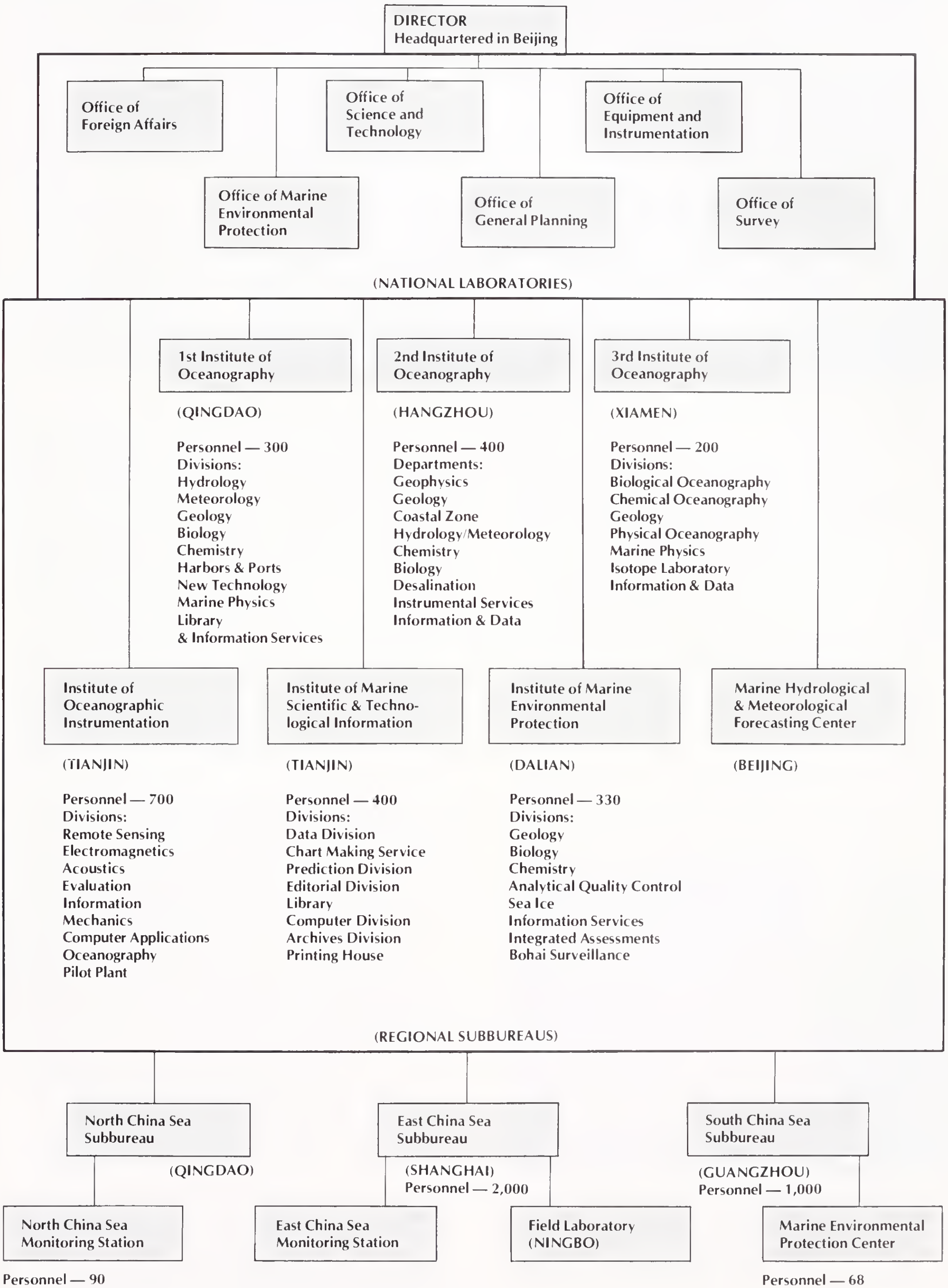
We visited one of the coastal substations on Kulangsu Island, where tidal heights were being measured continuously, along with measurements of tidal current, temperature, salinity, and surface meteorology. Daily summaries were forwarded to the Central Station. The Central Station, in turn, furnishes these to the East China Sea subbureau and the Data Center.

Institute of Marine Scientific and Technological Information, National Bureau of Oceanography, Tianjin (Tientsen): This Institute (IMSTI) was founded in 1964 under a different title, and in 1965 it was changed organizationally and functionally to its present name and mission. It is difficult to find an analogous organization in NOAA, as the IMSTI combines some functions of Environmental Data and Information Service (EDIS) and NOS together with minor elements of other NOAA groups. The major divisions are: Information Research; Chart Making (bathymetric and meteorological/oceanographic); Printing House; and Data Collection and Processing.

Data Collection and Processing performs most functions of a National Oceanographic Data Center (NODC) and operates as the Chinese Data Center with 500,000 physical/chemical collection sites. The mission of the division is to acquire, process, and disseminate oceanographic data from and to all organizations in China having marine interests. There are eight Groups of Branches as follows:

1) *Data Information:* this group acquires data (foreign and domestic) and provides services to customers.
2) *Basic Data Computation:* the people in this group process data and compile them into reports, including station, coastal observation, and tidal data.
3) *Environmental Atlas Compilation:* this group produces atlases of the China seas and specified ocean areas.
4) *Data Services:* this group manages and disseminates stored data records. The data base was said to contain the following items: 50,000 coastal sites' temperature and salinity values; physical/chemical information from 80,000 ocean sites; current measurements taken hourly for 24 hours; 4,000 variable-depth current profiles; 3,000 time-series sites; 24,000 foreign *Ship of Opportunity* observations; and 13,000 Chinese *Ship of Opportunity* observations. Standard ocean data-collection sites were increasing at the rate of about 3,000 per year and were expected to increase by 10,000 per year in the early 1980s.
5) *Data Processing:* primarily a tape-punching group.
6) *Programming:* this group does system design and programming, and implements processing and applications programs.

Organizational Chart of China's National Bureau of Oceanography.



Geophysical survey vessel Haiyang I, *built in 1972, converted from general research status to specialization in petroleum exploration. (Photo by George Saxton/courtesy of author)*

7) *Computer Maintenance:* this group operates and maintains the DGS computer.
8) *Tide and Tidal Current Prediction:* this group is responsible for analysis and prediction of tides and tidal currents for the China seas. It also researches tidal prediction methods.

Luo Chuanwei told us some of the NBO's plans for upgrading the Data Collection and Processing Division into an operational equivalent of NODC. These plans include expansion of all functional areas, development of standard systems and formats, regionalizations, international exchanges, training in modern computer hardware and software technology, new facilities, and new equipment, including a large mainframe computer.

Ministries

In addition to the NBO, the Chinese government administers marine-science research through several ministries:

Bureau of Aquatic Products: This is the national fisheries organization with institutes and laboratories in many provinces, both coastal and inland. Marine and freshwater fisheries are included. The Bureau conducts a number of large observational programs, looking at physical, chemical, and biological phenomena. It is a major contributor of data to the general data base for the China seas. We visited one bureau site, the *Yellow Sea Fisheries Research Institute, Bureau of Aquatic Products (Fisheries),* in Qingdao (Tsingtao), Shandong Province. Founded in 1946, this Institute had a scientific and technical staff of 150, plus seven research fellows and 48 assistant research fellows at the time of our visit. This organization primarily does research in the Yellow Sea and Bohai Bay, but similar groups exist for the South China and East China seas.

Ministry of Petroleum: Apparently well funded, with strong marine geology and geophysics components, this Ministry has institutes for petroleum geology on the Bohai Bay and the Yellow Sea, and is closely associated with the following provincial institutes.

Ministry of Transportation: This organization seems to have interests in marine projects similar to those of the U.S. Army Corps of Engineers, doing port and harbor construction and water transportation. It operates an Academy of Water Transportation and Development, an Academy of Waterway Engineering, Nanjing Water Research Academy, an Institute of Ship Research, and other learning centers. Data-collection efforts by the Ministry of Transportation include the operation of coastal stations, data related to dredging and port construction, and storm-surge research and prediction.

Ministry of Chemistry: As we understood it, this Ministry conducted marine chemistry research and observational programs, but no details were given.

Environmental Protection Bureau: This bureau has offices for Bohai Bay and the East China Sea. Though it may be conducting some programs of its own, this bureau generally sponsors programs within the NBO, Ministry of Petroleum, and others.

People's Republic of China Navy: The Navy operates an Institute for Ocean Science Research and collects data. We did not learn much more about the Navy programs.

Ministry of Education: This agency has overall responsibility for the college and university system.

Academia Sinica

Academia Sinica is China's Academy of Sciences. Unlike the U.S. Academy, this organization operates research institutions in all areas of science. We visited two of the leading marine institutes:

South China Sea Institute of Oceanology, Academia Sinica, Guangzhou (Canton): The South China Sea Institute of Oceanology of the Chinese Academy of Sciences was established in February, 1959. Its research orientation emphasizes comprehensive investigations of seas and oceans as well as basic research. Carried on at the same time are studies on coastal geology and geomorphology, experimental ecology, environmental protection, sea-air interaction, and application of new techniques. Eight laboratories and an Information Research Division have been established. The eight laboratories are: Physical Oceanography and Meteorology, Marine Physics, Marine Chemistry, Marine Biology, New Technology, Tectonics, Marine Sedimentation, and Coastal and Estuarine Processes. In addition, there are three "experiment" stations: one each in the cities of Zhanjiang and Shantou; at the time of our visit, the third was being built on Hainan Island. As of 1980, the scientific staff numbered 400. The Institute operates two research vessels; a third is being built.

As was the case with almost every information and data division we visited, the primary emphasis of the Information Research Division is the collection of hard-copy material into a library system. Also in every case, great efforts are being made to obtain English-language papers, journals, and publications, and to translate them into Chinese.

Qingdao Institute of Oceanology, Academia Sinica, Qingdao (Tsingtao): This Institute is the largest oceanographic research institute under the auspices of the Academy. It has been visited by a number of Western scientists in recent years, and its director, C. K. Tseng, once worked at the Scripps Institution of Oceanography. The institute was founded in 1950 as a marine biological laboratory, adding physics and chemistry in 1952-53 and geology in 1956. In 1959, it received its current designation.

This organization has a scientific and technical staff of 530 located in nine departments. Four of these departments are devoted to marine biological research, botany, invertebrate zoology, vertebrate zoology, and experimental zoology (mariculture). Another four departments are concerned with physics, chemistry, geology and geophysics, and instrumentation. Finally, there is a Department of Information.

The principal work being conducted here is in the China seas, nearby oceanic areas, and the Kurishio Current. Studies of marine plants and animals, geology of the continental shelf and marginal seas, shoreline dynamics, principles of mariculture methodology, marine pollution, circulation, tides, waves, marine meteorology, harbor models, optics, and acoustics are all being conducted. The institute publishes one or two journals of its own and contributes to other Chinese scientific journals. Most of the data collected as a result of the Qingdao Institute's research either remains in the hands of the researcher or is stored by the Department of Information.

A computer was not in place, but we were told that they were getting one associated with a seismic digital-data system. They also informed us that they were constructing a research ship that would carry five computers.

Universities

There are a number of colleges and universities in China that have both course curricula and research projects dealing with marine disciplines. In connection with research programs, they also collect and store data and information. The principal oceanographic education institution is the Shandong University School of Oceanography in Qingdao. A description of the one site we visited follows.

Shanghai Normal (Teachers) University: The total university enrollment of 5,000, including 300 graduate students, is divided among 13 departments staffed by a faculty of 1,500. In addition to being a teacher-training facility, the University has a number of research laboratories, some of which are concerned with estuarine, coastal, and oceanic processes. Much of the University's marine work is performed at the mouth of the Yangtze and other estuaries, and some 20 years' data have been collected. Because of the extremely large tidal range in the Yangtze estuary, much of the research there is devoted to the effects of tidal processes — on port and harbor development, on potential effects of channel dredging, and on sedimentation processes. Historical data are used to study the river's influence on shoreline development.

Researchers at Shanghai University are also doing ocean hydrology, mineralogy of sediments, geomorphology, and storm-surge effects studies. Some new studies include the application of remote sensing to sedimentation studies, carbon determination, and spore analyses. Mapping the Yangtze estuary and delta-bottom topography has begun. If this University is typical of others in China, they also may be good sources of data and information in coastal and estuarine areas.

Provincial Institutes

The coastal provinces of China run various institutes and laboratories dealing with science and technology, including the marine sciences. It is not quite clear just how these organizations are tied politically and administratively to the central government ministries and bureaus, but we were told that some observational and research programs are conducted by these "local" agencies. A site we visited in Shanghai is described.

How Wenfeng, director of the Data Collecting and Processing Division of the National Bureau of Oceanography's Institute of Marine Science and Technology, uses an automatic data plotter to greet the U.S. delegation in Chinese and English. (Photo by George Saxton/courtesy of author)

Shanghai Institute of Computation Technology, Shanghai: This is a research organization under the Provincial Government of Shanghai. The staff we spoke with seemed to be well aware of the latest developments in computer technology, and virtually all their hardware and software had been developed at the Institute. Research there included not only basic testing of computer hardware and software, but applications that could be put into use by other groups.

We were shown several computers. The most heavily used appeared to be one called the SJT-731 (built in January, 1973). The machine had 64K (6-byte) words, core memory, one multiplexor channel with 8 selector channels, 5 magnetic tape drives, a line printer, and X-Y plotters on-line. The operating system, as well as ALGOL and COBOL compilers, were developed by this Institute. The operating system allowed time sharing, batch processing, and multiprogramming.

These computers are linked to a university in Shanghai with another computer (SJT-761) and have been able to establish computer-to-computer links using rather low-speed line (200 bits per second). Applications work included some oceanographic calculations, such as tidal predictions for harbor construction, geostrophic currents, and a two-dimensional model of an estuary.

Research Vessels

We toured two of China's oceanographic research vessels and tried to evaluate them relative to American-vessel standards.

Geophysical Survey Vessel, Haiyang I: Built in 1972, this vessel was converted recently from a general-purpose oceanographic research vessel to a geophysical-research ship because of China's strong emphasis on offshore surveys for petroleum. The *Haiyang I* is 105 meters in length, has twin screw 9,000 horse power, a maximum speed of 20 knots, and a crew of 61. Scientific survey equipment, at the time of our visit, included seismic gear manufactured in Texas, a Magnavox satellite navigator, a gravimeter manufactured in West Germany, and a magnetometer produced in China.

James Churgin and George Saxton at the Great Wall of China. (Courtesy of author)

All the equipment was new and an American technician was on board testing the seismic instrumentation. The ship conducts regional reconnaissance along rather widely spaced track lines. All original records are stored at the Office of Marine Geology in Shanghai.

Research Vessel Xiang Yang Hong No. 9: This is a general-purpose oceanographic research ship capable of conducting deep-ocean and coastal measurements. Launched in 1978, 112 meters long and 15 meters wide with a draft of 5.5 meters, it can work for up to 60 days without resupply. Navigation equipment on the *R/V Xiang Yang Hong* included a satellite navigator, Loran A and C, and Omega. Oceanographic winches and instrumentation for physical, chemical, biological, and geological work were on board. It was my impression that this ship could be used for almost any kind of oceanographic experiment if modern instrumentation (including computers) and trained personnel were available.

Additional Development Initiatives

The United Nations Development Program (UNDP) opened its Beijing office in 1979 and is offering preparatory assistance: training, study tours to examine the state-of-the-art in other countries, a feasibility study, and systems analysis for hardware and software needs.

In addition to these organizations and agencies, we learned that there is a Commission on Science and Technology for China that operates at a very high level (roughly equivalent to the President's Scientific Advisor). The president of the Commission also is the president of Academia Sinica. This Commission has a Subcommittee on Oceanography with representatives from all the major ministries and bureaus having an interest in marine sciences. It was not clear as to how effective this group is in coordinating and directing the efforts of the agencies. Little was said regarding the work of this Oceanographic subcommittee. I got the impression that, at that time, it had only discussed some very high-level policy matters, but was not really functioning as an interagency coordinator.

The Chinese are extremely eager to "catch-up," both personally and as a matter of government policy. Most of the individual scientists we met were bright and eager to learn. The Cultural Revolution not only caused a setback in technological development but, because foreign languages (especially English) were forbidden, caused a communication gap that makes discussion at a detailed technical level difficult and slow. There is a major effort underway to overcome this problem, but it will take time.

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The Yangtze River
Past, Present, and Future

by John D. Milliman, Chen Ji-yu, Yang Zuo-sheng, and Ren Mei-o

The large murals cover entire walls of the new Beijing airport. They show the Yangtze River, known as the Changjiang in China, as it flows through the mountainous region of Sichuan Province. Chen Yi, the poet and army leader, described the river as follows:

The Emei and Minshan Mountains soar ten thousand feet;
The Kui and Wu block the west wind.
Yet the flow of the river cannot be stopped;
Its waters rush ever eastward.

The Yangtze holds a special spot in Chinese hearts as does the Rhine for Germans, the Nile for Egyptians, the Indus for Pakistanis, and more recently, the Mississippi for Americans. It has been, and still is, the gateway to the vast interior of China. It is a source of nutrient-rich waters, critical to maintaining China's agriculture. Many of China's most productive agricultural areas border the Yangtze. These factors alone are ample reason why such a large portion of the Chinese population lives in its nearly 2-million-square-kilometer drainage basin. Yet the river also is the source of periodic, disastrous floods, during which banks are breached and valuable crops, as well as villages, are destroyed.

For a marine scientist, the Yangtze holds another fascination: it is the fifth largest river in the world in terms of water discharge, the fourth largest in terms of sediment load. The Yangtze's 960 cubic kilometers of annual discharge is 50 percent greater than that of the Mississippi, and its 500 million metric tons of suspended load is more than twice the Mississippi's total. The annual sediment load of the Yangtze approximates the volume of material used in the construction of the Great Wall of China.

Understanding how the Yangtze's sediment reaches the ocean and is subsequently dispersed requires an understanding of the river, its estuary, and the offshore area. For years, the Chinese have collected extensive data in all these areas. More recently, the oceanography and sediment dynamics of the Yangtze estuary and the adjacent East China Sea have been studied via a joint United States-Chinese research effort sponsored by the U.S. National Oceanic and Atmospheric Administration and China's National Bureau of Oceanography. The importance of the Yangtze for shipping, and the adjacent East China Sea's potential for fisheries and petroleum production, should ensure continued, high-level research.

Flow of the Yangtze River

Studying the impact of any river on its estuary and offshore area requires knowledge of the river itself: how it flows, its sediment load, and local and seasonal variations in these parameters. Unfortunately, most large rivers are located in

These large murals of the Yangtze cover entire walls at the new Beijing Airport.

developing nations in which measuring and calculating water and sediment discharge are difficult. Problems arise not only in determining representative stations and taking correct measurements, but in measuring flood events when disproportionate amounts of water and sediment are transported and taking measurements can be logistically difficult and/or dangerous. Poor or nonrepresentative measurements result in misleading discharge and sediment-load estimates.

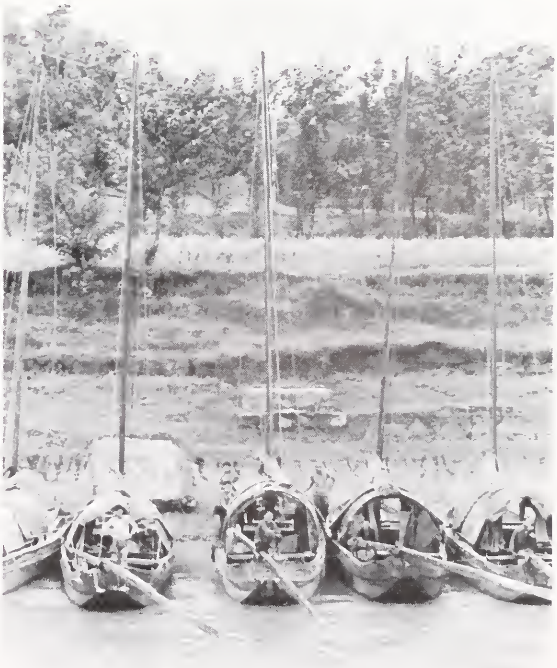
The Chinese have solved this problem by assigning teams of engineers to various stations along their rivers; by so doing, they have accumulated more than 30 years of reliable, contiguous data. Of the 21 largest rivers in the world, only five can be judged as having good to very good data bases for their suspended load estimates. Three of these are in China — the Yangtze, Yellow, and Haiho rivers; the other two are the Mississippi and the Danube.

The Yangtze has its origins in Tibetan plateaus where it flows eastward to the East China Sea. Although the Yangtze is essentially an east-west river, most of its water comes from north- or south-flowing tributaries. The flow patterns of southern rivers are largely functions of monsoon rains, with peak discharges in June and July. Northern rivers drain areas with lower rainfall but more easily eroded soils. As a result, discharge from the north is relatively low, but sediment loads are high.

Yangtze River discharge gains steadily as it flows downstream and an increasing number of northern and southern tributaries join the river. Sediment load also increases, but falls abruptly downstream of Yinchang, as the river leaves the famed Yangtze Gorges and flows into distributary lakes. The load again increases further downstream as more rivers join it, but sediment load never reaches the peak seen in Yinchang (Figure 1).

The Yangtze Estuary

Just before the Yangtze reaches the East China Sea, it divides into several distributary channels. A large island (Chongming) separates the river into north and south branches, and other islands and shoals subdivide the southern branch into three main channels. The river mouth and estuary, however, are



Midday mooring on the Yangtze. (Photo by Joan Cohen)

A junk sails past terraced fields and villages in Sichuan Province. (Photo by Joan Cohen)

continually evolving.* Prior to the 8th Century (as estimated from ancient Chinese maps), the estuary was funnel-shaped, and tidal bores (waves) were felt as far inland as Zhenjiang (Figure 2). Contemporary Chinese writers admired the bore, often mentioning it in their poems. Mei Che, a 2nd Century poet, wrote, "I am going to the Quijiang (River) in Guanglin (now Yangzhou) to watch the tidal bore on August 15"; perhaps not beautiful poetry in this translated version, but clear evidence of the bore's existence. This tidal bore disappeared as a result of the shoaling and progradation** of the estuary. Shoaling may have accelerated significantly after the 8th Century because of increased sediment loads carried by the Yangtze and Yellow rivers (to the north) in response to increased agricultural use (and corresponding deforestation) of their drainage basins.

A few hundred years ago, the north branch carried an appreciable amount of the Yangtze's water and sediment; as recently as the early part of this century, it carried about 25 percent of the flow. Since then, shoaling has reached the point where no fresh water escapes from the north branch; in fact, the north branch actually experiences a net flux of saline water into the estuary. The southern branch now provides the exit for the Yangtze, but it also has experienced recent change. Since 1966, the north channel of the south branch has been the major channel for discharge of water and sediment to the sea; before then, the south channel was the main conduit.

In most estuaries neither water nor sediment moves continually in an offshore direction. As underlying saline water mixes with outflowing freshwater, an onshore transport of salt water must

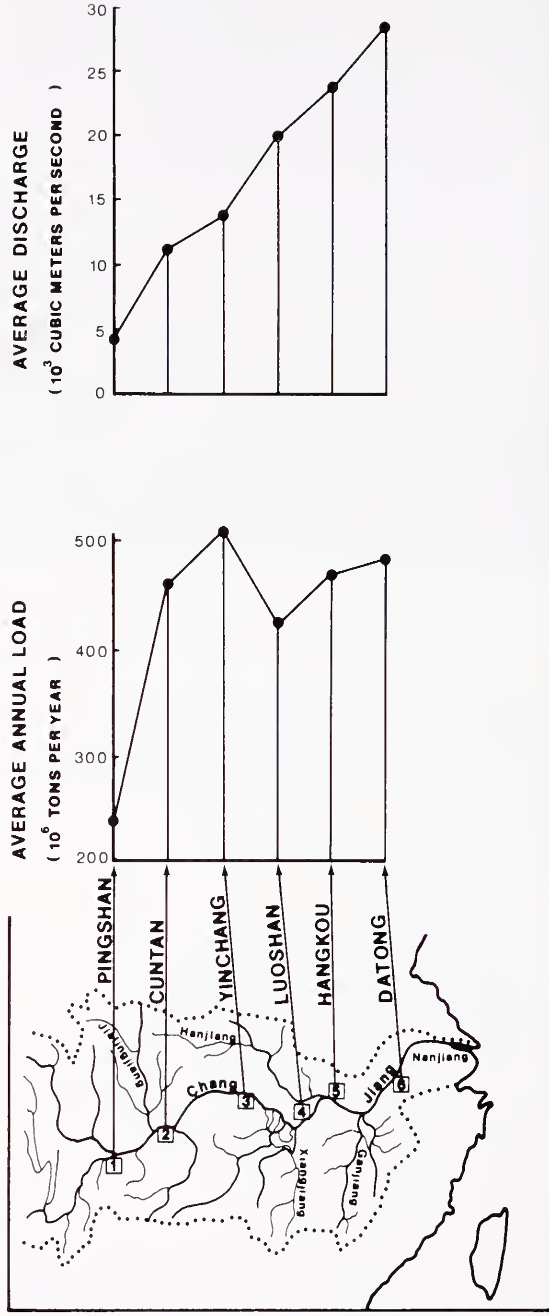


Figure 1. Twenty-year averages of water-discharge and sediment-load data for six stations along the Yangtze show a gradual downstream increase in water volume, but a marked decrease in sediment load downstream of Yinchang. This decrease is related to the Yangtze leaving the gorges and flowing through a number of distributary lakes in which much of the sediment is deposited.

be maintained for proper salt balance. Thus, many stratified or partly mixed estuaries experience a perceptible onshore transport of near-bottom water. In estuaries where tidal range is significant, onshore currents can be high. In the Yangtze, with spring-tide

*In the strict sense of the term, the Yangtze has no physical estuary, since freshwater usually mixes with seawater beyond the confines of land, the salt wedge often lying on the innermost East China Sea shelf. Still, tides strongly control river flow, and many typical estuarine phenomena occur (for example, shoaling), justifying the use of the term "estuary."

**Seaward advance of the shoreline caused by deposit of sediments from rivers.

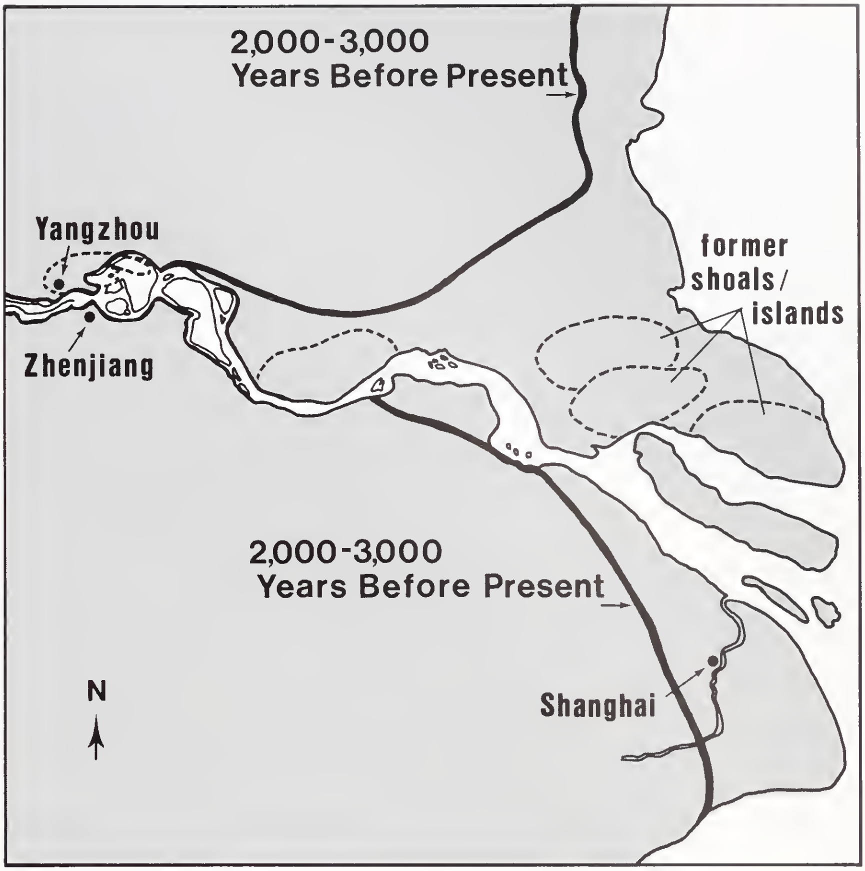


Figure 2. The Chinese have been mapping the Yangtze River mouth accurately for many thousands of years, affording researchers a unique opportunity to trace the evolution of this estuary. Two or three thousand years ago, the river mouth was funnel-shaped and tidal bores (waves) extended inland to Zhenjiang.

elevations up to 4 to 5 meters, onshore currents can be as great as 3 knots during flood tide. During the ebb, currents reverse and attain speeds of 5 to 6 knots in an offshore direction.

