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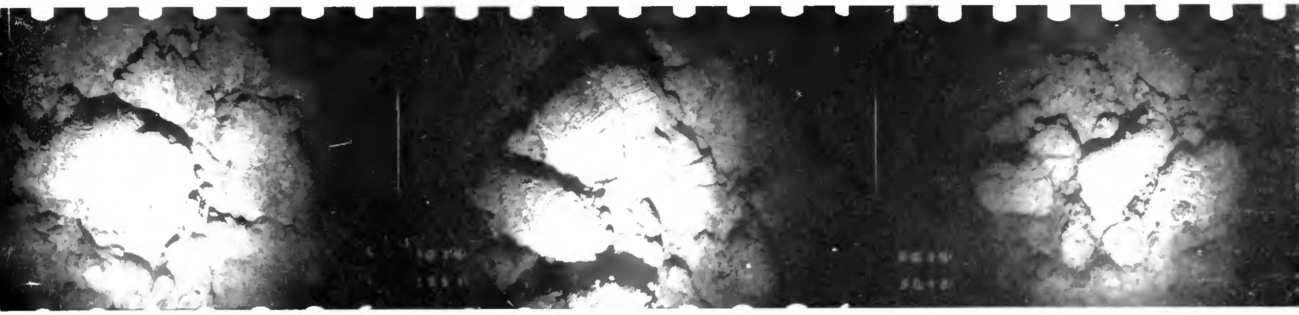
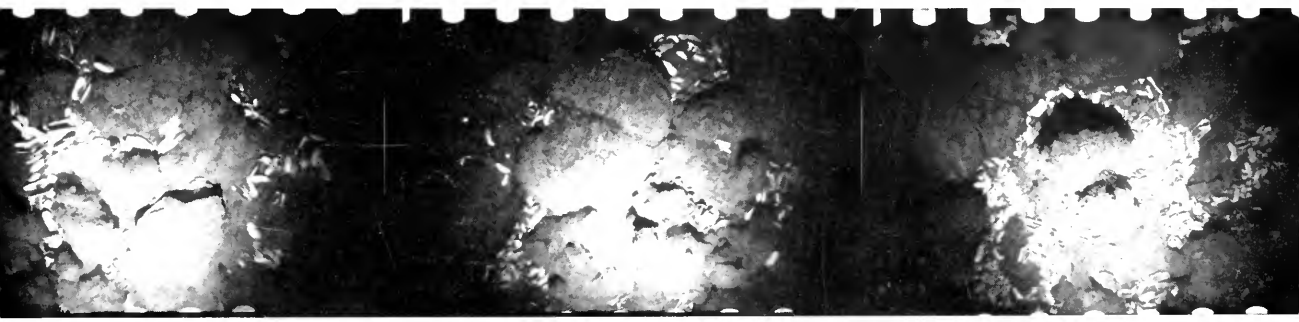
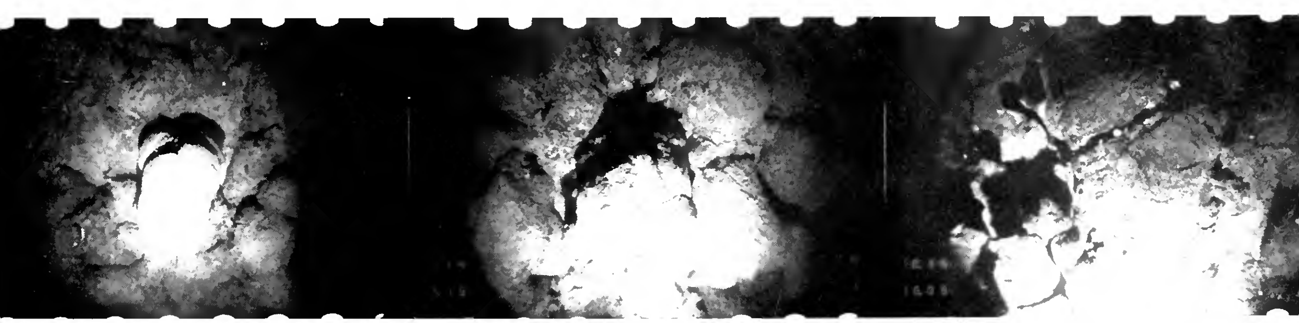


The 200-Mile Limit:
The New England Fisheries Council
The North Pacific Council
Border Problems With Canada



The Galápagos Rift Discovery
The Electromagnetic Sense of Sharks, Skates, and Rays



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The Illustrated Magazine of Marine Science

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PAUL MACDONALD FYE: AN APPRECIATION

EDITOR'S NOTE: Dr. Paul M. Fye steps down this October after 19 years as Director of the Woods Hole Oceanographic Institution. He will continue as President of the Institution's Corporation. His successor as Director is Dr. John H. Steele, an internationally recognized marine ecologist and the Deputy Director of the Marine Laboratory of the Department of Agriculture and Fisheries of Scotland.

The United States was deeply involved in massive war efforts when Paul Fye came to the Woods Hole Oceanographic Institution in 1942 to join the new Underwater Explosives Research Laboratory (UERL), which was also known as "Project 7." Although he had lived for a short time on Long Island, his working relationship with water up to this time had been largely limited to a pond at the Explosives Research Laboratory at the Bureau of Mines in Bruceton, Pennsylvania. E. Bright Wilson, Jr., professor of Chemistry at Harvard University, was recruited to be the first Director of UERL. The need for more extensive facilities was soon realized, and Woods Hole provided the seagoing scientific environment.

Paul was born in Johnstown, Pennsylvania, in 1912. He graduated from Albright College in 1935, and four years later received his Ph.D. in Chemistry from Columbia University. His doctoral research was in gas kinetics and photochemistry; his thesis was entitled "The Photochemical Decomposition of Phosgene." As a by-product, he developed great skill as a glassblower; many graduate students in chemistry at Columbia turned to him for help with their glassware apparatus.

Paul M. Fye, left, and William A. Nierenberg, Director of Scripps Institution of Oceanography, sharing a moment in October of 1965.

After his doctorate, Paul spent two years at Hofstra University, then found himself on the payroll of the Carnegie Institute of Technology doing war research on explosives at the Bureau of Mines, a project of the National Defense Research Committee. Within two years, he made his way to Woods Hole.

The UERL Project 7 group at the Oceanographic Institution was remarkable in many ways. Although the war research was highly classified, underwater explosions could scarcely be hidden from the Woods Hole community. This work soon became a center of controversy, with many dire predictions that Woods Hole could no longer remain a scientific center because of the alleged destruction of marine life caused by the devastating explosions. Many asserted passionately that the research should be banned. Nevertheless, under the leadership of Bright Wilson, and afterward Paul C. Cross, who would later become an officer of Carnegie-Mellon University, and with the patient understanding of Columbus O'D. Iselin, who had become Director of the Institution in 1940, the work went on, resulting in many technological advances for the war effort, and in the enhancement of the scientific community at Woods Hole. In addition to those already named, Project 7 included among its scientists and associates: Arnold B. Arons, Elizabeth T. Bunce, Robert H. Cole, James S. Coles, John C. Decius, George K. Fraenkel, Donald F. Hornig, William D. Kennedy, John G. Kirkwood, George B. Kistiakowsky, Alfred G. Redfield, William G. Schneider, Charles P. Slichter, and David S. Stacey. Many of these names will be recognized without further identification; seven later became Trustees of the Oceanographic Institution.* Several made significant scientific contributions to the Institution.

By the end of the war, Paul was Director of UERL. When the laboratory closed down in 1947, he joined the University of Tennessee as Assistant Professor of Chemistry. In 1948, he moved to the Naval Ordnance Laboratory as Deputy Chief (later Chief) of the Explosives Department. In 1956, he was named Associate Director of Research.

The Woods Hole Oceanographic Institution was a fledgling laboratory, barely a decade old, when World War II erupted. Shortly after the founding of the Institution in 1930, it had four full-time year 'round employees: Henry Bryant Bigelow, the first Director, the late William C. Schroeder, identified in the 1932 Annual Report as "Business Manager," a secretary, and a buildings and grounds superintendent. When the war broke out, Dr. Bigelow had just been succeeded by one of his students — the young, and long beloved Columbus Iselin. Even with the rapid wartime expansion of the scientific staff, Columbus visited all the laboratories almost every day, inquiring about the progress of research, offering encouragement and helpful suggestions. Dr. Iselin was succeeded by retired Coast Guard Admiral Edward H. Smith, who had taken his doctorate in oceanography at Harvard with Dr. Bigelow. Admiral Smith in turn was succeeded in 1956 by Dr. Iselin, who was drafted back into the directorship in a time of need.

In the late 1950s, the Trustees, and Dr. Iselin, realized that the Institution had grown to the extent that an effective administrative organization was required. They also realized that leadership for further growth was necessary if the nation's needs for expanded oceanographic research were to be met, and if Woods Hole was to remain one of the world's leading marine research centers. A laissez-faire attitude had worked well when the Institution had been largely staffed by part-time scientists who held full-time jobs at various universities. These scientists had been working in a broad new interdisciplinary field with loosely defined goals and boundaries. The year 1957, however, required a new outlook.

In 1940, the scientific staff had numbered 18 (of which 15 were part-time). The annual budget was $104,400. The plant consisted of the Bigelow Building, and one small dock for the 142-foot ketch *Atlantis* and the 40-foot workboat *Asterias*. By 1957, there were 65 full-time scientists and technicians, plus 106 support personnel, 8 buildings, 2 research vessels, and 2 docks. Operating costs in 1957 were $2.5 million, and $2.4 million of this came from the Federal government with the attendant complications of red tape, contracts, and auditors.

If the Institution was to gain a greater measure of independence in its programs, it became obvious to the Trustees and Members of the Corporation that, in addition to more effective administration, more money would be required from private sources to meet operating costs, build an endowment, and construct new facilities.

Such were the perceptions of the task desired of the Institution's leadership in 1958, when Paul Fye was asked to become the Director. The Trustees saw in him a scientist who both understood how to develop research and how to create the atmosphere for it, a man familiar with oceanography even though not trained in it (how many were in the 1950s?), and an administrator acquainted with the maze of Navy and other government funding and budgeting processes.

Paul had demonstrated two special talents that were to be extremely valuable to the Institution. The first was the ability to administer a scientific research enterprise — to bring together a group of diverse scientists and provide an environment within which they could work, including floating laboratories operating thousands of miles away from Woods Hole for months on end. The other was as an expositor of science to nonscientists, with the ability to interest them in the sciences.

**Wilson, Arons, Cole, Coles, Cross, Slichter, and Fye.*

It was the successful businessman or entrepreneur who would provide the independent resources needed by Woods Hole. Before support could be forthcoming, there had to be some understanding of the science on the part of the benefactor. In the almost two decades of his directorship, Paul Fye admirably fulfilled these expectations. He has left a mark on the Institution in the development of facilities, ships, endowment, scientific staff, and programs that will probably never be surpassed by any other individual. Beyond that, he proved himself a person of great humanity and warmth. His total motivation and effort has always been for the good of the Institution.

The cold statistics from 1957 to 1977 show a nearly ninefold increase in the operating expenditures ($2.5 million to $22 million); a threefold increase in scientific and technical staff (from 65 to 205); a twenty-eightfold increase in the value of the laboratory plant (from $578,401 to $16.1 million); a nineteenfold increase in the value of research vessels (from $364,983 to $7 million); and more than an elevenfold increase in endowment ($3.2 million to $38 million).

But Paul Fye did much more than this. He saw the need for formal training in oceanography at the graduate level, as well as the value of graduate students working in a research environment. In 1967, the joint Massachusetts Institute of Technology-Woods Hole Oceanographic Institution doctorate program was established at Woods Hole, with the identity of the Oceanographic Institution properly and carefully maintained. As Director, Paul also participated in national and international councils that dealt not only with understanding the oceans but also with the politics of the oceans and their resources. He was one of the first to perceive the need for people trained in marine policy and ocean managment and very early established such a program at Woods Hole.

Paul has served on nearly 30 committees and councils during his tenure. Among them are the Committee on Oceanography of the National Academy of Sciences, the Undersea Warfare Research and Development Planning Council, the President's Task Force on Oceanography, the Ocean Affairs Advisory Committee of the Department of State, and the Law of the Sea Advisory Committee. He also has served as trustee of the Bermuda Biological Station for Research, and of the International Federation of Institutes of Advanced Study. In addition, he has membership on several boards of directors. His recognitions include the Bureau of Ordnance Development Award, the President's Certificate of Merit, the Meritorious Award of the U.S. Navy, the Certificate of Commendation of the Secretary of the Navy, and several honorary degrees and other citations.

Ralph Waldo Emerson wrote: "An institution is the lengthened shadow of one man." At Woods Hole there are the shadows of many men, but the bright prospects and clear perceptions which we now see are those for which we must thank Paul MacDonald Fye.

James S. Coles

We're Going to Computer!

During the next several months, we will be completing our move to a computerized subscription fulfillment operation. We hope this will not inconvenience any of our readers, but should you experience a problem in receiving the magazine, please contact us directly at* Oceanus, *Woods Hole Oceanographic Institution, Woods Hole, MA 02543.

Excerpts from The U.S. Fishery Conservation and Management Act of 1976.

Public Law 94-265, 94th Congress, H.R. 200, April 13, 1976

Findings, Purposes and Policy

FINDINGS. — The Congress finds and declares the following:

(1) The fish off the coasts of the United States, the highly migratory species of the high seas, the species which dwell on or in the Continental Shelf appertaining to the United States, and the anadromous species which spawn in United States rivers or estuaries, constitute valuable and renewable natural resources. These fishery resources contribute to the food supply, economy, and health of the Nation and provide recreational opportunities.

(2) As a consequence of increased fishing pressure and because of the inadequacy of fishery conservation and management practices and controls (A) certain stocks of such fish have been overfished to the point where their survival is threatened, and (B) other such stocks have been so substantially reduced in number that they could become similarly threatened.

(3) Commercial and recreational fishing constitutes a major source of employment and contributes significantly to the economy of the Nation. Many coastal areas are dependent upon fishing and related activities, and their economies have been badly damaged by the overfishing of fishery resources at an ever-increasing rate over the past decade. The activities of massive foreign fishing fleets in waters adjacent to such coastal areas have contributed to such damage, interfered with domestic fishing efforts, and caused destruction of the fishing gear of United States fishermen.

(4) International fishery agreements have not been effective in preventing or terminating the overfishing of these valuable fishery resources. There is danger that irreversible effects from overfishing will take place before an effective international agreement on fishery management jurisdiction can be negotiated, signed, ratified, and implemented.

(5) Fishery resources are finite but renewable. If placed under sound management before overfishing has caused irreversible effects, the fisheries can be conserved and maintained so as to provide optimum yields on a continuing basis.

(6) A national program for the conservation and management of the fishery resources of the United States is necessary to prevent overfishing, to rebuild overfished stocks, to insure conservation, and to realize the full potential of the Nation's fishery resources.

(7) A national program for the development of fisheries which are underutilized or not utilized by United States fishermen, including bottom fish off Alaska, is necessary to assure that our citizens benefit from the employment, food supply, and revenue which could be generated thereby.

PURPOSES. — It is therefore declared to be the purposes of the Congress in this Act –

(1) to take immediate action to conserve and manage the fishery resources found off the coasts of the United States, and the anadromous species and Continental Shelf fishery resources of the United States, by establishing (A) a fishery conservation zone within which the United States will assume exclusive fishery management authority over all fish, except highly migratory species, and (B) exclusive fishery management authority beyond such zone over such anadromous species and Continental Shelf fishery resources;

(2) to support and encourage the implementation and enforcement of international fishery agreements for the conservation and management of highly migratory species, and to encourage the negotiation and implementation of additional such agreements as necessary;

(3) to promote domestic commercial and recreational fishing under sound conservation and management principles;

(4) to provide for the preparation and implementation, in accordance with national standards, of fishery management plans which will achieve and maintain, on a continuing basis, the optimum yield from each fishery;

(5) to establish Regional Fishery Management Councils to prepare, monitor, and revise such plans under circumstances (A) which will enable the States, the fishing industry, consumer and environmental organizations, and other interested persons to participate in, and advise on, the establishment and administration of such plans, and (B) which take into account the social and economic needs of the States; and

(6) to encourage the development of fisheries which are currently underutilized or not utilized by United States fishermen, including bottom fish of Alaska.

POLICY. — It is further declared to be the policy of the Congress in this Act –

(1) to maintain without change the existing territorial or other ocean jurisdiction of the United States for all purposes other than the conservation and management of fishery resources, as provided for in this Act;

(2) to authorize no impediment to, or interference with, recognized legitimate uses of the high seas, except as necessary for the conservation and management of fishery resources, as provided for in this Act;

(3) to assure that the national fishery conservation and management program utilizes, and is based upon, the best scientific information available; involves, and is responsive to the needs of, interested and affected States and citizens; promotes efficiency; draws upon Federal, State, and academic capabilities in carrying out research, administration, management, and enforcement; and is workable and effective;

(4) to permit foreign fishing consistent with the provisions of this Act; and

(5) to support and encourage continued active United States efforts to obtain an internationally acceptable treaty, at the Third United Nations Conference on the Law of the Sea, which provides for effective conservation and management of fishery resources.

Excerpts continued

The 200-Mile Limit I:

U.S. Fishery Conservation Zone

The New England Regional Fishery Management Council

by Henry Lyman

The Fishery Conservation and Management Act of 1976, commonly referred to as the 200-mile limit bill, was implemented on March 1 of this year. Those involved in passage of the Act and in administration of its provisions, myself included, thought that little or no effect upon the harvest would be realized by United States fishermen for at least two years because overfished stocks would take some time to recover. We were wrong, basically because we forgot simple mathematics.

When the late Dr. Henry B. Bigelow theorized many years ago that overfishing in marine waters would eventually destroy fisheries resources, he put it simply: "Take something away," he stated in referring to the fish off America's coasts, "and it isn't there any more."