This seesaw pattern of current flow accounts for sediments moving in a start-and-stop pattern. Coarser particles tend to settle out at slack tide, be resuspended and move offshore at ebb, settle again at slack, and then move upstream during the next flood. In most instances, there is a net offshore transport of sediment in all channels of the south branch of the Yangtze, but during low river flow (the winter months), little sediment may actually be transported. Where the salt wedge extends sufficiently upstream and associated flood currents are strong, a significant shoreward transport of sediment can occur. This is the case around Jiuduan Bank in the south channel; because this is a major shipping route to Shanghai, continual dredging is required to remove the shoaled sediments.

Patterns of Sedimentation

By comparing ancient and modern maps, it is estimated that the Yangtze estuary is accumulating about 250 million tons of sediment annually, or about half the sediment carried by the river. The other half presumably is deposited offshore. Part of this sediment is deposited in the nearshore region immediately beyond the river mouth. Comparison of charts made during the last 100 years shows that portions of the delta have migrated up to 16 kilometers seaward, an average accretion of nearly 155 meters per year.

Using various short-lived radio isotopes, David Demaster, Charles Nittrouer, and Brent McKee of North Carolina State University have shown that a layer of sediment up to 15 centimeters thick is deposited by the Yangtze in its shore area during annual flooding. With water depths of less than 45 meters, if these rates continued for only a few hundred years, the seafloor would shoal to the intertidal zone. Interestingly, however, long-term accumulation rates are much lower — a few centimeters or so annually — indicating that much of the sediment is resuspended and moved elsewhere. Presumably, this material is stirred up from the bottom during winter storms and transported southward by longshore currents; this theory is corroborated by winter-time observations of high amounts of suspended sediments in the water column in the nearshore zone.

Little Yangtze sediment is transported offshore, and even less escapes to the north. On the other hand, most of the sediment accumulating in Hangzhou Bay to the south comes from the Yangtze. At present, we guess that about 25 percent of the

Log rafts and tug on the Yangtze. (Photo by Joan Cohen)

Yangtze load is deposited in the nearshore area off the river mouth, and that another 25 percent is transported to the south, where it remains in the coastal environment.

The Yangtze in the Past

While it is doubtful that the Yangtze or Yellow rivers carried as much sediment prior to deforestation and disruption of native vegetation by human activity, they undoubtedly contributed vast quantities of sediment to the ocean throughout the Quaternary period (2 million B.C. to present). During high stands of the sea, as are presently observed, the rivers deposit most of their sediment in nearshore areas; little has escaped across the broad East China Sea. During glacial epochs, however, sea level fell by as much as 100 to 120 meters, which means that the Chinese shoreline was hundreds of miles east of where it is today. Presumably, the Chinese rivers emptied out into, or close to, the Okinawa Trough, where extensive sediment deposits have accumulated in the recent past.

With the gradual rise of sea level coincident with melting of glaciers (about 15,000 years ago), the shoreline began to retreat across the shelf, reaching the modern Chinese coast about 4,000 to 5,000 years ago. Old river channels were mostly buried by sediment deposited by the transgressing sea, but they can be detected in shallow seismic records, both as filled channels and locally as exposed river banks or levees (Figure 3). We can map the course of the ancient Yangtze offshore region from the

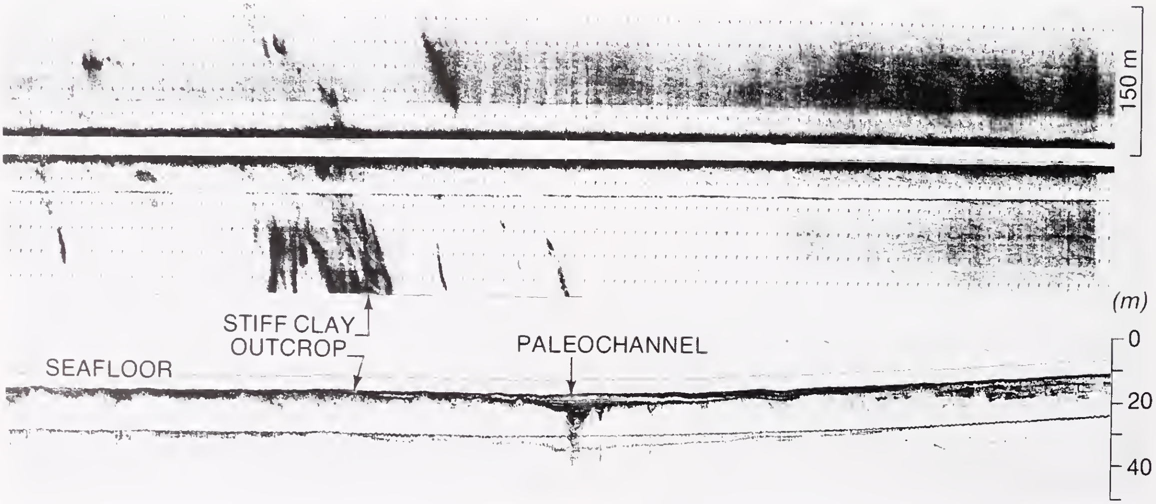


Figure 3. Side-scan sonar profiles in the western East China Sea display the seafloor morphology along a 300-meter wide swath. Linear features are, in fact, outcrops of old levees along the paleo-Yangtze. The main channel, as shown by a superimposed low-frequency echo-sounder profile, has been filled by modern Yangtze sediment. In contrast to the stiff nature of the relict levee, the modern mud is very soft, reflecting its young age and unconsolidated nature.

modern one; further seismic data may allow us to do the same with the ancient Yellow River channels.

The Future Yangtze

Undoubtedly, with future climate changes, the discharge patterns of the Yangtze also will change. On a shorter time scale, even more significant changes may occur. Increased soil conservation, for example, could lower the sediment load of the river considerably; conversely, periods of civil unrest or war are usually marked by poorer soil conservation and loss of vegetation and, therefore, extensive land erosion.

Even more significant is the possibility of dam construction along the river. One dam being built near Yinchang at the eastern edge of the Yangtze Gorges could alter downstream river flow and trap large quantities of sediment. Modulating river flow and utilizing more upstream river water (through irrigation) could result in less freshwater discharge, particularly during what are presently peak-flow periods. In the short term, this could impel a shoreward migration of the salt wedge in the estuary and a corresponding increase in the shoaling of the river, which would compound the difficulty of maintaining navigation channels. In the long run, decreased sediment load in the lower river could lead to increased shore erosion if incoming sediment supply does not equal the amount removed by normal coastal erosion. Since 1855, when the Yellow River changed its course, the pre-1855 delta has eroded about 16 kilometers inland. A similar scale of erosion off the Yangtze is potentially disastrous.

These scenarios must be evaluated prior to any major alteration of river flow, whether it be through conservation or construction of upstream dams. The Chinese, given their knowledge of the river and its estuary and coastal/offshore areas, and their concern for conservation, are more than able to account for these factors so as to minimize deleterious effects. If they do, the Yangtze should continue to ". . . rush ever eastward."

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Tectonic Evolution of the Yellow and East China Seas

by K. O. Emery

Events in places as far away as Antarctica and the Atlantic Ocean affect the geology of China. On the surface of our planet, continents break apart, move, and sometimes collide with one another; oceans rise and fall; and, in the course of geologic time, events on a truly global scale are responsible for much of the detail in the structures of lands and seas as we know them.

By such movements, the Yellow and East China seas evolved. This arm of the Pacific Ocean extends inland for about 1,000 kilometers between the east coast of China and Korea and the Ryukyu Islands, with the Yellow Sea to the north. It receives the waters of the Yangtze River, and Shanghai, China's major seaport, is at the mouth of the Yangtze on the East China Sea. Aside from its part in the broader structure of Earth, scientists are interested in this area as a possible source of petroleum. Some oil already is being recovered from the Yellow Sea's underlying rocks, but few exploratory wells have been drilled. Research into the geological makeup of the East China Sea may reveal its potential for petroleum.

Plate Tectonics and the Work of Geologists

Investigation into the movements of Earth's crustal plates began less than 75 years ago. In 1912, Alfred Wegener, a German meteorologist, published the first theory of continental drift. He theorized that the continents began as one "supercontinent," which gradually broke apart, the pieces drifting away from each other. This idea is supported by several facts, including the discovery of similar fossils throughout the lands of the Southern Hemisphere, and that the continents of Africa and South America appear to fit together like pieces of a jigsaw puzzle.

In the early 1960s, two important discoveries — the mid-oceanic ridge systems and the symmetrical zebra-stripe pattern of magnetic anomalies in the rocks flanking these ridges — led geologists to hypothesize about seafloor spreading, a concept that supplements the idea of continental drift. Plate tectonics, developed in the late 1960s, interrelates these ideas and geologic events into one theory by postulating that the Earth is divided into a dozen plates, which are 40 kilometers thick under the continents and 5 kilometers thick under the oceans. There are considered to be three types of crustal plate boundaries: divergent belts (mid-oceanic ridges where basaltic magma rises to create new crust); translation belts (where the crustal plates slide past one another); and convergent belts (where crusts underthrust and are destroyed).

Marine geologists readily accepted the theory of plate tectonics, because it well explains the evolution of the deep-ocean floor (where all rocks and sediments were emplaced less than 200 million years ago). However, some land geologists have been less inclined to adopt the new theory; rocks on continents are as much as 20 times more ancient than those under the oceans, and some have been so altered and moved about during the lives of oceans now vanished that evidence of crustal movements is obscured.

The separation of the work and thought of marine and land geologists is apparent in their maps, few of which cross the boundary of the shore: on one side, ships cannot go; on the other, geologists cannot walk. The techniques used by land and marine geologists are different, and the time periods they recognize and study are different. Land geologists often integrate their work into geologic, paleogeographic, or geotectonic maps. Geologic maps show the ages and kinds of surface rocks and give some information about folding, faulting, and igneous activity. Paleogeographic maps summarize patterns of sediment ages and the general nature of bodies of rock to depict areas of ancient seas and lands. Tectonic or geotectonic maps are of several kinds: some concentrate on positions of faults and folds; others on positions of massifs (mountainous masses or their eroded remains) and other structural complexes, igneous features, foldbelts, and platform deposits; still others use contour lines to detail the thicknesses of layers of rock (strata). Many tectonic maps reflect certain geophysical disciplines — seismic or gravity studies, geomagnetics, heat flow or acoustic property studies — but few reveal the stages of growth of a crustal region.

On the other hand, maps of oceanic crust made by marine geologists are based on measurements of magnetic anomalies, ages of igneous rocks, and ages of fossils found in immediately overlying sediments. These maps do illustrate the stages of emplacement and folding.

In the process of subduction, one oceanic plate underthrusts (descends beneath) another and is destroyed. Usually one plate has a continental crust, in which case volcanic mountains are likely to develop along the continental margin. Since most new crusts are destroyed by subduction, the existence of former oceans can be inferred only from the remnants of foldbelts found on modern continents. Foldbelts are groups of folds or bends in layers of rock, presumably of common origin. They are younger than the rocks of which they consist, of

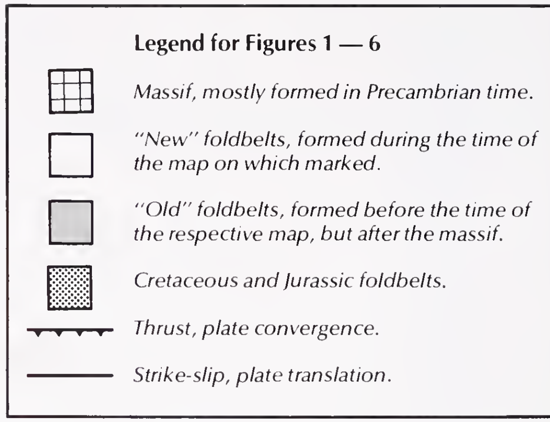
Geologic Time Scale

Eon	Era	Period		Epoch		Years Before the Present (B.P.)
PHANEROZOIC	CENOZOIC	Quaternary	Neogene	Holocene (recent)		11,000
PHANEROZOIC	CENOZOIC	Tertiary	Neogene	Pleistocene (glacial)		1,600,000
PHANEROZOIC	CENOZOIC	Tertiary	Neogene	Pliocene		5,000,000
PHANEROZOIC	CENOZOIC	Tertiary	Neogene	Miocene		22,500,000
PHANEROZOIC	CENOZOIC	Tertiary	Paleogene	Oligocene		36,000,000
PHANEROZOIC	CENOZOIC	Tertiary	Paleogene	Eocene	*India collides with Asia, causing change in the direction of crustal movement and creating the Tibetan plateau.*	55,000,000
PHANEROZOIC	CENOZOIC	Tertiary	Paleogene	Paleocene		65,000,000
PHANEROZOIC	MESOZOIC	Cretaceous			*Mesozoic foldbelts surround Paleozoic continental crust (Figure 5).*	136,000,000
PHANEROZOIC	MESOZOIC	Jurassic				195,000,000
PHANEROZOIC	MESOZOIC	Triassic				230,000,000
PHANEROZOIC	PALEOZOIC	Permian			*Atlantic Ocean begins to open up (Figure 4).*	280,000,000
PHANEROZOIC	PALEOZOIC	Pennsylvanian (Late Carboniferous)				310,000,000
PHANEROZOIC	PALEOZOIC	Mississippian (Early Carboniferous)				345,000,000
PHANEROZOIC	PALEOZOIC	Devonian			*In southern Siberia and northern Mongolia, the Caledonian foldbelt further separates the Asian crust (Figure 3).*	395,000,000
PHANEROZOIC	PALEOZOIC	Silurian				435,000,000
PHANEROZOIC	PALEOZOIC	Ordovician			*Disruption and separation of the Asian massif by the Baikalian foldbelt (Figure 2).*	500,000,000
PHANEROZOIC	PALEOZOIC	Cambrian			*Asian continental crust is situated where northeastern Asia is now (Figure 1).*	600,000,000
PROTEROZOIC	PRECAMBRIAN TIME					2,600,000,000
ARCHEOZOIC	PRECAMBRIAN TIME					4,600,000,000

The Geologic Time Scale combines the classical time classification of rocks long used by geologists with numerical time boundaries based on radiometric age measurements (which are constantly being updated as techniques of measurement are refined). The three major time divisions — Cenozoic, Mesozoic, and Paleozoic eras — were named for recent, middle, and ancient life, respectively. Note the unequal duration of the three eras. "Paleogene" and "Neogene" are the periods that make up the Cenozoic era, as specified by the International Geological Congress; "Tertiary" and "Quaternary" are the Cenozoic periods usually recognized in the United States.

course. Some incorporate pieces of extremely ancient rock complexes; many are capped by more recent sediments and volcanic flows. Therefore, reconstruction of major episodes in the evolution of continents cannot be based solely on geologic maps (those showing the ages and distributions of surface rocks), and, while tectonic maps are helpful, most do not indicate when massifs were disrupted nor when foldbelts were created. (In contrast, evolution of younger and relatively simpler oceanic crust is fairly easy to determine.) These limitations mean that maps which purport to explain the evolution of continental crusts are based on "geopoetry" as well as conventional geology. Such maps, including those presented here, are intended to promote broad thinking, and are best used as models against which new ideas can be tested.

To enhance understanding of crustal growth, I have used certain generalizing techniques with this material. Maps are kept simple, since too many tectonic and other details could obscure growth patterns. The larger structural segments of modern Asia are identified by order of their appearance in time, and are assigned either to ancient geologic formations or to more recent additions. Only large faults are depicted — those most related to convergence, divergence, and translation between crustal plates. Regressing through time, we can examine the Asian crust at each major crustal addition, back to the beginning of the Phanerozoic eon (600,000,000 years ago), and then reconstruct this history in chronological order. By putting together knowledge from marine and land geology, we can begin to see how the East China and Yellow seas arrived at their present form — a result of events in Siberia, India, North America, and elsewhere.



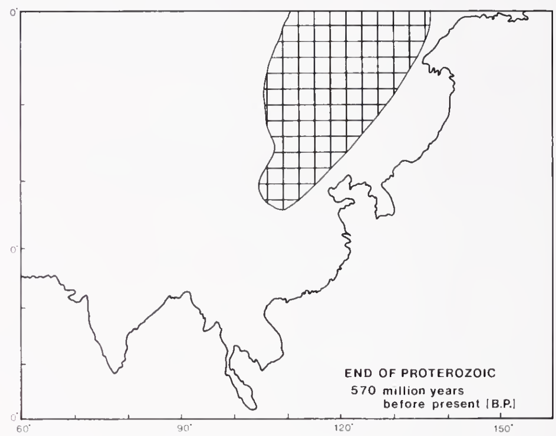


Figure 1. Northeastern Asia at the end of the Proterozoic eon — a massif of igneous and metamorphic rocks that records a complex sequence of Archeozoic and Proterozoic intrusions and foldbelts. An outline of the modern coast of Asia is included to provide scale and relative position.

Evolution of Asian Crust

At the beginning of the Cambrian period, the outset of the Phanerozoic eon, the largest presently recognized piece of Asian continental crust was situated where northeastern Asia is now (Figure 1). This crust is a massif of the remains of foldbelts from very ancient times, the Archeozoic and Proterozoic eons; some are as old as 3,500,000 years. Originally, this massif probably was much larger, but some parts drifted away to become major parts of other continents. Evidence of such ancient crustal fragmentation and foldbelts implies that seafloor spreading and plate tectonics occurred long before the Phanerozoic eon, the time when animals developed hard parts capable of being fossilized.

During the Early Cambrian period of orogeny (mountain-forming by folding and thrusting) in the region of Lake Baikal, the massif rifted and the part west of present Lake Baikal shifted northwestward toward the present Arctic Sea (Figure 2). During the separation, the space between these two pieces of crust filled with ocean, and sedimentation took place. The pieces of massif did not move very far apart, and the ocean opening was followed by partial closing, during which many of the sediments were converted to foldbelts (similar to the formation of the Appalachians and Alps). We do not know the positions of other crustal fragments at that time.

Though their exact positions are unknown, by the end of the Silurian period (400,000,000 years ago) the crustal fragments probably had moved well beyond the area shown in Figure 3, so that marine sediments occupied all of the region around the remaining massif. The Silurian period was marked by further rifting of the Asian massif, sedimentation on the ocean floor in the rift, and partial closing of another ocean basin — the Caledonian orogeny, which raised the mountains of Scandinavia and Scotland. Beginning just west of the present Sea of Okhotsk, ophiolites — fragments of ancient oceanic crust — reveal the locations of plate convergence.

The great Variscan orogeny, in the late Paleozoic era (about 300,000,000 years ago), created some of the borders of the Atlantic Ocean and brought about rifting and separation of the Asian massif and foldbelts (Figure 4). Marine sediments deposited within the rift regions became foldbelts when the ocean contracted between and around larger fragments of the massif. Ophiolites that remain along the boundary between Silurian and Variscan foldbelts south of Lake Balkhash may be small remnants of more extensive lines of plate

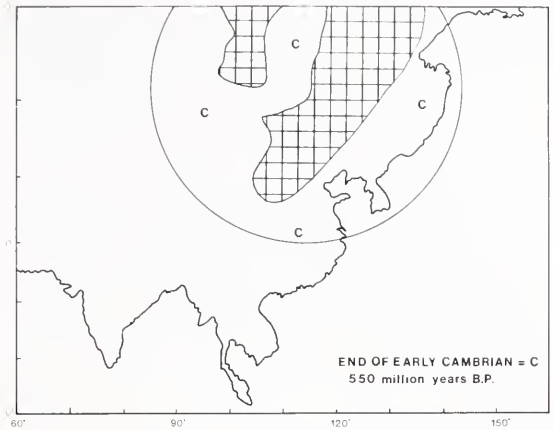


Figure 2. Disruption and separation of the massif by emplacement of the Baikalian foldbelt (near Lake Baikal, just north of modern Mongolia) forces the western part of the massif farther west and north. The circle is meant to demonstrate our ignorance about the extent of Baikalian sediments and foldbelts.

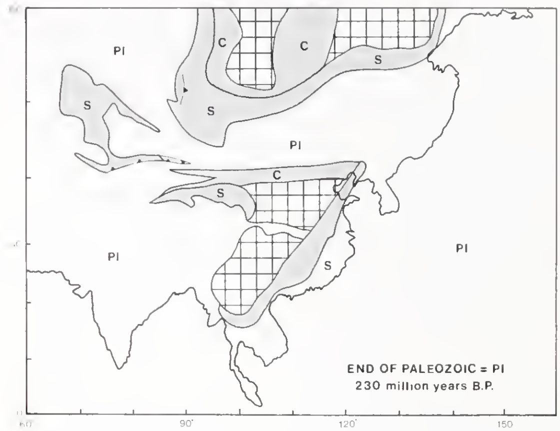


Figure 4. Considerable separation of the massif and attached foldbelts by the extensive Variscan foldbelt, especially in northern China, pushes the southern part of the continental crust farther south to southern China and Indochina.

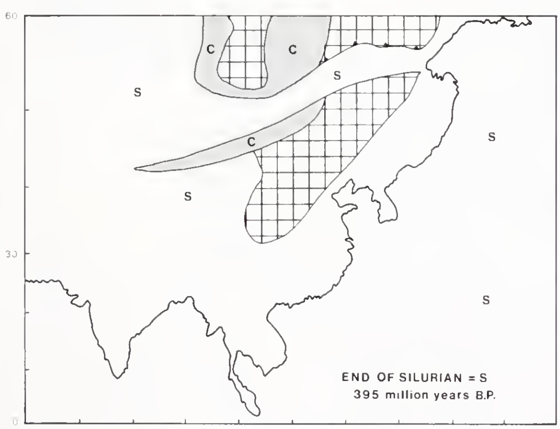


Figure 3. Further disruption and separation of continental crust by the Caledonian foldbelt in what are now southern Siberia and northern Mongolia.

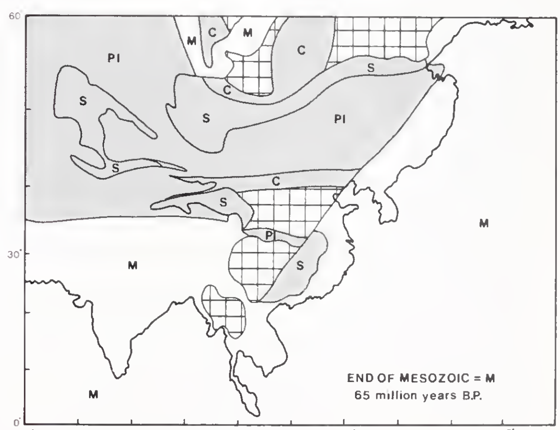


Figure 5. Mesozoic foldbelts surround Paleozoic continental crust, causing minor internal disruption. In the upper right-hand corner, Mesozoic sediments directly contact part of the Precambrian massif.

subduction. As this rifting occurred, over quite a long time, the new ocean and its sediment-covered floor broadened. There may have been other lateral movements that we cannot yet reconstruct accurately. Platform deposits from the late Paleozoic are on the wide plains east of the Ural Mountains. This mountain range is a foldbelt between the Asian and European continental crusts, indicating tectonic convergence of these two crusts.

At least two tectonic episodes — the Indosinian and Yenshan — occurred during the Mesozoic era (230,000,000 to 65,000,000 years ago), so that by the end of the Mesozoic the Asian massifs had become slightly more fractured. The principal change, however, was addition of foldbelts and platform deposits on the southern and eastern perimeters of the Asian continental crust. These were once sediments contiguous with those on the floors of the Indian and Pacific oceans, where seafloor spreading actively produced oceanic crust. This crust moved toward Asia; as it did, subduction probably removed some Paleozoic sediments, bringing Mesozoic sediments into direct contact with parts of the Precambrian massif (Figure 5).

The Cenozoic era, extending from 65,000,000 years ago to the present, has had great tectonic activity. The chief event was India's collision with Asia about 40,000,000 years ago. India was a piece of Antarctica that rifted and drifted away during early Mesozoic times. Trails of volcanic rocks and continental debris mark the travel route. Impact of India with Asia was severe; northern India pushed beneath Asia, so that the total continental crust there is two continents thick, which explains the high Tibetan plateau. At the same time, the overlying Mesozoic and Cenozoic sediments were crumpled into the Alpine foldbelt. Thus, sediments from the floor of the ancient Tethys Ocean became the Himalayas, Alps, and Pyrenees.

India penetrated at least 2,000 kilometers into Asia, underthrusting and pushing southeastern Asia eastward (Figure 6). Four triangular "slices" widen eastward from near the northernmost part of the subduction belt north of India. Lateral movement started with the southernmost slice and gradually shifted northward; the northernmost slice has moved least. Movements of these slices further rifted the Precambrian massif, producing large grabens, or troughs, that then filled with sediments of nonmarine and marine origin (varying according to access by the ocean). The extensive southeastward movement also must have been a factor in producing the many Cenozoic basins and ridges associated with subduction belts on the present ocean floor.

Crustal growth in the North Pacific Ocean during the Mesozoic and Cenozoic eras was relatively simple. In early Mesozoic time, the Atlantic Ocean began to open. Seafloor spreading at the East Pacific Rise added belts of oceanic crust along both sides of the rise. North America, moving westward as the Atlantic opened, overrode parts of the new crust, ultimately destroying most oceanic crust east of the divergence. Even part of the divergence itself is now beneath California. This subduction produced the Rocky Mountains, Coast Ranges, and the Aleutian island arc.

On the other (west) side of the East Pacific Rise, seafloor spreading affected the Asian foldbelts. The oceanic crust was moving in the general direction of southeastern Asia (actually traveling north-northwest relative to its mantle source, the Hawaiian hot spot). In the late Paleogene, at about the time of India's collision with Asia, the crust's direction of movement shifted, a change which can be seen in the sharp bend in the Emperor-Hawaiian seamount chain.