He was right, and domestic commercial and recreational fishermen have had a greater supply of some species as a result. The reason: there has been a dramatic decrease in the number of foreign fishing vessels within the 200-mile limit since the Act became effective. For example, during a single week this spring, the U.S. Coast Guard sighted 29 such craft off the coasts of New England and the Middle Atlantic States. During a comparable week in 1976, there were 130 in the same waters.

Although these foreign ships in many cases did not conduct a directed fishery in 1976 for species like cod and pollock, their by-catch allowed under the International Convention for the Northwest Atlantic Fisheries (ICNAF) for many years totalled as much as the directed efforts of many segments of the United States fleets. From Eastport to Cape May this season, estimates of cod and pollock catches by recreational anglers have nearly doubled. According to National Marine Fisheries Service (NMFS) figures, the overall landings of all species at eight New England ports between January and April increased by 15 million metric tons over the 83 million tons taken in 1976. Some of this increase undoubtedly was due to biological factors, yet there is no question that some also was due to escapement of fish formerly taken by foreign fishermen.

This foreign fishing activity was the basic cause of the Act. For years, both commercial and sport fishermen claimed that American catches were steadily declining, and placed the blame primarily on nondomestic catches in excess of what the stocks could withstand. ICNAF was established to control overfishing through mutual treaties among approximately 20 compacting nations. Agreements on catch quotas, seasons, fishing areas, and enforcement methods were drawn up in an attempt to save the stocks. Although this country took a much firmer stand concerning ICNAF conservation regulations in 1976 than it ever had in previous years, political pressures built up to the point that the United States withdrew from the Convention, effective January 1, 1977.

There were three major reasons why ICNAF did not succeed. First, although American fishermen were penalized for violations of its regulations, such penalties apparently were minimally applied by foreign governments to vessels and personnel under their jurisdiction. Second, several nations, such as Korea and Cuba, which were not officially parties to the Convention, fished without any restrictions in the ICNAF area. Finally, all too often conservation measures recommended by qualified biologists were sacrificed to political expediency. In addition, reports from observers now stationed on foreign vessels indicate that many violations of ICNAF regulations in the past went undetected.

With ICNAF a failure from the point of view of United States fishermen, grass roots political pressure steadily increased to declare a 200-mile fishery limit. The U.S. State Department opposed this pressure by pointing out that the Third United Nations Law of the Sea Conference (LOSC) would be dealing with the problem at the international level. Unilateral action, the State Department maintained, would jeopardize negotiations on many points. Weight was given to this stand by the declaration of then U.S. Fisheries Ambassador John R. Stevenson in 1974 in Caracas, Venezuela. He stated that the United States would have no objection to the concept of a 200-mile limit as it affected marine natural resources, but would object most strenuously to a 200-mile territorial limit. The Act reflects this governmental position, for it includes provisions for amendments to comply with any regulations that may be set at future LOSC meetings.

At the 1974 LOSC, there appeared to be good progress among approximately 150 participating nations. Cynics suggest that from this point onward, disagreements mounted at each subsequent session because each nation called in a battery of lawyers. It soon became apparent that definite LOSC action on the 200-mile concept would be years away. The U.S. Congress therefore moved unilaterally after several Latin American countries passed 200-mile legislation. When the Act was passed on April 13, 1976, the United States obtained control over its marine fisheries up to 200 miles from shore. A notable exception was control over highly migratory members of the tuna family, although efforts are now being made to amend the Act to control them, too. In addition, the Congress, under Section 404 of the Act, urged that the Secretary of State vigorously pursue an international program for marine mammal protection even beyond the 200-mile limit. Under separate legislation, fisheries resources on the Continental Shelf are also under United States jurisdiction, even though the Shelf limits may lie beyond 200 miles.

An Experiment in Government

During the drafting of the Act, publicity centered on getting rid of foreign fishing fleets. The cry was: "Throw the rascals out!" Many supported the bill from this aspect alone, while ignoring the many other provisions it contained. The major problem concerned controls that had to be placed on United States fishing fleets so that fisheries,

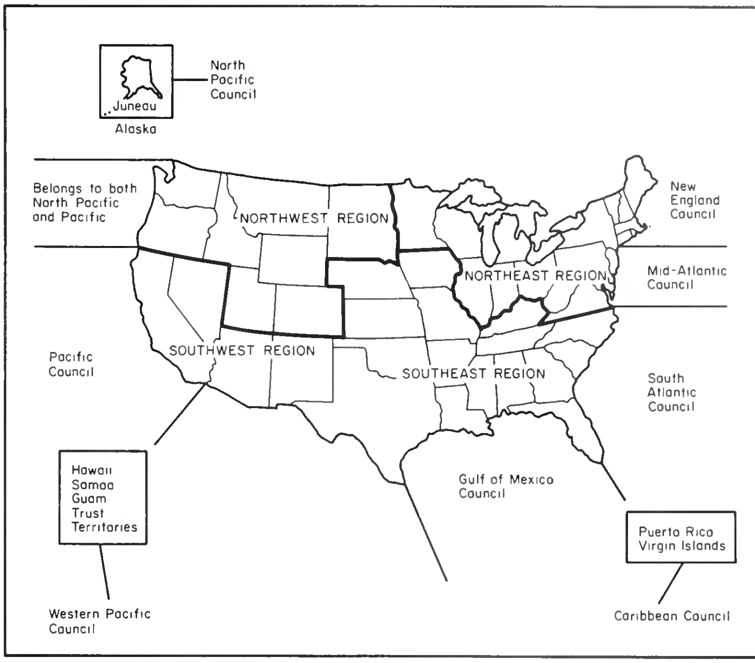


Figure I. The eight council jurisdictions and National Marine Fisheries Service regions.

saved from the foreign fleets, would not be decimated by local fishermen.

In discussions that followed, commercial and recreational fisheries interests cooperated in an unprecedented manner. Legislators, representatives of governmental departments and agencies, and a great many private citizens drafted a document which, although not perfect, is surprisingly complete. It also may be considered a unique experiment in government. The Act turns basic control of marine fisheries resources over to representatives of groups interested in those fisheries. This control now lies with the Regional Fishery Management Councils. Actions of the councils, however, are subject to federal review. Input from the general public is mandated by hearing proceedings outlined in the Act.

There are eight councils covering various sections of this country's coastline (Figure 1). The number of members on each varies, depending on the relative importance of the resources involved. There are certain mandatory members: the regional director of the National Marine Fisheries Service (NMFS) in each area, and the principal state official with marine fisheries management responsibility. The majority of voting members, however, are selected by the Secretary of Commerce from lists submitted by the governor of individual states. Nonvoting members include the regional director of the U.S. Fish and Wildlife Service, the commander of the Coast Guard district, the executive director of the Marine Fisheries Commission for the geographical area concerned, and a representative of the Department of State.

In the New England Regional Fishery Management Council (NERFMC), there are 17 voting members, 11 of whom were appointed by the Secretary of Commerce, plus four nonvoting members or their designees. Terms for the initial year of operation are staggered, but eventually all will be named for three years. The chairman is elected by secret ballot of the Council. With the NERFMC primarily represented by commercial fishing interests, I was surprised to find that I, a representative of sport fishing interests, was selected. My first thought was that I was chosen as a whipping boy, but I am glad to report that cooperation by the commercial fishing members has been excellent.

Under the Act, there are two major concerns for the Council to address: (1) control of foreign fishing; and (2) management plans designed to rebuild fishery stocks to provide optimum yield (OY). A week-long workshop held this June to define OY did not

Excerpts Public Law 94-265

The term "optimum," with respect to the yield from a fishery, means the amount of fish —

(A) which will provide the greatest overall benefit to the Nation, with particular reference to food production and recreational opportunities; and

(B) which is prescribed as such on the basis of the maximum sustainable yield from such fishery, as modified by any relevant economic, social, or ecological factor.

Excerpts continued

result in a pat answer to be applied to all fisheries, but rather in a series of options that Council members should consider. OY does not involve simply the supply of fish. It must take into account economic and social benefits to United States citizens, among which is the vague concept of angling pleasure. This item alone can result in many months of discussion. Would you rather catch a great many small fish, one very large fish, or a few very elusive fish?

During early technical sessions, workshop participants involved in a variety of disciplines, such as economics, sociology, biology, and coastal resource planning, naturally emphasized the need to start consideration of OY from their particular point of view. When council representatives later joined the group, a consensus developed that the starting point should be with the status of the fishery stocks. Thereafter, councils must weigh the relative importance of all other factors on a fishery-by-fishery basis. White marlin, for example, have little commercial value, yet are highly prized as a sport fish, so the scales in this case would tip toward maximizing recreational use. Squid, on the other hand, although valuable to anglers as forage for species they seek, have no recreational value *per se*; and emphasis, therefore, should be placed on commercial value.

Confusion on the Fishing Grounds

The effective date of withdrawal from ICNAF by the United States was January 1, 1977. The Act did not go into effect officially until March 1. For two months, there was considerable confusion on the fishing grounds. Some foreign governments accepted the Act immediately, while others fought it down to the deadline and beyond. Those nations which cooperated found their path made easier after the law was in place.

It should be emphasized at this point that the Act definitely does *not* forbid all fishing by other nations inside the U.S. 200-mile limit. They may take surpluses of stocks that cannot be harvested at this time by American fishermen, although capabilities of such harvesting may increase in the future. Such surpluses were determined originally through preliminary management plans drawn up by the Department of Commerce through the National Marine Fisheries Service. Allocations of these surpluses to other nations is made by the State Department after consultation with Commerce, and with the major law enforcement agency, the Coast Guard. Obviously, these allocations may favor those nations cooperating with United States conservation efforts.

To operate within the 200-mile limit, each nation must first sign a Governing International Fishery Agreement (GIFA) with the United States. This is, basically, a mini-treaty in which the nation agrees to abide by regulations set within the 200-mile zone, permits boarding by enforcement personnel, and allows observers on board its ships for extended periods. Although recommendations of the Council are considered, final approval of each GIFA rests with Congress.

After a GIFA has been approved, the country must then apply for prepaid permits for each vessel that intends to fish. Council comments on such permits are taken into account before they are approved. Because of the short time frame for consideration of permits in 1977, almost all were granted even though the New England Council in many cases objected. It was the Council's feeling that the number of vessels often far exceeded the number realistically required to harvest the allocated surpluses. Hopefully, this legal weapon to limit the amount of fishing will be used more effectively as the Act comes of age. As this is written, permit fees for 1977 have totalled more than $10 million for the U.S. Treasury.

Enforcement action against foreigners by the Coast Guard and NMFS officials early this year was good, but approval of recommended action left much to be desired. Just which governmental agency vetoed seizure of some violators is buried in a bureaucratic mire. Finally, however, a Soviet trawler was seized, as was the cargo of a Soviet factoryship, after President Carter made known his intentions to have the Act strictly enforced. Heavy fines on the offenders resulted, and observance of the law has since improved (Figure 2).

Placing United States observers on board foreign vessels is an action which the New England Council has heartily endorsed. Only recently, reports from some of these

Figure 2. Coast Guard enforcement officers boarding Soviet vessel to inspect catch and fishing gear. (Courtesy U.S. Coast Guard)

observers, who, incidentally, were well treated by their hosts, have become available. This information is extremely valuable to the Council when considering law enforcement procedures and biological data. For example, on one vessel the by-catch of fish for which there was no allocation — and which was run over the side — ranged from 18 to 25 percent. This unnecessary destruction must be taken into account when estimates of the stock biomass are made.

A small minority of United States fishermen in both the commercial and recreational fields apparently feel that the Act should not apply to them. Their argument is that they supported passage of the measure and therefore should be allowed to ignore it. Citations by the Coast Guard, which the Council approves of completely, are helping to diminish violations on the part of domestic fishermen.

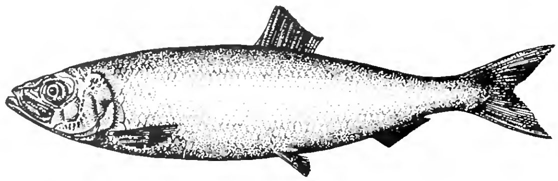
Although approval of strict enforcement has caused some to think that Council members no longer wear the white hats of those committed to "throwing the rascals out," the graying of those hats really has been caused by attempts to set up management plans for various fishery stocks. Such plans are truly juggling acts in which compromises abound. If the aim of the New England Council were simply to rebuild stocks, naturally the quickest method would be to forbid all fishing.

It is not that simple. Even though the definition of OY in the Act is fuzzy, Congress made it clear it had no intention of wiping out the commercial fishing industry. A balance, it insisted, had to be maintained between the rebuilding of stocks and continuing an economic asset. Such a balance is not necessarily conflicting.

Matters are further complicated because of the recreational fishing industry, which now involves more people and more dollars than its food-producing peer. Statistics on marine catches made by sport fishermen are scarce, yet those catches must be considered when attempting to structure a plan dependent on biological data, sizes of stocks, growth rates of fish, year classes, and a host of other factors. A recent survey, for example, indicated that the recreational catch of bluefish off the Middle Atlantic area was double the commercial catch, a management factor that cannot be ignored. In many cases, there is conflict between commercial and recreational fishing, as well as conflict among the various groups within each classification: inshore draggers versus lobstermen, trollers versus surf casters, even petroleum seekers versus all fishermen.

The Case of Atlantic Herring

Resolution of such conflicts results in compromise. In any such compromise, someone's interests are bound to be hurt. The image of the Council usually suffers, but the NERFMC is not in the business of image-building. It has come to grips in detail only recently with the goals each fishery management plan should set after having



Herring *(Clupea harengus)*

received input from scientists, economists, foreign emissaries, sociologists, politicians, the general public, and, in some cases, wild-eyed fanatics. Options are many, yet the Council is responsible for the final judgment. This is as it should be, but it does not make the decisions easier!

Of great help in reaching such decisions is advice provided by two groups, the Scientific and Statistical Committee and the Industry Advisory Committee. The former is made up of professionals in the fields of biology, economics, sociology, and other disciplines relating to marine resources. The latter consists not of a single small committee, but of a pool of more than 150 people with known expertise in various areas of fisheries activity. A selected number from this pool is contacted when a particular fishery, such as that for yellowtail, is being discussed.

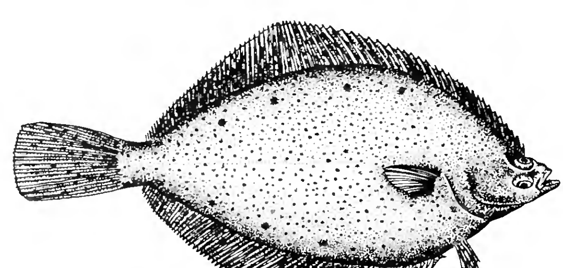
An example of the complications that arise when attempting to prepare a management plan for a specific stock is well illustrated in the case of Atlantic herring. Stocks are depleted, so the Department of Commerce, in accordance with provisions of the Act, prepared a preliminary management plan (PMP) in which it was stated that 33,000 metric tons of adult herring could be harvested while still maintaining OY. It further claimed that, although the United States fleet might have the capacity to take this harvest, it would not do so because of the low price of $65 per ton. Therefore an allocation of 22,000 tons was made to foreigners. By the time the PMP was in print, domestic prices had jumped to $90 per ton. As this is written, Polish interests are offering Canadian fishermen $125 per ton for the same fish, which means that American interests may well wish to harvest the foreign allocation.

To muddy the waters further, the traditional fishery for herring in Maine is for juveniles used to produce Maine sardines. Some of these are caught within the three-mile state territorial limit and others, outside that limit. Maine officials feel so strongly that allocating adults to foreigners will affect the catch of juveniles that they are suing Commerce. At present, biologists cannot state definitely that offshore stocks of herring are separate from those inshore, nor have they determined how much intermingling there might be if there are, indeed, two separate stocks. In addition, after the PMP had been prepared, additional scientific data indicated that the total population was in worse shape than had been previously believed.

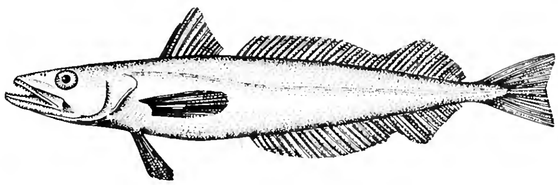
The New England Council is in the process of drawing up its own final management plan (FMP). The conditions cited must be taken into consideration, and there are others (Table 1). Seaward boundaries between the United States and Canada have not been settled and, while discussions continue, both nations have agreed to exclude all others from the disputed area (see page 24). Obviously Canadian catches must be taken into account when determining OY. What is the volume of that catch? Should it be subtracted from the United States quota and, if it is, how can regulations be enforced? Add to

Table I: New England Council Priorities for Final Management Plan (FMP)

Priority	Species	Status of FMP
1.	Haddock, cod, yellowtail flounder	Completed
2.	Atlantic herring	In progress
3.	Sea scallops	In progress
4.	Silver hake	In progress
5.	Redfish and pollock	Pending
6.	Red crab	Pending
7.	Squid and red hake	Pending



Yellowtail *(Limanda ferruginea)*



Silver hake *(Merluccius bilinearis)*

this the plea of recreational fishermen that an unknown percentage of herring stocks should be left alone to provide forage for species of angling importance, and it is evident that the NERFMC has a challenge that even Solomon might have shunned.

Council Frustrations

The New England Council has faced problems that have plagued other councils along the coasts. First among them is that almost everything has been done to date on an emergency basis. When the United States withdrew from ICNAF, for example, there was a two-month period when heavily depleted stocks of haddock and cod on Georges Bank apparently could be fished by domestic commercial fishermen without restriction. Foreigners still in ICNAF could not take these species legally. Fortunately, an industrious attorney discovered that catch regulations on United States citizens still applied, even though this country was no longer an ICNAF member.

Given this brief breathing spell, the Council, with major help from the NMFS, worked out a Groundfish Management Plan after the 300-day normal time for preparing such a plan had been waived. To gain some control over those who would exploit the fishery with no thought for the future, the Secretary of Commerce declared an emergency regulation to be in force until the whole Plan was in place. Such hurried action is not ideal if management plans are to be truly effective and reasonable. Fortunately, such plans can, and will, be modified as more information on stocks, rates of harvesting, economic impact, and many other factors come to light. "Conservation and management measures shall be based on the best scientific information available," the Act states. That information changes constantly.