To determine average seafloor spreading rates, the width of each belt of oceanic crust is divided by its approximate formation time. Between the Gulf of California and the western edge of the (Jurassic) crust at the Marianas Trench, the average rates, in centimeters per year, are: Neogene, 4.1;

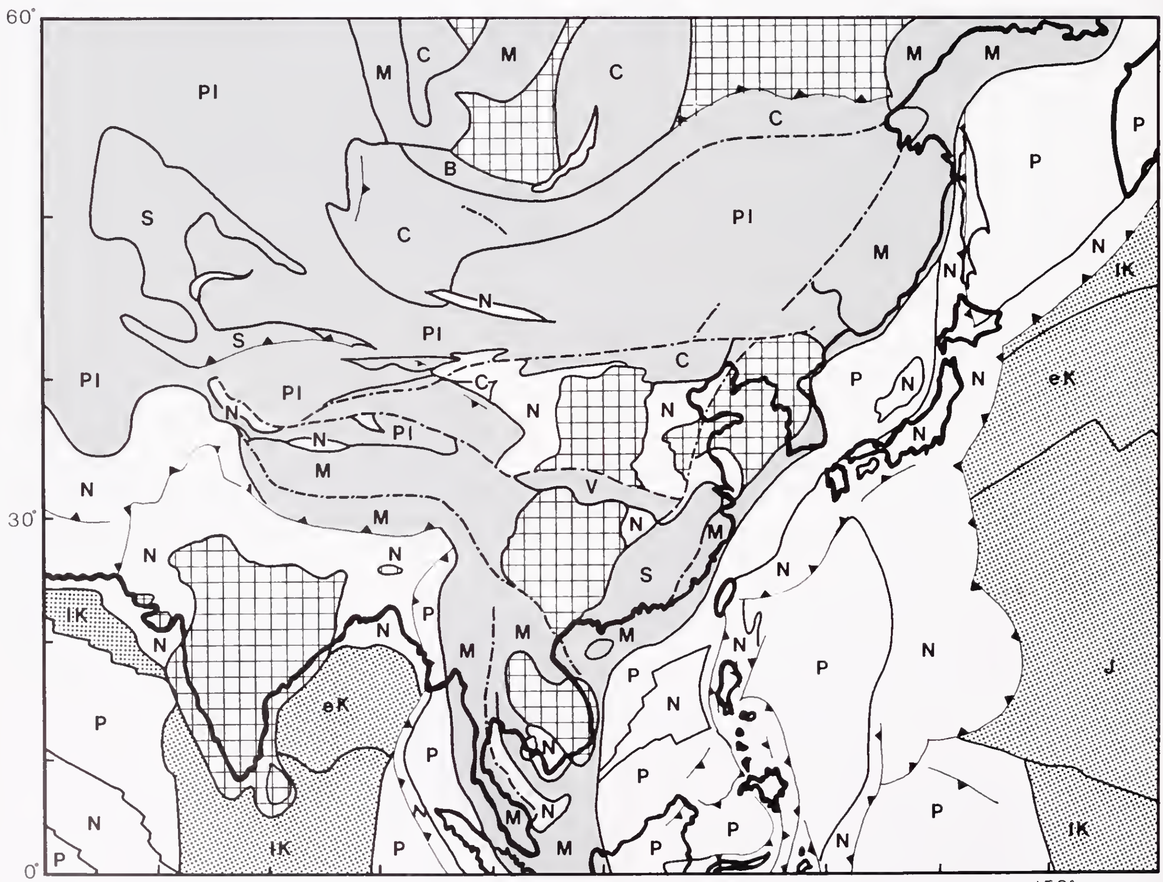


Figure 6. Crustal convergences culminate with the collision of the Indian subcontinent against southern Asia during Late Paleogene time. The collision thrusts the northern part of the Indian massif beneath Asian crust, folding the overlying sediments into the Himalayan mountains and producing large strike-slip faults in Asia that further separate the fragments of the original massif and open large grabens to receive Cenozoic sediments. This eastward displacement of Asian crustal slices is reflected in the complex topography of the ocean floor between Indonesia and Japan. N = Neogene; P = Paleogene; J = Jurassic; eK = Early Cretaceous; lK = Late Cretaceous.

Paleogene, 5.6; Late Cretaceous, 6.0; Early Cretaceous, 7.1; and Jurassic, 6.0+ (part of this crust has been lost by subduction). Possibly, the general slowing is an effect of the collision of India with Asia. However, we do not know when Pacific crust began to be subducted and what width of oceanic crust has been lost through subduction.

The geomagnetic orientation of sedimentary and volcanic rock of known ages supplies some information about Asian crustal movements, although the data we have are scanty. The general implications of our measurements are that the region moved sharply to the north during early Paleozoic time, south during Mesozoic time, and north again during the Cenozoic. Unfortunately, however, the paleomagnetic measurements are so sparse that little credence can be given this reconstruction. In fact, a broad program of paleomagnetic studies is needed for Asia, and especially for China, if we are to improve our reconstruction of geological events there.

Tectonics in the Yellow and East China Seas

The structure underlying the Yellow and East China seas controls the patterns of sedimentation there. Precambrian massif underlies most of the shallower area; the highest portion of this massif is above sea level, projecting into the sea at the Shantung and

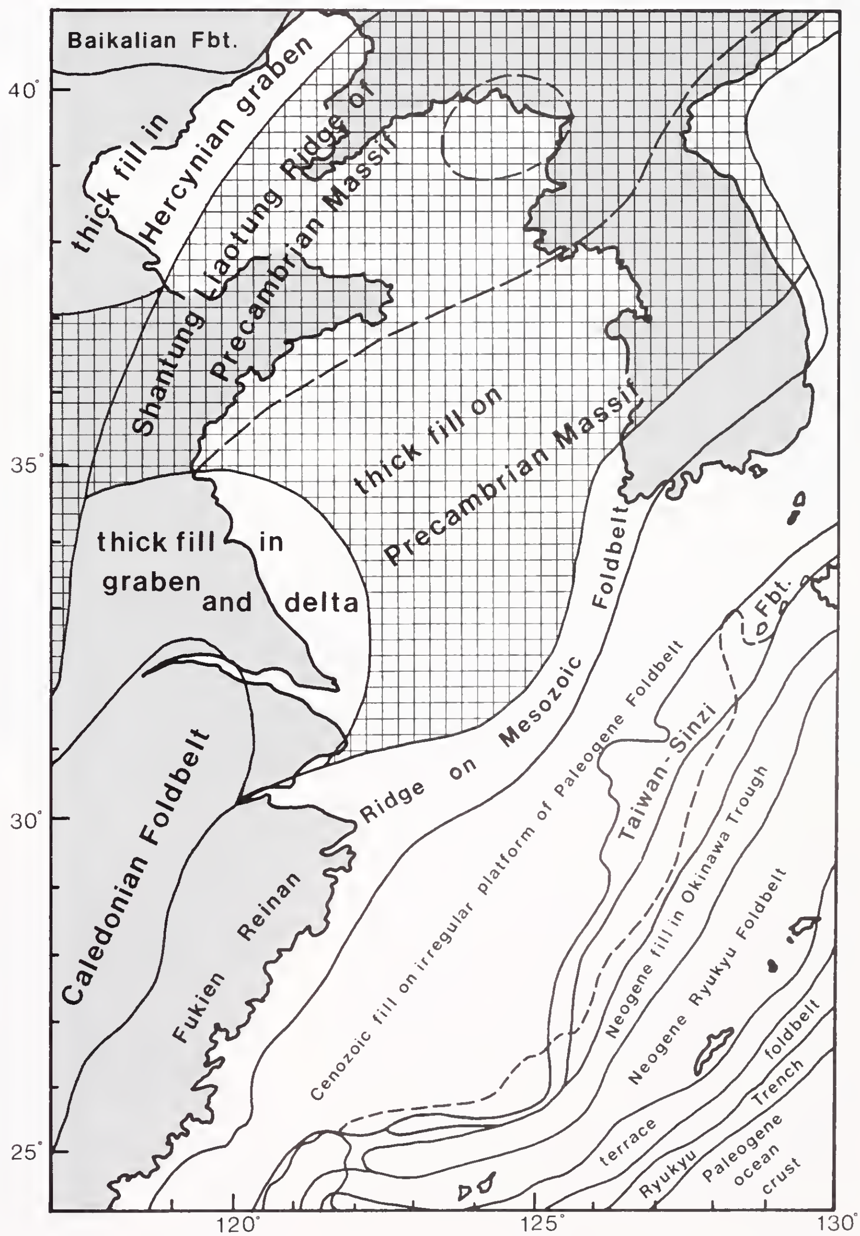


Figure 7. Areas of massif and foldbelts in the East China-Yellow Sea region, with respect to present topography and general thicknesses of subsequent sediments.

Liaotung peninsulas and bordering the entrance of the Gulf of Bohai. The rest of the massif is underwater and has an irregular surface in the basins of which nonmarine detrital sediments accumulate, forming a nearly flat seafloor. The thickest sediments appear to be in the southwestern part of the Yellow Sea and the northwestern part of the East China Sea, posing good possibilities for petroleum resources.

Northwest of the massif, very thick Cenozoic and some Mesozoic sediments underlie the North China basin, which includes the northwestern side of the Gulf of Bohai. This basin, the Ordos basin farther west, and many smaller ones were formed as grabens caused by the collision of India with Asia. Although most are nonmarine, the thick sediments in at least some of the basins have proven to be petroliferous. Several fields in the North China basin provide a large part of China's total petroleum production. In contrast with the stability of the Precambrian massif, tectonism continues in the Gulf of Bohai, as illustrated by the enormously destructive earthquake at Tangshan on 28 July 1976.

The Alpine graben southwest of the Precambrian massif is smaller and probably has thinner Cenozoic sediments than the Gulf of Bohai. In both areas, a single river is the chief supplier of new sediments.

The remaining structural units of the Yellow and East China seas are on land, too: parts of the Baikalian foldbelt in the northwest and the Caledonian foldbelt in the southwest (Figure 7). Both foldbelts contribute only minor volumes of sediment to the ocean.

Addition of platform sediments (later to become foldbelts) on the periphery of Asia began during the Early Mesozoic era. In the East China Sea, the result is the Fukien-Reinan foldbelt. Initially, it probably acted like a dam, holding out the ocean and allowing only nonmarine sediments to accumulate atop the broad Precambrian massif there. Probably by the Late Paleogene or Early Neogene the dam was eroded enough to allow ocean water in and, subsequently, marine sediments to be deposited. The Fukien-Reinan foldbelt has hilly topography on land and a subseafloor ridge across the mouth of the Huanghai Sea.

The next stage of platform deposition, during the Paleogene, was a belt of nonmarine and marine sediments. The outer edge of the platform crumpled into the Taiwan-Sinzi foldbelt, which also may have temporarily blocked entrance of ocean water to the adjacent platform and farther inland. The fill contains petroleum, shown by actual production west of Taiwan, and a test flow of 1,000 barrels of gas condensate per day from two exploratory wells drilled in 1981, 300 kilometers east of Shanghai. Intense exploration of the region has lagged because of sovereignty questions and other issues, but one can confidently predict that many productive oil platforms will be sited in this basin. Finally, Paleogene oceanic crust and marine sediments were deposited on the deep-ocean floor, where they remain southeast of the Ryukyu Trench.

Mesozoic oceanic crust, with its sediment overburden, continued to push beneath Asia during the Neogene along the Ryukyu Trench. This caused uplifting of the Ryukyu foldbelt, along with volcanism and seismic activity which continues to the present. Seafloor spreading like that west of the Marianas Trench was induced, and the Okinawa Trough opened. A belt of plate divergence may exist on the shallow floor of the trough (deepest point about 2,200 meters), and future studies will investigate possible thermal circulation, hot springs, and base-metal deposits along its axis. Underthrusting along the Ryukyu Trench also crumpled ocean-floor sediments, forming a foldbelt between the trench and the largely volcanic Ryukyu foldbelt. Between the two foldbelts, a trough filled with sediments from the northwest forms a terrace.

Summary

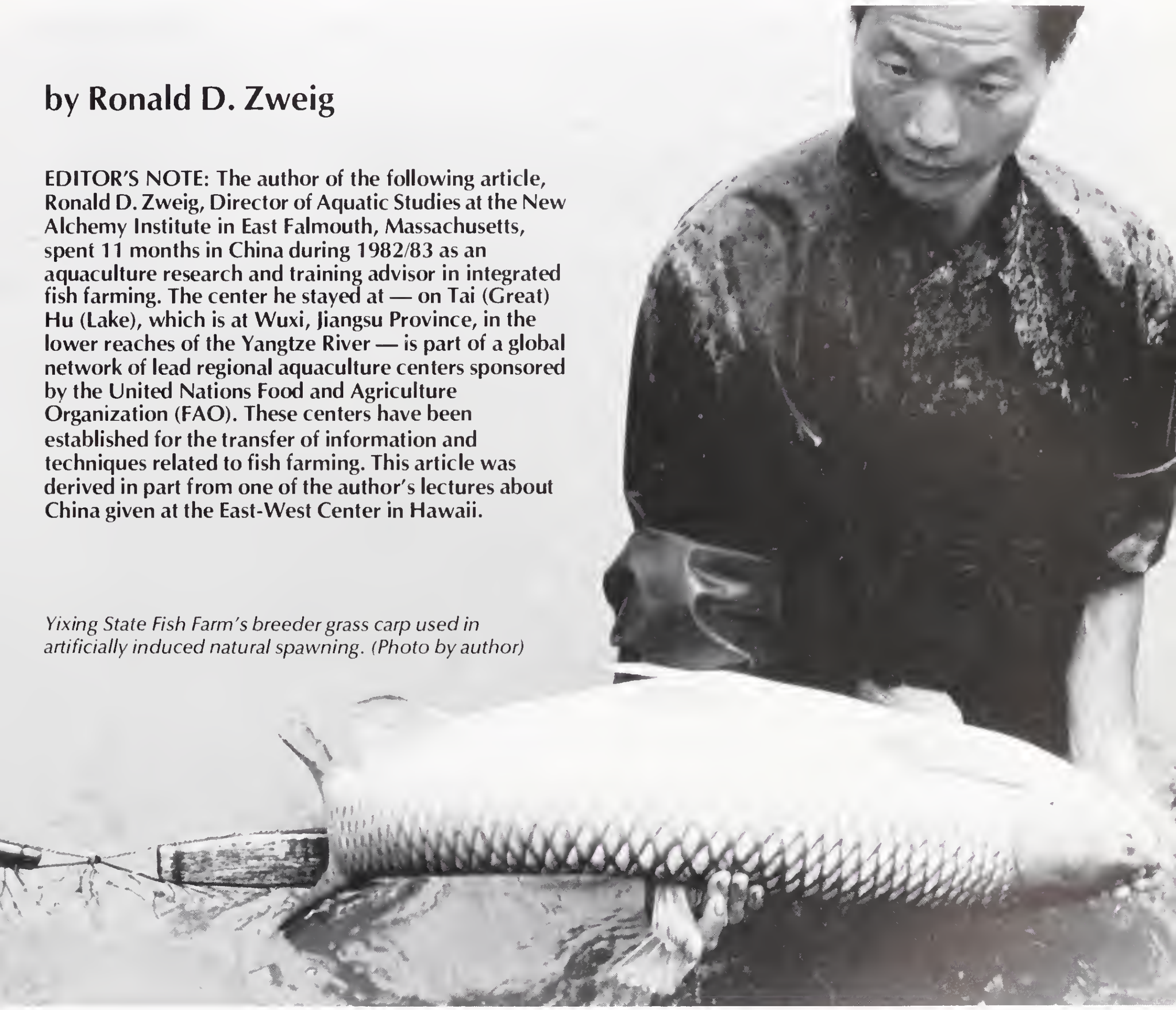
The region of the Yellow and East China seas is a compact, representative portion of Asia, reflecting in its structure tectonic events of the entire continent and of far more distant regions. These events can be traced by studying the movements of massifs and associated foldbelts composed of marine and nonmarine sediments deposited in a wide range of environments and climates in the course of more than a billion years. Present sediments are similar to many of the ancient ones, and they give us an opportunity to measure many depositional parameters that are beyond reach in vanished seas. To increase our knowledge of these vanished seas, we must be guided by concepts of plate movements, and not just by the patterns of rock ages and divisions of strata that were the basis for paleogeographic maps only a few decades ago. Modern sedimentology and knowledge of plate movements have already brought about changes in our conception of geologic evolution. Further surprises can be expected from studies more detailed than this.

K. O. Emery is Bigelow Oceanographer emeritus at the Woods Hole Oceanographic Institution. He presented a more technical version of this article at a symposium held in Hangzhou, China, in April, 1983. Dr. Emery is presently working with Dr. Elazar Uchupi, also of the Woods Hole Oceanographic Institution, on a broad synthesis of the geology of the Atlantic Ocean.

Aquaculture Strategies in China

by Ronald D. Zweig

EDITOR'S NOTE: The author of the following article, Ronald D. Zweig, Director of Aquatic Studies at the New Alchemy Institute in East Falmouth, Massachusetts, spent 11 months in China during 1982/83 as an aquaculture research and training advisor in integrated fish farming. The center he stayed at — on Tai (Great) Hu (Lake), which is at Wuxi, Jiangsu Province, in the lower reaches of the Yangtze River — is part of a global network of lead regional aquaculture centers sponsored by the United Nations Food and Agriculture Organization (FAO). These centers have been established for the transfer of information and techniques related to fish farming. This article was derived in part from one of the author's lectures about China given at the East-West Center in Hawaii.



Yixing State Fish Farm's breeder grass carp used in artificially induced natural spawning. (Photo by author)

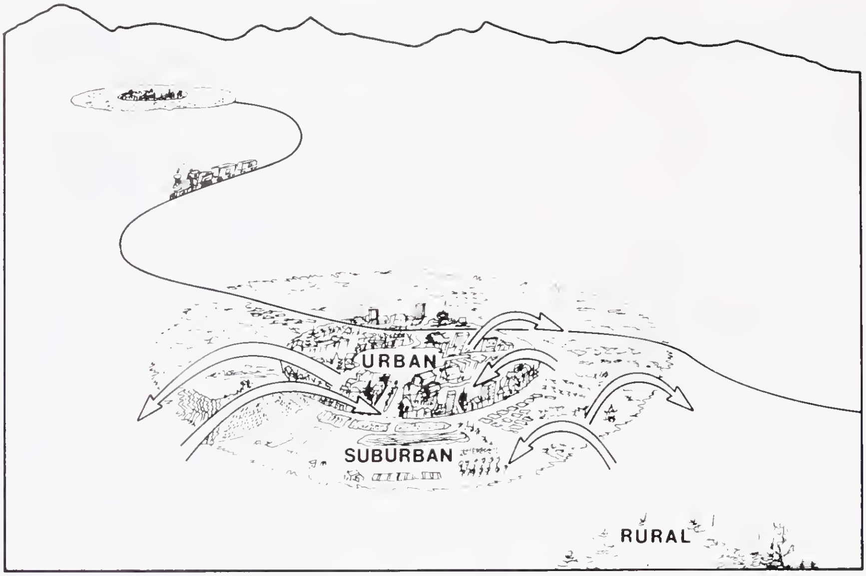
That aquaculture has a philosophical base in the East and a scientific base in the West has far-reaching implications. In the East it is culture, it is life: culture to improve life by providing food and employment. It is embedded in the social and economic infrastructure. All that science can and must do is to make this culture more effective. In this respect, the East has much to learn from the West. In the West, aquaculture is science and technology, embodied in industry and providing profits: money. It has no social infrastructure. The economic infrastructure has yet to be created. In this, the West has much to learn from the East.

It is on this meeting, this merger, that food for the world and peace for the world largely depend.

Elisabeth Mann Borgese
Seafarm

An exploration of the Chinese landscape shows a most interesting interplay between humanity and the environment. Generally, the society is regionally self-reliant for food production and regionally interdependent for industry and energy requirements. People's diets, for the most part, are confined to the variety of foods that can be grown in their immediate locale. Railroad transport and shipping by canal to a lesser degree are used for the dispersion of most raw materials for industry, manufactured products, and energy supplies, such as coal and oil.

With a population exceeding a billion people, the society's pressures on available resources are extreme, especially since approximately 93 percent of the population lives in less than 50 percent of the country's land area. Roughly 10 percent of the total



The interface zone between urban centers and agricultural landscape, illustrating the impact on landscape design.

land area is arable, leaving approximately 0.1 hectare (0.25 acres) of agricultural land per inhabitant as compared to about 1.5 hectare per person in the United States, which has less than a quarter the population.

The structure of Chinese society and its agricultural strategies have a number of parallels to the way natural ecosystems evolve, function, and interrelate. For example, the interfaces between ecosystems have been found to be the most highly, biologically productive zones, as in intertidal and salt marsh areas at the edge of the seas, or at the bottoms of ponds where aerobic and anaerobic micro-environments are in contact. In each case of this kind, symbiotic and commensal relationships occur where by-products of the indigenous organisms' biological activities are exchanged and cycled as nutrients or resources for each other. Similarly, zones of high, agricultural productivity exist in the Chinese landscape and are found in bands of land area surrounding population centers ranging in size from rural villages to large cities. The food production activities within these areas vary and are dependent upon the characteristic advantages and liabilities, resources, and climatic restrictions of each bioregion.

Fan Li, father of fish aquaculture and author of the classic text on rearing common carp, written circa 473 B.C. (Courtesy of author)

Within the society's structure, there is a human-population density gradient that is high in urban and village centers and decreases into the rural landscape. Population transitions of this kind are found all over the world. In the primarily rural areas of China, extensive agriculture produces grains, rice, and wheat. This, too, is not uncommon. However, between the high population centers of villages or cities and the surrounding extensive agriculture of the rural countryside, a rather unique intermediate zone of activity exists where intensive food production takes place. This intermediate margin can be looked on as the interface between what can be characterized as urban and rural ecosystems. By-products of agricultural production from the rural areas and food-processing wastes and nightsoil (human waste) from the urban centers are used in this intensive zone. Definitive cycles of nutrient use, both within and between this zone and the urban and rural environments, provide the capacity for extremely high food production on small areas of land. At the same time, needs for food transport are minimized, reducing costs and providing fresh produce. In places with sufficient freshwater supplies, particularly in the lower reaches of the Pearl and Yangtze river basins, integrated fish farming plays a predominant role in optimizing space and nutrient utilization.

Roughly 60 percent of freshwater fisheries output comes from the Yangtze River Basin with 30 percent from the Pearl River area. The total

Re-formed modern fish polyculture and integrated fish ponds. (Photo by author)

freshwater fish production is 10 percent of the world's output, or a million metric tons a year; half of it is derived from aquaculture. Although this seems a large figure, it only amounts to an average of 1 kilogram per person per year, with China's population of more than a billion equalling nearly a quarter of the world's people.

3,000 Years of Aquaculture

Aquaculture practices in China date back at least 3,000 years, with the first document on common carp monoculture techniques written by Fan Li in 473 B.C. Through the centuries, the methods have been refined and increased in complexity, particularly since the Tang Dynasty (618-907 A.D.) when fish polyculture was initiated, leading to a successful and efficient approach to aquaculture. As with many discoveries, the reasons behind them are not necessarily the result of the analysis of gradually improving techniques. During the Tang Dynasty, the emperors' surnames were "Li," which is the same as the Chinese for "common" carp. As a result, the killing of common carp was banned, so alternative fishes were sought to replace it. A number of indigenous species was found with characteristically different feeding habits, and they could also be effectively cultured together in ponds creating the classic Chinese fish polyculture strategy. Among the fishes discovered, silver carp feed on phytoplankton. Grass carp and Wuchang fish ingest land grasses and higher aquatic plants. Bighead carp consume zooplankton. Black carp eat snails. Mud carp feed on bottom detritus, and common carp and crucian carp on most of the above, except plankton. Presently, some of the tilapias, native to Africa and the Middle East, are being used in combination with the aforementioned carps. (These fishes are differentially stocked in ratios to match the quality of external nutrient inputs and pond-generated feeds.)

Because of this wide variety of niches in ponds being exploited, a broad range of nutrient resources that otherwise have little direct food value to humans can be put into the ponds and efficiently used. Aquaculturist Gerald L. Schroeder describes the function of aquaculture ponds "as a sunlit rumen wherein mineral and organic fractions of feeds and fertilizers are converted by autotrophic and heterotrophic activities into a complex of algae, bacteria, protozoa, and their mucopolysaccharide exudates which serve as the food base for fish growth."*

Integrated fish farming in China uses fish polyculture in ponds as its predominant activity. Direct linkages exist between fish culture, animal husbandry, and agriculture within the farms. Fish yields exceeding 13,000 kilograms per hectare per year have been achieved in some areas, as compared to good catfish production in the United States at 3,000 kilograms per hectare per year on nonintegrated farms dependent on costly fishmeal-based feeds.

Two main fish culture strategies are implemented in China: stocking and harvesting in rotation, and multi-grade conveyor culture. The rotation method begins by stocking a pond with up to three size-classes of each fish species cultured in it. Through the growing season, fish of harvestable size are captured every two to three months. At the same time, additional fingerlings are added to replace the fishes removed. This technique is mostly *practiced in drainable ponds* in the temperate areas of China.

The multi-grade conveyor method is generally used in undrainable ponds in the south of China. Combinations of fish species are size-classed and reared in separate ponds. As the fish grow, the larger ones are culled out and moved to the next pond containing larger fish in lower densities. The last

*Schroeder, G. L. 1983. Stable isotope ratios as naturally occurring tracers in the aquaculture food web. *Aquaculture* 30: 203–210.

Aquaculture Scenes in China

All Photos by Ronald D. Zweig

Catching parent fish from parent fish pond. Buildings in background are pig sties; pig dung is commonly used for fertilizer.

Boat full of aquatic weeds from Tai Hu to be used as green fodder for grass carp.

Mr. Chuan, engineer of the Yixing Fish Farm, prepares LRH-A, a synthetic hormone used to induce breeding in grass carp.

Ducks living over fish pond at the Wuxi Ho Le People's Commune.

Fish cages at the Dian Shan Lake Farm in Shanghai county.

Spreading fine feeds over pond surface; tub is transport to assure even distribution.

Yixing State Fish Farm. Carp hatchlings are put in net cages for conditioning prior to sale.

Fan Li Garden, named for the father of fish aquaculture, overlooking Tai Hu, the vicinity where Fan Li's pioneering work was completed.

LRH-A is injected into grass carp.

pond, generally the fifth in the sequence, is the food-fish pond from which the fish are harvested at market size.

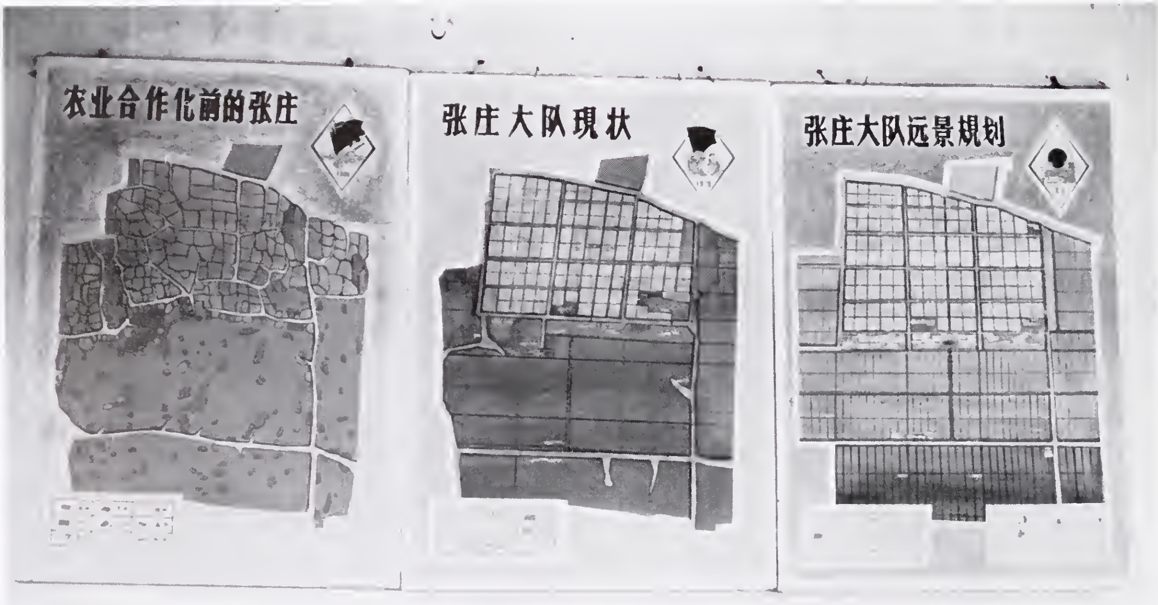
The combination of fish culture with animal husbandry and agriculture on integrated fish farms increases efficiency through ingenious use of beneficial nutrient subcycles within the farm itself. Pond-bottom humus is used as a fertilizer for crops grown adjacent to ponds or directly on their dikes, including fish feeds (green fodders and some grains) and human foods (vegetables, sugar cane, bananas, or tree crops). Livestock manures (pig, duck, goose, chicken, cow, sheep, etc.) and nightsoil are used as pond fertilizers for plankton production. Agricultural by-products — such as dregs from wine processing, wheat and rice chaff, cotton or rape seed meal after oil extraction — also are put into the ponds as fish feeds. In addition, floating aquatic plants — such as water hyacinths, water peanuts, and water lettuce — are grown on canals adjacent to ponds. Presently, anaerobic digesters are being used on integrated fish farms to produce methane gas as an energy source from agricultural wastes and manures. The nitrogen-rich, slurry residues are then used to fertilize ponds. Even with this great variety of pond inputs, the limited quantity of locally available nutrients is the central factor restricting pond-area expansion where integrated fish farming is presently practiced.

Silk Produced

Some integrated fish farms also produce silk, an ancient practice in China. Mulberry plants are grown adjacent to ponds or directly on their dikes. The leaves are harvested and used as feed for silkworms. Silkworm feces as well as cocoon-processing wastewater are used as fertilizer for the ponds and some of the silkworm pupae are fed to fish. (However, if weather permits efficient drying outdoors, the pupae are now predominantly processed for a medicinal extract to remedy high blood pressure.)

With the immense variety of nutrient inputs used in Chinese aquaculture, management of the ponds is the key factor for consistently producing high fish yields. Such high production is primarily the result of the savvy of the fish farmers whose families have practiced fish culture for many generations. They represent a rare exception to the statement by Eugene Odum in *Fundamentals of Ecology* that "man's very existence is being threatened by his abysmal ignorance of what it takes to run a balanced ecosystem."

Using simple, visual cues — such as pond-water color, turbidity, and fish behavior — the farmers are able to maintain highly tuned, productive ponds. For instance, when they are asked what the best color is, they simply reply "fresh brown." A measurement not easy to define precisely, and, therefore, difficult to use for technology transfer. For success with this type of management, between 10 and 20 years of experience are usually necessary. In addition, well developed techniques for natural and artificial propagation of fishes cultured, disease control, and harvesting and stocking contribute to the overall success. In Wuxi, Jiangsu Province, where the highest yields are attained, there are only about a half-dozen of these highly skilled practitioners. This is one of the predominant factors that limits the expansion of integrated fish farming in China needed to meet the demands of the increasing human population, which has doubled since 1950.



Progress of the Zhang Zhwang fishery team at the Huang Qiao Commune in Jiangsu Province. The poster at left shows the 600-year-old ponds circa 1958; center, re-formed ponds and expansion circa 1976; right, projected development.

Closing ceremonies of 4-month course on integrated fish farming given at Wuxi, Jiangsu Province. Sixteen graduates represented Pakistan, Thailand, Nepal, India, Burma, Papua-New Guinea, Malaysia, Bangladesh, the Philippines, and Sri Lanka. (Photo courtesy of author; fourth from right at table)

Joint FAO/China Program

Attempts are now being made to scientifically quantify the pond dynamics and assess the efficiency of management tactics, including the use of electricity for aeration and water pumping, inorganic fertilizer, grain-based pelleted feeds, and others, so useful technology transfer may be possible within and outside of China. A project for this purpose has been developed by the Chinese Government with assistance from the Food and Agriculture Organization (FAO) of the United Nations and the United Nations Development Program. These coordinated efforts are an example of how a modern scientific approach can be applied to assess a traditionally practiced technology to determine its usefulness and develop the means for its transfer to other places.

The project is based in Wuxi at the Asian-Pacific Regional Research and Training Center for Integrated Fish Farming. This Center is one of seven Regional Aquaculture Lead Centers established around the world and assisted by the Aquaculture Development and Coordination Programme based at FAO headquarters in Rome. The precepts of the overall program are to conduct research, training, and information exchange of local aquaculture practices globally. Through the research efforts, techniques practiced in an area are being defined, assessed, and refined with successful ones being adapted for use in other regions. Aquaculture training courses and study tours are coordinated by some of the centers, providing first-hand experience and practice in the broad range of aquaculture techniques employed in each region. For example, a four-month training course in integrated fish farming is conducted at the Wuxi center each year with between 16 and 18 participants from countries in the Asian-Pacific community invited to attend. The primary focus of information collection, documentation, and dissemination activities is on indigenous knowledge successfully implemented at the local level by practitioners but not documented in the scientific literature.

Through this program, seeds of additional information can be provided and may allow for broader use of aquaculture for food production. Accordingly, the fish-culture methods transferred will need to be woven into the cultural fabric of the societies, whether the approaches are complementary to existing aquaculture techniques or are completely new programs. This is a major challenge to the transfer and development of all food-production strategies among cultures, and it must be met to benefit humanity, particularly where food shortages exist.

Ronald D. Zweig is Director of Aquatic Studies at the New Alchemy Institute in East Falmouth, Massachusetts.

Marine Pollution in China

Bridge spanning the Grand Canal

Street scene in Wuxi, a city of 800,000. (Photo by Ronald Zweig)

The anti-intellectualism of the Cultural Revolution had great impact on marine science and oceanography in the People's Republic of China between 1966 and 1976, mainly via the closing of all universities and basic- and applied-research institutions. Genuine scientific writing and teaching virtually ceased during this period. It was not until the Gang of Four* were removed in 1976 that development of science and technology was again recognized as fundamental to modernization and academic and research institutions were reopened. Therefore, it was not until 1981 that qualified graduates began to emerge and focus on marine science and oceanography. An entire generation of scientists was missing, and marine-pollution problems arising from agricultural practices and extensive industrialization had gone unnoticed or unstudied. Consequently, the impacts of pollution only recently have been identified, studied, or corrected in China. The enactment of the first Chinese marine environmental law in 1983 is a direct result of the re-emergence of environmental consciousness, analogous to the environmental movement in the United States in the late 1960s and the 1970s.

Dramatic progress is now being made in China toward overcoming effects of the Cultural

*Jiang Quiang (widow of Mao Tse-tung), Wang Hongwen, Zhang Chunquiao, and Yao Wenyuan constituted the Gang of Four. Holding various posts in the Communist Party, the four appropriated political power and were viewed as the leaders of the Revolution until their banishment.

by D. A. Wolfe,
M. A. Champ,
F. A. Cross,
D. R. Kester,
P. K. Park,
and R. L. Swanson

Wuxi. (Photo by Ronald Zweig)

Shanghai harbor. (Photo by Audrey Topping/PR)

Revolution. As a result of expanded communication and exchange between China and the United States, numerous American scientists are once again visiting and promoting scientific interchange with working scientists in China.

Under the auspices of a bilateral agreement between the United States' National Oceanic and Atmospheric Administration (NOAA) and China's National Bureau of Oceanography (NBO), a marine pollution delegation visited the People's Republic during June and July of 1983. Our objectives were to learn about marine-pollution problems in China and the existing research capabilities and programs that address those problems, and to explore the potential for intergovernmental cooperation in this field. The delegation (the authors of this article) visited government and academic research laboratories in Beijing, Tianjin, Qingdao, Dalian, Shanghai, Hangzhou, Xiamen, and Guangzhou (Table 1).

Marine-Pollution and Water-Quality Standards

China's Marine Environmental Protection Law became effective on 1 March 1983. This law covers pollution and damage from coastal projects, offshore petroleum exploration, land-originated pollutants, boats and ships, and the dumping of wastes. The Director of NBO, Luo Yuru, was recently quoted in the China Daily (27 February 1983) as saying that the purpose of this law is for China to use its marine resources more profitably. Marine environmental laws become more important as the volume of international trade and exchange increases. Violators of the law have to remedy pollution within a specific period of time, pay a pollution-discharge fee, defray

Table 1. Institutions visited by the marine pollution delegation.

National Bureau of Oceanography Headquarters	— Beijing
Institute of Oceanographic Instrumentation, NBO	— Tianjin
Institute of Scientific & Technological Information, NBO	— Tianjin
North China Sea Subbureau, NBO	— Qingdao
First Institute of Oceanography, NBO	— Qingdao
Academia Sinica	— Qingdao
Yellow Sea Fisheries Institute	— Qingdao
Shandong College of Oceanology	— Qingdao
Institute of Marine Environmental Protection, NBO	— Dalian
East China Sea Subbureau, NBO	— Shanghai
East China Normal University	— Shanghai
Second Institute of Oceanography, NBO	— Hangzhou
Third Institute of Oceanography, NBO	— Xiamen
Xiamen University	— Xiamen
South China Sea Subbureau, NBO	— Guangzhou
Academia Sinica	— Guangzhou

the expenses for pollution removal, and compensate for the damage sustained by the state. In addition, warnings will be served and fines will be imposed. The Ministry of Urban and Rural Construction and Environmental Protection is in charge of marine environmental protection, and the NBO is responsible for scientific research and the prevention of pollution caused by oil exploitation in offshore areas. Harbor and fishery departments, army units, and provincial governments will take care of environmental protection in the areas in their own jurisdiction. According to Luo, three vessels based in Qingdao, Shanghai, and Guangzhou began on 28 February 1983 to patrol the sea areas under China's jurisdiction for pollution monitoring and surveillance of marine resources.

The NBO issued marine water-quality standards in response to the Marine Environmental Protection Law of 1 March 1983. Water bodies are classified according to use for regulatory purposes — for example, a harbor is normally classified as a Class III water — and standards vary according to classifications. The NBO is beginning to consider designation of ocean-dumping sites, but we were unable to determine whether specific sites and/or wastes are under consideration at this time.

Waste Treatment

At Tianjin, the U.S. delegation was briefed by Yu Xi-chen, Senior Engineer for the Environmental Protection Bureau of Tianjin; then it visited an oil refinery near Dagang, about 50 kilometers southeast of Tianjin.

The central metropolitan area of Tianjin occupies approximately 160 square kilometers and supports about 4,000 factories and a population of 3.3 million. The total area of Tianjin is 11,000 square kilometers; with a population of 7.7 million, it is the third largest city in China, after Shanghai and Beijing. Tianjin discharges about 1 million cubic meters of sewage daily into two waste streams that enter Bohai Bay in the same vicinity (Figure 1). One of these streams receives an additional 1 million cubic meters of discharge from Beijing. Only about 10 percent of this total is treated prior to discharge into the streams, although 1,000 of the Tianjin factories have pretreatment facilities to reduce the toxic organics, metals, and pigments in their effluent streams.

A new treatment plant, with a capacity of 260,000 cubic meters per day, will go into operation in Tianjin in 1984, using an activated sludge process. The two open waste streams carrying the combined wastes of Beijing and Tianjin are used as sources of water and fertilizer in the irrigation of agricultural land. The Haihe River is the primary water supply for Tianjin. According to Yu, the Bohai receives about 700 million metric tons per year of discharge, of which 400 million metric tons enter Bohai Bay, the balance entering the Bohai mainly via Dalian and Jinzhou bays. Approximately a third of the wastes entering Bohai Bay are of industrial origin.

At the Dagang refinery, the delegation was shown the waste-treatment facility that treats the combined wastes of the refinery operation and all the laboratory and toilet facilities in the plant. The treatment plant uses flotation, flocculation, and biological-digestion processes with a capacity of 500 metric tons per hour. The wastes enter a pumping well by gravity flow and are directed into primary flotation tanks where floating oil is skimmed off the surface and returned to the refinery. A flocculant (alum or $FeCl_3$ or both) is then added to the aqueous phase, which is strongly aerated as it enters a second flotation-process stream. Floating petroleum material is skimmed off at this stage and disposed of (possibly by burning or burial), and the aqueous-waste stream enters the biological

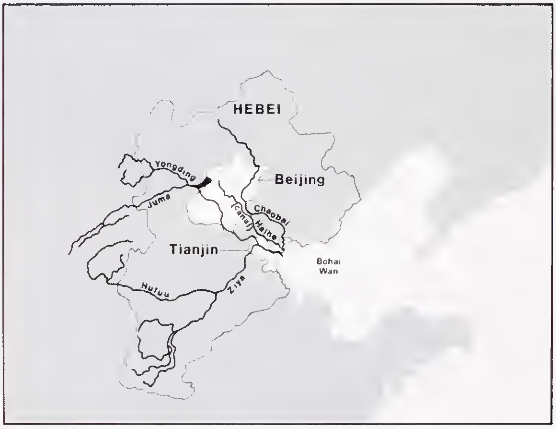


Figure 1. Major water sources and waste streams for Beijing and Tianjin municipalities. Most wastes from Beijing are discharged into the Chaobai River or into a canal that flows into the Haihe River. The Chaobai and Haihe rivers both discharge into Bohai Bay. The Yongding River (and the Guanting Reservoir) supply most of Beijing's water. The Haihe River and its tributaries upstream from Tianjin provide water for that city. (Reconstruction of briefing by Yu Xi-Chen, chief engineer, Tianjin Environmental Protection Bureau)

digestion tanks, where recycling of activated sludge takes place. The effluent from this final step enters the waste stream to Bohai Bay, while the sludge is used as fertilizer for reforestation projects. Oil content of the aqueous phase after flocculation and the second flotation step is 15 to 20 parts per million; after biological digestion, it is reduced to 2 to 3 parts per million. The effluent stream is monitored for several parameters, which must meet standards imposed by the Environmental Protection Bureau, as shown in Table 2.

In Shanghai, the NOAA delegation visited the Jiojan sewage treatment plant, which services the Jiojan apartment complex. About 90,000 people live there; no industrial wastes or storm sewers are directed to the sewage. The nominal jurisdictional boundary between Provincial and Federal authorities is the 12-mile limit, but the NBO is currently considering coastal waters as well as offshore waters. Regional monitoring of marine pollution is carried out by the monitoring stations of the three regional subbureaus. The Institute of Marine Environmental Protection in Dalian has access to the monitoring information from all regional subbureaus and analyzes the data to evaluate pollutant distributions, transport, transformation, and effects; environmental capacity for pollutants; and recovery capacity.

Approximately 400,000 square kilometers of coastal waters (100,000 square kilometers in the South China Sea Subbureau region) are currently being monitored for about 20 parameters, with routine sampling three times per year (May, August, and October). The NBO sampling has been predominantly in depths greater than 10 meters. Monitoring parameters include: mercury, cadmium, zinc, copper, chromium, lead, chemical oxygen demand (COD), biological oxygen demand (BOD), dissolved oxygen (DO), chlorinity, petroleum, DDT and DDE, hexachlorobenzene (BHC) and hexachlorocyclohexane (666), and radionuclides (total alpha emitters and strontium-90). Sediments and water, but not biological tissue, are analyzed for appropriate parameters. In addition, biological monitoring for trace metals in mussels will be initiated along the coast of China as part of the Western Pacific regional monitoring program.

Some 6 billion tons of domestic and industrial wastes are introduced annually into Chinese coastal waters, mainly from runoff from rivers, ships, and harbors. Petroleum and metals are the main pollutants of concern, but BOD and COD are also of concern because of their potential contribution to coastal organic enrichment and oxygen depletion. Red-tide blooms have occurred in Bohai Bay and in the coastal areas of the East China Sea. While the largest polluted area is the Bohai, concentrations of contaminants are generally higher at the mouth of the Changjiang (Yangtze) in the East China Sea; offshore waters are generally unpolluted, as most serious problems occur in bays and estuaries.

Petroleum

An estimated 60 percent of the petroleum pollution in coastal waters is derived from riverine sources. Concentrations of total petroleum hydrocarbons at the marine-monitoring stations (measured by ultraviolet absorption or fluorescence spectrophotometry) range from 0.01 to 0.32 parts per million, with an average of 0.05 parts per million. Five percent of the samples from the Bohai, Yellow and East China seas exceed the water quality standard of 0.05 parts per million. The water of the Zhujiang (Pearl River) estuary and delta between Guangzhou and Hong Kong, however, frequently exceeds water-quality standards for petroleum, with measurements in the range of 0.04 to 0.108 parts per million. In the Zhujiang, the main sources of petroleum are refineries, transportation, and fisheries plants. Administration and regulation of petroleum input are complicated by significant additions from runoff and atmospheric input, and by contributions from natural sources. Some 13,000 tons of petroleum enter the Zhujiang estuary annually, making parts of the area unsuitable for fish and shellfish culture and recreation. The Chinese have designated two levels of water-quality standard for petroleum: first-rate is 0.050 parts per million and second-rate is 0.100 parts per million.

Table 2. Monitoring parameters and discharge standards applied to the Dagang refinery effluent stream.

Parameter	Standard
total oil	10.0 ppm
cyanide	0.5 ppm
sulfate	1.0 ppm
phenol	0.5 ppm
acidity	6.0-9.0
chemical oxygen demand	100.0 ppm
particulates	150.0 ppm

The NBO's Institute of Marine Environmental Protection has studied Jinzhou Bay, a small (125 square kilometers) bay northwest of Dalian. The main contaminants here are from an oil refinery and a zinc-processing plant. In Jinzhou Bay, petroleum concentrations of 0.01 to 2.6 parts per million have been observed, and the concentration decreases exponentially with distance from the source. In this area, only 8 species of macrofauna remain in the intertidal zone (*Perinereis* species, *Macroplathalmus* species, and *Glaucomya* species are dominant). In this same area, oyster tissues contain 0.06 to 0.47 parts per million of mercury and 0.03 to 13.8 parts per million of cadmium (wet-weight basis). A mathematical model is being developed by NBO scientists at Dalian for calculating the capacity of Jinzhou Bay for contaminants.

Organic Loading

About 600,000 to 700,000 metric tons of COD enter China's coastal waters annually, with approximately half of that coming from the Changjiang. The water-quality standard is 3 parts per million, and observed values are in the range of 0.19 to 5.5 parts per million. The standard is exceeded most frequently in the Bohai (22 percent of stations), followed by the East China Sea (7 percent) and the South China Sea (2.7 percent). Areas of greatest concern are Jiaozhou Bay at Qingdao, Bohai Bay and Laizhou Bay, both in the Bohai, and the mouths of the

Changjiang and Zhujiang estuaries. Red-tide blooms occurred in May, 1983, in the Zhujiang estuary near Hong Kong (with extensive fish mortalities), and massive mortalities of oysters (*Ostrea plicatula*) have occurred near Hangzhou. Scientists at the Second Institute of Oceanography were attempting to relate this latter observation to toxicants in the area, but the mortality resembled a classic example of high BOD/COD following spring plankton blooms — a situation that could have been aggravated by increased runoff of nutrients from the surrounding, chemically fertilized, agricultural lands.

Heavy Metals

Generally speaking, it was reported that heavy metal concentrations were not considered a problem. NBO sampling programs have been analyzing seawater and sediment samples for several years. The Dalian laboratory is currently analyzing seawater samples for mercury, cadmium, lead, zinc, and copper. The Second Institute at Hangzhou has measured copper, cadmium, lead, zinc, cobalt, nickle, manganese, magnesium, and iron in seawater, pore water, and sediment since 1979. The concentrations of mercury were highest in the East China Sea, followed by the South China Sea and Bohai. Concentrations of cadmium were highest in the South China Sea. Lead concentrations were highest in the Zhujiang estuary.

Effects on Fisheries

In recent years, fisheries production has declined in the East China Sea, particularly catches of croakers. Age and size of the fish caught also have been decreasing, suggesting that overfishing may be a cause of the decline. New laws have been passed to regulate fishing, especially during spawning periods, and the number of fishing boats is now being controlled. The largest fishery is for yellow croaker (*Pseudosciaena crocea* Richardson), which is landed at a rate of about 100,000 tons per year from the East and South China seas. The second most important fishery is for little yellow croaker (*P. polyactis* Blecker) from the Bohai, followed by hairtails (*Trichiurus haumela* Forsskal), and cuttlefish (*Sepiola inermis = maindroni* de Rochebrune).

In the area of Fuzhou to Xiamen, razor clams (*Sinonovacula constricta* Lamarck) are cultured intensively in the intertidal zone. Until recently, the intertidal area was sprayed with arsenic to eliminate predators, parasites, and competitors. The Chinese have since stopped this practice because of unacceptable arsenic levels in the harvested clams.

Research on fisheries is conducted under the Ministry of Agriculture, Fisheries, and Husbandry through three federal fisheries institutes, located at Qingdao, Shanghai, and Guangzhou. The NOAA delegation visited the Yellow Sea Institute in Qingdao. In the area of marine pollution, the Yellow Sea Fisheries Institute performs acute- and chronic-pollutant lethality tests with metals and pesticides on marine organisms, and on the basis of these (96-hour TLM) bioassays, recommends water-quality criteria for both marine and fresh waters. Effects of refinery operations and seismic geologic tests have been examined using *in situ* cage bioassays with fish and shrimp. Fish also are sampled and analyzed for trace metals, and nearshore samples generally contain higher metal concentrations than those from offshore. At most of the NBO laboratories visited by the delegation, there seemed to be little awareness of the activities underway at the Fisheries institutes. This is unfortunate, because very little biological sampling, analysis, or biological-effects research is done at the NBO laboratories. At the South China Sea Subbureau of the NBO, however, we were told that exchange of data, participation in joint research cruises, and intercalibration all occur with the South China Sea Fisheries Institute in Guangzhou.

Marine Pollution Problems of Concern

The general areas of marine pollution of concern to Chinese scientists include petroleum hydrocarbons, pesticides, radionuclides, and heavy metals. We did not find a great deal of attention to the potential effects of nutrient enrichment of coastal waters from domestic sewage discharges. The major activities regarding pollutants in coastal waters are baseline inventories, monitoring techniques, and some

Flotation tank and skimmer at the Dagang oil refinery waste-treatment plant. Skimmer in foreground removes wastes from surface of the effluent; effluent is then channeled to a biological digestion tank and discharged via a canal to the open sea. (Courtesy of authors) marine-process research. As noted, a first-order assessment has been made of selected marine pollutants in the coastal waters of China.

With respect to marine-process studies, Chinese scientists generally know where problems lie and how they can be approached, but they were only in the early stages of conducting such studies. One specific example is the area of chemical speciation of heavy metals, in which there is a high level of interest at the Second and Third Institutes. There also is a demonstrated interest in understanding the exchange of pollutants between seawater and particulate phases.

Instrumentation and Methodology

New instrumentation is being obtained and installed at several institutions, especially for analyzing heavy metals and petroleum hydrocarbons. Most of the modern equipment is American and Japanese, but many instruments also are being built in the People's Republic, frequently modelled on American instruments.

Radioactivity measurements are being taken at several locations, including Academia Sinica and the First Institute of Oceanography in Qingdao, Marine Environmental Protection Institute in Dalian, Third Institute of Oceanography at Xiamen, and the Marine Environmental Protection Center of the South China Sea Subbureau in Guangzhou. Carbon-14 and lead-210 are used for age determination of samples at several locations. Low-background alpha counting is underway at Academia Sinica at Qingdao, the Third Institute of Oceanography in Xiamen, and at the South China Sea Subbureau in Guangzhou, apparently for monitoring of environmental samples. Strontium-90 is also being monitored at these three institutes. The First and Third Institutes of Oceanography both have 512-channel gamma spectrometers. Zhou Ben Chaun at the First Institute is measuring cesium-137, zinc-65, and cobalt-60, samples from the Bohai, using a 7.6-centimeter by 7.6-centimeter sodium iodide crystal; the Third Institute has two lithium-drifted germanium detectors which were not yet in use (shielding had not been installed). At the South China Sea Subbureau, we were told that the concentration of radionuclides was somewhat high in the water and sediments of Zhujiang estuary, but neither the compositions of isotopes nor their origins were identified for us.

Pesticides are being analyzed by gas-liquid chromatography at several institutes. In most cases observed, large-diameter packed columns, 1.5 to 2 meters long, were in use. Capillary columns were in use only at the Second Institute of Oceanography (for normal alkanes) and at the South China Sea Subbureau (pesticides). Pesticides analyzed always included DDT, DDE, and 666, but BHC (hexachlorobenzene) and PCBs also were mentioned occasionally. The Institute of Marine Environmental Protection also had prepared standards for dieldrin. During discussions at the Third Institute of Oceanography, the delegation was advised that DDT and 666 were still used extensively in China (with heavier usage of 666), though China had halted production of both compounds as of 1 March 1983.

Atomic absorption spectrophotometer at the South China Sea Subbureau in Guangzhou. This Chinese-built double beam instrument with background correction was not yet in use at the time of the delegation's visit. (Courtesy of authors)

Approximately four types of organophosphorus pesticides also are in use; these are not yet being analyzed in marine systems.

The use of packed-column gas-liquid chromatography severely constrains the analysis of chlorinated hydrocarbon pesticides and petroleum hydrocarbons in environmental samples. Hydrocarbon resolution is not sufficient to permit either reliable, state-of-the-art distinction of petrogenic from biogenic materials or tracking of petroleum in the environment to its source.

Nearly every laboratory possesses one or more atomic absorption spectrophotometers (AAS) for measuring metals in either sediments or seawater. Most of the institutions also are equipped for anodic stripping voltammetry (ASV). Atomic absorption spectrophotometry is routinely used in analyses of metals (usually total, by HF digestion) in sediments, whereas ASV is used for analysis of dissolved metals (copper, cadmium, zinc, and lead) in seawater. Only the Second and Third institutes were set up to preconcentrate metals from seawater for AAS; there, scientists are using solvent extraction. The delegation could not judge if Chinese scientists had adequate control over contamination to be able to measure metals in seawater at the nanomolar level and below. Only the Second Institute of Oceanography, however, was attempting to use state-of-the-art "clean" procedures for their metal analyses. The Chinese have developed an ASV instrument and some small electrodes that are considerably different than those used in the United States. A comparison of electrochemical methods between the two countries could prove useful.

Generally, conventional manual methods are used for nutrients. Members of the delegation observed many Chinese-made spectrophotometers modeled after the Beckman DU. We saw one Technicon autoanalyzer, but it was not functional. Automated chemical analyses will greatly benefit Chinese scientists in the future.

Marine Science Library and Computer Facilities

The U.S. delegation visited the marine-science libraries of a number of the institutes. They have good coverage of western journals and textbooks, but only a fair collection of specialized reference books. Many journals and texts are not original editions; photocopies are bound for distribution within China. It was evident that Chinese scientists are closely following technical literature.

Since 1980, many marine-science institutions have been publishing marine-science journals. The NBO Institute of Marine Scientific and Technological Information in Tianjin publishes *Oceanic Abstracts,* which abstracts international literature, and *Collected Oceanic Works,* which presents English translations of papers selected from the Chinese marine-science literature. Table 3 lists marine-science journals recently established in China.

There is a general lack of experience and equipment for marine-data analysis. The NBO computer at Tianjin is badly outdated. Members of the delegation saw a Cromenco microcomputer system at the Second Institute that was being used for teaching computer programming, but we were unable to learn if application programs had been developed. The Third Institute has a recently installed DEC minicomputer; the few computer terminals we saw were not, in general, used for scientific work.

Closing Perspective

The marine scientists we met at the oceanographic institutes of NBO, at the Academia Sinica laboratories, and at the academic institutions conveyed a sense of broad awareness of contemporary facets of marine research comparable in scope to that of marine scientists in the United States and Europe. Many of our introductory sessions at various laboratories included a historical summary of the work. While quite a number of marine programs in China were initiated in the late 1950s and the early 1960s, it was often indicated that their work was substantially curtailed during the Cultural Revolution (1966 to 1976). Consequently, in many instances it is only during the last seven years that marine scientists in China have been able to pursue their work intensively. We have a clear sense of the considerable progress made in recent years, and that the state of marine science in the People's Republic of China is advancing very rapidly.