Another difficulty is the frustration that Council members feel when confronted with the incredible machinations of governmental agencies. Normal operations of the faceless bureaucracy are bad enough. Add to these a new system of government in which no precedents have been set and you discover a host of would-be precedent-setters. Communication delays and paper-shuffling have been the rule rather than the exception. One example from many: I wrote to the Secretary of Commerce on April 6 of this year, pointing out that recommendations by the New England Council concerning foreign permit applications apparently had been ignored. Fifty-five days later a reply was received in which the Council was mildly castigated for delay in responding to permit applications!

There are those in the Federal establishment who were against the whole council concept from the start. They appear to spend most of their time building paper roadblocks against normal progress. Slowly, very slowly, this noncooperative group is getting word from higher echelons that the tail is no longer wagging the dog. A few forced changes in personnel have occurred already, and there may be more before cooperation is complete. Those in some safe bureaucratic

Excerpts Public Law 94-265

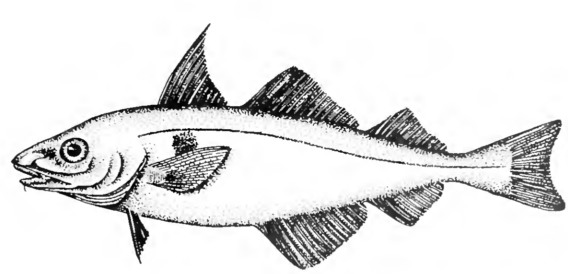
The term "conservation and management" refers to all of the rules, regulations, conditions, methods, and other measures (A) which are required to rebuild, restore, or maintain, and which are useful in rebuilding, restoring, or maintaining, any fishery resource and the marine environment; and (B) which are designed to assure that —

(i) a supply of food and other products may be taken, and that recreational benefits may be obtained, on a continuing basis;

(ii) irreversible or long-term adverse effects on fishery resources and the marine environment are avoided; and

(iii) there will be a multiplicity of options available with respect to future uses of these resources.

Excerpts continued



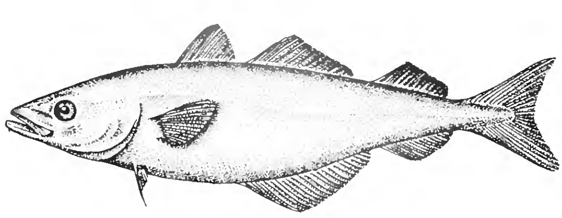
Haddock *(Melanogrammus aeglefinus)*

FOREIGN FISHING ALLOCATIONS FOR THE NORTHEAST COAST OF THE UNITED STATES 1977 (in metric tons)

COUNTRY	MACKEREL	SILVER HAKE	RED HAKE	LOLIGO (Shortfin Squid)	ILLEX (Longfin Squid)	BUTTER-FISH	HERRING	OTHER FINFISH	TOTAL
BULGARIA	4,000	1,570	0	0	400	0	100	2,000	8,070
CUBA	0	0	0	0	0	0	0	0	0
FRANCE	0	0	0	0	0	0	1,000	200	1,200
WEST GERMANY	1,100	0	0	500	0	0	4,725	200	6,525
EAST GERMANY	12,400	0	0	0	0	0	4,825	3,000	20,225
IRELAND	0	0	0	0	0	0	0	0	0
ITALY	300	0	0	1,640	980	400	0	900	4,220
JAPAN	0	0	0	7,820	3,440	3,300	0	7,000	21,560
NIGERIA	0	0	0	0	0	0	0	0	0
POLAND	20,200	0	0	850	4,910	0	5,100	6,200	37,260
ROMANIA	1,100	0	0	0	0	0	100	200	1,400
SOUTH KOREA	0	0	0	0	0	0	0	0	0
SPAIN	0	0	0	4,390	4,910	1,500	0	3,600	14,400
SOVIET UNION	22,800	72,150	30,080	1,000	7,370	0	3,400	31,100	167,900
TOTAL	61,900	73,720	30,080	16,200	22,010	5,200	19,250	54,400	282,760

positions apparently have ignored the fact that the Act is a mandate from the people through Congress. Council members do not hesitate to contact Congressmen when the red tape becomes too tangled. In years to come, it may well be that the NMFS will evolve into the working arm of the councils, and the councils will have budgetary and organizational control over it.

Finally, at least as far as the New England Council is concerned, members have taken far too long in deciding exactly what the aims should be in each fishery management plan. It is easy to refer questions to other organizations and individuals. When the replies simply raise more questions, it is evident that the Council must make some difficult decisions on its own. If aims were the same for each fishery stock, the task would be far easier. In fact, aims are often entirely different. What may apply to mackerel does not necessarily apply to scallops. Add to this the huge gaps in both scientific and economic knowledge concerning almost all marine species, and it is evident that the task of preparing management plans for the more than 25 fisheries off the New England coast will take years.



American pollock *(Pollachius virens)*

The Task for the Future

At present, news media have emphasized that some foreign governments are in the process of circumventing the primary purposes of management plans and of the Act itself. For example: South Korea has suggested the possibility of anchoring one of its fishing factory vessels inside the 200-mile limit and purchasing directly from American craft. Technically, this would be legal and the catch would be considered part of the United States quota of the species. If such a practice becomes common, denying a permit to the Korean vessels would provide a simple answer.

Other maneuvers are more complicated and consequently more difficult to solve. Purchase of a controlling interest in an American commercial fishing company would provide a foreigner fishes taken legally under domestic quotas, yet those fishes might be trans-shipped, processed, and consumed out of the country. They might even be processed and sold back to United States consumers at prices lower than those domestic interests could meet. Several bills are in the drafting stage at present to overcome this problem. The route of Executive Order is also being explored. I doubt that American industry, which has thrived on competition, will be unable to meet such a challenge, nor do I feel that such a problem will undermine the Act itself.

American trawler working in Maine waters. (Courtesy Maine Department of Marine Resources)

No one claims that the Act is perfect. Amendments to clarify certain sections, to cut red tape, to cover problems that were not anticipated until the councils became operational are already being submitted. Frankly, it is amazing that the Act has worked as well as it has to date. As noted, fishing by United States citizens has improved. At first, prices were high to commercial fishermen to satisfy the demands of a depleted market. The law of supply and demand took over. Cod, for example, sold dockside for 30 cents a pound when the Act first went into effect, but is now about half that figure. However, the total tonnage of fresh fish available to commercial and sport fishermen continues to be high. By the time the two industries gear up to take advantage of this temporary increase, hopefully sound management plans for heavily exploited species will be in effect so that the increase in stocks will be more permanent.

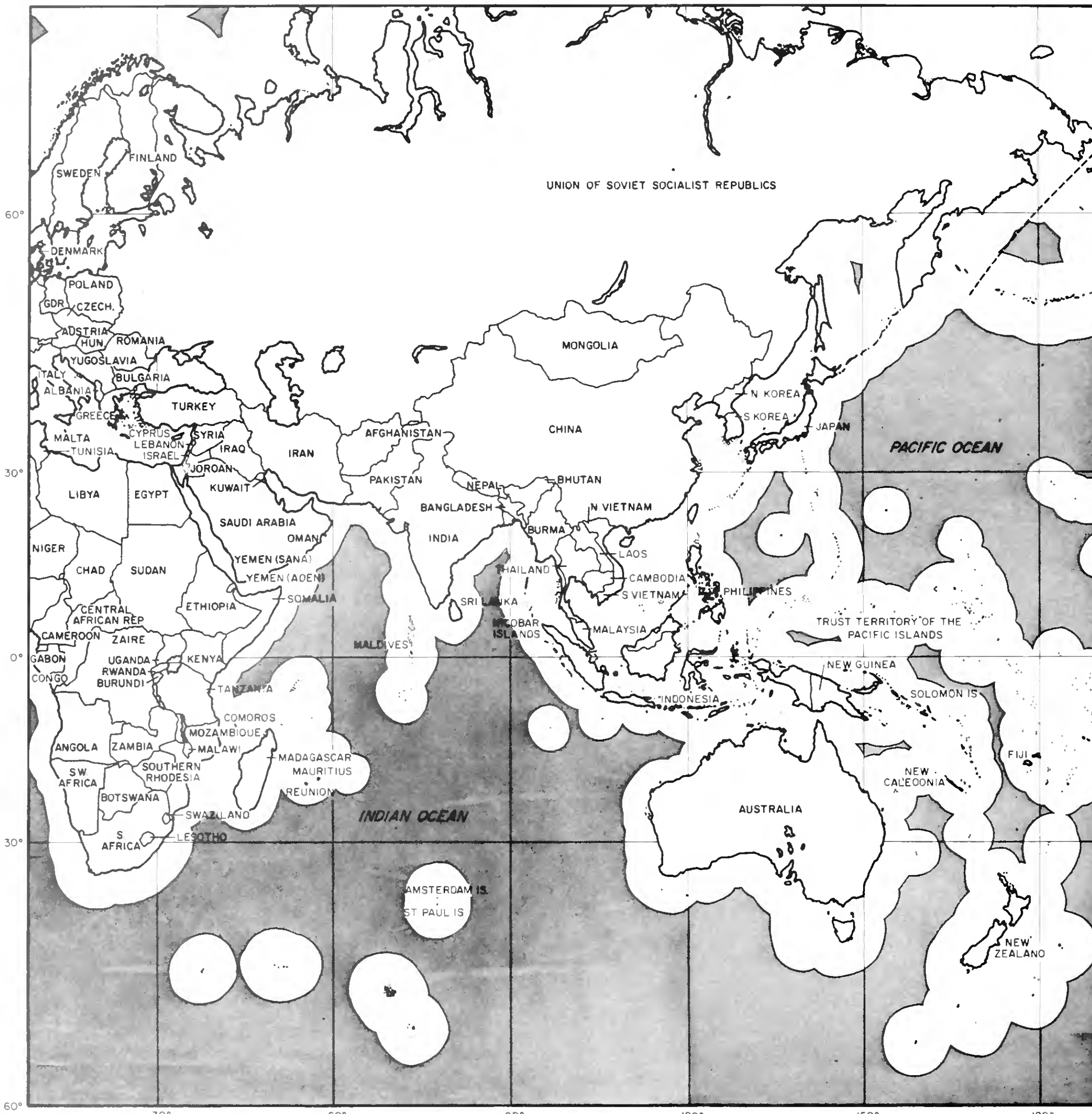
New England fishermen inspecting a mixed catch. (Courtesy National Marine Fishery Service, Woods Hole)

The task for the future, while formidable, is attainable. The Council is in harness and the road ahead, visible and predictable. Benefits should be attainable for all, ranging from the man casting a lure from a windswept beach to the housewife broiling a fillet. The alternative of returning to the biological and economic chaos of the past is too frightening to consider.

Henry Lyman is Chairman of the New England Regional Fishery Management Council. He also is President and Publisher of the Salt Water Sportsman, a monthly magazine on marine angling.

Drawings by Nancy Barnes, after Bigelow and Schroeder.

Global Effect of 200-Mile Claims



NATIONAL FISHING MARITIME CLAIMS

in Nautical Miles, as of May 1977
[TERRITORIAL SEA CLAIMS IN BRACKETS]
(200-MILE ECONOMIC ZONES IN PARENTHESES)

3 Miles — 9 Countries

Bahrain [3]
Barbados [3]
German Dem. Rep. [3]
Grenada [3]
Guyana [3]
Jordan [3]
Qatar [3]
Singapore [3]
United Arab Emirates [3]
(Sharjah-12)

6 Miles — 3 Countries

Greece [6]
Israel [6]
Lebanon [No Legislation]

12 Miles — 56 Countries

Algeria [12]
Australia [3]
Bahamas, The [3]
Belgium [3]
Bulgaria [12]
Cambodia [12]
China (PRC) [12]
China (ROC) [3]
Colombia [12]
Cyprus [12]
Egypt [12]
Equatorial Guinea [12]
Saudi Arabia [12]
Seychelles [3]
South Africa [6]
Spain [12]
Sudan [12]
Surinam [3]
Sweden [4]
Ethiopia [12]
Fiji [3]
Finland [4]
Honduras [12]
Indonesia [12]
Iraq [12]
Italy [12]
Ivory Coast [6]
Jamaica [12]
Kenya [12]
Korea, North [12]
Korea, South [3]
Syria [12]
Thailand [12]
Togo [12]
Trinidad & Tobago [12]
Tunisia [12]
Turkey [6 — 12 in Black Sea]
Venezuela [12]
Kuwait [12]
Libya [12]
Malaysia [12]
Mauritius [12]
Monaco [12]
Nauru [12]
Netherlands [3]
New Zealand [3]
Papua New Guinea [3]
Poland [3]
Romania [12]
Sao Tome & Principe [6]
Vietnam [12]
Western Samoa [12]
Yemen (Aden) [12]
Yemen (Sana) [12]
Yugoslavia [10]
Zaire [12]

15 Miles — 1 Country

Albania [15]

20 Miles — 1 Country

Malta [6]

Source: Office of Geographer, U.S. State Department

30 Miles — 3 Countries
Congo [30] Ghana [30] Nigeria [30]

36 Miles — 1 Country
Mauritania [30]

50 Miles — 6 Countries
Gambia, The [50] Iran [12] Madagascar [50] Oman [12] Tanzania [50] Cameroon [50]

70 Miles — 1 Country
Morocco [12]

100 Miles — 1 Country
Cape Verde [100]

130 Miles — 1 Country
Guinea [130]

150 Miles — 2 Countries
Gabon [100] Guinea-Bissau [150]

200 Miles — 41 Countries
Angola [20]
Argentina [200]
Bangladesh [12] (200)
Benin [200]
Brazil [200]
Burma [12] (200)
Canada [12]
Chile [3]
Comoros [12] (200)
Costa Rica [12]
Cuba [12] (200)
Denmark [3]
(Plus Greenland
and Faroes)
Dominican Republic [6] (200)
Ecuador [200]
El Salvador [200]
Germany, Fed. Rep. [3]
France [12]
Guatemala [12] (200)
Haiti [12] (200)
Iceland [4]
India [12] (200)
Ireland [3]
Japan [12]
Liberia [200]
Mexico [12] (200)
Mozambique [12] (200)
Nicaragua [3]
Norway [4]
Pakistan [12] (200)
Panama [200]
Peru [200]
Portugal [12] (200)
Senegal [150] (200)
Sierre Leone [200]
Somalia [200]
Soviet Union [12]
Sri Lanka [12] (200)
(Ukrainian SSR) [12]
United Kingdom [3]
(Br. Virgin Islands)
United States [3]
Uruguay [200]

The 200-Mile Limit II:

A U.S. observer and Japanese fisherman inspecting catch of pollock from Bering Sea. (Courtesy Northwest and Alaska Fisheries Center)

THE NORTH PACIFIC FISHERY MANAGEMENT COUNCIL

by Dayton L. Alverson

The North Pacific Fishery Management Council is unique in terms of its large geographic area of concern, and the magnitude and complexity of the fisheries for which it is responsible. The area under the jurisdiction of the Council extends from southeastern Alaska to the Arctic Ocean (Figure 1). Major fisheries are located throughout most of this area — off southeastern Alaska, throughout the Gulf of Alaska to Unimak Pass, westward along the Aleutian Islands, and throughout much of the eastern Bering Sea. It is the only Council that has an area of responsibility located entirely off one state. Nevertheless, the area of continental shelf involved is equal to or greater than that within the jurisdiction of the seven other Councils combined.

Major domestic fisheries within this area include: shrimp, scallop, crab (king, Tanner and Dungeness), herring, halibut, and salmon. The harvest by foreign fisheries within

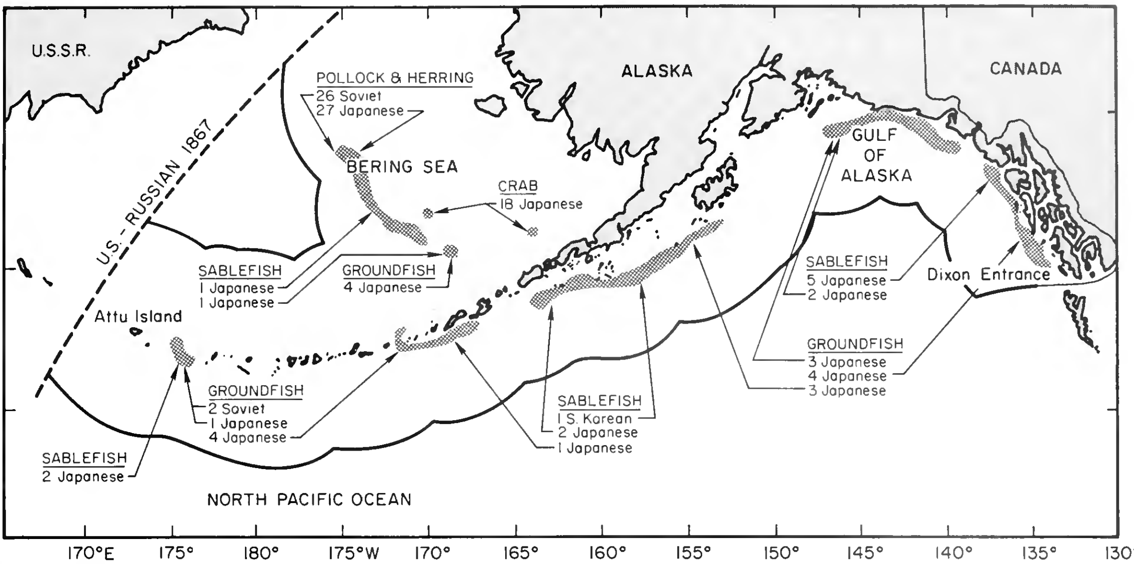


Figure 1: Waters seaward of the coast of Alaska over which the North Pacific Fishery Management Council has fisheries authority. (The waters of the northern Bering Sea or Arctic Ocean are not shown.) Also indicated is the foreign fishing off Alaska from April 1 to 22, 1977, by country, number of vessels, principal fishing grounds, and species fished. (Adapted from supplement to Alaska Seas and Coasts, *June 1977)*

the Council's area of jurisdiction historically has exceeded 2 million metric tons annually, or about two-thirds of the total foreign catch taken within 200 miles of the coast of the United States. There has been a very large trawl fishery for bottom fish in the Bering Sea and Gulf of Alaska by Japan, the Soviet Union, and South Korea; a longline fishery for black cod in the Bering Sea and Gulf of Alaska by Japan, South Korea, and China; a pot fishery for crab in the Bering Sea by Japan and in the past by the Soviet Union; a pot fishery for snails in the Bering Sea by Japan; and a fishery for a variety of other species by several countries.