Table 3. Marine science journals currently being published in the People's Republic of China.

Acta Oceanologica Sinica		
Chinese	**Vol. 5, No. 1**	**Jan 1983**
English	**Vol. 1, No. 1**	**Jun 1982**
Collected Oceanic Works (semiannual) in English starting 1982	**Vol. 5, No. 1**	**Aug 1982**
Journal of Shandong College of Oceanology	**Vol. 13, No. 1**	**Mar 1983**
Marine Science Bulletin (bimonthly) English abstracts	**Vol. 2, No. 1**	**Feb 1983**
Ocean Technology (quarterly) English abstracts	**Vol. 1, No. 1**	**Mar 1982**
Oceanic Abstracts (monthly) Multilingual, Chinese abstracts		**1983**
Oceanologia et Limnologia Sinica (bimonthly)	**Vol. 14, No. 1**	**Jan 1983**
Studia Marina Sinica English abstracts	**No. 19**	**Sept 1982**
Taiwan Strait (semiannual) English abstracts	**Vol. 1, No. 1**	**Jul 1982**
Tropic Oceanology (quarterly) English abstracts	**Vol. 1, No. 1**	**Aug 1982**

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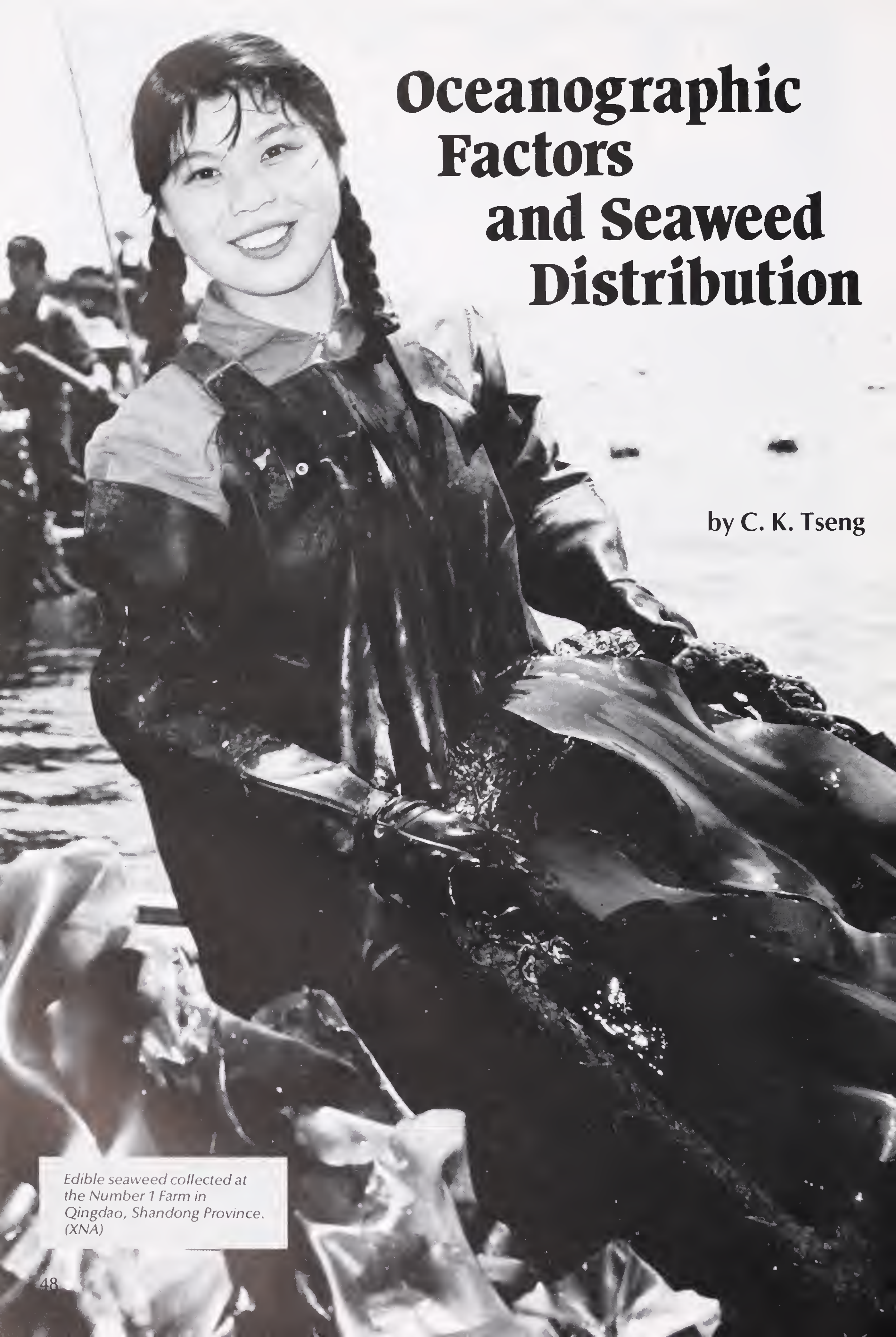
Oceanographic Factors and Seaweed Distribution

by C. K. Tseng



Edible seaweed collected at the Number 1 Farm in Qingdao, Shandong Province. (XNA)

The geographic distribution of seaweeds along China's coasts is influenced by oceanographic conditions extending over certain time periods. These distribution patterns can be better understood by explaining the role of the oceanographic factors involved. This is an important problem in marine biology but, regretfully, it has been neglected. In the late 1950s and early 1960s, a few papers were published in China on this subject. It is desirable, therefore, to summarize these views with the object of furthering discussion among fellow marine botanists.

Factors in the Distribution of Seaweeds

Seaweeds are benthic marine algae and, unlike animals, are unable to leave their substrates once they are attached to them. In order to maintain their lives, they have to adapt themselves to the environment and tolerate the rigor of the environmental extremes within their growth period, which in the case of perennials may mean extreme temperatures in some temperate regions (near-freezing temperatures in the winter and as high as 27 to 28 degrees Celsius in the summer). Any seaweed unable to cope with such extremes will not be able to establish itself in such a locality. The presence of the seaweed in healthy and normal conditions, naturally, reflects its ability to adapt to the locality; all such localities taken together constitute the pattern of its geographic distribution. Temperature is undoubtedly the crucial one among the important, basic oceanographic factors. The other factors such as light, salinity, and chemical nutrients also are important, but to a lesser degree, and only locally.

Although seaweeds are not motile and are unable to move from one place to another, they have reproductive units — the spores and/or zygotes — which act just like seeds of the land plants in their dispersal. The medium of dispersal, of course, is water. If the water is stationary, the dispersal area will be very limited. It is the moving water mass that helps the seaweeds disperse to faraway places. That the same seaweed can be found in different places very far from each other, even on coasts of different continents, is due to the presence of ocean currents and their branches and subbranches, which are instrumental in their successful dispersal.

However, the spores and zygotes can remain viable only for a certain length of time, and their transport from one place to another must be completed within the viable period. Therefore, movement of water mass, especially ocean currents and their branches, is the other crucial oceanographic factor in determining the pattern of its geographical distribution.

Thus, successful dispersal of a seaweed depends, at least, on two crucial factors. Its reproductive units must be transported by the moving water mass from one place to another, which constitutes the first factor for successful dispersal. Once the spores and/or zygotes arrive at another place away from "home" and attach to the right kind of substrate — on the right tidal level, receiving the right light intensity, and in water of the right salinity and chemical nutrients, and at the right temperature — they will germinate and grow to sporelings in the new locality. However, that does not guarantee successful establishment of seaweeds.

Environmental conditions are changing all the time, and the seaweed has to adapt itself and cope with them, particularly the changing temperature, to grow and reproduce normally and healthily and, finally, to give rise to new generation, before it can be really established in its new "home." Thus, temperature constitutes the second crucial factor for successful dispersal. In the course of the long history of dispersal, the localities in which it is distributed and established may be connected with each other, forming a very long distributional string or even a very copiously branched distributional tree. This is the pattern of its geographical distribution.

When all the species of a locality are taken together and dealt with *in toto,* they constitute the marine flora of that locality. Oceanographic conditions, therefore, especially the two crucial factors (movement of the water mass and temperature) shaping the pattern of geographical distribution of the individual species, are similarly involved in explaining the characteristics of the marine flora. We have studied several cases of the geographical distribution of seaweeds and have selected two examples for this article (Figure 1).

Pelvetia siliquosa

In 1953, we discovered a new species of *Pelvetia, P. siliquosa* (Tseng and C. F. Chang) from the Huanghai Sea coast and discussed its distribution on the China coast as well as the world distribution of the genus *Pelvetia* (Tseng and C. F. Chang, 1953, 1958). *P. siliquosa* is distributed on the eastern end of the Shandong Peninsula, from Wendeng County in the south to Jimingdao in the north, and on the Liaodong Peninsula, from Changhai County (Changshan Islands) in the east to Changxing Island of the Fuxian County in the Bohai Sea in the west. The *Pelvetia* is not found, however, in the Yantai-Weihaiwei region, only some 10 kilometers west of Jimingdao in the northern part of the Shandong Peninsula, or in the Qingdao region, also some 10 kilometers west of the Wendong County in the southern part.

For a long time, we had suspected that the so-called dwarf form of *Pelvetia wrightii,* reported to occur on the southern and southwestern coast of the Korean Peninsula, was nothing but plants of the present species. Our suspicion was fully confirmed 13 years after the discovery of the species, when Noda (1966) published his new species *Pelvetia minor* based on specimens collected from the southern and southwestern Korean coasts, and from Dalian, Liaodong Peninsula, where we also collected our specimens of *P. siliquosa.* Noda's description and photographs of his species left no doubt in our mind that *P. minor* is synonymous with our *P. siliquosa.*

There are, therefore, three regions where *Pelvetia siliquosa* is distributed: Shandong Peninsula, Liaodong Peninsula, and Korean Peninsula. It was speciated many years ago in an earlier geological era in one of the three regions and then spread to the other two regions. Although we have selected the specimen from Mashan of the Shandong Peninsula as the type specimen, it does

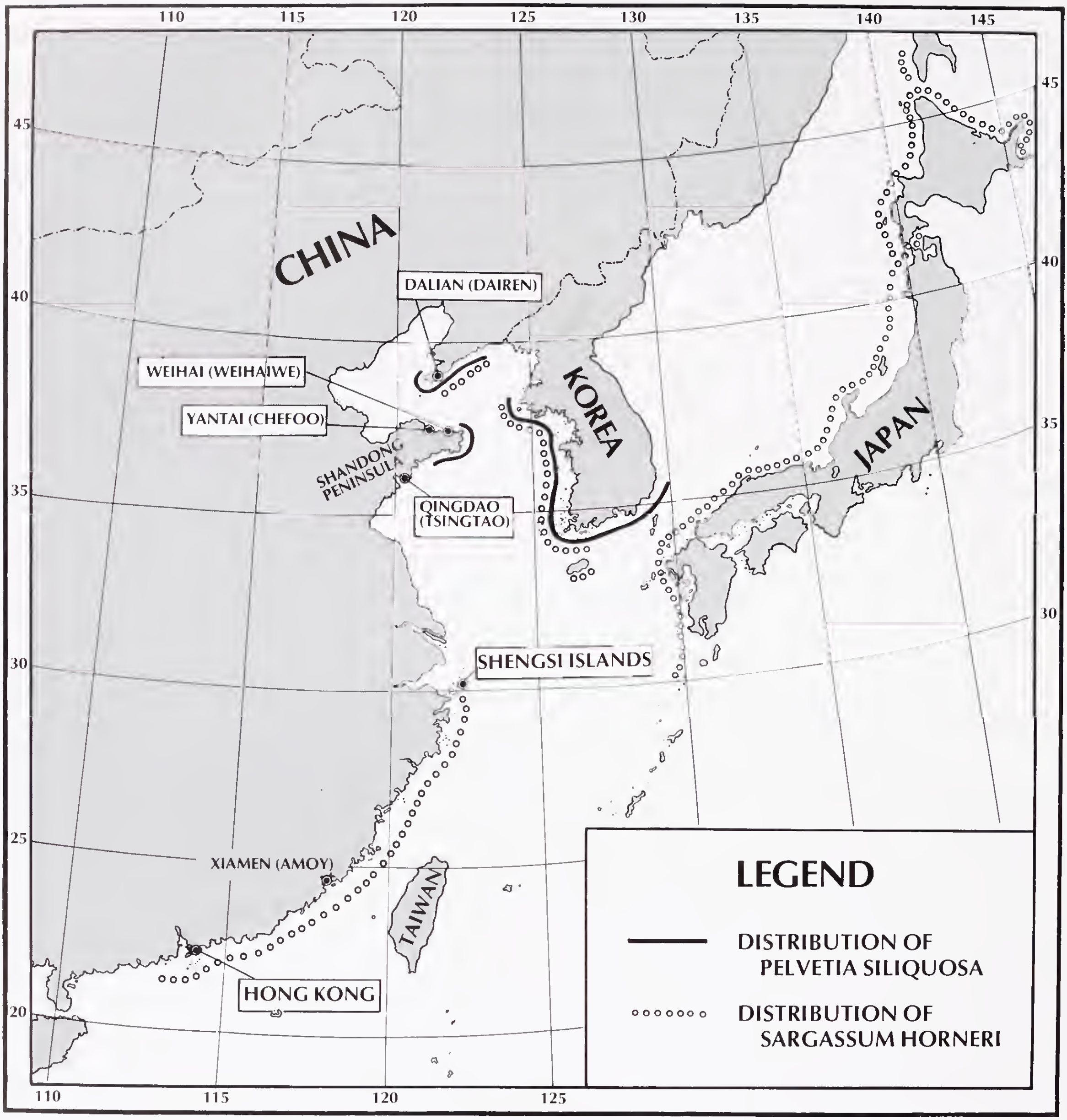


Figure 1. Geographical distribution of two Chinese seaweeds.

not necessarily mean that this species was speciated there and then spread to the other two peninsulas. Generally speaking, the locality where a species was speciated should have much larger quantities and more varieties and forms.

Although we do not have the opportunity to visit and observe the growth of this species in the Korean localities mentioned by Noda, we have reasons to believe that *P. siliquosa* grows much more luxuriantly in larger quantities in the Korean Peninsula than in China. This is based on the fact that for many years, perhaps hundreds of years, Korea had exported to China large quantities of this seaweed, which were sold on the market in North China under the vernacular name *Lujiaocai* (meaning "deer-horn vegetable"). In recent years, probably because of lesser quantities of import or larger quantities of consumption, the seaweed *Ishige okamurai* and the juvenile thalli (young sprout) of the seaweed *Sargassum (Hizikia) fusiforme* were marketed as its substitute, also known on the market as *Lujiaocai.* On this basis, and also for other reasons, we are led to believe that *P. siliquosa* was speciated in southern Korea, then spread to the western Korean coast, then further distributed to the Liaodong and the Shandong peninsulas. In fact, the distribution in western Korea is almost continuous with that in the Liaodong Peninsula, the only barrier being the delta of the Yalu River.

Before discussing the oceanographic factors involved in shaping the present pattern of the geographical distribution of the *Pelvetia*, a few words about its ecology and reproduction are necessary. This seaweed grows on middle intertidal rocks and, therefore, is exposed to the drying effect of air and sun several hours a day. Being a perennial, its thalli have to withstand hot summers and cold winters; therefore, it is found only in such places where the summers are not too hot, generally not over 25 degrees Celsius, and the winters not freezing, about 1 to 2 degrees Celsius. It grows in places where water flows swiftly but wave action is not too strong. It matures sexually and liberates eggs in the summer, especially August to September when the fertilized eggs (the zygotes), assisted by the movement of the surface current, will be dispersed from one place to another. Therefore, the critical period for its dispersal is late summer.

The principal current in the Huanghai Sea is the Huanghai Sea Warm Current, which is a branch of the Tsushima Current, itself a branch of the famous warm current Kuroshio (Figure 2). In August, the Huanghai Sea Warm Current, after passing through the Huanghai Sea off the eastern coast of the Shandong Peninsula, divides into two branches. One of these branches turns eastward and moves southward along the western Korean coast, while the other turns westward, forming the extension of the current, part of it entering the Bohai Sea via the channel between Laotiashan of the Liaodong Peninsula on the north and Huangcheng Island of the Miaodao Islands on the south, and the remaining

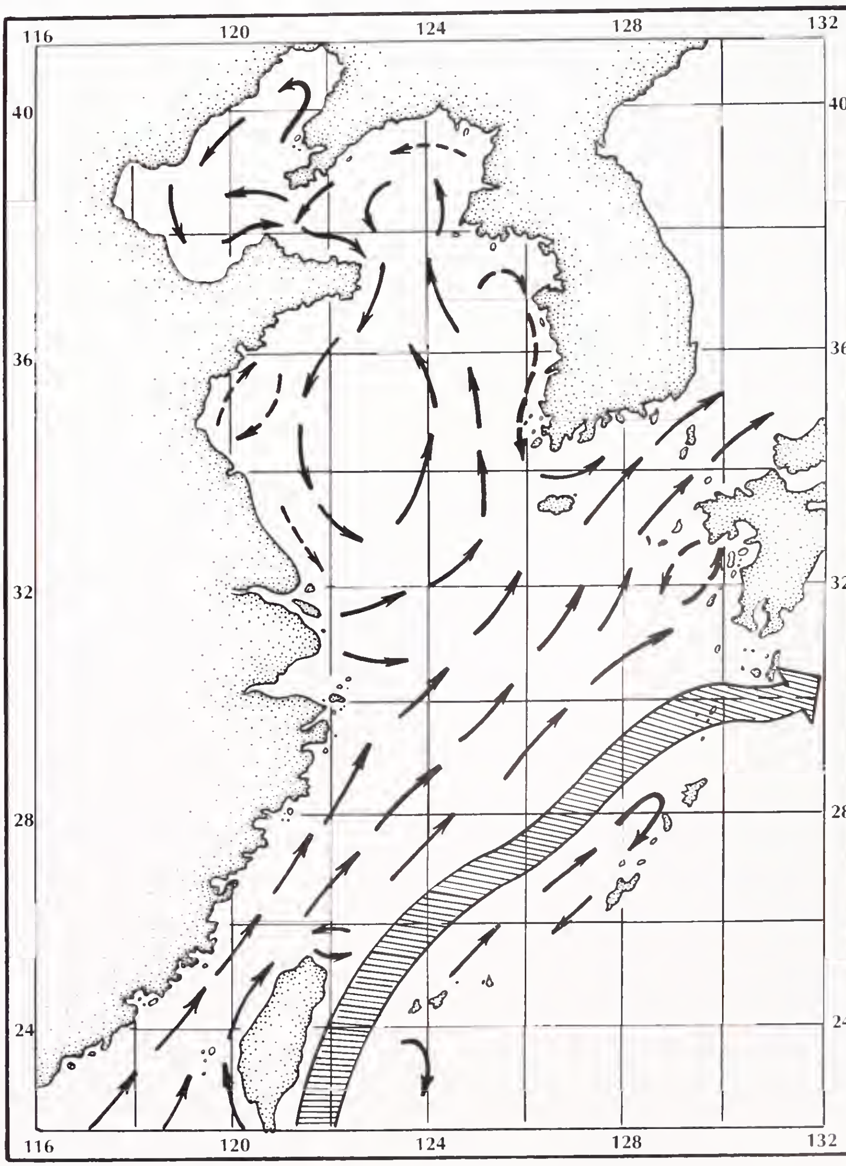


Figure 2. The summer surface currents in the Bohai, Huanghai (Yellow), and East China seas. (Guan, Bingixian, and others)

part turning southward, pushed eastward by the water mass coming out from the southern entrance of the Bohai Sea and eventually mixing with it and moving southward along the eastern coast of the Shandong Peninsula.

Therefore, it may be postulated that after the speciation of *Pelvetia siliquosa* somewhere on the southern Korean coast, it was helped by the northward moving Huanghai Sea Warm Current to establish itself on the western Korean coast. In the second stage of dispersal, its zygotes were brought by the extension of the same current to some place on the Liaodong Peninsula. Finally, in the third stage of its dispersal, its zygotes from the growth on the Liaodong Peninsula were helped by the southward moving branchlet of the extension of the Huanghai Sea Warm Current, which did not enter the Bohai Sea, to establish themselves somewhere on the eastern coast of the Shandong Peninsula.

The previously mentioned branchlet did not reach Yantai or Weihaiwei, where, to date, this seaweed is not found. Qingdao lies on the concave coast between two protruding points, namely, the Shandong Peninsula on the north and the Changjiang (Yangtze River) delta in the south; this part of the coast, near which are many small eddy currents, is beyond the influence of the branches of the Huanghai Sea Warm Current and the *Pelvetia* zygotes will have no chance of arriving at the Qingdao region where summer temperatures reach 27 to 28 degrees Celsius, intolerable to the growth of *P. siliquosa.* That the *Pelvetia* is not found in the Yantai-Weihaiwei region in the north and the Qingdao region in the south of the Peninsula is therefore understandable (Tseng and C. F. Chang, 1953, 1958).

Sargassum horneri

In one of our papers, we discussed four cases of discontinuous distribution of seaweeds on the China coast (Tseng and C. F. Chang, 1959). *Sargassum horneri* is one of them, and a typical one. In China, it is a very common seaweed in the Xiamen (Amoy) region, its distribution extending southward to the Hong Kong and Macao region, eastward to Penghu (Pescadores) Islands of Taiwan Province, and northward to the Chengsi (East Saddle) Islands of Zhejiang (Chekiang) Province; then, its distribution jumped over to the Dalian region of the Liaodong Peninsula in the western part of the North Huanghai Sea. Thus, this seaweed does not occur in the vast area of the Shandong and Jiangsu (Kiangsu) coasts. In the other part of the Northwestern Pacific, this seaweed has a very wide distribution, found in Korea on the southern and western coasts, in Japan from the Ryukyu Islands in the south to Hokkaido in the north, and even to the Kuriles.

Before discussing the distribution of *Sargassum horneri* on the China coast, a note on its ecology and reproduction is necessary. This seaweed grows on rocks in the lower intertidal to subtidal belt. It reproduces in the Xiamen region from March to May, in the Chengsi Islands from April to June, and in the Dalian region from June to July. Being a subtropical seaweed, its general distributional direction is from south to north. In the East China Sea, there is in summer a strong Taiwan Warm Current moving northward but deflected to the east by the Changjiang water mass and, thus, unable to help dispersal of the *Sargassum* to the Jiangsu and Shandong coasts. Evidently, the presence of this seaweed on the Liaodong coast has nothing to do with the Taiwan Warm Current. Because of its occurrence on the southern and western coast of Korea, its distribution to the Liaodong Peninsula is made possible by the Huanghai Sea Warm Current and its branches, just as in the case of *Pelvetia siliquosa.* That it is as yet not found on the eastern coast of the Shandong Peninsula cannot be explained by the current system and may be due to a shorter period of viability of the *Sargassum* zygotes. I shall not be surprised, however, if this seaweed is eventually found to grow in the deeper part of the subtidal belt, somewhere on the eastern part of the Shandong Peninsula, where very little investigation of subtidal flora has been made so far.

Characteristics and Classification of Marine Flora

A flora is composed of a number of species that are taken together as a single unit. The characteristics of a marine flora, therefore, are the total of those of all the component species. To date, studies on marine flora are generally limited to the enumeration and description of species, and very little attention has been directed to the analysis of the nature of the flora and its origin.

Representative Species of Marine Flora

We have segregated the component species of a flora into five different groups on the basis of the abundance of their growth, their common occurrence, and their distribution in the region under consideration. The first group consists of the dominant species, occurring in large quantities in the region; for instance, *Sargassum pallidum* in the western Huanghai Sea and *Ishige okamurai* in the western East China Sea.

The second group consists of the common species, commonly met with and widely distributed in the region, but not necessarily in large quantities; for instance, *Plocamium telfairiae* in the western Huanghai Sea and *Symphyocladia marchantiooides* in the western East China Sea.

The third group consists of the locally abundant species, distribution restricted but in large quantities when found; for instance, *Pelvetia siliquosa* in the western Huanghai Sea.

The fourth group consists of the minor species, distribution restricted and in small quantities; *Bryopsis plumosa* in the western Huanghai Sea, for example.

The fifth group consists of rare species, distribution very limited, only occasionally found and in small quantities; *Dictyopteris undulata* in the western Huanghai Sea.

Among these five groups, the dominant species and common species either originated in the region or dispersed to the region from other places but are already well naturalized and established; these are the principal representatives of the region. The locally abundant species, although limited in distribution to some part of the region (but, there very abundant and luxuriant), therefore, have certain representative value. Seaweeds of these three groups are regarded as representative species of the flora of the region, and their analysis will be of value in explaining the true picture of the characteristics of the flora in the region concerned (Tseng and C. F. Chang, 1960; Tseng, 1963).

Temperature Factors

We used to say that "this is a tropical seaweed" and "the flora of this region is tropical." But, what is "tropical," "subtropical," or "temperate"? Surprisingly, there is as yet no generally accepted standard. A marine flora is tropical if the majority of its component species is tropical in their temperature nature, by which it is taken for granted that the seas where these species were speciated in a previous geological era were tropical. Therefore, it is of primary importance to characterize the parts of the oceans and seas according to their temperature natures objectively. We proposed in 1960 a plan of characterizing the temperature nature of the divisions of the oceans (Tseng and C. F. Chang, 1960), which I revised in 1963 (Tseng, 1963). In this article, I find it is necessary to make some slight revisions.

According to the present system, three temperature superzones are recognized. The first is the cold-water superzone, characterized by an average annual surface-water temperature of 0 to 5 degrees Celsius, with temperature ranging from less than 0 degrees Celsius to as high as 10 degrees Celsius. The second is the temperate-water superzone, characterized by an average annual surface-water temperature of 5 to 20 degrees Celsius, with temperate ranging from 0 to 25 degrees Celsius. The third is the warm-water superzone, characterized by an average annual surface-water temperature of 20 to 25 degrees Celsius, with temperature ranging from 15 to more than 25 degrees Celsius, or even 30 degrees Celsius. Each of the three temperature superzones is further subdivided into two zones. Thus, we have altogether six temperature zones: the frigid and subfrigid zones of the cold-water superzone, the cold-temperate and warm-temperate zones of the temperate-water superzone, and the subtropical and tropical zones of the warm-water superzone (Table 1).

Temperature Nature of Seaweeds

As mentioned earlier, the temperature nature of a species depends on that of the sea in which it was speciated. For instance, a species speciated in a warm-temperate sea would be expected to be adapted to growth and development in seas where the water temperature is warm-temperate. On this basis, a seaweed may be cold-water (frigid or subfrigid), temperate-water (cold- or warm-temperate), or warm-water (subtropical or tropical) in nature.

Determination of the temperature nature of a seaweed species may be effected by geographical method or biological method, the latter further differentiated into specimen-analysis method and experimental method (Tseng and Chang, 1960; Tseng, 1963). To find out the temperature nature of a seaweed by the geographical method, one has to find the center of its geographical distribution, and the temperature characteristic of the distributional center will naturally be the temperature nature of the species concerned. If one has abundant specimens collected from the same locality in different seasons of the year, the specimen-analysis method can be employed. By this method, one has to study the specimens available to find the season, or still better, the month when it grows most luxuriantly and also carries on normal reproductive activity; the temperature of the season or month may be employed to indicate the temperature nature of the species.