The area under the jurisdiction of the Council is also noteworthy in that there are still a number of latent resources that have not been significantly exploited despite the large-scale foreign and domestic fisheries. For example, large populations of squid and capelin are known to occur off Alaska, as well as populations of sub-tidal clams on the extensive continental shelf of the eastern Bering Sea. These and other latent resources offer potential for future fisheries, as well as conflicts.

Structure of the Council

The North Pacific Council held its first meeting in Juneau, Alaska, on October 5 through 8, 1976. Like many of the seven other councils, the first sessions were largely devoted to organizational matters that had to be completed before the real work could begin. The Council has an Executive Director, who is responsible for coordinating meetings and insuring that the proper scientific and technical documentation is prepared in support of Council decisions. The current operational structure of the Council is shown in Figure 2.

The Council provides general guidelines and operational terms of reference for its Executive Director, who in turn provides guidance and coordination for management teams selected by the Council to prepare fishery management plans. These teams, which may be conceived of as the bodies responsible for the main thrust of the Council (developing regulatory programs for the various fisheries under its jurisdiction) are recommended by the Scientific and Statistical Committee (SSC) of the Council. For example, the Council identifies management units (fisheries or fisheries complexes) that it wishes to prepare management plans for. The Council then sets its management objectives. The Scientific and Statistical Committee subsequently selects the composition of the management teams, along with technical

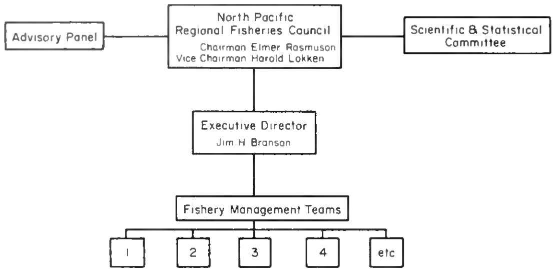


Figure 2: The operational structure of the North Pacific Regional Fisheries Council.

advisors, and submits the recommendations to the Council. To insure user group input during the preparation of the plans, key members of the industry advisory group are nominated to work with the management team during this time.

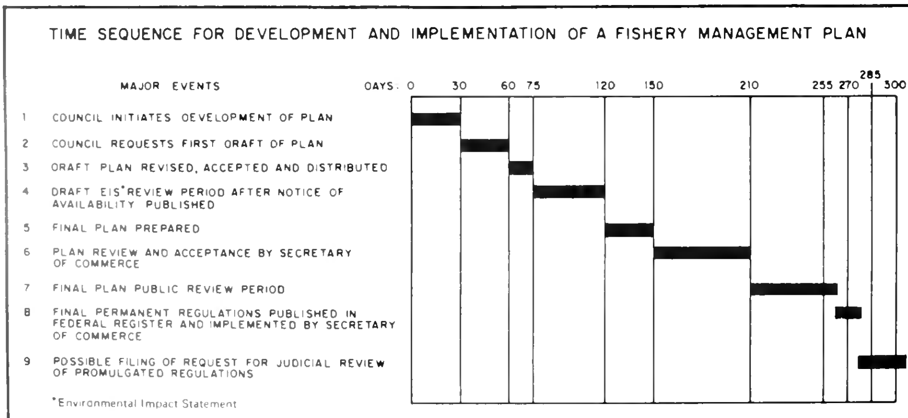
When the plan has been completed, it is submitted to the Council by the Executive Secretary of the team. The Council then submits the plan to its two advisory bodies — the SSC and its user advisory group. This interaction provides the management team with the final in-Council critique. The plan is subsequently modified and either accepted or rejected by the Council.

The industry advisory body of the North Pacific Council is comprised of twenty-five members, representing diverse fishery user groups. Both the industry advisory body and the SSC can meet between Council meetings or concurrent with the Council's official sessions. The SSC is comprised of ten members; three are members of academia, one a federal employee, and six scientists from state conservation agencies. To date, the SSC of the North Pacific Council has been extensively used to provide a scientific overview of the various technical documents received by the Council, and to assist the Council in initiating the preparation of management plans.

Development of Management Plans

Because of the many domestic and foreign fisheries under the jurisdiction of the North Pacific Council, there has been feverish activity within the Council, as well as by supporting state and federal agencies, to prepare fishery management plans. At least ten plans are now being drafted by the Council. These include managing the large trawl fishery in the Bering Sea and Gulf of Alaska, the king crab and Tanner crab fisheries of both the Gulf of Alaska and Bering Sea, the shrimp and scallop fishery of the Gulf of Alaska, the clam fishery of the Bering Sea, and troll salmon and high-seas salmon fisheries.

The Council faces the difficult task of managing salmon fisheries which, in the case of Japan's high-seas mothership fishery, operate on stocks of both Asian and North American origin within 200 miles of the U.S. coast. Any plan that allows a substantial number of salmon to be intercepted by Japan's high-seas fishery would be in opposition to the initial concept of the extended jurisdiction act, which states that where the United States has the capacity to fully utilize its resources, no surplus can be allotted to other nations. However, to deny Japan access to salmon of Asian origin within 200 miles of the United States could result in the fishery shifting to other areas beyond 200 miles where salmon of North American origin might be even more vulnerable to high-seas fishing. Hence, there



Excerpts Public Law 94-265

National Standards for Fishery Conservation and Management

In General. —Any fishery management plan prepared, and any regulation promulgated to implement any such plan, pursuant to this title shall be consistent with the following national standards for fishery conservation and management;

(1) Conservation and management measures shall prevent overfishing while achieving, on a continuing basis, the optimum yield from each fishery.

(2) Conservation and management measures shall be based upon the best scientific information available.

(3) To the extent practicable, an individual stock of fish shall be managed as a unit throughout its range, and interrelated stocks of fish shall be managed as a unit or in close coordination.

(4)Conservation and management measures shall not discriminate between residents of different States. If it becomes necessary to allocate or assign fishing privileges among various United States fishermen, such allocation shall be (A) fair and equitable to all such fishermen; (B) reasonably calculated to promote conservation; and (C) carried out in such manner that no particular individual, corporation, or other entity acquires an excessive share of such privileges.

(5) Conservation and management measures shall, where practicable, promote efficiency in the utilization of fishery resources; except that no such measure shall have economic allocation as its sole purpose.

(6) Conservation and management measures shall take into account and allow for variations among, and contingencies in, fisheries, fishery resources, and catches.

(7) Conservation and management measures shall, where practicable, minimize costs and avoid unnecessary duplication.

Excerpts continued

is need to develop a management regime to control the existing high-seas fishery by Japan in a way that would minimize the interception of stocks of interest to the United States.

So far, the Council has given highest priority to plans for the trawl fishery and the Tanner crab fishery. This is because the trawl fishery represents the largest foreign fishing activity off Alaska, and because there is extensive interaction and conflicts among the various exploiters of the crab resources. The schedule calls for completion of the plans in the summer of 1977, with their subsequent submission to the Secretary of Commerce.

Those responsible for developing the plans are having considerable difficulty in accomplishing the task. State and federal personnel working on the plans have found themselves spread very thin, particularly in developing required socio-economic information. Nevertheless, the Council has made good progress. It has developed and accepted a standard outline for plan development that has been adopted in part by two other Councils; it has established a set of operational definitions; and it is well along in developing plans for the trawl and Tanner crab fisheries. Plans for several other fisheries have begun, with working groups beginning to investigate trans-boundary species problems. They will recommend institutional arrangements for dealing with these problems.

Special Problems

The North Pacific Council is comprised of individuals from the states of Alaska, Oregon, and Washington. It is, nevertheless, dominated by individuals with Alaskan interests. This introduces the possibility of a parochial interest in decision making. The Council will have to guard against designing its plans in such a way as to provide special protection or opportunities for Alaskan fishermen vis-à-vis those from other states (for example, Oregon and Washington). Although the Council is comprised of very competent individuals, there remains the possibility of polarization between the southern and northern groups, and hence internal conflict. There has been a tendency at past sessions to split on an issue along regional lines rather than on the substance of the matter.

Alaska is a major target area for large-scale foreign ventures, both in terms of investment in Alaskan-based processing companies and attempts to buy catches from U.S. fishermen at sea for processing aboard foreign factoryships. Whether the latter kind of venture will be permitted is a major policy issue of national concern. There are many who think that U.S. fishermen should be allowed, at least for an interim period until better domestic fish processing facilities become available ashore, to deliver catches to foreign processing vessels at sea. At present, however, the North Pacific Council has recommended against permitting a large-scale Korean purchase of pollock from U.S. catcher vessels.

Because of the large fishery resources within the Council's jurisdiction, many of which are not yet exploited by domestic fishermen, one can expect foreign fishing to continue off Alaska. Although it may be reduced from that which occurred preceding the 200-mile legislation, it will nevertheless be

FOREIGN FISHING ALLOCATION OFF ALASKA BY COUNTRY

(1,000's metric tons)

1977

SPECIES/AREA	JAPAN	USSR	ROK	TAIWAN	POLAND	TOTAL ASSIGNED	UNASSIGNED	TOTAL FOREIGN ALLOCATION	U.S. CAPACITY	TAC
POLLOCK:										
Bering Sea/Aleutians	792.3	112.7	40.0	5.0	0	950.0	0	950.0	0	950.0
Gulf of Alaska	44.1	63.1	35.8	0	6.0	149.0	0	149.0	1.0	150.0
SABLEFISH:										
Bering Sea	3.6*	0.6†	0.4*	0.2†	0	4.8	0.2	5.0	0	5.0
Aleutians	2.0*	0.2+	0.2*	0	0	2.4	0	2.4	0	2.4
Gulf-Southeast**	3.75	0	0	0	0	3.75**	0	3.75**	2.2	22.0††
Gulf-Central & Western**	10.15	0	1.6	0	0	11.75**	0	11.75**	0.3	
PACIFIC COD:										
Bering Sea/Aleutians	38.1	17.2	0	0	0	55.3	2.7	58.0	0	58.0
Gulf of Alaska	1.6	0.6	0	0	0.1	2.3	0	2.3	4.0	6.3
YELLOWFIN SOLE:										
Bering Sea/Aleutians	62.1	40.8	0	0	0	102.9	3.1	106.0	0	106.0
OTHER FLOUNDERS:										
Bering Sea/Aleutians	61.5	40.4	0	0	0	101.9	3.1	105.0	0	105.0
FLOUNDERS:										
Gulf of Alaska	18.7	1.8	0	0	0	20.5	0	20.5	3.0	23.5
HERRING:										
Bering Sea/Aleutians	5.8	13.6	0	0	0	19.4	0.6	20.0	1.0	21.0
PACIFIC OCEAN PERCH:										
Bering Sea	2.8	3.5	0	0	0	6.3	0.2	6.5	0	6.5
Aleutians	6.5	8.1	0	0	0	14.6	0.4	15.0	0	15.0
Gulf of Alaska	19.8	8.7	0.5	0	0	29.0	0	29.0	1.0	30.0
OTHER ROCKFISH:										
Gulf of Alaska	2.7	1.2	0.1	0	0	4.0	0	4.0	1.0	5.0
SQUID:										
Bering Sea/Aleutians	10.0	0	0	0	0	10.0	0	10.0	0	10.0
ATKA MACKEREL:										
Gulf of Alaska	0	21.0	0	0	1.0	22.0	0	22.0	0	22.0
OTHER GROUNDFISH:										
Bering Sea	40.4	17.4	1.6	0.2	0	59.6	0	59.6	0	59.6
Aleutians	23.1	9.9	0.89	0.11	0	34.0	0	34.0	0	34.0
Gulf of Alaska	4.2	11.8	0.1	0	0.1	16.2	0	16.2	0	16.2
TANNER CRAB:										
Bering Sea	12.5	0	0	0	0	12.5	0	12.5	22.7	35.2
SNAILS:										
Bering Sea/Aleutians	2.7	0	0	0	0	2.7	0.3	3.0	0	3.0
TOTALS:										
Bering Sea/Aleutians	1,063.4	264.4	43.09	5.51	0	1,376.4	10.6	1,387.0	23.7	1,410.7
Gulf of Alaska	105.0	108.2	38.1	0	7.2	258.5	0	258.5	12.5	275.0
Grand Total	1,168.4	372.6	81.19	5.51	7.2	1,634.9	10.6	1,645.5**	36.2	1,685.7††

* Includes incidental trawal catch
† Incidental catch only
** Does not include 4,000 metric ton allowable incidental trawl sablefish catch in Gulf of Alaska
†† Includes 4,000 metric ton allowable incidental trawl sablefish catch in Gulf of Alaska

Prepared by NMFS, Alaska Region, March 3, 1977 substantial and a source of irritation to Alaskan fishermen. There will be attempts, of course, to find mechanisms to reduce foreign fishing activities, and it will be the Council's responsibility to insure that the intent of the law is not circumvented.

As with many Councils, the overall objectives of optimum yield (OY) are not understood very well, and this confusion was evident at a meeting early this summer of all the councils in Houston, Texas. A panel examining the concept of OY, representing members from the various SSCs, did a great deal to crystallize a common perspective on OY. There was, nevertheless, a general view that the concept reflected a strategy designed to insure that a holistic approach is taken in the development of plans to manage living resources and the people who use or enjoy them.

The North Pacific Council has accepted the fact that, in establishing OY, a variety of factors (sociological, ecological, economic), in addition to the status of a fishery, must be taken into account in establishing the regulatory regime. At the present, the mechanism and nature of quantifying certain parameters associated with OY are somewhat nebulous, at least at the Council level, and leave the budding OY embryo without shape or dimension. In the end, many feel that politics at the Council level are likely to play a major role in influencing the objectives and goals for a particular fishery, which ultimately may lead to a metamorphosis of the OY embryo into a more reasonable creature. Paraphrasing Peter Larkin, a scientist at the University of British Columbia: "We may have given birth to Heaven or Hell, but which remains to be seen."

A Look Ahead

The North Pacific Council is fortunate to have good scientific talent and technical support from state and federal personnel, who have extensive experience in both national and international fishery management activities. The Council's membership is rich in fisheries experience, and its advisory bodies take a strong interest. The area under the Council's jurisdiction is extensive and there are a number of major domestic and foreign fisheries that must be brought under management. The Council, however, has the potential for internal conflict that could diminish its effectiveness, particularly if its members polarize along regional lines. To date, however, the Council appears to be making reasonable progress in the development of its management plans, and in the sorting out of its problems. If Council members can direct their attention to resolution of the substantive issues and attempt to cleave away from parochial interests, its chances for successful management are good.

Dayton L. Alverson is Director of the Northwest and Alaska Fisheries Center, NMFS, Seattle, Washington.

Excerpts Public Law 94-265

Contents of Fishery Management Plans

REQUIRED PROVISIONS. —Any fishery management plan which is prepared by any Council, or by the Secretary, with respect to any fishery, shall –

(1) contain the conservation and management measures, applicable to foreign fishing and fishing by vessels of the United States, which are necessary and appropriate for the conservation and management of the fishery . . . . and consistent with the national standards, the other provisions of this Act, and any other applicable law;

(2) contain a description of the fishery, including, but not limited to, the number of vessels involved, the type and quantity of fishing gear used, the species of fish involved and their location, the cost likely to be incurred in management, actual and potential revenues from the fishery, any recreational interests in the fishery, and the nature and extent of foreign fishing and Indian treaty fishing rights, if any;

(3) assess and specify the present and probable future condition of, and the maximum sustainable yield and optimum yield from, the fishery, and include a summary of the information utilized in making such specification;

(4) assess and specify —

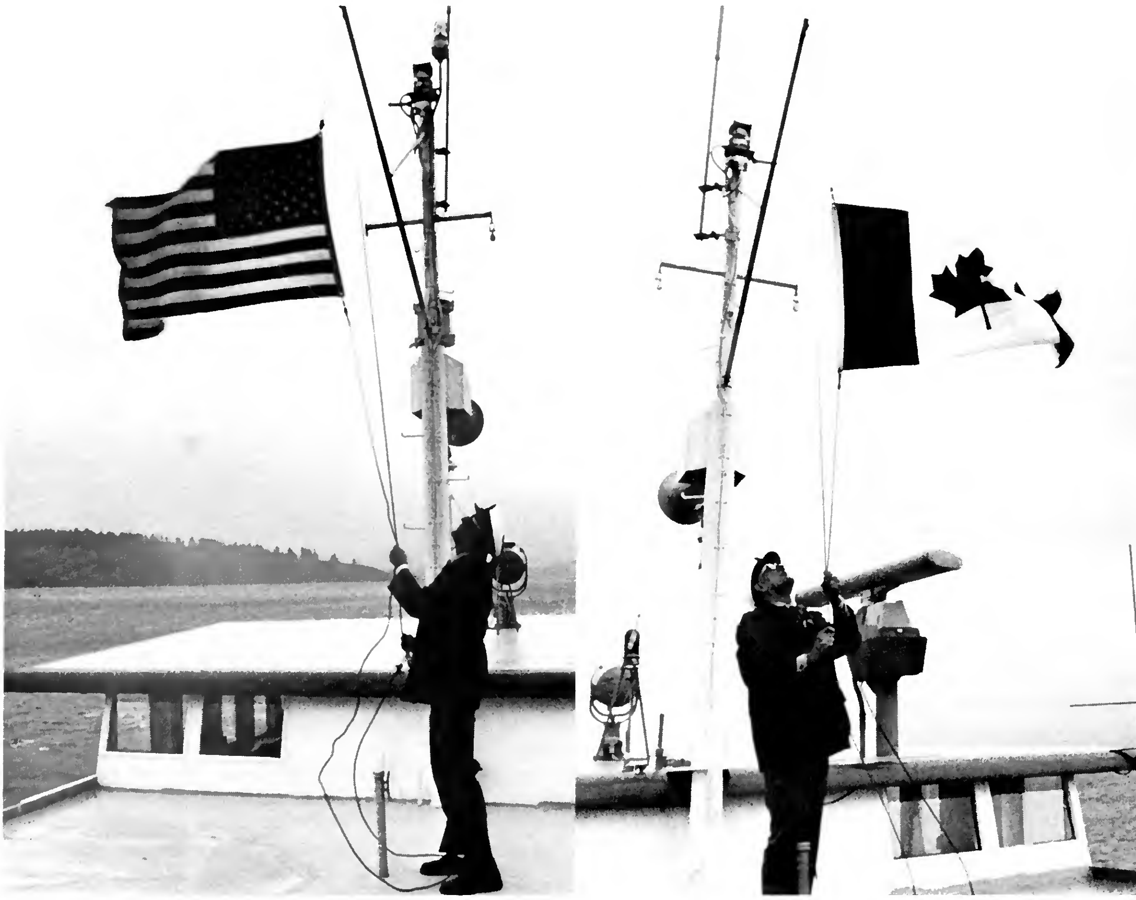
(A) the capacity and the extent to which fishing vessels of the United States, on an annual basis, will harvest the optimum yield specified under paragraph (3), and

(B) the portion of such optimum yield which, on an annual basis, will not be harvested by fishing vessels of the United States and can be made available for foreign fishing; and

(5) specify the pertinent data which shall be submitted to the Secretary with respect to the fishery, including, but not limited to, information regarding the type and quantity of fishing gear used, catch by species in numbers of fish or weight thereof, areas in which fishing was engaged in, time of fishing, and number of hauls.

Excerpts continued

The 200-Mile Limit III:



Changing flags in the Strait of Juan de Fuca. Sailor on the ferry between Anacortes, Washington, and Sidney, British Columbia, raises and lowers flags whenever the ship crosses the international border. (Courtesy Between Friends/Entre Amis, National Film Board of Canada)

Maritime Problems Between the U.S. and Canada

by Lewis Alexander and Virgil Norton

The recent extensions of fisheries control zones by the United States and Canada out to 200 nautical miles from the coast have served to intensify some of the differences in marine policy between the two countries. Canada, partly because of the sensitivities of its Arctic environment, tended in the past to be more "protectionist" of its offshore areas than the United States. Canada's subsidization programs for its domestic fishing industry have no U.S. counterparts. Further, the United States and Canada have long-standing disagreements about their common maritime boundaries — differences that have been exacerbated by the extensions of jurisdiction to 200 miles offshore.

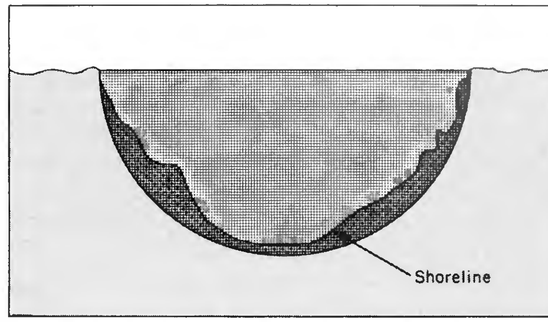
Jurisdictional Limits

Assertions of authority over internal and territorial waters differ between the two countries. The United States claims a territorial sea of 3 nautical miles, while Canada's claim is

12 miles. The U.S. measures its territorial sea from the low-water line along the coast, and from the closing line of "juridical" bays, providing such lines do not exceed 24 miles in length (Figure 1). The U.S. does not employ straight baseline regimes along rugged or island-fringed coasts.

Canada's territorial sea is measured from the low-water line, and in part from straight baselines joining the outermost points along irregular coasts. In addition, Canada closed off the waters of Hudson Bay as "historic" (and therefore, internal), and constructed a series of fisheries "closing lines" across coastal water bodies, such as the Bay of Fundy, the Gulf of St. Lawrence, and Queen Charlotte Sound. The enclosed water bodies are not claimed as historic, but within them Canada enjoys exclusive fishing rights subject only to treaty obligations with the United States, France, and other countries.

Both countries have ratified the 1958 Convention on the Continental Shelf, which defines the shelf as extending "to a depth of 200 meters or beyond that limit to where the depth of the superjacent waters admits of the exploitation of the natural resources." Based on this "exploitability" criterion, both Canada and the United States could extend their jurisdiction over seabed and subsoil resources down the continental slope and out onto the rise, when technology permits. But presently, this criterion has been superseded by the desire of both governments to extend jurisdiction to the "outer edge" of the continental margin.



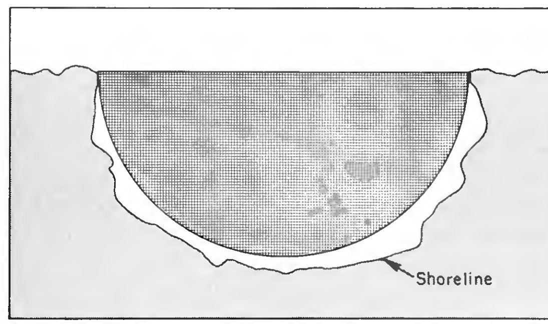


Figure 1. The "Semicircle" Rules for Bays. Top: water areas of bay less than area of semicircle; baseline follows low-water mark of the coast. Bottom: water area of bay greater than area of semicircle; baseline follows the closing line. Closing line must be less than 24 miles in length.

Maritime Boundaries

The offshore areas of the two countries are contiguous to one another in four places: the Gulf of Maine; the Strait of Juan de Fuca, between the state of Washington and British Columbia; Dixon Entrance, between British Columbia and Alaska; and the Arctic slope. At the moment, the most controversial is the boundary in the Gulf of Maine.

The Gulf of Maine is a semicircular-shaped water body bounded on the northeast by the Canadian provinces of Nova Scotia and New Brunswick, as well as by the Bay of Fundy, and on the north and west by the states of Maine, New Hampshire, and Massachusetts. The distance across the entrance from Cape Cod to Cape Sable Island is approximately 300 nautical miles. In terms of the lengths of the United States and Canadian coastlines bordering the Gulf of Maine area, the ratio is approximately 4 to 1 in favor of the United States, if the measurement is taken following the general direction of the coastline. This calculation does not include the coastline of the Bay of Fundy, whose waters are considered by the Canadian government to be internal for fisheries purposes. Extending east-northeast from the Cape Cod coast is Georges Bank, a shallow subsurface feature, less than 180 meters in depth. It stretches more than halfway across the entrance to the Gulf of Maine before it is terminated by the Northeast Channel, separating Georges from Browns Bank and Nova Scotia. The Channel is a U-shaped depression with depths of up to 360 meters.

The maritime boundary in the Gulf of Maine area has been delimited by international agreement only in its northernmost part. Starting at the mouth of the St. Croix River, separating Maine from New Brunswick, the agreed boundary trends southeast through Passamaquoddy Bay and then southwest for a short distance between Grand Manan Island and the coast of Maine. Beyond this, its position has yet to be settled. Two basic points are involved. First, should the maritime boundary south of Grand Manan Channel follow an equidistant line measured from appropriate basepoints along the coasts of the two countries, or some other line that is based on the existence of "equitable principles?" Second, regardless of the delimitation method used, there is an unresolved problem concerning which of the two countries has sovereignty over Machias Seal Island and its associated North Rock, located off the coast of northeastern Maine.

The Machias Seal Island controversy is a long and complicated one. If the United States owns the island, the equidistant line boundary would pass to the east, separating Machias Seal from Canada's Grand Manan Island. But if Machias Seal Island belongs to Canada, the maritime boundary would pass between the island and the coast of Maine. The area between the alternative boundary lines is approximately 450 square nautical miles, and constitutes an important fishing ground. There is no indication of an early resolution of the Machias Seal Island dispute.

South of Machias Seal Island, the choice of boundary delimitation methods is important. The Canadians favor a strict, equidistant line through the Gulf of Maine, trending generally south to the area of Georges Bank, and then south-southeast, cutting across the northeastern portion of the Bank (Map 1). The United States, basing its case on equitable principles, contends that the maritime boundary should follow the Northeast Channel between Georges and Browns Banks. In the central portion of the Gulf of Maine, between Georges Bank and Machias Seal Island, the choice of a mid-channel line would mean that the international boundary lies somewhat to the west of the equidistant line. But in exchange for losing up to 1,400 square nautical miles in the central part of the Gulf through choosing the mid-channel over the equidistant line, the United States would gain some 5,500 square nautical miles in the Georges Bank area, including the northeastern portion of the Bank with its fisheries and potential hydrocarbon resources. The U.S. also would gain a considerable area of the outer continental margin seaward of Georges Bank.

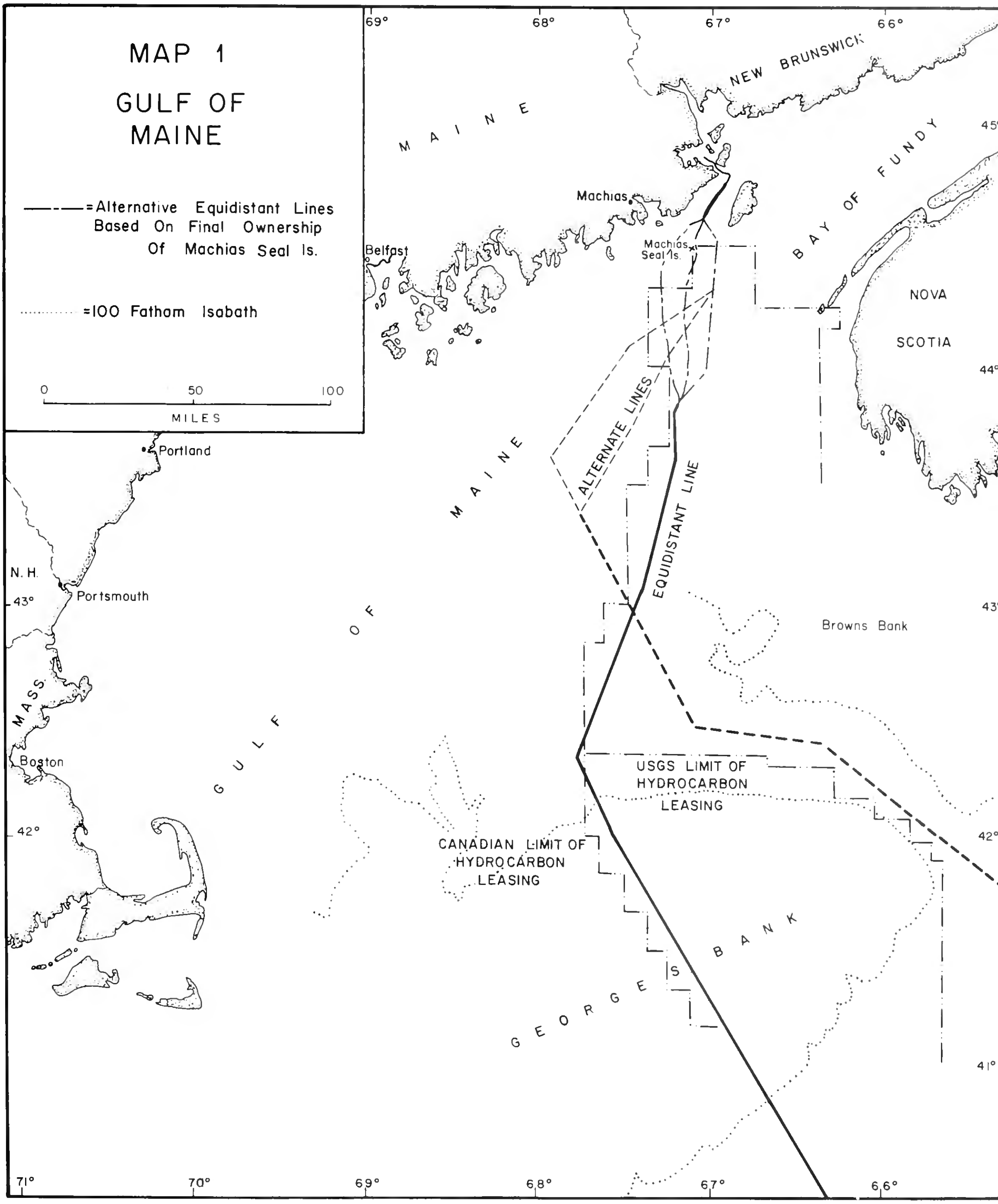
What are the special circumstances on which the United States bases its claim? One is that Georges Bank is a "natural prolongation" of the United States, extending out to the Northeast Channel. The International Court of Justice in the 1969 North Sea Continental Shelf Cases, noted that offshore boundary delimitations between countries should be effected in such a way "as to leave as much as possible to each Party all those parts of the continental shelf that constitute a natural prolongation of its land territory into and under the sea . . ."

A second U.S. contention is that the United States' coastline on the Gulf of Maine is largely concave in shape. As the International Court found in its 1969 decision, it is inequitable to draw equidistant lines seaward from such a coast since they tend to converge at a point offshore, rather than to parallel one another.

A third circumstance relates to the proportionality between the extent of the continental shelves of the states concerned and the length of their coastlines. If the length of the U.S. coastline on the Gulf of Maine is four times that of Canada's, and if, as the International Court found, there should be "a reasonable degree of proportionality . . . between the extent of the continental shelf appertaining to the States concerned and the lengths of their respective coastlines" then the United States' combined share of the Georges Bank/Browns Bank areas should be considerably greater than Canada's.

Finally, the Court noted that in the boundary delimitation process, consideration should be given to the unity of deposits existing in a boundary area. Very little is known of the hydrocarbon potential on the northeastern part of Georges Bank, but an analogy may exist between delimitation of the shelf itself and of the superjacent waters — in which case consideration should be given to the unity of living resources. A majority of the fish stocks on Georges Bank are associated with the Virginia faunal grouping, while those of the Browns Bank are associated with the Boreal faunal grouping. As long as it is necessary to draw any boundary, rational fishery management would suggest the Northeast Channel.

Canada has rebuttals to all of the U.S. arguments. Basically, the Canadians claim that



there are insufficient reasons for deviating from the equidistant-line method of boundary delimitation. At this time, there seems to be little prospect of a prompt resolution of the Georges Bank boundary controversy.

In October 1976, the Canadian government published an *Order in Council* specifying the geographic coordinates of the turning points of what it considers to be the boundary in the Gulf of Maine. The United

Canada's View of the Gulf of Maine/Georges Bank Boundary Line

U.S. Position

The United States has taken the position that the rule laid down in the 1958 Geneva Continental Shelf Convention must be interpreted in the light of the 1969 decision of the International Court of Justice in the North Sea Continental Shelf Cases. The United States maintains that a maritime boundary in the Gulf of Maine area should reflect "special circumstances" which it alleges exist in the area and, specifically, that a maritime boundary in accordance with "equitable principles" should allocate all of Georges Bank to the United States. In the view of the United States, the concavity of the New England coastline and the convexity of the Nova Scotian coastline causes an equidistant line to be "pulled" toward the United States coastline, thereby creating a boundary that is not in accordance with "equitable principles." Also, the United States believes that the geological, geomorphological, and ecological nature of Georges Bank indicates that it is physically and legally the "natural prolongation" of the United States and that a boundary in accordance with "equitable principles" should reflect this alleged fact. An important point of the United States argument is that the proportional relationship between the lengths of the relevant coastlines should be reflected in the area to be delimited.

Canadian Position

The Government of Canada is of the view that, as both Canada and the USA are parties to the 1958 Geneva Convention on the Continental Shelf, they are bound to settle their continental shelf boundaries in accordance with the Conventional regime and, in particular, with the equidistance-special circumstances rule set out in Article 6. Since it does not believe that any "special circumstances" exist in the Gulf of Maine/Georges Bank area, it holds that the boundary should be determined by the application of the equidistance principle.

Canada does not accept that the regime of customary international law, as defined and applied by the International Court of Justice between states not bound by the Continental Shelf Convention, is applicable to the determination of continental shelf boundaries between Canada and the USA. Moreover, it does not accept the factors identified by the International Court of Justice as being legally relevant to the delimitation of the continental shelf boundary in the North Sea Cases are present in the Gulf of Maine area. In particular, it does not believe that the geology, geomorphology, and ecology of the area show that Georges Bank is the "natural prolongation" of the USA. It believes that models based on a proportional relationship between the length of coastlines and the area to be delimited can be constructed according to varying criteria and can be used to support the positions of both governments. It maintains that the coastline of Nova Scotia must be accorded due weight in the delimitation of maritime boundaries and that the concavity of the coast in that area is amply compensated by the peninsula and islands protruding seaward of Massachusetts in the area of Cape Cod. Thus, even if the regime of customary international law based on "equitable principles" as defined by the International Court of Justice were applicable in the Gulf of Maine area — a proposition which the Government of Canada does not accept — Canada is of the view that the most equitable means of determining the boundary would be through the application of the principle of equidistance.