The experimental method is the most accurate but laborious, and can be employed only in some cases. For instance, in determining the temperature nature of *Laminaria japonica* under cultivation in China, we did a series of experiments on the optimal temperature for the growth and development of both the macroscopic sporophytes and the microscopic gametophytes. It was found that for the sporophyte stage, the optimal temperature for growth is 5 to 10 degrees Celsius, and that for the development of the sporangia, 10 to 15 degrees Celsius. For the gametophyte stage, the optimal temperature for vegetative growth is about 15 degrees Celsius, and for sexual reproduction, about 10 degrees Celsius. Sporangia production stops at about 20 degrees Celsius, and sexual reproduction at

Table 1. Temperature zones of the oceans and seas and their temperature characteristics.

Temperature Superzones and Zones	Surface-Water Temperature Annual Average Degrees Celsius	Surface-Water Temperature Monthly Average Degrees Celsius Minimum	Maximum
1. Cold-water Superzone	<0° to 5°	<0°	0° to 10°
1a. Frigid Zone	0°	<0°	0° to 5°
1b. Subfrigid Zone	0° to 5°	<0°	5° to 10°
2. Temperate-water Superzone	5° to 20°	0° to 15°	10° to 25°
2a. Cold-temperate Zone	5° to 12°	0° to 5° (10°)	10° to 20°
2b. Warm-temperate Zone	12° to 20°	(0°) 5° to 15°	20° to 25°
3. Warm-water Superzone	20° to 25°	>15°	>25°
3a. Subtropical Zone	20° to 25°	15° to 20°	>25°
3b. Tropical Zone	>25°	>20°	>25°

< = less than; > = more than

Recreational beach in northeast Dalian with weirs for seaweed collection in the background. (Photo by Joan Cohen)

18 to 20 degrees Celsius. Thus, 10 degrees Celsius is the temperature for growth and reproduction of both stages of the life history, and the average optimal temperature about 11 to 12 degrees Celsius, ranging from 5 (0) to 18 (20) degrees Celsius. As a result of the experiments, it was decided that *Laminaria japonica* is a cold-temperature seaweed.

Classifying Marine Flora

While the temperature nature of a seaweed species is determined by that of the seas in which it was speciated, similarly the temperature nature of a flora is determined by the temperature natures of all the component species taken together as a whole. This, however, only gives the temperature nature of a flora. There are other characteristics of the flora that one has to study — for instance, origin of the flora — and one has to consider its developmental history as a whole. For the intertidal and shallow-water fauna, a system of classifying and characterizing different levels of the fauna systematically was proposed by Ekman (1953). Since there was no equivalent system for seaweed floras, and since certain similarities exist between the seaweed floras and the intertidal faunas, we developed a system of classifying and characterizing different levels of the seaweed floras based on the Ekman system, with some modification (Tseng, 1963).

In the Ekman system, seven faunas or faunal groups of the first level have been differentiated. In our system, the following five floras are recognized in the first-level classification: 1) Arctic marine floras, 2) boreal marine floras, 3) warm-water marine floras, 4) austral marine floras, and 5) Antarctic marine floras. These are further divided into nine floristic regions, as follows:

Flora	*Region*
Arctic Marine	Arctic (Marine Floristic)
Boreal Marine	North Pacific (Floristic)
	North Atlantic (Floristic)
Warm-water	Indo-west Pacific (Floristic)
	Atlantic-east Pacific (Floristic)
	Mediterranean-Atlantic (Floristic)
Austral Marine	Upper Austral (Marine Floristic)
	Lower Austral (Marine Floristic)
Antarctic Marine	Antarctic (Marine Floristic)

It is to be noted that the word "region" is reserved for the second-level groups in the system, since these will have more popular use than the first-level groups. For the first-level group, therefore, we used "floras," without a special term for the group. For the third-level group (that is, subregions), discussion will be only in connection with the Chinese marine flora. China is so completely isolated from the Arctic that there is practically no connection whatsoever between the Chinese marine flora and the Arctic marine flora.

In the Chinese marine flora, there are numerous North Pacific elements, especially in the flora of the Bohai and Western Huanghai seas. The latter appears to belong to the Eastern Asiatic Subregion of the North Pacific Floristic Region. Major elements of the Chinese marine flora belong to the Indo-west Pacific Floristic Region. Ekman (1953) differentiated a Subtropical Japanese Fauna.

In our floristic system, we have similar flora that we propose to call Sino-Japanese Subregion of the Indo-west Pacific Region, since in the Subregion, Chinese marine flora occupies just as an important position as the Japanese. The Chinese marine flora on the western coast of the East China Sea, including that of the Zhejiang and Fujian coasts, as well as part of the coast of Taiwan Province and that on the Guangdong and Guangsi Provinces (including a part of Hainan Island), are constituents of the Sino-Japanese Subtropical Subregion of the Indo-west Pacific Region. To the Indo-Malayan Subregion of the same region belong floras of the southern part of Hainan, the South China Sea coral islands, including the Dongsha, Xisha, Zhongsha, and Nansha islands, and the southern and eastern parts of the Taiwan Province (Tseng and Chang, 1963).

Some Final Words

Patterns of geographical distribution of seaweeds are principally determined by two oceanographic factors. The movement of water masses — especially oceanic currents and their branches and branchlets

The Yellow Sea (Huanghai) breaks against rocks near Qingdao. The pagoda at top left houses an aquarium as well as one of China's oldest marine research centers. (Photo by George F. Mobley© National Geographic Society, 1982. From the book Journey Into China.)

— determines the general pattern of seaweed dispersal, but success of dispersal resulting in establishment depends on water temperature. The characteristic of the marine flora of a region depends on that of its component species taken as a whole, hence also determined by the same oceanographic factors. The temperature nature of a seaweed species took shape in the sea in which it was speciated ages ago and may be revealed today by where it occurs as a dominant or common species. It is therefore of primary importance to classify oceans and seas according to their temperature natures. A system of classification is thus proposed, dividing oceans and seas into three temperature superzones, each subdivided into two zones.

The temperature nature of a seaweed may be determined by geographical or biological methods. A system of phytogeographically classifying marine floras is proposed and five marine floras subdivided into nine floristic regions are differentiated. Applying the system to Chinese marine floras, we find that, with the exception of the flora of the Bohai Sea and the Western Huanghai Sea, which appears to belong to the Eastern Asiatic Subregion of the North Pacific Floristic Region, the other Chinese floras appear to belong to the Indo-west Pacific Region, with the flora of western East China Sea, western Taiwan Coast, and the northern South China Sea belonging to the Sino-Japanese Subtropical Subregion, and that of the rest, including the southern Hainan Coast, the South China Sea coral islands, and the Southern and Eastern Taiwan coasts belonging to the Indo-Malayan Subregion.

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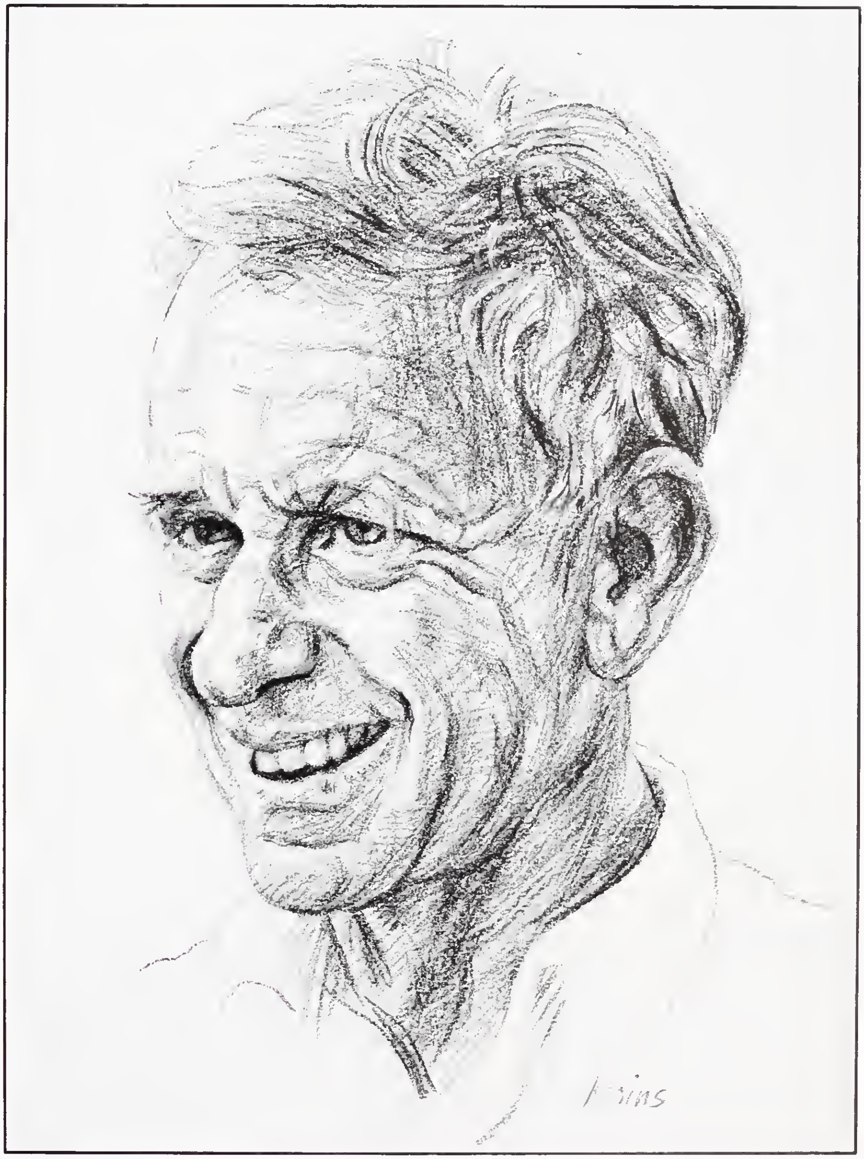
*In Chinese with English abstracts or summaries.

profile Walter H. Munk



Portrait by Charles Kerins

Unifier of Ocean Fields

by Bill Sargent

Oceanographers on the West Coast are strangely cursed by everyday machinery that seems willfully unreliable. In *The Log from the Sea of Cortez,* John Steinbeck reported an encounter with a malevolent Seagull outboard motor that plagued an otherwise fruitful biological collecting trip around the Baja peninsula in 1940 with Edward F. "Doc" Ricketts, the celebrated marine biologist and central character in *Cannery Row.*

Carl Wunsch, Professor of Planetary Sciences at the Massachusetts Institute of Technology (MIT) and Gordon MacDonald, vice president and chief scientist at the MITRE Corporation, described a similar mishap. The incident occurred in the Munks' home near the University of California's Scripps Institution of Oceanography in La Jolla, California. This time the machinery was a refrigerator — make unreported, operation irregular. Munk and Princeton University statistics professor John Tukey, characteristically clad in bathing suits, labored over the recalcitrant machine throughout one long, hot summer day. As history would have it, it was Tukey, using Latin squares, who made the refrigerator work, and the geophysicist, Munk, who was responsible for the machine's irregularities thereafter.

Every 10 years or so Munk moves on to a new problem, each one admittedly, "more fun and interesting than the last."

Walter Heinrich Munk adopts a similar approach when attacking the dynamics of the planet Earth. According to his frequent collaborator, Wunsch, "Walter is exciting to work with. He prefers to join a small team of one or two colleagues from allied fields. He has a singular concentration, which he turns toward the problem. He reads the pertinent literature, asks knowledgeable questions about the most minute technical detail. Quite often he comes up with an elegant new theory to explain the phenomenon." The entire process may take as long as 10 years, at which point Munk moves on to a new problem, each one admittedly "more fun and interesting than the last."

Munk was born in Vienna, into a family with no apparent scientific inclination. His grandfather founded a bank, later became a socialist and renamed the institution the People's Bank of Austria; the bank's founder retained all the shares. The oceanographer-grandson wryly notes that the new name was a mild expression of socialism, at best.

Despite the eventual failure of the People's Bank of Austria, Munk was sent to New York in 1934 to learn the family business. Fortunately for oceanography, evening classes at Columbia University introduced him to physics. In 1937, in an effort to get as far away as possible from New York and banking, Munk bought a car and drove to the West Coast where "I did something terribly naive."

Munk paid a visit to the dean of the California Institute of Technology and announced, "I am going to be one of your students for the upcoming year." The dean stood and began to search for the student's file, but was spared the effort: "You don't have my file. I haven't registered." The dean was so aghast that he gave Munk the entrance examination and, ultimately, admitted him. "I don't think I had even made an appointment. You see, I thought you *could* just show up and say you wanted to study."

Asked what actually caused him to pursue oceanography, Munk pauses just long enough for effect, looks up: "I suppose you want an honest answer, don't you? When I went to Cal Tech I had a girlfriend in La Jolla. The only way I could see her was to get a summer fellowship at Scripps. But I've loved oceanography ever since." The romance with the girl was not as enduring.

In fact, Munk was the only resident graduate student at Scripps at the time. "It was wonderful to be there. The total staff numbered 15 — and that included the gardener, I think. Of course, by then (the late 1930s and early 1940s) Scripps was very well established, unlike that *nouveau* institution on the East Coast, the younger brother on Cape Cod."

In the words of Roger Revelle, former director of Scripps and presently Professor of Science and Public Policy at the University of California at San Diego, "The undergraduate fellowship program has continued in the hope that it would be able to produce another Walter Munk. But we have never been able to do so, perhaps for the obvious reason — Walter is unique."

Formal education was again interrupted when Munk enlisted in the United States Army, largely motivated by "the so-called Anschluss. My stepfather was a member of the last democratic government in Austria. It was very sad, though my entire family was able to escape to England, which is to say that we were much more fortunate than most." Though they held on to property in Austria, only recently have family members begun to visit their homeland. "Home, now, is America."

Assigned to the Army ski battalion at Mount Rainier, Washington, for several months, Munk recalls the frustration of "practicing and practicing for a war that I believed would begin the day after I enlisted. My brilliant career — I advanced from private to corporal — was suspended when Sverdrup and Revelle invited me to join in the research at the newly established University of California Division of War Research at Point Loma."

Munk was granted his discharge so that he could accept the civilian assignment, working on surf-condition predictions to aid the Allied troops' winter invasion of Africa. Foreign-born, both Munk and Sverdrup were subjected to security restrictions that often made them ineligible to read the classified reports that they had written. "It was a miserable thing, something I never quite understood and something I don't really want to know anything more about. More important is that this assignment was the beginning of a lifelong association with the Navy — and there has never been any sort of difficulty since that time."

During the course of World War II, Revelle recalls that he spent about two days a month straightening out Munk and Sverdrup's security status. His method was direct. He and another Navy officer of equally commanding presence would stride down the length of the

Office of the Bureau of Ships Security and glower at the officer in charge. As a result, "Harald and Walter would be cleared for another month," to carry on with defense-related research.

Munk developed a model for predicting surf conditions with Sverdrup that was put to a critical test when the Allies staged their landing in Sicily. Severe storms hampered the fleet's approach toward the coast. Using the calculations worked out at Point Loma, the fleet's aerologist predicted that the tempestuous surf would die down in time for the landing. The troops were ordered onward, despite much trepidation. The next morning, right on schedule, the forces encountered only moderate surf and were transported safely. The prediction is remembered as one of the most important of the war.

Munk completed his Ph.D. and continued at Scripps, recording swell patterns on the West Coast. Among the best remembered and most infamous outgrowths of this early work originated during a winter Munk spent at the Woods Hole Oceanographic Institution (WHOI), "working with Allyn Vine, Bill Von Arx and many other distinguished scientists on this wave forecasting research. It was an absolutely wonderful time." In the midst of their research, the scientists struck on the notion of experimenting with methods of dampening wave action. Gallons of peanut oil were spread off Gay Head, Martha's Vineyard. It was soon apparent that the oil was doing little to settle the waves, and that "we had made a terrible mess of things."

Undaunted, Munk resumed his work when he again returned to Scripps. "It was a pure research problem. You see, surfers had always known that the long swells came in during the summers, but no one paid any attention to this fact. Then it was observed that aerial photography shown backwards revealed that these longer swells were originating somewhere south of the West Coast. Quantitatively, we still had no idea what we were looking at for distances."

Theorizing that swells of decreasing period and frequency arriving on successive days could have originated from very distant storms, Munk teamed up with Frank Snodgrass to oversee establishment of a series of recording stations from New Zealand to Alaska. "We secured funding from the newly established Office of Naval Research (ONR). We were their first contract," thanks to Revelle who had helped organize the founding of ONR. The lone graduate student assigned to the project volunteered for Alaska, while Munk, his wife Judith, and their 3- and 6-year-old daughters opted for Samoa, where they spent four months without power or plumbing, recording waves and enjoying scuba diving.

"This was a very romantic time for us. We were interested in the origins of the surf and our method for collecting data. I had seen some use of arrays in work done for astrophysics and radioastronomy and thought it should be applied to oceanography. This was a first. And our research gave surprising, clear results.

A breakfast on the Munks' patio with Brandy Alexanders and the American Miscellaneous Society led to Project Mohole.

"To our amazement, the waves proved not to lose much energy at all. The distance they were traveling was greater than the Pacific Ocean. In fact, they were moving from Australia and Antarctica along the Great Southern Route on their way to the West Coast of the United States." This success marked the beginning of Walter Munk's interest in large-ocean experiments, and explains his present enthusiasm for the ocean acoustic tomography research pioneered by his friends, Carl Wunsch of MIT and Robert Spindel of WHOI.

The hallmark of Munk's career is collaboration. Many of his papers present cogent syntheses of his work with other distinguished associates. In 1950, he integrated the work of Sverdrup and Henry Stommel, a world-renowned physical oceanographer at WHOI, to produce his classic work on wind-driven ocean circulation; the paper will be reread as long as there are oceanographers. A self-proclaimed "poor experimentalist," he relies on associates for help with this. "At sea, they are always afraid that I am going to throw a switch — but I enjoy being there anyhow. Usually, I am asked to run the winches."

As a spokesman and advocate, Munk has been a major force in most of the oceanographic initiatives of the last several decades. In the late 1950s, while reviewing oceanographic proposals for the National Science Foundation (NSF), he and other panelists were frustrated by the limited scope of the projects under consideration. What was wanting was a project that could significantly alter the level of understanding about the Earth's dynamics, an experiment capable of commanding international interest and attention, much in the way space flights were beginning to capture scientific and public attention — and funding.

The much told tale of a breakfast on the Munks' patio with Brandy Alexanders is part of the lore of the American Miscellaneous Society, whose annual meeting was then underway. An informal society of scientists allied by virtue of having had projects turned down by ONR because they were deemed too far-fetched, this group devised Mohole: a project to drill through the Earth's crust to the Mohorovičić discontinuity, the dividing line between the outer crust and the mantle, or inner layer of Earth. "This was an exciting proposition. Our judgment of the technology was sound. We were drilling for the first time in the deep seas. The problem of drill re-entry — they would wear out — was deemed solvable. In fact, the scientific and technological problems were less worrisome than we thought. It was our political judgment that proved to be naive."

Despite the National Science Foundation's rebuke of the sponsorship of the American Miscellaneous Society, the controversial project gained momentum. At its peak, Mohole garnered worldwide interest of an order not achieved by any other oceanographic endeavor. Written record of the early at-sea work was turned over to John Steinbeck, who boarded the drilling ship *CUSS* and described it as having "the sleek racing lines of an outhouse standing on a garbage scow." Admiring Steinbeck's dedication while aboard, Munk invited the novelist to his home for lunch after the cruise. "He was so tired that he fell asleep after eating a sandwich and woke just in time to catch his flight to the East Coast. A week later Judith and I received a note: I bet not many of your guests fall asleep right after you've fed them, he wrote, but I bet you wish more would."

Munk believes that initial commitments to Mohole were such that the very best personnel and technology were appropriated for the effort. President Kennedy wired his congratulations on the completion of the first hole, calling it "a historic landmark in scientific and engineering progress." This level of commitment informs Munk's remark: "when the thing finally failed, it was a traumatic experience." In retrospect, he cites two major reasons for that failure.

Revelle "made it possible for me to establish an institute at Scripps to work on nonoceanographic problems," especially the geophysics of the Earth's rotation.

"Everything started to go sour when the Texas firm of Brown and Root was awarded the drilling contract by the Johnson Administration." It was at this point that Mohole became a futile quest to drill a single hole straight through to the mantle. Hollis Hedberg, now emeritus Professor of Geology at Princeton University, led the opposition to this approach. Munk agreed that slower progress with several drillings to sample sediment at increasing depths would have provided more information more cost-efficiently and more feasibly — albeit, decidedly less dramatically.

Brown and Root were committed to the vaster dimensions. "Their attitude in meetings when it was suggested that they had no scientific experience whatsoever was dismissive. I will never forget when the firm's president replied, 'If necessary, I can always go out and hire an acre of scientists.'"

Controversy over expenditures intensified in Congress. Brown and Root became increasingly unruly, unwilling to listen to the advice of the scientists involved. Finally, the president of the National Academy of Sciences withdrew his support for the project.

But, Walter Munk is not willing to let it go at that. "I still think that had we done better, it would not have failed. We never really made up our minds that this project was all or nothing. Several of us would appear in D.C. a few days a month and then return to our respective institutions and projects. We were not prepared to make it our major goal, and in that way, did not carry out our full responsibility."

Still, that the notion was born in the Munks' house seems fitting. The rambling structure is an unofficial extension of the Institute for Geophysics and Planetary Physics (IGPP) founded by Munk in 1960. Both the house and the IGPP were designed from native California redwood by Judith Munk, a sculptor and architect. The IGPP, with a staff of more than 100, grew out of Munk's discontent with the Scripps programs, which he brought to the attention of then-director Revelle — along with news of offers of professorships at both Harvard and MIT. "Roger made it possible for me to establish an institute here at Scripps to work on nonoceanographic problems — especially the geophysics that can be extrapolated from the slight irregularities of the Earth's rotation — and eventually I found my way back to the sea."

Judith Munk's standing interest in architectural solutions to laboratories was put to test. University officials initially raised objections about the site and building material selected by Judith and her collaborating architect: First, "the building could someday slide into the Pacific"; second, "redwood would only last a century." Presumably, the criticisms discounted each other. Today, the building is among the most attractive research buildings on American university campuses.

"Carl Wunsch and I have forged a partnership in using acoustics to study the oceans. Carl has pioneered the use of satellites and I am sharing in this work now . . ."

The Munks' home is a sprawling mecca for visiting scientists, former students, and associates from the city outside the University. "Judith and I are compulsive builders. She does the thinking and the bossing and I do the plumbing and the wiring. And we have a lot of problems with the plumbing and the wiring. Otherwise, the house is very good."

Having turned over the responsibility of the IGPP after serving as director for 24 years (his present title at Scripps is Professor of Geophysics), Walter Munk is again heading toward the sea — though from a decidedly new direction. "Carl Wunsch and I have forged a partnership in using acoustics to study the oceans. Carl has pioneered the use of satellites and I am sharing in this work now . . ."

Munk believes that the ocean acoustic tomography (OAT) work being led by Wunsch and Spindel is the real vanguard. He is involved in the use of OAT to record mesoscale features of large ocean areas. Mesoscale features are the currents, eddies, and meanders generated by large, more stable circulation features like the Gulf Stream system; these can be thought of as "underwater weather," as correspond to atmospheric climate.

Potentially, OAT could enable oceanographers to map ocean temperatures, layer by layer, over large expanses of the oceans. Using an array of far-flung moorings, the operation of OAT is roughly analogous to obtaining CAT scans of the brain. The system relies on underwater sounds to produce approximations of the interior features of the ocean. Initial trials made during the Mid-Ocean Dynamics Experiment (MODE) in 1981 off Bermuda demonstrated that OAT is potentially more effective and less expensive than purely ship-based mapping techniques (see Spindel in *Oceanus*, Summer, 1982).

Certainly, even these projects do not convey the range of Munk's contributions. He has written or co-authored more than 200 scientific papers. *The Rotation of the Earth,* by Munk and Gordon MacDonald, was awarded a monograph prize by the American Academy of Arts and Sciences. Moreover, he has

"I was offered a chair at WHOI. And though I still think at times the change might have been worthwhile, I realized that I was not limited by anything here but my own limitations."

worked with, and influenced, some of the world's most eminent oceanographers and inspired a generation of students.

Munk prefers to downplay his own accomplishments. "I am a terrible Jack-of-all-trades. I work on something for 10 years and then go on to something else. This is very difficult for some people to understand." And he does not regret his long stay on the West Coast, though he admits to once very nearly returning to the East Coast. In fact, it was an offer from the "younger brother on Cape Cod." "I was offered a chair at WHOI. And though I still think at times the change might have been worthwhile, I realized that I was not limited by anything here but my own limitations."

Limitations are not what he is known for. He sees great promise in the future of space observations "principally because it provides for adequate sampling. Ocean problems often cannot be solved from one or two ships chasing around the ocean. Still, the great changes are always those of understanding. Like Hank Stommel (senior scientist at WHOI): he had the great ideas for an entire generation."

Walter Munk has had a few ideas of his own. On a recent trip to China, he was constantly being approached by Chinese scientists: "Excuse me, I probably do my English very badly, but was that your father who wrote the paper on tides? Do you have a relative who worked on waves? Was that your cousin's research on circulation?" Of course, all the work had been done by one man — Walter Munk, a scientist of restless curiosity, charm, and good humor.

Bill Sargent is a free-lance writer living on Cape Cod. He is the author of Shallow Waters, A Year on Cape Cod's Pleasant Bay.

concerns

High Sea Levels and Temperatures Seen Next Century

A National Research Council committee has recently* concluded that atmospheric carbon dioxide (CO_2) levels will "most likely" double by late in the next century, causing an increase in average Earth temperature of between 1.5 and 4.5 degrees Celsius.

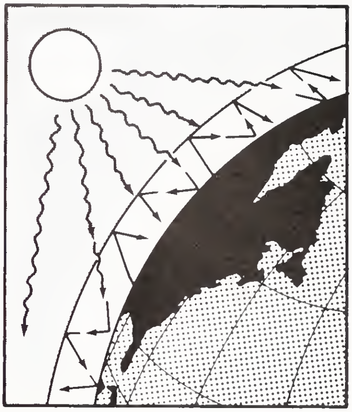
Such a warming trend, the committee added, "would have few or no precedents in the Earth's recent history." Temperature increases would likely be accompanied by dramatic changes in precipitation and storm patterns and a rise in global average sea level.

The committee's two-year study, entitled *Changing Climate*, was the result of a Congressional mandate contained in the Energy Security Act of 1980. The Act directed the White House Office of Science and Technology Policy to request that a Research Council committee study both the rate at which atmospheric CO_2 could be expected to increase and the likely effects of such increases on global climate, agricultural productivity, sea level, and other parameters.

The report, compiled by the Carbon Dioxide Assessment Committee,** noted that CO_2 was not the only climate-affecting substance injected into the atmosphere. It stated that several other gases*** besides CO_2 could affect future climate patterns and that "if we project increases in all these gases, climate changes can be expected significantly earlier than if we consider CO_2 alone."

The committee said it was "most likely" that the atmospheric CO_2 concentration would pass 600 parts per million (ppm) in the third quarter of the next century. The current level is more than 340 ppm, up from 315 ppm in the last generation. It added, however, that there was about a 1-in-20 chance that doubling could occur before 2035. The report attributed the increase in CO_2 primarily to the burning of coal, oil, and gas, but also to deforestation and certain types of land use.

The report recommended that no major policy changes should be undertaken at this time. Instead, it took the position that "the knowledge we can gain in coming years should be more beneficial than a lack of action will be damaging; a program of action with a program of learning could be costly and ineffective." It urged "caution, not panic," with the watchwords for the future being "research, monitoring, vigilance, and an open mind" (Table 1).



Heat radiation from the Earth and atmosphere is trapped by carbon dioxide and cannot escape into space.