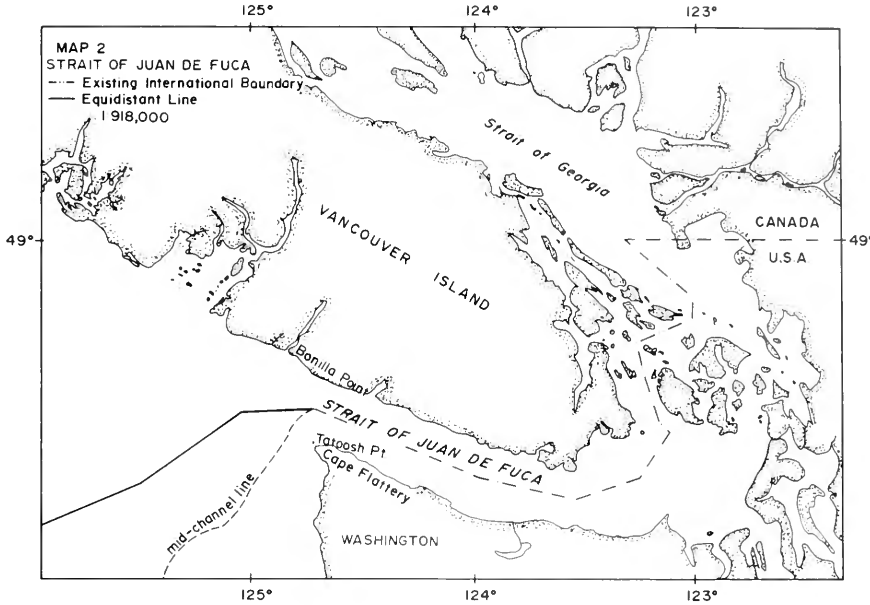
Canadian officials are of the view that Canada's legal position is strengthened by the fact that it has exercised jurisdiction over the continental shelf through the issue of oil and gas permits up to the line of equidistance dating from 1964. In 1965, there was an exchange of letters between Canadian and USA officials in which a USA official, in effect, indicated tacit agreement to the equidistance line as the continental shelf boundary between the two countries. Although the USA government was aware of the Canadian permits, it did not formally indicate its dissent until 1969.

Department of External Affairs,
Ottawa, Ontario, Canada
June 10, 1977

States government promptly responded by publishing a description of the U.S. version of the boundary line in its *Federal Register.* For the time being, the two countries have developed a reciprocal agreement for fisheries in the disputed portion of Georges Bank, while delaying offshore oil and gas exploration until some temporary procedures for development can be agreed on.

Other maritime boundary concerns between the United States and Canada are less complex. In the Strait of Juan de Fuca, a boundary has been established that goes through the middle of the channel west to a location between Tatoosh Point, Washington, and Bonilla Point, Vancouver Island (Map 2). From here an equidistant-line boundary, proposed by the United States, would trend west and southwest into the Pacific Ocean, while a line following the midpoint of Juan de Fuca Channel would lie considerably closer to the coast of the United States.

With respect to Dixon Entrance, a problem exists because the wording of the 1903 award of the Alaska Boundary Tribunal leaves it unclear as to whether or not a

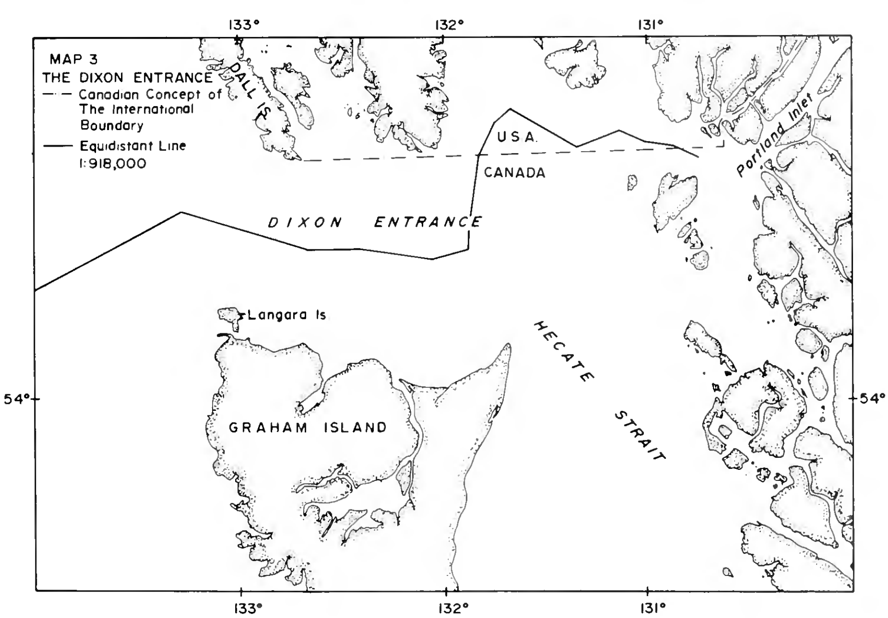


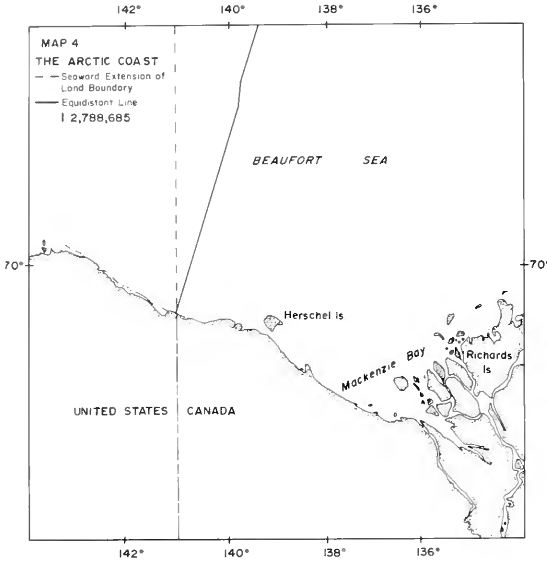
territorial sea exists in the southernmost part of Alaska's Dall Island (Map 3). In one interpretation, the waters of Dixon Entrance are Canadian, behind a closing line from Dall Island south-southwest to Langara Island, British Columbia. The United States views it as an equidistant line from the mouth of Portland Inlet, passing westward through Dixon Entrance. If this were the case, Alaska would have territorial and exclusive fisheries zones in Dixon Entrance, yet there would be a corridor of high seas through the Entrance. In this instance, the equidistant line through Dixon Entrance would be very close to a mid-channel line.

The other maritime boundary in dispute — the Arctic Ocean — concerns the fact that in 1825 the eastern boundary of Alaska was fixed at the 141st meridian. North of the intersection point of this line with the Arctic coast, the maritime boundary might be drawn as continuing along this meridian, as shown on Map 4. But if the offshore boundary is interpreted as following the equidistant line, it would trend to the east of the meridian and, since more offshore area would be included, would be of advantage to the United States.

Competence Claims in Offshore Areas

The United States and Canada adhere to traditional international practice with respect to assertions of authority in internal and territorial waters. As noted earlier, Canada claims Hudson Bay as a historic bay and has asserted exclusive fishing rights in other coastal areas, such as the Gulf of St. Lawrence and Queen Charlotte Sound. The enactment of the 200-mile zone legislation has made





Canadian claims to competence become most complex in Arctic waters. Both the United States and Canada regard the Arctic waters beyond territorial limits as high seas, but within this context the Canadians have three caveats. The first is their asserted right to regulate shipping in the interest of pollution control within 100 miles of the coast. The second is their insistence that the narrow waterways of the "Northwest Passage," such as Barrow, McClure, and Prince of Wales Straits, do not have the status of "straits used for international navigation," and thus there

such fisheries claims superfluous because all such water bodies are encompassed within the 200-mile zone.

The United States and Canada both claim exclusive fisheries management and conservation rights in their respective 200-mile zones. The Canadians also have indicated an interest in securing preferential fishing rights in certain areas beyond 200 miles, particularly in the important commercial fishing grounds of the Flemish Cap, which is more than 300 miles east of Newfoundland. In the future, Canada also may claim fisheries jurisdiction over the Grand Banks, more than 200 miles from shore to the south of Newfoundland.

In June 1970, Canada enacted the Arctic Waters Pollution Prevention Act, asserting its right to regulate all shipping in zones up to 100 nautical miles off the Arctic coast. At the time of the enactment, the United States strongly protested the legislation on the ground that it constituted undue interference with freedom of the high seas. Thirteen months later an amendment to the Canada Shipping Act extended the provisions of the 1970 Act to Canadian waters south of the 60th parallel, but the provisions of the 1971 legislation as yet have not been implemented. Canadian spokesmen have repeatedly stressed their government's interest both in extending national pollution control regulations throughout the 200-mile zone, and in restricting foreign oceanographic research activities within the 200-mile zone if such research is being conducted primarily for economic or military purposes. The United States does not support either of these Canadian suggestions.

Excerpts Public Law 94-265

International Fishery Agreements

Treaty Renegotiation.—The Secretary of State, in cooperation with the Secretary, shall initiate, promptly after the date of enactment of this Act, the renegotiation of any treaty which pertains to fishing within the fishery conservation zone (or within the area that will constitute such zone after February 28, 1977), or for anadromous species or Continental Shelf fishery resources beyond such zone or area, and which is in any manner inconsistent with the purposes, policy, or provisions of this Act, in order to conform such treaty to such purposes, policy, and provisions. It is the sense of Congress that the United States shall withdraw from any such treaty, in accordance with its provisions, if such treaty is not so renegotiated within a reasonable period of time after such date of enactment.

International Fishery Agreements.—No international fishery agreement (other than a treaty) which pertains to foreign fishing within the fishery conservation zone (or within the area that will constitute such zone after February 28, 1977), or for anadromous species or Continental Shelf fishery resources beyond such zone or area—

(1) which is in effect on June 1, 1976, may thereafter be renewed, extended, or amended; or

(2) may be entered into after May 31, 1976. . . .

Boundary Negotiations.—The Secretary of State, in cooperation with the Secretary, may initiate and conduct negotiations with any adjacent or opposite foreign nation to establish the boundaries of the fishery conservation zone of the United States in relation to any such nation.

Nonrecognition.—It is the sense of the Congress that the United States Government shall not recognize the claim of any foreign nation to a fishery conservation zone (or the equivalent) beyond such nation's territorial sea, to the extent that such sea is recognized by the United States, if such nation—

(1) fails to consider and take into account traditional fishing activity of fishing vessels of the United States;

(2) fails to recognize and accept that highly migratory species are to be managed by applicable international fishery agreements, whether or not such nation is a party to any such agreement; or

(3) imposes on fishing vessels of the United States any conditions or restrictions which are unrelated to fishery conservation and management.

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would be no guaranteed freedom of transit by vessels of all nations. Thirdly, Canada thinks it is necessary to take unilateral pollution control measures in its sector of the Arctic Ocean beyond the area affected by the Arctic Waters Pollution Prevention Act, because the northern waters are ice-infested and require special protection. The United States has reservations about all three Canadian exceptions.

Petroleum Management

There are indications of good chances for commercial finds of oil and gas on Georges Bank. The United States has already determined first-sale lease tracts, and has prepared environmental impact statements related to the sale. Canada also has designated lease areas on parts of Georges Bank. Generally, the tracts offered by the U.S. government are south and west of the disputed area, or the region on Georges Bank between the Northeast Channel and the midline crossing Georges Bank (Map 1). The U.S. government withdrew from the first sale 28 tracts located in the disputed area.

If the final boundary line allows Canada to share in the Georges Bank petroleum resources, both countries should consider certain possibilities for joint management. For example, to minimize costs of exploitation and preemption of trawling space, both countries should cooperate in designating platform locations, and collection and transportation systems. Specifically, production pipeline sites (area-to-shore) should be jointly planned.

Also, mutual regulations to control the throwing of debris overboard, and to prevent well construction in vulnerable spawning areas should be considered. In cases where a petroleum pool might be divided by the boundary, attention should be given to joint unitization of the pool to prevent waste of the resource and over-capitalization.

To this point in time, little consideration has been given to the question of joint United States/Canadian rational management of potential petroleum resources on Georges Bank.

West Coast Fisheries Management

Some important species and fisheries will be affected by the final boundary determinations in the Strait of Juan de Fuca (Map 2) and the Dixon Entrance (Map 3). Among these species are halibut, several salmon stocks, and certain groundfish and shellfish. Exploitation and management of some of these species traditionally have been of concern between the United States and Canada. For example, negotiations on the Fraser River and Columbia River salmon stocks have been taking place for many years. The large catch of Columbia River salmon off the coast of British Columbia by Canadian fishermen has been a point of contention; the Columbia River runs are maintained at high cost through U.S. government-financed fish ladders, hatcheries, and other programs. There also have been bilateral negotiations and agreements concerning the harvesting and landing of halibut.

Lengthy negotiations will be required before agreements relative to management and fishing access are finalized. The content of the conventions agreed to by the two countries will set the stage for either rational or competitive fishery management. If it is the latter, because of the common property nature of the fishing resources, the result will likely be waste for both countries.

East Coast Fisheries Management

The final boundary designation on the East Coast has important implications for traditional United States fisheries. In 1976, cod, haddock, red fish, flounder, herring, scallops, and lobster accounted for more than 75 percent of the value of New England landings. The distribution of these species includes the disputed area and therefore access by U.S. fishermen to these stocks will be affected by where the boundary is set.*

Other species found in the disputed area that are becoming more important to the United States as a result of increasing markets and potential foreign fishing fees include: shortfin squid; red, silver and white hakes; and to a lesser extent butterfish and mackerel.

Because of the distribution and migration of these species, a line drawn across Georges Bank would appear to make unilateral management unwise and wasteful. Although a line through the Northeast Channel would

*For an in-depth discussion of the distribution of the various species, see Grosslein and Bowman, 1973.

reduce the number of trans-boundary stocks, independent management of certain important species, such as herring, would still be undesirable. Furthermore, because of the distribution of the various stocks in the Gulf of Maine, any boundary line will result in significant trans-boundary stocks. Therefore, regardless of where the boundary is set, appropriate management of all species on a unilateral basis is not possible.

Proposed Management Arrangements

There are three types of management arrangements being considered for the East Coast trans-boundary stock situation; a Reciprocal Fishing Agreement, the establishment of a United States-Canadian Management Commission, and a Multilateral Cooperation Convention.

Under the United States-Canadian Reciprocal Fishing Agreement, a short-term arrangement is already in force, primarily for the 1977 fishing season. The principal points in the Reciprocal Agreement relate to the amount of U.S. fishing allowed off the east coast of Canada, and the amount of Canadian fishing allowed off the east coast of the United States. Under this agreement, only Canada and the United States are allowed to fish in the disputed Georges Bank area. Each country will enforce these regulations on its own citizens in the disputed zone. It is clear that this is an interim arrangement, and does not address the broad question of rational management of trans-boundary stocks.

To address this issue, consideration is being given to the establishment of a United States-Canadian commission for the management of trans-boundary stocks. Although neither government has formally commented on such a commission, the New England Regional Fisheries Management Council endorsed this type of arrangement at its May 1977 meeting. While such an endorsement implies no U.S. government accord, the Council's recommendations will be considered by the State Department. The Council's recommendations for a United States-Canadian commission include:

1) The negotiations on trans-boundary stock management be conducted by a commission of six United States and not more than six Canadian members.

2) The United States membership include: three New England Regional Fisheries Management Council members (NERFMC), one Mid-Atlantic Fisheries Management Council member (MAFMC), one National Oceanic and Atmospheric Administration member, and one State Department member.

3) The commission function with the assistance of advisors from industry.

4) The NERFMC and the MAFMC shall each determine its specific representative(s) on the commission.

5) The appropriate Council management plan shall set the total allowable catch for each species to be considered by the commission. This total allowable catch shall not be a negotiable quantity.

6) The United States' or the Canadian share within the total allowable catch may be negotiated, taking into account harvesting capacities and other relevant considerations.

7) Any joint United States-Canadian commission position may be referred to the Council for approval only if at least four of the U.S. members of the commission support the position.

8) Only those species which are trans-boundary with reference to a boundary through the Northeast Channel may be negotiated by the commission.

9) Consideration of any species by the commission shall include a pre-negotiating statement by each party that describes the full extent of government subsidies or other programs of financial assistance that bear upon the harvesting, processing, or export of that species.

10) The commission shall operate under a formal charter that shall include a description of the relation between the Council, the Department of Commerce and State, and the commission in developing management plans and in negotiating for the international management of appropriate species in accordance with those plans. The Charter shall make provision for the specification of those particular management issues which, for any species, are or are not negotiable.

Attention also has been given to establishing a multilateral arrangement covering the Northeast Atlantic. This action was initiated by Canada, primarily as a result of its concern over traditional fishing stocks

An early morning mist rises from the waters of the Lubec Narrows. The Narrows separates the province of New Brunswick from the State of Maine – Canada from the United States. Off the tip of Campobello Island and Quoddy Head, the Narrows enters the Grand Manan Channel. The Canada-United States border runs south and slightly west through the Channel, with Grand Manan Island on the left in Canada, and, on the right, the coast of Maine. West of Grand Manan, the border ends. The Channel joins the Bay of Fundy, and a little farther south from there, the Bay of Fundy joins the Atlantic Ocean. (Courtesy Between Friends/Entre Amis, National Film Board of Canada)

outside the Canadian 200-mile limit. The first meeting of the International Preparatory Conference on Future Multilateral Cooperation in the Northwest Atlantic Fisheries was held in Ottawa from March 14 to 24, 1977. The conference was attended by delegates from all International Convention for the Northwest Atlantic Fisheries (ICNAF) member countries, the European Economic Community, and the United States.

A. W. H. Needler of Canada was elected chairman, with D. Booss of the Federal Republic of Germany and A. Volkov of the Soviet Union as vice-chairmen. During the meeting, amendments were made to a draft convention prepared by Canada. Neither the draft nor the amendments were made available to the public. The conference recommended that a diplomatic conference be convened in October 1977 to consider the adoption of a new convention on future multilateral cooperation in the Northwest Atlantic fisheries.

The U.S. government has not publicly commented on the proposed "Northwest Atlantic Fishery Consultative Organization" (NAFCO). The New England Fisheries Council, again at its May 1977 meeting, recommended that the U.S. should participate on any scientific committee of NAFCO, but that care should be taken to assure that the NAFCO convention area specifically excludes the U.S. Fishery Conservation Zone. The concern of the Council on the latter point is that NAFCO might represent an infringement on the authority and responsibility given the Council and the U.S. Department of Commerce under the Fisheries Management and Conservation Act of 1976.

Both the commission concept and NAFCO represent important alternatives for dealing with the complexities of

Riding at anchor at Jonesport, Maine, near the mouth of the Bay of Fundy, where tides rise as high as 18.3 meters (60 feet). (Courtesy Between Friends/Entre Amis, National Film Board of Canada)

trans-boundary stocks. But at this point in time it is only possible to speculate about the establishment of either. Out of the various preliminary discussions relating to these matters, one point of emphasis is emerging. The U.S. appears prepared to stress market and economic considerations. Recommendation nine of the Council was representative of this trend. It is logical that such a point emerge. James Wilson (1977), and Susan Capalbo and others (1977), indicated that tariff and subsidy disadvantages faced by United States fishermen are great. Lack of consideration of these factors in any negotiations will place United States fishermen at a disadvantage, both in competing for the resource and in the market.

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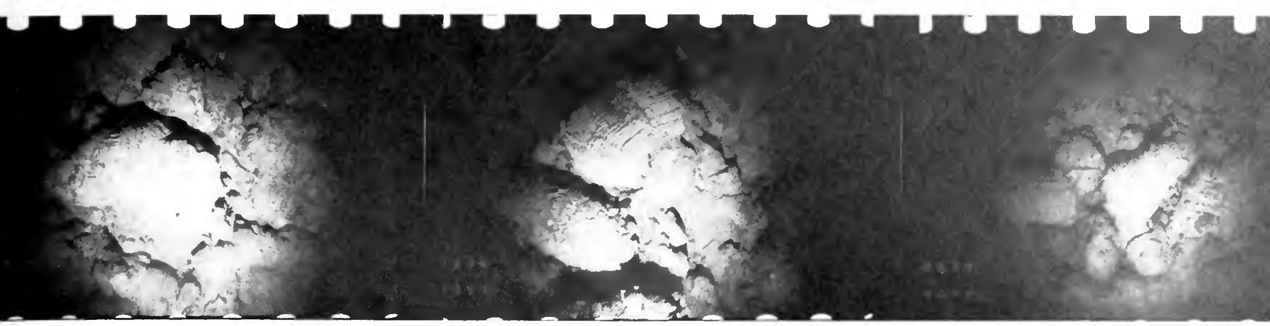
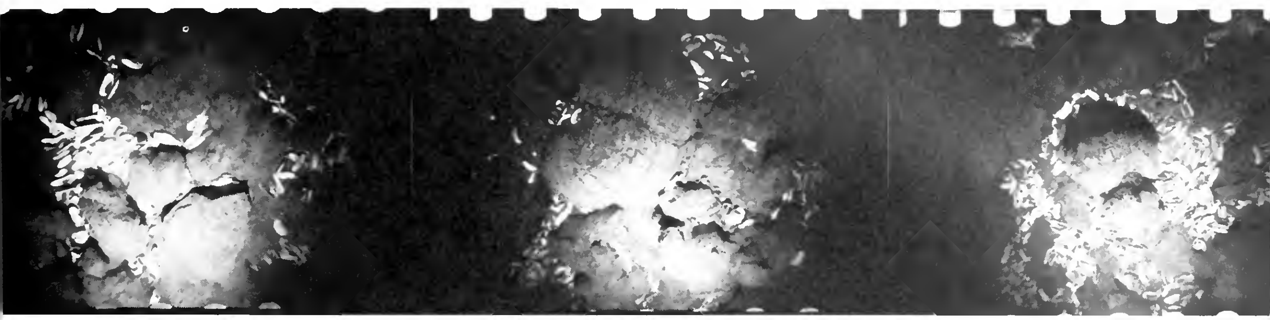


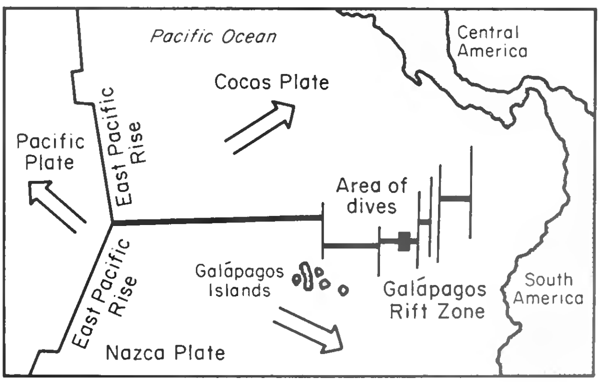
NOTES ON A MAJOR OCEANOGRAPHIC FIND

by Robert D. Ballard



Editor's Note: Since 1974, there have been a series of scientific expeditions to deep-sea areas to explore firsthand the centers of sea-floor spreading (see Oceanus, *Winter, 1974). That year the area for exploration was the Mid-Atlantic Ridge, last year it was the Cayman Trough near Cuba, and early this year it was the Galápagos Rift, a name that evokes the memory of Darwin and his* Origin of the Species. *Some 30 scientists and three research vessels participated in the expedition this February and March, where, for the first time, colonies of marine animals, some as yet unidentified, were found thriving around four hot-water geysers on what was thought to be a barren ocean floor. What follows is a description of that significant discovery. The Galápagos Rift expedition, which was part of the International Decade of Ocean Exploration sponsored by the National Science Foundation, was followed in the summer of 1977 by a return to the Cayman Trough area, where a series of dives were planned by the U.S. Navy Bathyscaph* Trieste II *to approximately twice the depth of the Galápagos dives. The search to find more life existing without the aid of sunlight is under way.*

The research vessel *Knorr* of the Woods Hole Oceanographic Institution steamed out of the Panama Canal February 8, 1977, headed for the Galápagos Rift in the Pacific Ocean some 330 kilometers northeast of the Galápagos Islands and 640 kilometers west of Ecuador. The vessel was on a mission to make a detailed study of several hot water vents on the ocean floor in depths of between 2,500 and 2,700 meters. The voyage marked the third major expedition in the last four years to spreading centers where molten lava from the earth's mantle periodically erupts and pushes adjacent crust



aside. *Lulu,* the mother ship of the Institution's submersible *Alvin,* was scheduled to follow four days after the *Knorr* finished its preliminary work.

On February 12, after four days at sea, a series of fixes taken on orbiting satellites indicated that the *Knorr* was in the general area of the Rift. With speed reduced and the ship's forward cycloidal propellers secured for quieter running, the bottom echo sounder was turned on and the ship began making a series of north-south runs across the rift valley floor. Among the principal members of the scientific party aboard were: Dr. Richard Von Herzen and myself from the Woods Hole Oceanographic Institution; Dr. John B. Corliss, Dr. Jack Dymond and Dr. Louis Gordon of Oregon State University; Dr. John Edmond and Dr. Tanya Atwater of the Massachusetts Institute of Technology; Dr. Tjeerd H. van Andel of Stanford University; and Dr. David Williams of the United States Geological Survey.

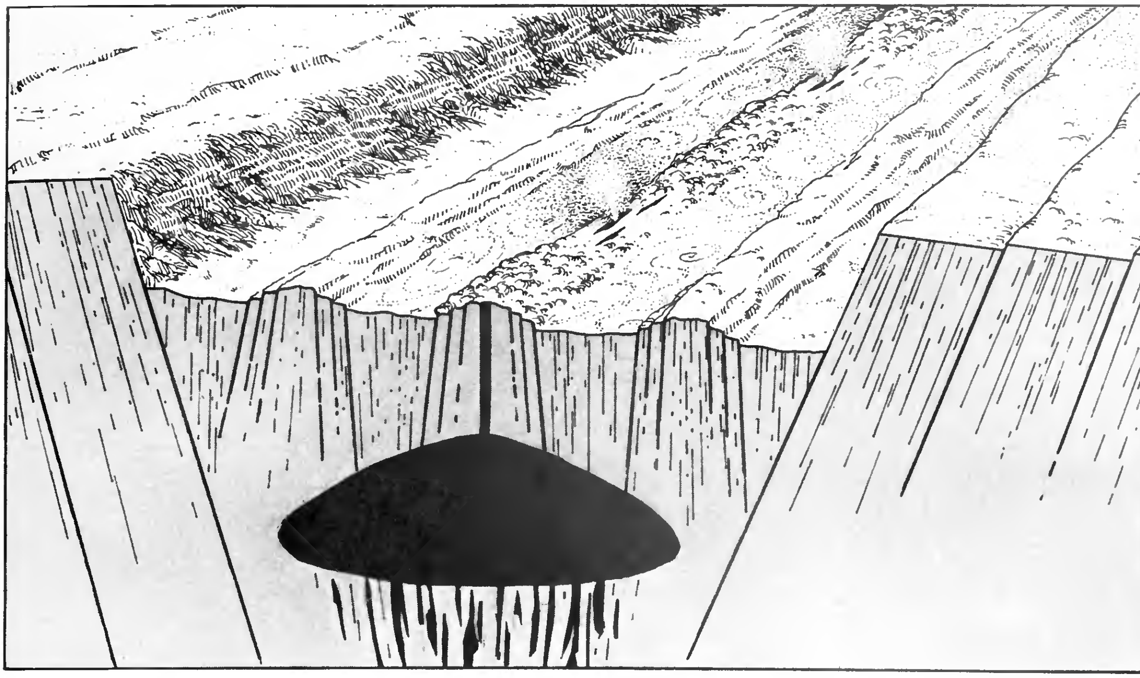
In 1976, the U.S. Navy conducted a detailed bathymetric survey in the area of the Rift, using a highly sophisticated multi-narrow-beam mapping system. As a result, the *Knorr* had aboard fine-scale topographic maps of the valley. As the ship crossed back and forth, the echo-sounding profiles were compared to the maps. Slowly, features on the ocean floor became recognizable. The north and south walls that flank the inner rift valley were located, as well as the central axis running down the middle of the valley. Later, individual volcanoes were identified. Assured by these profiles that the ship was in the proper area, preparations were made to install a network of bottom transponders that would serve as reference beacons once work began (see *Oceanus,* Sound in the Sea, Spring 1977). Both *Alvin* and the unmanned *Angus* (Acoustically navigated geophysical underwater system) sled would be tracked by this network of acoustic transponders.

The network consisted of a grid pattern of transponders installed in the valley and on its flanking walls. The exact shape of the pattern was determined by the proposed tracks and the nature of the bottom relief. Since acoustic signals would be used to communicate with the transponders, it was important that they be emplaced on high ground to insure that each transponder could acoustically "see" either *Alvin* or *Angus*. Once the beacons were dropped into position, the ship moved to a number of different locations and ranged on the transponders. It sent out a 7.5-kilohertz (kHz) signal that traveled through the water to the various transponders, each of which returned a signal having a different frequency — Sleepy at 13.5 kHz, Dopey at 13.0, and Bashful at 12.5. After several hours of ranging, the data were fed into a computer and the precise configuration of the transponder net was determined.

Earlier Trips to the Rift

From the results of earlier studies in the Galápagos Rift area we can reconstruct an interesting story. The Rift, for example, is part of a global mid-oceanic ridge system. In this system, the crust of the earth is separating under the influence of what are thought to be convective processes within the earth's interior. Previous studies indicate that not only is the Galápagos Rift similar to other regions of crustal separation, such as the Mid-Atlantic Ridge and the East Pacific Rise, but that the temperature of the crust in this region showed unusual patterns when measured by heat flow probes. As further expeditions were made to the Rift, it became clear that hydrothermal circulation within the upper segment of the newly formed oceanic crust might be responsible for the pattern of heat flow values. If this proved to be true, the possibility would exist that hot water could be flowing out of the crust into the sea at the bottom interface. This condition was discovered in 1972 by the Woods Hole Oceanographic Institution and confirmed in 1976 when the Deep Tow system of the Scripps Institution of Oceanography detected warm water anomalies within the Rift valley, among other means by collecting samples having an unusual chemistry suggestive of hot-water discharge from the crust.

When the Deep Tow operation was completed in 1976 aboard Scripps' *R/V Melville* (sister ship to the *Knorr*), two of their acoustic transponders were left on the bottom to mark the area where these anomalies were recorded. While the *Knorr* was echo sounding and the transponder net was being installed, ranging on the Scripps transponders further pinpointed the ship's location.



An artist's rendering of the Galápagos Rift valley, showing hot vent areas in the center of the valley. These vents are located along the boundary between the Cocos and Nazca plates, which are slowly moving apart. The valley is caused by this pulling apart. Due to a release in pressure related to this rifting, the hot plastic interior of the earth undergoes a partial melting process. This hot magma then rises up the rift or crack to form a magma chamber that feeds the volcanic eruptions on the floor of the valley.

Search Begins for Vents

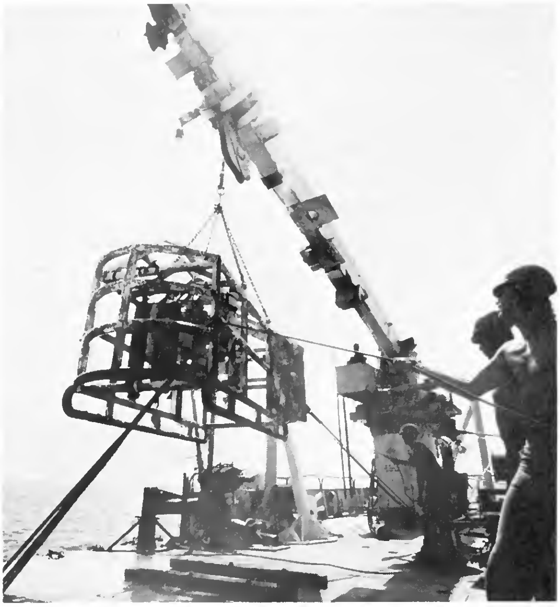
After the net was installed and surveyed, the search began for the hot-water vents. The two-ton *Angus* sled was readied; its camera and strobe lights were checked, as well as its bottom pinger and water temperature telemetry unit. The first lowering lasted 12 hours and was conducted in a weaving pattern back and forth across the central axis of the valley floor. This was the region where the most recent volcanic eruptions were thought to have occurred.

Getting the *Knorr* into position took some time. Although the surface of the ocean was flat with very little wind blowing, the ship's tracking data indicated a 1½-knot current was pushing the ship to the west. Using the ship's two cycloidal units, fore and aft, the *Knorr* was brought into a stationary position and the heavy *Angus* sled was lowered over the side. At the same time, the tracking system was shifted to the ship/fish mode, and a second dot tracing began to appear on the television screen in the main lab.

The ship began a tracking cycle by sending out its 7.5-kHz signal to which the transponders replied. These data were automatically fed into a computer, and a dot came on the screen. The ship then sent out another signal at 8.0 kHz. The transponders ignored this signal, but the sled did not. It responded by sending out its own 7.5-kHz signal that traveled directly back to the ship, as well as to the transponders that then responded to the ship. These data (along with the ship's position, which was determined seconds earlier) were used by the computer to calculate the location of the sled within a three-dimensional frame of reference.

As the sled was lowered, its altimeter telemetered back the distance to the bottom. At 90 meters off the bottom, the winch operator was told to slow the descent. From this point on, we began carefully to lower the sled the remaining distance. With the bottom near, we started moving the ship forward, increasing the speed over the bottom until the computer indicated both ship and sled were moving about three-quarters of a knot across the floor.

Forty-five minutes into the lowering, the camera automatically turned on and began taking pictures by strobe light every 10 seconds. At the selected speed, this gave us a continuous photographic strip beneath the camera some 6 meters in width as we raised and lowered the sled, trying to keep it no more than 4.5 meters above the bottom. Periodically, the bottom would suddenly rise,



Deck hands steady Angus sled. (© National Geographic Society)

and, if the winch operator did not raise the sled fast enough, it would crash into the bottom. On numerous occasions, the tension of the wire rose rapidly; if it had exceeded 20,000 pounds, the cable would have snapped with the loss of approximately $100,000 in equipment.

Fortunately, it never did. Within a few minutes the towing operation had stabilized, and we settled into an all-night vigil — one person monitoring the sled altitude and telling the winch operator "up one, down two, up fast, damn!"; another watching the computer plots, asking the bridge to "change course to 150, reduce speed on the aft cycloid," or "secure the forward cycloid, we're losing tracking"; and a third watching the temperature of the water that the sled was passing through.

Six hours into the watch — after a lot of coffee, popcorn, and listening to record albums — the telemetered water data indicated a major temperature anomaly that lasted less than three minutes. The precise time was noted, the computer print-out of the navigation data was reviewed, and the X and Y coordinates of the time of the temperature anomaly were circled. When the temperature returned to normal (approximately 2.01 degrees Celsius), the vigil began again.

After 12 hours, the *Angus* sled camera was out of film, having taken 3,000 color photographs. Sixteen kilometers of bottom terrain had been traversed, with only one temperature anomaly recorded. The order was given to raise the sled; an hour later it was aboard. The sled had been in near-freezing water, so, to prevent condensation from damaging the film, we waited two hours for the camera housing to warm up before unloading the film. The 400-foot roll was then taken to the film lab for processing. In the meantime, the ship had been turned over to the heat flow team, while the *Angus* crew caught some sleep. By mid-morning, the film had been developed, dried, and was ready for viewing.

The first few frames were blue because the camera had turned on just before reaching the bottom. The first picture of the sea floor showed that it was covered by a massive and complicated pile of fresh "pillow" lava. As the crust of the earth is pulled apart under the forces of sea-floor spreading, cracks develop in the floor of the rift valley. These cracks widen and deepen with time, eventually releasing pressure at depth, which leads to a partial melting of the hot interior. The newly formed magma rises up through the fractured crust to the valley floor, where it flows out as lava at a temperature of 1,250 degrees Celsius. The lava comes into contact with cold seawater that has a temperature of 2 degrees Celsius; it quickly cools, forming pillows that resemble mounds of toothpaste.