In the preface to the report, William A. Nierenberg, Chairman of the Carbon Dioxide Assessment Committee and Director of the Scripps Institution of Oceanography, stated that the CO_2 issue was so "diverse in its intellectual components that no individual may be considered an expert on the entire problem." The report stressed that there are "fundamental gaps in our understanding of the physical

*Study released 21 October 1983.

**William A. Nierenberg of the Scripps Institution of Oceanography, La Jolla, California, chaired the Carbon Dioxide Assessment Committee. Serving with him were: Peter G. Brewer, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts; Lester Machta, Air Resources Laboratory, National Oceanic and Atmospheric Administration, Rockville, Maryland; William D. Nordhaus, Economics Department, Yale University; Roger Revelle, Program in Science, Technology, and Public Affairs, University of California, San Diego; Thomas C. Schelling, JFK School of Government, Harvard University; Joseph Smagorinsky, Geological and Geophysical Sciences Department, Princeton University; Paul E. Waggoner, Connecticut Agricultural Experiment Station, New Haven, Connecticut; and George M. Woodwell, The Ecosystems Center, Marine Biological Laboratory, Woods Hole, Massachusetts.

***Chlorofluorocarbons, nitrous oxide, and methane (natural gas).

Table 1. CO_2-induced climatic change: framework for policy choices (from *Changing Climate,* Report of the Carbon Dioxide Assessment Committee, National Research Council, 1983).

Possibly Changing Background Factors	Policy Choices for Response[a] (1) Reduce CO_2 Production	(2) Remove CO_2 from Effluents or Atmosphere	(3) Make Countervailing Modifications in Climate, Weather, Hydrology	(4) Adapt to Increasing CO_2 and Changing Climate
Natural warming, cooling, variability			Weather Enhance precipitation Modify, steer hurricanes and tornadoes	Environmental controls: heating/cooling of buildings, area enclosures Other adaptations: habitation, health, construction, transport, military
Population global, distribution: nation, climate zone, elevation (sea level), density				Migrate — internationally, intranationally
Income global average distribution				Compensate losers — intranationally, internationally
Governments				
Industrial emissions Non-CO_2 greenhouse gases Particulates			Climate Change production of gases, particulates Change albedo ice, land, ocean Change cloud cover	
Energy Per capita demand Fossil versus nonfossil	Energy management Reduce energy use Reduce role of fossil energy Increase role of low-carbon fuels	Remove CO_2 from effluents Dispose in ocean, land Dispose of by-products in land, ocean		
Agriculture, forestry, land use, erosion Farming and other dust	Land use Reduce rate of deforestation	Reforest Increase standing stock, fossilize trees		Change agricultural practices: cultivation, plant genetics
Agricultural emissions (N_2O, CH_4)	Preserve undisturbed carbon-rich landscapes			Change demand for agricultural products, diet Direct CO_2 effects Change crop mix Alter genetics
Water supply, demand, technology, transport, conservation, exotic sources (icebergs, desalinization)			Hydrology Build dams, canals Change river courses	Improve water-use efficiency

[a]Responses may be considered at individual, local, national, and international levels.

processes" that govern changes in climate.

Changes in Sea Level

The report warned that if a global warming of about 3 or 4 degrees Celsius were to occur over the next 100 years, "it is likely that there would be a global sea-level rise of about 70 centimeters (about 2 feet), in comparison with the rise of about 15 centimeters (4½ inches) over the last century. It noted that more rapid rates in the rise of sea level could occur if the West Antarctic Ice Sheet should begin to disintegrate as a result of the warming. It added that the warming trend might also bring about changes in the Arctic ice cover, "with perhaps a disappearance of the summer ice pack and associated changes in high-latitude weather and climate."

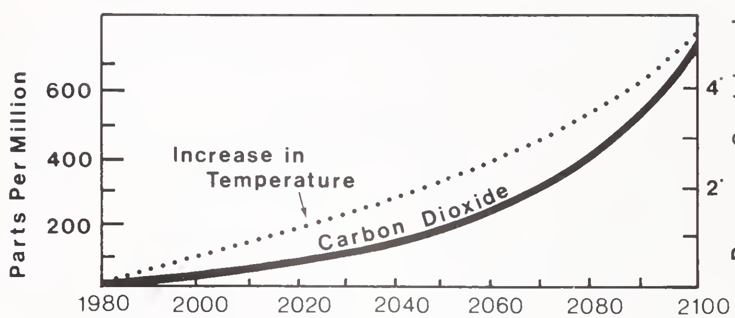
While noting that the warming trend could bring many benefits to some communities, it also cautioned that such a "climate change could well be a divisive rather than a unifying factor in world affairs." The effects of a warmer and drier climate on rain-fed agriculture in the United States, the report stated, "suggests that over the next couple of decades negative effects of climate change and positive effects from CO_2 fertilization both will be modest and will approximately balance. The outlook," it added, "is more troubling for agriculture in lands dependent on irrigation."

In the longer term, the committee noted that a warming of 2 degrees Celsius and decreases in precipitation and associated runoff could "severely affect" the Texas Gulf, Rio Grande, upper and lower Colorado River regions, California, and other western areas. Much of the irrigated farmland in these areas "might have to be abandoned unless water could be imported from other regions with more abundant supplies."

Defensive Measures

Among the 14 individually authored research papers contained in the study is one by Thomas C. Schelling of Harvard University, who points out that a defense against a rise in sea level of several meters has received little attention in the United States. He reminds the reader that more than 7 million Dutch people presently live below sea level.

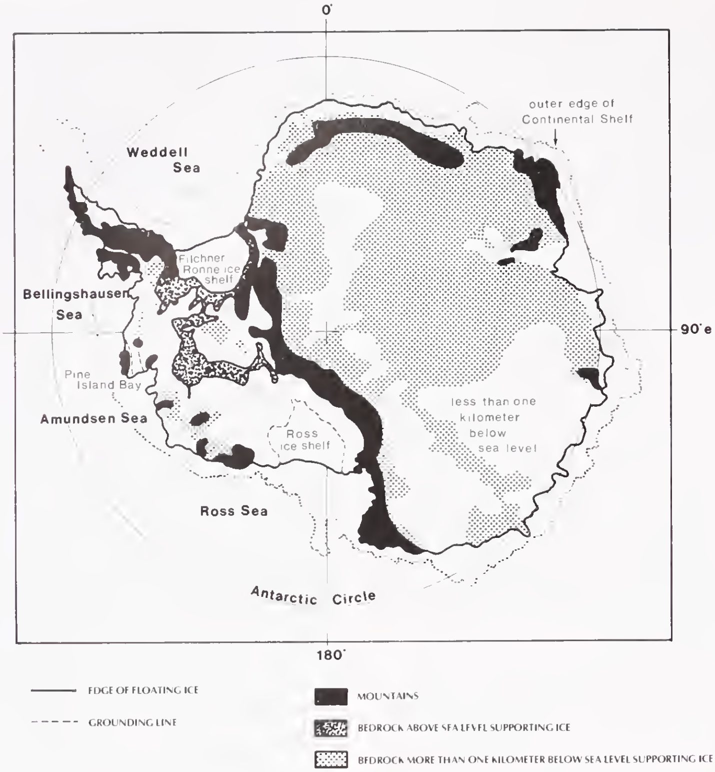
The economics of dikes and levees, Schelling states, "depends on the availability of materials (sand, clay, rock); on the configuration of the area to be protected; on the differential elevation of sea level and internal water table; on the depth of the dike where it encloses a harbor or estuary; on the tide, currents, storm surges, and wave action that it must withstand; and on the level of security demanded for contingencies like extreme ocean storms, extreme internal flooding, earthquakes, military action, sabotage, and uncertainties in the construction itself."



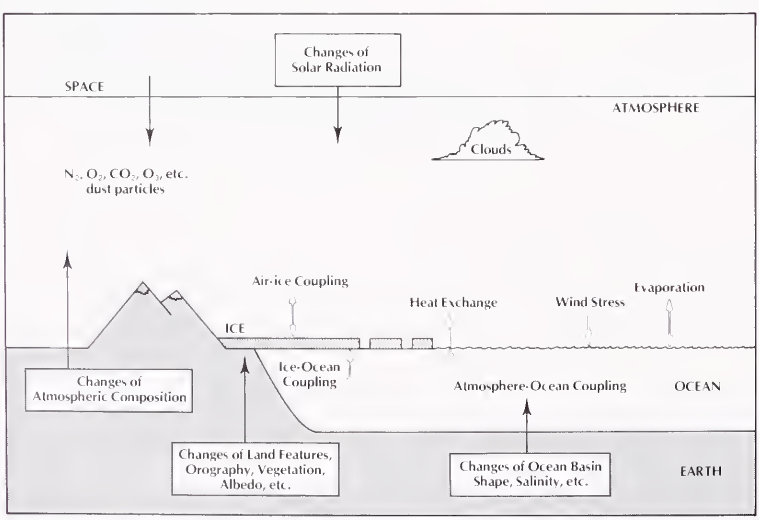
Effect of carbon dioxide on atmospheric temperature.

Schelling points out that a rise in sea level of 5 meters would cover most of downtown Boston. Beacon Hill, the site of the State House, would be an island separated by about 3 kilometers from the nearest mainland. Most of nearby Cambridge would be underwater. However, it would take only 4 kilometers of dikes, most built on land that now is above sea level, Schelling believes, to defend the entire area. One way of avoiding the political issues of choosing what to save and what to give up would be a dike of 8 or 10 kilometers in length that would enclose all of Boston Harbor.

Should such a plan be adopted, new deep-water port



The West Antarctic Ice Sheet (WAIS) lies north and west of the Transantarctic Mountains (shown in black). It is believed to be unstable because most of it lies on rock below sea level. Disappearance of the ice above sea level would raise the world oceans by 5 to 6 meters. At present, the ice sheet is held back by the Ross and Filchner-Ronne ice shelves which, though mostly floating, are pinned by high places on the seafloor. (Revelle, Carbon Dioxide and World Climate, *courtesy of Scientific American)*



The coupled atmosphere-ocean-ice-earth-climatic system. The solid arrows identify external processes; the open arrows identify internal processes. (U.S. Committee for the Global Atmospheric Research Program)

facilities would have to be constructed outside the enclosed harbor with locks along the Charles and Mystic rivers. While there is no professional estimate of what such a system would cost, "guesswork suggests that at today's values the cost of defending against a 5-meter rise in sea level is less, perhaps by an order of magnitude, than the value preserved."

Where defense is not practicable, Schelling comments "retreat is inevitable." In urban concentrations, where buildings may last a century, good 100-year predictions of sea-level change should permit orderly evacuation and demolition of buildings, he adds.

While Schelling terms his paper a "relatively calm assessment" of the CO_2 issue, he notes that changing climate within the coming century will take us "outside the boundaries experienced within the past 10,000 years." He cautions that there may be some surprises in store for society in the next 100 years and that "In our calm assessment, we may be overlooking things that should alarm us."

The Oceans and CO_2

In another paper contained in the study, Peter G. Brewer of the Woods Hole Oceanographic Institution assesses the role of the oceans in relation to the CO_2 problem.

He points out that "the ocean acts as a giant regulator not only of CO_2 but also of climate and thus occupies a central role in the debate over the effects of increasing atmospheric CO_2 levels on our society."

Brewer explains that the capacity of the ocean for CO_2 uptake is a function of its chemistry and that the rate at which the capacity can be brought into play is a function of ocean physics. In addition to these direct and present contributions, he adds, the deep-ocean carbonate sediments provide, on a larger time scale, a vast buffer against chemical change. "The natural vertical gradient of CO_2 with depth in the oceans is driven by the biological flux of particulate matter," he states.

Each year the ocean, on average, takes up an amount of CO_2 approximately equal to 40 percent of the fossil fuel CO_2 added to the atmosphere by man. The warming accompanying the rise in atmospheric CO_2 will affect the ocean, Brewer states. Storage of heat in the upper layers of the ocean will mitigate, but not prevent, climate change. In fact, the warming of the ocean will reduce CO_2 solubility and expel further CO_2 to the atmosphere.

Brewer stresses that there are "significant uncertainties" about the role played by the ocean in CO_2 transfer. "It is quite possible," he writes, "to measure the changing CO_2 properties of the ocean with time using modern techniques, although no ongoing program yet exists to do so."

The Woods Hole scientist concludes that "Nature has vast resources with which to fool us; the last glaciation was apparently accompanied by massive CO_2 transfers to and from the ocean, the causes, consequences, and explanations of which are poorly understood today."

Reaction to Study

Despite the avowed "conservative" nature of the report and the appeal for "calm, not panic," this writer was struck by the large number of uncertainties cited in this study.

Perhaps the most disconcerting note was the recommendation that no major policy changes be undertaken at this time. It would seem that a number of steps could and should be taken at this time. In a separate study released in September entitled "Can We Delay a Greenhouse Warming?" the Environmental Protection Agency (EPA) determined that only a ban on the use of coal instituted in the year 2000 would effectively slow the rate of temperature change and delay a 2 degree Celsius change until 2055. A ban on both coal and shale oil would delay the change an additional 10 years. The study added, however, that such a ban "appears to be economically and politically infeasible."

George A. Woodwell, Director of the Ecosystems Center at the Marine Biological Laboratory in Woods Hole, Massachusetts, and a member of the Carbon Dioxide Assessment Committee, told this writer that, while he supported the general findings of the study, he felt that certain policy actions, such as reforestation projects (the clearing of forests has released large amounts of CO_2 to the atmosphere), should be implemented at this time.

Paul R. Ryan

U.S.-Mexican Parley Debates Relations on Marine Resources

A conference* on *"U.S.-Mexican Relations on Marine Resources,"* held at the University of California at San Diego on September 15th and 16th, 1983, brought together distinguished marine analysts and policy makers from both Mexico and the United States, including former Mexican President Luis Echeverria, to discuss issues that both unite and separate the two nations.

Significant differences of opinion were expressed by government, interest-group, and academic representatives from each nation. The major topics discussed were: 1) the implications of the changing international context for bilateral U.S.-Mexico relations (most prominently, the recent adoption of the Law of the Sea Convention [LOS]); 2) the domestic forces (political, administrative, social, and economic) that shape bilateral relations on marine issues between the United States and Mexico; 3) conflicts over the management of tuna; 4) conflicts over the conduct of marine scientific research.

As regards the implications of the changing international situation, speakers highlighted the fact that, given Mexico's status as a leader of the Third World, and the United States position as a highly developed nation and a nonsignatory to the Convention, the evolution of bilateral relations between Mexico and the United States should be watched carefully as a bellwether of how the developed and developing worlds will adapt to the changing international context in the aftermath of the Law of the Sea (LOS) Convention.

U.S. speaker addresses conference in San Diego on U.S.–Mexican Relations on Marine Resources.

Speakers disagreed, however, about the likely evolutionary pattern of these relations. United States speakers posited that the fact that Mexico signed the LOS Convention and the United States did not, need not pose problems in the bilateral relationship. Outstanding issues between the two countries related to delimitation of marine boundaries, resource utilization, transboundary pollution, and the conduct of marine scientific research, could be solved — they thought — via bilateral negotiation.

Speakers from Mexico strongly disagreed, pointing to the fact that the developing world had fought long and hard for the adoption of the Convention. With the LOS model now as accepted fact, they did not expect Mexico or other developing states to craft specially tailored bilateral approaches outside of the convention.

As a leader of the Third World, Mexico was an active participant in the LOS negotiations, and is justly proud of its contribution to the forging of a new international ocean regime. Moreover, in its domestic actions (such as in the

**The conference was co-sponsored by the University of California Consortium on Mexico and the United States; the Center for U.S.-Mexican Studies, University of California, San Diego; the California Sea Grant College Program; the Centro de Estudios Económicos y Sociales del Tercer Mundo, Mexico City; the Institute of Marine Resources, University of California, San Diego; the Marine Policy Program, Marine Science Institute, University of California, Santa Barbara; and the Marine Policy and Ocean Management Program, Woods Hole Oceanographic Institution. For further information about the meeting, please contact Dr. Biliana Cicin-Sain, Senior Fellow, Marine Policy and Ocean Management Program, Woods Hole Oceanographic Institution, Woods Hole, Mass. 02543 (617) 548-1400, ext. 2449.*

creation of the Mexican Exclusive Economic Zone [EEZ] in 1976), Mexico has closely followed the LOS model. By contrast, in the United States, opinions are quite divided over the Law of the Sea Convention. After many years of participation in the negotiations, the United States has decided not to sign the Convention.

San Jose Tuna Pact

Debate also centered on the merits of the recently concluded San Jose Tuna Pact (involving the United States, Costa Rica, Panama, Honduras, and Guatemala). Speakers from the United States thought the accord represented a good way to accommodate both U.S. and Latin American views on the management of highly migratory species.

Mexican speakers objected to the accord, maintaining that although the accord is cast as a "regional arrangement," it includes the United States (which has few tunas passing through its waters), and excludes Mexico, in whose waters tunas are most abundant. Mexico operates the largest and most advanced tuna fleet of Latin American nations in the region. Mexican and U.S. representatives also disagreed on whether Mexico had been properly invited to participate in the accord.

Each nation tends to manage its marine resources in very different ways — reflecting significant differences in culture, history, and world position. In Mexico, the government has been the major force in the development of marine resources, and, in recent years, has made significant investments to catapult Mexico into position as a world-class fishing power. Key features of this expansion include the launching, in 1977, of a $1.3 billion fishery-development program, the expansion of the tuna fleet from 27 vessels in 1976 to a projected number of 113 by the end of 1983, and the elevation of the fish bureaucracy — PESCA — to Cabinet (or Secretaría) status in 1982.

By contrast, in the United States, notwithstanding the fishery development provisions contained in the Magnuson Fishery Conservation and Management Act and the American Fisheries Promotion Act, the fishing sector remains virtually 100 percent private. Government policy makers prefer to rely on market forces and the free-enterprise system.

Tuna Management

The session on tuna management highlighted the problems that both nations are experiencing because of their divergent stances on tuna management. Since the late 1970s, when it declared its Exclusive Economic Zone and withdrew from the Inter-American Tropical Tuna Commission, Mexico has been enforcing its 200-mile limit and seizing U.S. tuna boats fishing within this zone.

In response, the U.S. tuna fleet has moved its operations to the Western Pacific, and the U.S. government, as mandated in the Magnuson Act, has imposed an embargo on all Mexican tuna products, closing to Mexico one of the largest tuna markets in the world.

This state of affairs is clearly harmful to both nations (fishing operations in areas much further offshore are obviously more costly to the U.S. tuna fleet). Mexico is suffering the economic losses associated with the unmarketed catch (tuna cans sitting on warehouse shelves) notwithstanding efforts to open

Representatives to San Diego conference listen to former Mexican President Luis Echeverria.

up new markets in Europe and elsewhere. Representatives could not agree on solutions to this stalemated situation.

Speakers from the United States stressed the potential present in the San Jose Treaty, while Mexican representatives advanced novel proposals for the granting of Mexican licenses for tuna boats in exchange for a lifting of the U.S. tuna embargo, coupled with a guaranteed share of the U.S. tuna market for Mexican products.

Speakers in other sessions, however, also stressed that, notwithstanding deteriorating formal relations between the two countries, cross-border interactions among marine industries continue to prosper. Labor, parts and supplies, capital, vessels, and fishery products themselves continue to flow between the fishery-related industries of the two countries — in larger quantities than ever before in many sectors.

Even in the direct cross-border harvesting of tuna and shrimp, proposals are currently being negotiated — outside the arena of formal bilateral negotiations — with respect to joint shrimp ventures in the Gulf of Mexico and the resumption of near-shore tuna harvesting by U.S. vessels in the Mexican EEZ. In a sense, the direction taken in the formal governmental arena has been divorced from the commercial-industrial direction; normative statements by the governments are sometimes at odds with the pragmatic actions of industry.

Domestic Management Session

Discussions in the session on Domestic Management stressed the differences between the two domestic regimes and the implications of these differences for bilateral relations.

The framework for governing marine resources in the United States can be characterized as highly complex, decentralized, and with multiple points of access — open to interest group pressure from a large number of variegated interests. The bureaucratic system in the U.S., moreover, is

The Mexican consumer has been paying higher prices for tuna, while the U.S. embargo has caused tuna cans to pile up in Mexican warehouses.

dominated by experts with a strong scientific background who tend to move up the ranks of state and federal bureaucracies with little movement to and from other policy areas.

The Mexican system for managing marine resources (most prominently fisheries), on the other hand, is highly centralized, with major direction emanating from the President and his cabinet in Mexico City. Executive authority in Mexico extends much further than in the United States — bolstered by a strong, centralized bureaucracy, and largely unhampered by a weak legislature and weak interest groups. Groups that play a major role in U.S. policy making, such as sports and conservation groups, are still largely absent in the Mexican context. Bureaucratic leaders in Mexico, moreover, often are not technical experts, but generalists whose career paths take them to and from different policy areas.

Such differences in domestic political and administrative processes in each country often produce outcomes (government decisions) that are difficult for the other nation to understand, increasing problems of communication at the negotiating table. Each nation, moreover, tends to frame issues in a very different way from one another — reflecting divergent cultural styles and historical backgrounds.

Marine Research

The session on marine scientific research discussed the problems of conducting research in the aftermath of the LOS Convention. Speakers from both nations expressed optimism about the cooperative nature of the scientific relations between the two countries.

Speakers from the United States advocated bilateral scientific agreements to introduce more order, rationality, and predictability into the scientific permit process.

Speakers from Mexico reviewed the historical record of U.S. marine scientific research in Mexican waters over the past several years, which reveals extended stays by U.S. research vessels with little Mexican participation in the planning or conduct of the research cruise, or in the analysis of data gathered. Mexican scientists also highlighted the bureaucratic problems involved in the permit-granting process in Mexico, and discussed possible approaches to prevent bureaucratic delays.

While the differences that exist between the two nations were evident in the frank discussions that took place in San Diego, outstanding issues were clarified and potential areas of agreement and disagreement were identified. Most speakers stressed that the time was at hand for moving beyond the "tuna war" and the "action/retaliation" mode that has characterized bilateral relations in recent years. Interdependent as they are in their marine activities and resources, the two nations ought not to dwell on past problems, but must look ahead to forge effective, cooperative solutions.

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book reviews

***Treasures of the Sea: Marine Life of the Pacific Northwest* by James Cribb. 1983. Oxford University Press, New York, N.Y. 128 pp. $24.95.**

***Beneath Cold Seas: Exploring Cold Temperate Waters of North America* by Jeffrey L. Rotman and Barry W. Allen. 1983. Van Nostrand Reinhold, New York, N.Y. 154 pp. $29.95.**

There is a popular conception that underwater scenery consists of colorful tropical fishes darting along the convoluted contours of a tropical coral reef. Two handsome volumes, *Treasures of the Sea* and *Beneath Cold Seas,* reveal the variety and beauty of marine life in a much less exotic arena, the north-temperate shores of most of the United States and Canada. Diving and underwater photography in this environment are more challenging than in the clear Caribbean. Cold water, strong tidal currents, poor visibility, and a rocky and dangerous shoreline add up to greater risk and difficulty. But the beauty of the cold-water environment makes it well worth the effort.

These books are similar in size and general design, with splendid color reproduction on heavy, coated paper. They diverge somewhat in their approaches to the subject, and one or the other may appeal more to individual readers. Cribb's book is essentially a photo gallery. Ninety-six plates are presented, one to a page. Captions, which the author finds distracting when in juxtaposition to pictures, are placed ahead of each group of 12 plates. The captions give the common name and size of the subject, the depth at which it was photographed, and a line or two describing its appearance or habits. An appendix provides photographic data for each plate and a short index facilitates retrieval of particular pictures. The photographs are very good — indeed some are arresting in brilliance of color and sharpness of form. A few are disappointing in sharpness or composition, but only a few. Taken together, they provide ample proof of the richness of the seafloor just off our coasts.

The collaboration by Rotman and Allen has the same thesis — that temperate waters harbor as wondrous a collection of living things as do the tropics. Again, the photographs are excellent. The format is rather different. A substantial body of text before and after the color pages provides oceanographic and biological backgrounds for the photographs, as well as a more personal narrative of diving expeditions in New England and on the West Coast. There are brief explanations of the circulatory patterns which produce cold-temperate eddies on the East and West coasts and the patterns of distribution of animals in the intertidal and subtidal zones. The photographs themselves are more varied in scale than are Cribb's, ranging from shots of divers with animals to very-close-up studies. Often several related photos are grouped on a page, and all are directly accompanied by captions. Rotman and Allen

include scientific names for the animals but omit technical photographic data.

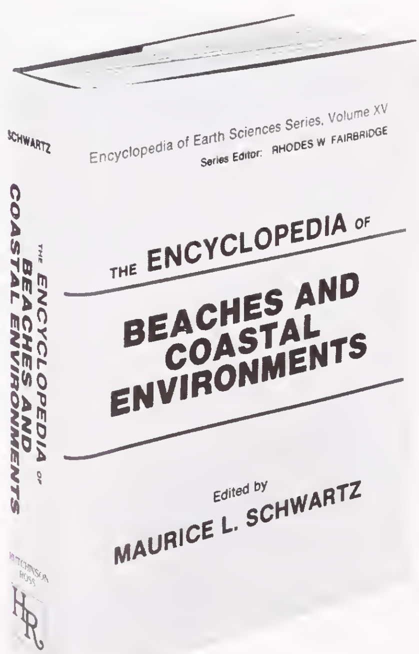
Either of these books will captivate the reader with a glimpse into the nearby yet alien world under our temperate waters. *Treasures of the Sea* may appeal more to those who appreciate photographs as images and prefer to respond to them on a strictly visual basis. Cribb's pictures are boldly presented with little accompanying information.

Beneath Cold Seas is a book to be read as well as viewed, and may appeal more to divers and amateur naturalists because of the more complete text and scientific information. It also would be more useful to biologists because of the inclusion of scientific names. Marine scientists value a fine photograph of an identified organism in its natural habitat as much as the lay reader enjoys the brilliant colors and other-worldly forms of these creatures of the sea.

Larry Madin,
Associate Scientist,
Department of Biology,
Woods Hole Oceanographic Institution

***The Encyclopedia of Beaches and Coastal Environments*, Maurice L. Schwartz, ed. 1982. Scientific and Academic Editions, Van Nostrand Reinhold, New York, N.Y. 940 pp. $95.00.**

Most people connected in some way with coastal environments have occasion to bemoan the absence of the one reference necessary for completing a task at hand. Often, dozens of books and journals must be combed before a reasonably complete definition



of the offending term or concept is retrieved from an appropriate source — poorly indexed, of course.

Maurice Schwartz has painstakingly edited a reference book that should alleviate many of these dilemmas. In a 940-page volume, Schwartz has compiled a well indexed, cross-referenced list of terms, covering a variety of marine disciplines, complete with references to the literature and illustrations. Such an undertaking is laudable, with promise of much satisfaction among readers and perhaps an equal amount of criticism. The result, here, is a book that is useful to professionals in coastal studies (how many of you remember what a buller is?), as well as to interested lay people (searching for a description of rip currents, for example).

Because of the diversity of topics incorporated into the description of beaches and coastal environments, treatment inevitably is uneven across disciplines. In *The Encyclopedia,* geology and biology are the best represented disciplines, with engineering, chemistry, and physical oceanography more poorly represented. A great variety of key words causes some duplication (and occasional contradiction), while some subjects are covered so briefly that the information is of questionable utility. Some topics are covered by experts from different fields, leaving the reader unsatisfied with the synthesis. The references too often are parochial or incomplete: future efforts should emphasize general references, not just those that come readily to mind. Recent advances in many subjects are sacrificed from the discussions and classical ideas expounded instead (sediment transport, for example).

Despite these shortcomings, *The Encyclopedia* is a valuable reference, reasonably broad, and easy to use with its excellent index and cross-references. This work should find its way to the libraries of many professionals in coastal sciences and lay people interested in coastal studies.

David G. Aubrey,
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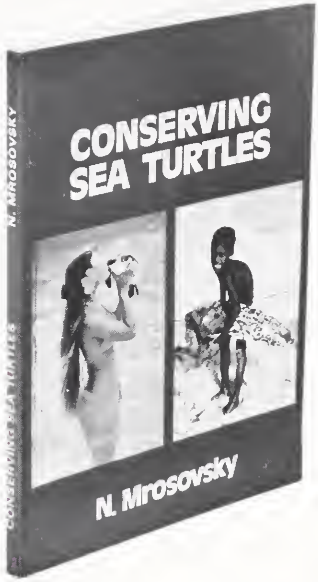
Woods Hole Oceanographic Institution

***Conserving Sea Turtles* by Nicholas Mrosovsky. 1983. British Herpetological Society, London, England. 176 pp. $10.00.**

It is generally agreed that all seven species of sea turtles have been severely reduced in numbers and are in need of stringent conservation efforts. As editor of *Marine Turtle Newsletter,* Nicholas Mrosovsky is certainly well aware of the various practices currently applied toward sea turtle protection around the world. However, *Conserving Sea Turtles* is much more than a roster of present conservation techniques. It is a thorough criticism of nearly all that is being done to conserve sea turtles and contains suggestions for future action that are certain to prove controversial. Few of us truly appreciate rigorous criticism of our work even when



we ask for it. This tough assessment by one so thoroughly familiar with the subject is sure to cause some agitation among practitioners of sea turtle conservation.

After briefly introducing us to the life history of marine turtles, Mrosovsky proceeds to assess the various methods being used in their conservation, including tagging programs, "head-starting" (the practice of raising turtles in captivity for up to a year before releasing them into the wild), translocating eggs or hatchlings to beaches from which turtles have disappeared, and incubating eggs in styrofoam boxes. In each case, he reminds us that the technique is rarely based on knowledge of the turtles' life cycles or ecology. He also chastises those conservation programs that are poorly designed and do not further our knowledge of the turtles' basic biology. Throughout the book, Mrosovsky urges us to abandon the "alarmist" strategy, to plan conservation efforts with our heads rather than with our hearts alone, and to judge them with good science rather than for their public-relations value. The message is this: "Conservation and science must go hand in hand."

This type of criticism is long overdue for marine turtle conservation. Mrosovsky has taken on the persona of a graduate research professor reviewing the work of his student. His intent is not to belittle those engaged in sea turtle conservation but to arrive at better conservation based on sound knowledge of sea turtle biology. His effort will surely be applauded by those who are willing to put their hurt feelings aside and accept the challenge he offers.

Even those who are willing to accept the faultfinding in the first half of the book may not be amenable to the suggestions made in the latter half. Mrosovsky goes beyond questioning present practices to examine available evidence on whether sea turtles are even endangered at all. He points out that some long-term studies indicate that populations are stable or increasing rather than declining and insists that "The real situation is that most of the sea turtle species are not in immediate danger of extinction, not even, probably, in danger if the factors presently affecting them continue operating." Whether one agrees with his assessment or not, it is imperative that we continually reassess the status of sea turtle stocks using the best information obtainable.

In the final chapter, Mrosovsky offers his own approach to sea turtle conservation, advocating a blend of protection and utilization. Reminding us that developing nations may not be able to afford complete protection of species that are edible or commercially valuable, Mrosovsky outlines a plan whereby some eggs might be harvested for market or for raising on turtle ranches while others would be protected from predators and poachers. Many of the eggs laid on natural beaches are "doomed" to be washed away by high tides or eaten by predators. By protecting a portion of the "doomed" eggs and harvesting others, Mrosovsky believes that we may be able to increase the number of hatchlings entering the sea and at the same time provide income for conservation projects by selling other eggs. Such a plan is sure to be controversial and will be received with categorical disapproval by many sea turtle conservationists.

The main value of Mrosovsky's book is that it provides arguments not usually encountered in printed discussions of sea turtle conservation. By playing devil's advocate, urging us to consider both sides of each question, and demanding that we base our conservation efforts on the best possible science, Mrosovsky is insisting that we improve our efforts rather than rest on our laurels. The book should be required reading for anyone thinking of entering into sea turtle conservation. It also is strongly recommended for those presently engaged in such activities.

Nat B. Frazer,
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Compendium of Seashells **by R. Tucker Abbot and S. Peter Dance. 1983. E. P. Dutton, Inc., New York, N.Y. 420 pp. $50.00.**

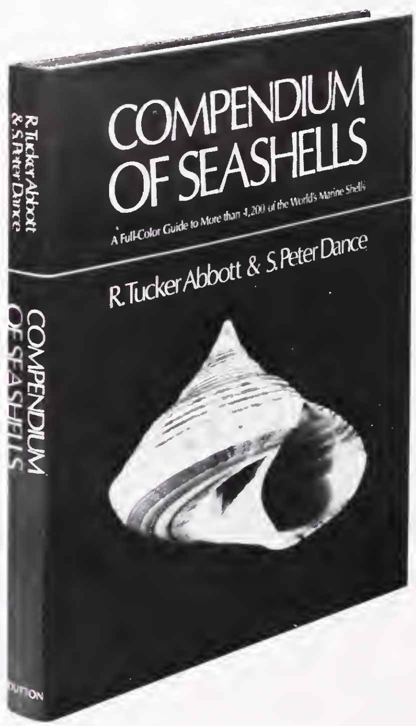
(com-pen-di-um — *brief and condensed summing up of a subject, summary.)*

This is a beautiful book that will find a large and appreciative audience. According to the authors (one might rather call them editors, as this is essentially a picture book with relatively little narrative text), "Shell collecting as a hobby has had a remarkable resurgence in the last few years. To a considerable extent this has been brought about by an increasing interest in ocean life and a deep concern for anything to do with our fragile natural environment." The claim is no doubt true, despite its sounding like grant-proposal (or more likely, book prospectus) puffery; for Abbot and Dance are the reigning pros of conchology. They are surely in as good a position as anyone to gauge this hobby's growing popularity.

It seems slightly ironic, though no doubt accurate, to associate the growth in shell collecting with heightened environmental consciousness. With modern awareness that people's activities are capable of inflicting irreversible damage on the world's biota, shell collecting has actually come to be viewed with increasing suspicion by the ecologically vigilant. Although not subject to the same degree of censure as clearing a redwood forest, collecting shells, and particularly still living "specimens," is seen by many as a somewhat more offensive activity than, say, stealing eggs from a robin's nest. Personally, I would much sooner take the life and shell of a marine snail, to provide lasting and renewable pleasure in contemplation of its beauty, than take the life of its cousin clam for fleeting gastronomic gratification.

The real problem comes not from collecting by individuals for their own cabinets or for trade with others but from the establishment of commercial markets on an industrial scale. In fact, most hobbyists lucky enough to do their own collecting are diligent in abiding by a widely-shared set of conservation rules: 1) observation and photography of living mollusks can be more rewarding and useful than collecting; 2) be selective, collecting living specimens only in minimum numbers to satisfy needs of study and returning immature or imperfect ones; 3) never damage the habitat, always put rock and coral back in place; 4) be alert for shell eggs and protect them. It is well to recite these rules here, for exposure to *Compendium of Seashells* could trigger a raging fever to collect.

With its 4,200 color photographs, the book amply communicates the powerful appeal of seashells. It would be difficult even to glance through this volume without appreciating the profound beauty and rich variations on a few simple themes that shells exhibit. All categories of marine shells are described and illustrated, including individual color photographs and geographical and ecological data on 180 species of cowries, 334 cones, more than 350 murexes and near relatives, 132 volutes, 140 scallops, helmets, and many others. The authors have



attempted to give full coverage to those species most popular among collectors, but they have made a real contribution by including many examples of more subtly varied species. For instance, there are 56 examples of *Haliotidae* (abalones), 100 *Naticidae* (moons), 92 *Cymatiidae* (tritons), 94 *Fasciolariidae* (tulips and spindles), 15 *Scaphopoda* (tusks), 59 *Polyplacophorae* (chitons), and 6 *Tridacnidae* (giant clams).

There is a 16-page introduction that would have been more useful if it contained more detail and history about the book itself. From pages 379 to 390, the authors provide a taxonomically ordered bibliography, including references on all the families and on the major genera. There is a short index of popular names, followed by a well-organized index of scientific names.

Without question, *Compendium of Seashells* will become a standard reference, of value to professionals as well as to amateurs. Every library should be encouraged to have it. At a price of $50, many collectors may decide not to buy their own; but it would make a welcome gift. The price is not unreasonable for a book so well suited to do double duty: not only is it incomparably useful as an identification guide, it is also engaging and sumptuous.

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Books Received

Biology

***Breeding Biology of the Adélie Penguin* by David G. Ainley, Robert E. LeResche, and William J. L. Sladen. 1983. University of California Press, Berkeley, Cal. 244 pp. + xii. $27.50.**

This report is the result of 15 years of field research on a group of Adélie penguins at Cape Crozier, Ross Island, Antarctica. In the course of this long-term study of vertebrate population ecology, the authors found that some of their ideas about the lives of birds formulated from short-term study results had to be revised. All aspects of penguin life are covered, from occupation of the rookery to the position of the nest in the colony. Also included are an introduction to methods, a list of definitions, and appendices containing tables of data gathered during the research. One important aspect of this research is that it provides baseline information for future studies on the effects of krill harvesting on Antarctic ecosystems.

***Radiolaria* by O. Roger Anderson. 1983. Springer-Verlag, New York, N.Y. 355 pp. + x. $59.00.**

Radiolaria have been relatively neglected by biologists, according to the author of this volume, though the fossilized remains of these planktonic protozoa are often studied by micropaleontologists. These diversely formed creatures, which occur solitarily and in colonies, are widely distributed in the oceans and are potentially interesting to scientists of many disciplines. This book is organized to proceed from the fundamentals of morphology, structure, and taxonomy, to physiology, ecology, and distribution, and ultimately, paleoecology and radiolarian evolution.

China

***The Marine Flora and Fauna of Hong Kong and Southern China. Volume 1, Introduction and Taxonomy; Volume 2, Ecology, Morphology, Behaviour and Physiology.* Brian Morton and C. K. Tseng, eds. 1982. Hong Kong University Press, Hong Kong. 933 pp. $228.50 (Hong Kong).**

Fifty original research papers on a wide variety of topics — taxonomic assemblages; studies on corals, sea urchins, decapods, benthic fishes; trawl surveys; and more — make up these volumes. They are the result of a 3-week workshop held in Spring 1980, when 42 biologists gathered in Hong Kong to study the relatively unknown marine flora and fauna there. Interest in this work grew out of concern over the polluted waters of Hong Kong. Because of expanding population and coastal zone development, Hong Kong's marine life is threatened and has yet to be adequately studied. Aside from promoting the pleasures of working together, the sponsors of this workshop hope to cultivate interest in researching the many aspects of marine life in Hong Kong and southern China.

Environment

Synthesis and Modelling of Intermittent Estuaries: A Case Study from Planning to Evaluation. **Lecture Notes on Coastal and Estuarine Studies, Volume 3. W. R. Cuff and M. Tomczak, Jr., eds. 1983. Springer-Verlag, New York, N.Y. 302 pp. + v. $22.50.**

Presented here are some of the findings and conclusions of the Port Hacking Estuary Project, a multidisciplinary study of an estuarine ecosystem in Australia. Predictive dynamic models of ecosystems are much needed for anticipating the flow of chemicals in different environments, such as the case of acid rain. However, scientists have not had much success producing such models: this project involved some 20 researchers in the course of 5 years, studying the flow of carbon into, within, and out of a small estuary, but in the end the desired model could not be produced. Close scrutiny of the project's activities, as done here, may help future workers in multidisciplinary studies deal with the problems inherent in such work.

Remote Sensing Applications in Marine Science and Technology, **Arthur P. Cracknell, ed. 1983. D. Reidel Publishing Company, Boston, Mass., in cooperation with NATO Scientific Affairs Division. 466 pp. + xii. $78.00.**

This volume is made up of the written texts of lectures presented at a "summer school" of remote sensing held in Dundee, Scotland, in August 1982, as part of a program of postgraduate education in that field undertaken by the European Association of Remote Sensing Laboratories. The major topics were: general principles of remote sensing with reference to marine applications, applications to physical oceanography, marine-resources applications, and coastal monitoring and protection. Participating were some 24 lecturers and 56 attendees, from Europe, China, Africa, the Philippines, India, and North America; their names and addresses are given at the end of the book. Also included are 8 pages of color pictures obtained by remote sensing.

Geology

Depositional Systems: A Genetic Approach to Sedimentary Geology **by Richard A. Davis, Jr. 1983. Prentice-Hall, Inc., Englewood Cliffs, New Jersey. 669 pp. + xvii. $35.95.**

This is a textbook on sedimentation and stratigraphy, approaching the subject from the study of genesis of stratigraphic units and the rocks they contain. The purpose is to give undergraduate geology students a broad understanding of sedimentary geology. The chapters discuss numerous topics briefly, providing references for in-depth information. There are 4 parts, the first on principles of sedimentary geology, containing background information for those new to the science; the second covering terrestrial environments; the third, transitional environments (intertidal areas, and so on); and the fourth, marine environments.

Marine Policy

Coastal Area Management and Development, **United Nations Department of International Economic and Social Affairs, Ocean Economics and Technology Branch. 1982. Pergamon Press, Elmsford, N.Y. 188 pp. $40.00.**

This volume discusses economic, scientific, and technical problems associated with establishing a national program of coastal management, particularly in developing countries. The coastal area, because it encompasses the interactions of land and sea, includes both terrestrial and marine resources. The objective of coastal-area management (as put forth herein) is to ensure a level and type of development consistent with the continuing viability and productivity of the natural systems on which the productivity is based. In this book, Part I includes guidelines for implementing coastal-management programs; Part II is on the legislative and regulatory aspects of national coastal-area management.

Origin and Development of the Law of the Sea: History of International Law Revisited **by R. P. Anand. 1982. Martinus Nijhoff Publishers, Kluwer Boston, Boston, Mass. 249 pp. $49.50.**

Author Anand looks at the origin and acceptance of the freedom of the seas through the centuries and how this acceptance has been changed and modified in recent years. He begins with maritime law in ancient Rhodes and the Mediterranean and discusses the practices and customs of trade and navigation in ancient Asian states in the Indian Ocean, and conditions that led Europeans to go to Asia in search of spices. The history of maritime conventions is covered, right up to Britain's domination at sea and the effects of the Industrial Revolution. The final chapters cover struggles over the freedom of the seas since World War II, and how the discovery of mineral resources in the seabed has again changed attitudes about freedom of the seas.

Nature Guides

Seashore Life of the Northern Pacific Coast: An Illustrated Guide to Northern California, Oregon, Washington, and British Columbia **by Eugene N. Kozloff. 1983. University of Washington Press, Seattle, Wash. 378 pp. $40.00 (hardcover); $19.95 (paperback).**

From Monterey Bay to Vancouver Island, zoologist Kozloff explores the plants and animals of the rocky shores, sandy beaches, bays and estuaries of the North Pacific, concentrating on invertebrates and seaweeds. This guide covers more than 650 species, with 299 color illustrations and 400 black-and-white photographs and line drawings of sponges, molluscs, crustaceans, seaweeds, and many other kinds of seashore life. The book is organized according to habitat, to encourage the association of certain species with particular environments: floating docks and pilings, rocky shores of Puget Sound, rocky shores of the open coast, sandy beaches, and quiet bays and marshes. The text describes the size, color, activities, and peculiarities of the plants and animals, and is cross-referenced with the figures and plates.

Seabirds: An Identification Guide **by Peter Harrison. Illustrated by the author. 1983. Houghton Mifflin Company, Boston, Mass. 448 pp. $29.95.**

This beautiful book includes many birds painted in full color, 312 species of seabirds in all. Seabirds are defined as those birds whose habitats and food sources are the sea, including coastal, pelagic, and offshore birds. Concentrating on plumage sequences and distributions rather than biology, the book has color plates and distribution maps, species descriptions, black-and-white drawings, and identification keys.

The purpose is to enhance the reader's ability to precisely identify individual species.

The Sierra Club Handbook of Whales and Dolphins **by Stephen Leatherwood and Randall R. Reeves; paintings by Larry Foster. 1983. Sierra Club Books, San Francisco, Calif. 302 pp. + xviii. $25.00 (hardcover); $12.95 (paperback).**

This paperback handbook contains small but clear and lovely reproductions of Larry Foster's whale paintings. There also are quite a few black-and-white photographs, illustrating the actual size and appearance of whales and dolphins — beached, swimming, leaping from water, and so on. The text gives an introduction to Order Cetacea and is organized taxonomically, divided into parts by suborder (Mysticeti and Odontoceti), and subdivided by family. Species are treated individually within those divisions; each is introduced with a color painting of a typical individual, portrayed from the side with tail and flippers posed to show the reader what it looks like. Also given for each species is the scientific name and its derivation, a list of distinctive features, a general description, natural history (if known), population distribution and status, and an explanation of potentially confusing look-alikes.

Oil and Gas

Offshore Adventure: A Pictorial History of the Norwegian Petroleum Industry **by Thorvald Buch Hansen, Odd Jan Lange, Håkon Lavik, and Willy Håkon Olsen; Leif Berge, photographer. 1983. Universitetsforlaget, Norway; distributed by Columbia University Press, New York, N.Y. 160 pp. $44.00.**

On 13 April 1965, the Norwegian continental shelf was officially opened for oil and gas exploration; larger and more discoveries were made than anyone anticipated. Thus, the petroleum industry will affect the lives of generations of Norwegians. This book presents a historic outline of the business and politics of Norwegian oil. Every aspect of oil producing in Norway is explored in the text, diagrams, and numerous dramatic color photographs. Much of the material is on what it is like to live and work in the industry — life on a drilling platform; expanding roles for women in a male-dominated industry; and the families of the workers.

New Technologies in Exploration Geophysics **by H. Roice Nelson, Jr. 1983. Gulf Publishing Company, Houston, Texas. 281 pp. $32.95.**

A review of the latest geophysical exploration and interpretation methods and equipment used for finding oil and gas, this was written for oil-exploration professionals and others interested in new developments in the field. Organized around the steps used in treating seismic data, the book begins with a description of the application of geophysics to petroleum exploration. There are chapters on technological trends, acquisition developments, data processing, graphics, and interpretation, and a conclusion on the need for industry and academe to work together to train the scientists who will be needed to conduct this kind of work.

Underwater Acoustic Positioning Systems **by P. H. Milne. 1983. Gulf Publishing Company, Houston, Texas. 284 pp. + x. $49.95.**

With the development of offshore industries has come a growing need for underwater-survey techniques — to explore seafloor bathymetry and subseabed conditions, position drilling templates, aid in seabed pipeline construction, and so forth. This book covers underwater acoustic positioning (a technology that enables engineers to relocate a spot on the seafloor) in detail, including theory, computations, and available commercial systems. There are chapters on specific applications to seabed surveys, field development, and platform maintenance and inspection. An appendix provides BASIC computer programs for testing the accuracy and suitability of specific applications of each method.

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General

Guide to the Soviet Navy, **Third Edition, by Norman Polmar. 1983. Naval Institute Press, Annapolis, Md. 465 pp. $36.95.**

A comprehensive look at the Soviet Navy in the 1980s. Included are detailed descriptions of Soviet ships, aircraft, weapons, and electronics; discussions of the Soviet Navy's organization, missions, personnel, and support activities, and a history of the Soviet Navy. This edition is completely revised and updated, and illustrated with drawings, tables, maps, and nearly 400 photographs.

Weather for the Mariner, **Third Edition, by William J. Kotsch. 1983. Naval Institute Press, Annapolis, Md. 315 pp. $16.95.**

Since the release of the second edition of this book 6 years ago, many changes in the science of weather forecasting have occurred, which inspired the author to extensively rewrite and expand on his classic guide. New subjects include increasingly sophisticated weather forecasting and reporting, acid rain and its effects on mariners and their equipment, the latest information on navigational and safety aids, and, by reader request, expanded coverage of land and sea breezes. *Weather* also contains plenty of information and advice on clouds, air masses, high- and low-pressure areas, winds and waves, and much more. Appendices provide conversion tables, recommended readings, and worldwide, permanent names for tropical storms, hurricanes, and typhoons.

Schooners in Four Centuries **by David R. MacGregor. 1982. Naval Institute Press, Annapolis, Md. 144 pp. $15.95.**

Four centuries long, the history of the schooner stretches from its beginning in Holland in the 1600s to the present. Vast numbers of these boats have been built, for numerous purposes. They have carried every conceivable cargo from fish to slaves, worked up and down rivers, along coasts, and across the oceans. Though generally 2-masted, in the last century the schooner has had up to 7 masts. This historical account includes many photographs of schooners in the last 100 years, and plans and reproductions of paintings and drawings of schooners that existed earlier in history.

Shipwreck Anthropology, **Richard A. Gould, ed. 1983. The University of New Mexico Press, Albuquerque, N.M. 273 pp. + xiv. $27.50.**

Man's relationship to the maritime environment is explored here through the study of shipwrecks, using techniques of historical, classical, and anthropological traditions in archaeology. Eleven authors contributed, writing on method and theory in shipwreck archaeology, shipwrecks as data base for human behavioral studies, the archaeology of war at sea, and eight other topics of shipwreck archaeology. One point reinforced by these discussions is that sunken ships hold a wealth of anthropological and historical information that can be lost to uncontrolled "treasure hunting."

***Little Sparrow: A Portrait of Sophia Kovalevsky* by Don H. Kennedy. 1983. Ohio University Press, Athens, Ohio. 341 pp. + ix. $25.95 (hardcover); $12.95 (paperback).**

A biography of the 19th-Century Russian mathematical genius and first woman professor of higher mathematics, this book was written after extensive work translating and organizing the correspondence and other works of Kovalevsky, her family, and peers. Born in 1850 into the Russian nobility, at age 18 Sophia Kovalevsky entered into a sham marriage as her only means of escaping Russia to study abroad. Since she was a woman, she had to get special permission to study at Heidelberg; after being rejected for advanced study at Berlin University, she was accepted as a special pupil by Professor Karl T. W. Weierstrass, the foremost mathematics teacher of the age. Throughout her life, Kovalevsky suffered the plight of intellectual women scientists in Russia and Europe in the 19th Century; now she is a heroine of science in the Soviet Union.

***The Tea Clippers: Their History and Development 1833-1875,* Third Edition, by David R. MacGregor. 1983. Naval Institute Press, Annapolis, Md. 256 pp. $24.95.**

Much new information, including many new ship biographies and 3 times the number of pictures in earlier editions, is incorporated into historian MacGregor's book. The crack sailing vessels of the 19th-Century tea trade captured the public's imagination; this book details the history of the tea trade and the business involved in sailing from the China Sea. It includes profiles of many ships, arranged in historical sequence, and seven appendices of data, routes, dimensions, and so on.

Books Policy

Oceanus *welcomes books from publishers in the marine field. All those received will be listed and a few will be selected for review. Please address correspondence to Elizabeth Miller, editor of the book section.*

***Voyage Through the Antarctic* by Richard Adams and Ronald Lockley; photographs by Peter Hirst-Smith. 1983. Alfred A. Knopf, New York, N.Y. 160 pp. $13.95.**

Richard Adams, author of *Watership Down,* with ornithologist-naturalist Ronald Lockley, photographer Peter Hirst-Smith, and 75 others set out from Tierra del Fuego on a 2-month journey through Antarctica to New Zealand. In this account, the two writers describe all aspects of their trip, including their preparations, the wildlife they came across, and their feelings and impressions. The excitement of the adventure shines through the prose, accented by many color and black-and-white photographs. In a final chapter, Hirst-Smith relates his preparations as a photographer leaving on a long voyage (he carried an incredible 350 rolls of film) through a harsh environment.

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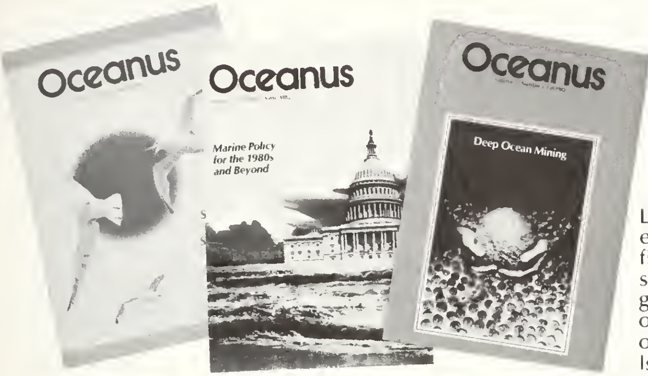

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Issues not listed here, including those published prior to Spring 1977, are out of print. They are available on microfilm through University Microfilm International; 300 North Zeeb Road; Ann Arbor, MI 48106.

- **Offshore Oil & Gas,** Vol. 26:3, Fall 1983 — Historical accounts of exploration methods and techniques, highlighting development of seismic theory, deep-sea capability, estimation models, as well as environmental concerns, domestic energy alternatives, and natural petroleum seeps.
- **General Issue,** Vol. 26:2, Summer 1983 — Articles cover the effects of carbon dioxide buildup on the oceans, the use of mussels in assessments of chemical pollution, a study of warm-core rings, neurobiological research that relies on marine models, the marginal ice zone experiment, and career opportunities in oceanography. A number of "concerns" pieces on the U.S. Exclusive Economic Zone round out the issue.
- **Seabirds and Shorebirds,** Vol. 26:1, Spring 1983 — This issue contains articles on the feeding methods, breeding habits, migration, and conservation of marine birds.
- **Marine Policy for the 1980s and Beyond,** Vol. 25:4, Winter 1982/83 — The articles focus on the problems of managing fisheries, the controversy over dumping wastes in the oceans, the lack of coordination in United States Arctic research and development, military-sponsored oceanographic research, the Law of the Sea, and the potential for more international cooperation in oceanographic research. Each author makes recommendations for the future.
- **Deep Ocean Mining,** Vol. 25:3, Fall 1982 — Eight articles discuss the science and politics involved in plans to mine the deep ocean floor.
- **General Issue,** Vol. 25:2, Summer 1982 — Contains articles on how Reagan Administration policies will affect coastal resource management, a promising new acoustic technique for measuring ocean processes, ocean hot springs research, planning aquaculture projects in the Third World, public response to a plan to bury high-level radioactive waste in the seabed, and a toxic marine organism that could prove useful in medical research.
- **Oceanography from Space,** Vol. 24:3, Fall 1981 — Satellites can make important contributions toward our understanding of the sea.
- **General Issue,** Vol. 24:2, Summer 1981 — A wide variety of subjects is presented here, including the U.S. oceanographic experience in China, ventilation of aquatic plants, seabirds at sea, the origin of petroleum, the Panamanian sea-level canal, oil and gas exploration in the Gulf of Mexico, and the links between oceanography and prehistoric archaeology.
- **The Coast,** Vol. 23:4, Winter 1980/81 — The science and politics of America's 80,000-mile shoreline.
- **Senses of the Sea,** Vol. 23:3, Fall 1980 — A look at the complex sensory systems of marine animals.
- **A Decade of Big Ocean Science,** Vol. 23:1, Spring 1980 — As it has in other major branches of research, the team approach has become a powerful force in oceanography.
- **Ocean Energy,** Vol. 22:4, Winter 1979/80 — How much new energy can the oceans supply as conventional resources diminish?
- **Ocean/Continent Boundaries,** Vol. 22:3, Fall 1979 — Continental margins are being studied for oil and gas prospects as well as for plate tectonics data.
- **Oceans and Climate,** Vol. 21:4, Fall 1978 — *Limited Supply only.*
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