We viewed this barren lava terrain frame after frame, witnessing an endless variety of sculptured pillow forms. After about an hour, we noted that the sled had moved out across a

The tracking vigil aboard the Knorr. (© National Geographic Society)

Normal volcanic landscape in a tectonic plate spreading zone. The single sea anemone is typical of the sparse occurrence of living creatures. Scientists think that these large open fissures are the avenues through which seawater enters the crust at near-freezing temperatures. It is warmed by the hot magma beneath the crustal surface and emerges through hot geysers in the center of the Galápagos Rift valley at temperatures up to 17 degrees Celsius.

massive flat-lying surface to the south of the pillowed central axis. Here, the lava forms were quite different. Instead of pillows, the lava resembled forms previously observed near Hawaii called "pahoe-hoe" flows. Having a fresher and glassier outer surface, these flows were clearly younger in age. Their smooth surface and ropey, often whirly features suggested a much faster outpouring of magma.

The 13-Frame Discovery

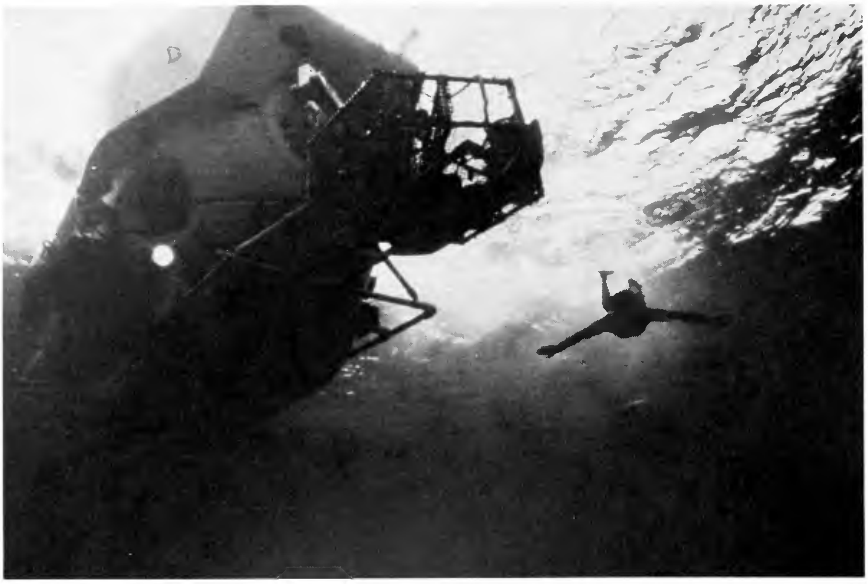
The sled soon crossed back into pillow lava terrain, which made up the low relief volcanoes running down the central axis. As we watched the film, we also kept an eye on the time (in the lower left hand corner of each frame there was a notation of the precise time). As midnight of the previous night approached, we knew the camera was nearing the point where the temperature anomaly had taken place. The photograph taken just seconds before the temperature anomaly showed only barren, fresh-looking lava terrain. But for thirteen frames (the length of the anomaly), the lava flow was covered with hundreds of white clams and brown mussel shells. This dense accumulation, never seen before in the deep sea, quickly appeared through a cloud of misty blue water and then disappeared from view. For the remaining 1,500 pictures, the bottom was once again barren of life.

By the time the review of the film was completed, *Lulu* had arrived on station and *Alvin* was ready to dive. With the X and Y coordinates of the thirteen frames in their back pockets, Corliss, Dymond, and Edmond jumped into a Boston Whaler and headed over to *Alvin's* support ship. With the transfer completed, the locus of activity shifted to *Lulu* as the *Knorr* headed south to begin work in another region 16 kilometers away suspected to be hydrothermally active.

While the final checks were being made on *Alvin*, the science navigator moved *Lulu* to the launch site over the location of the clam and mussel pictures. Using the transponder tracking system, a final check was made on the current drift. *Alvin* was then lowered on its cradle, and Corliss and van Andel climbed aboard, along with the pilot of the submersible, Jack Donnelly. When the launch was completed and the handling lines removed, the submersible flooded its air tanks and sank toward the bottom at the rate of 30 meters per minute. After an hour and a half, *Alvin* reached the bottom (approximately 2,700 meters) about 270 meters south of the target.

Driving first across the fresh, glassy pahoe-hoe flows and then up onto the pillow

Alvin preparing to leave mother ship Lulu prior to dive in the Cayman Trough. Jack Donnelly, the pilot, is in the conning tower. (© National Geographic Society)



Alvin, beginning a descent into the Cayman Trough. (Photo by John Porteous)

lavas of the central axis, the scientists inside the submersible observed the same features that had been captured through the lens of the *Angus* camera the night before. But when they reached their target coordinates, *Alvin* and its three-man crew entered another world. Coming out of small cracks cutting across the lava terrain was warm, shimmering water that quickly turned a cloudy blue as manganese and other chemicals in solution began to precipitate out of the warm water and were deposited on the lava surface, where they formed a brown stain. But even more interesting was the presence of a dense biological community living in and around the active vents. The animals were large, particularly the white clams (up to 30 centimeters or 12 inches). This basis of life was only 50 meters across and totally different from that of the surrounding area. What were the organisms eating? They were living on solid rock in total darkness.

An answer to this question began to emerge later when the water samples obtained from inside the vents by *Alvin* were opened for analysis aboard the *Knorr*. As the chemists drew the first water sample, the smell of rotten eggs filled the lab. Portholes were quickly opened. The presence of hydrogen sulfide was the key. The cracks in the floor of the rift valley provided avenues for cold seawater to enter and circulate within the hot, newly formed crust. As the seawater traveled deeper into the hot crust, the water temperature rose and its chemical composition began to change. Losing some chemicals to the rock, the seawater picked up others. The sulfate in the seawater was converted to hydrogen sulfide. Now heated, this altered water began to rise back to the surface, mixing with fresher seawater from above. Traveling up the small cracks, some of the warm water flowed out of the rock at 8-16 degrees Celsius to form a series of vent areas. The hydrogen sulfide in this warm water was quickly taken up by bacteria that rapidly multiplied. A food chain was thus initiated in total darkness independent of the sunlight at the surface.

Giant mussel, top, and clam taken from near Galāpagos Rift vent area. Samples show that the water welling up through the vents is rich in hydrogen sulfide, which scientists think might provide the bacteria that support marine life in the area. (Photo by Emory Kristof © National Geographic Society)

Five Vent Areas Probed

By early into the second leg of the expedition, *Alvin* and *Angus* had located and investigated four more vent areas along an 8-kilometer stretch of the central axis. Four of the vents were active, while one vent was inactive with only dead clam and mussel shells found scattered over the lava flows. A massive kill apparently had taken place when the vent was closed off, and the bottom organisms were unable to move to an active vent, some 225 meters to the east.

Another interesting aspect of these isolated worlds was that no two were alike. The first vent area was dubbed "Clambake I." It was characterized by large white clams, brown mussels, and numerous white crabs. In addition, a purple octopus, one of the few predators in the area, was observed. The second vent region was called "Clambake II," but no warm water was found, and all the animals were dead. Hundreds of clam and mussel shells were observed slowly dissolving in the cold water, which was unsaturated in calcium carbonate. The third site was termed the "Dandelion Patch" for its abundance of a small animal (still unidentified at this writing), about 2.5 centimeters in diameter, that resembled a dandelion gone to seed. Instead of being on a stalk, however, this organism held itself in place several centimeters above the bottom, using an intricate pattern of radiating fiber elements up to 16 centimeters long. This vent area, having a fairly simple population, appeared to have become active relatively recently. The fourth site, called the "Oyster Bed," did not have any oysters, but what's a geologist to know (there wasn't a single biologist on the entire cruise — only geologists, geophysicists, chemists, geochemists, physicists, and a science writer).

The fifth vent area was the most interesting. It was one of the larger areas and had several active vents. It was termed "the Garden of Eden" for its numerous and interesting life forms. Saturation photographic runs by *Angus* showed this vent area to have distinct rings about the active vents in which certain organisms dominated. The outer ring consisted of dandelions and white crabs. The next ring contained a small worm attached to the rock surface. The dandelions then disappeared close to the vent. Limpets, pink fish, and tall, white-stalked worm tubes with bright red tops were observed at the entrance to the vents themselves.

(Editor's Note: The following italicized material is part of a memorandum sent to Dr. Paul M. Fye, Director of the Woods Hole Oceanographic Institution, on March 10, 1977, from Corliss and Ballard. It gives a sense of the scientific procedures that were followed by the cruise participants.)

As a part of our overall scientific investigation of the hydrothermal regions within the Galapagos Rift, we are presently carrying out a comprehensive series of geological, geophysical, geochemical, and biological studies.

To date we have located and investigated four regions of active hydrothermal vents within the rise crest. All of these sites are located with fresh lava terrain containing no sediment pockets; thus, the collection of routine sediment samples is impossible.

At each of these sites we have obtained 50-100 liters of water, ranging in temperature from 8 to 16 degrees Celsius. The samples were taken from directly within the active vents. At all times and particularly during the sampling periods, the following parameters were displayed in real time and recorded within the pressure sphere on magnetic tape 10 times per second: conductivity, temperature within the vent to .002 degrees Celsius, temperature of the water flowing through the sampling system to the same precision, dissolved oxygen content, pH, precision depth, altitude, and precision time. The precision time base is then used to tie this information to color photographs of the bottom being taken every 10 seconds . . . .

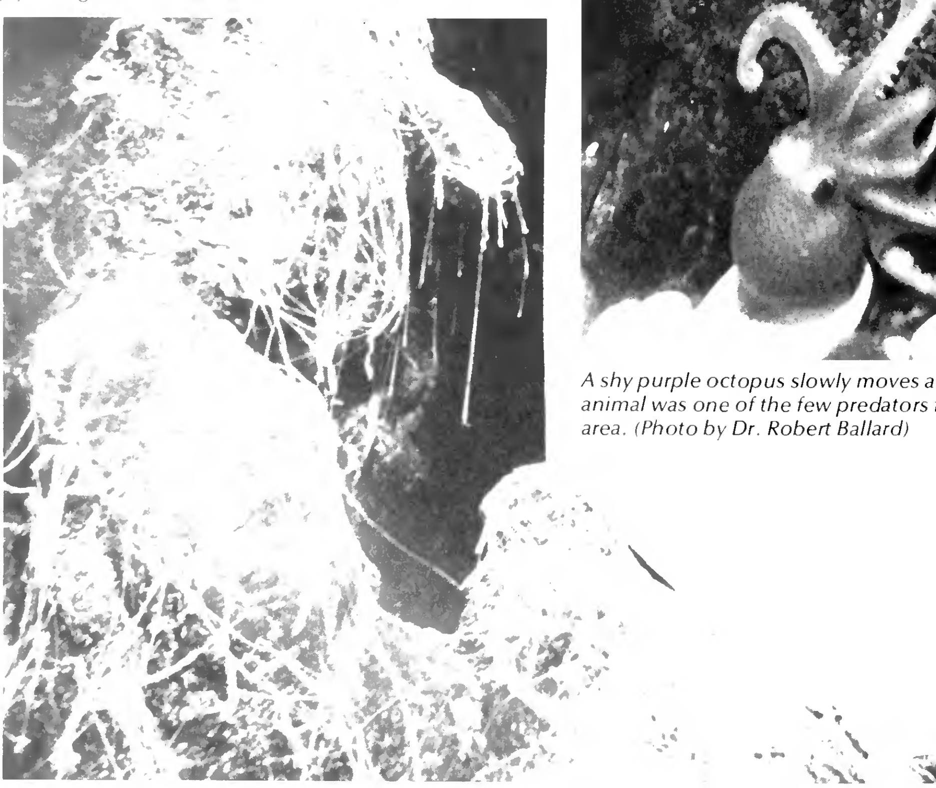
The water samples collected have been analyzed aboard ship within a 24-hour period for the following parameters: salinity, chlorinity, dissolved oxygen, phosphate, silica, nitrate, nitrite, ammonia, hydrogen sulfide, pH, alkalinity, total carbon dioxide, dissolved hydrogen, radon, calcium, and magnesium. During the sampling period in situ filtrations at .4 microns have been made in each area.

In addition, we have placed a long-term ocean bottom monitoring system at two vent areas. Lowered to the bottom by the Knorr *and placed over an active vent by* Alvin, *this system*

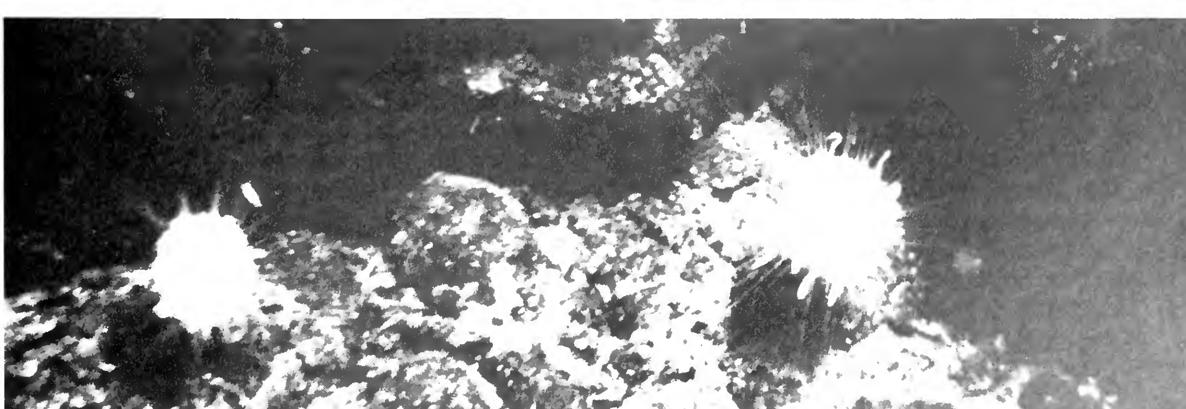
Crab, 15 centimeters across (about 6 inches) crawling across a pillow lava rock covered with worm tubes and brown manganese oxide, which precipitates out of the water. In the upper right hand corner, there is a dead clam shell that is slowly dissolving in the water, which is low in calcium carbonate. (Photo by Dr. Robert Ballard)

A shy purple octopus slowly moves away from Alvin. This animal was one of the few predators found in the geyser area. (Photo by Dr. Robert Ballard)

Unusual spider-like tube worms that were found near the geyser region, but not within it.



Stalk-like worm tubes found close to the vent areas. These were 36 to 46 centimeters (14 to 18 inches) long, much larger than those generally known to marine biologists. Limpets, crabs, sea worms and as yet unidentified fish can also be seen. The photograph was taken by Dr. John Edmond of the Massachusetts Institute of Technology, using a hand-held camera from inside Alvin.



The first organism found on the outer perimeter of the geyser was a small spherical animal that researchers dubbed "dandelion." These animals, which are 2.5 to 5 centimeters (1 to 2 inches) across, used web-like fibers to position themselves above the bottom in an apparent feeding position. (Photo by Dr. John Corliss)

Alvin's mechanical arm picks up large clam specimen from Clambake I. Clam measured 30 centimeters (about 12 inches). (Photo by Dr. Robert Ballard)

measures the water flowing vertically out of the vent and the temperature on four thermistors nearby every 14 seconds for 10 days.

To determine the flux of biogenous and inorganic detritus to the benthic environment, Alvin *closed and recovered three large, near-bottom sediment traps that had been installed seven months earlier by the* R/V Melville . . . .

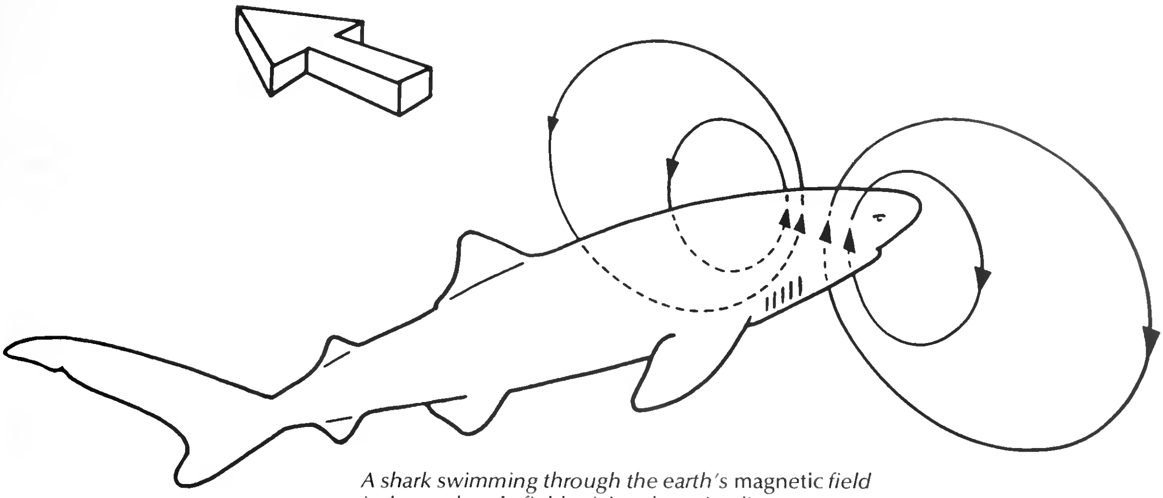
More specifically, the following biological samples have been collected in this total rock terrain; at two sites water samples were drawn by Alvin *and bacteria cultures prepared in accordance to instructions given to us prior to the cruise; at three sites samples of water were drawn and filtered in situ to collect the slimy material covering the rock surface near the vent. This material was later refrigerated. At least three species of both living and dead pelecypods, two species of living gastropods, arthropods, and a variety of tube worms were collected and either frozen or placed in a buffered formalin.*

In addition, a wide-angle time-lapse camera system with color film has been placed in one vent area by Knorr *to take pictures every four minutes for two days. The camera is baited and in one instance included a baited trap to collect specimens. . . .*

At this point in time we have five more potential dives remaining; three in the vent region and two in the mounds area. . . .

In all, two months were spent investigating the Galāpagos Rift and the hydrothermal deposits to the south. Twenty-four dives were made, numerous samples were collected, and more than 100,000 color pictures were taken. The discoveries made on this expedition will likely have a major effect on all disciplines of oceanography.

Robert D. Ballard is an Associate Scientist in the Department of Geology and Geophysics at the Woods Hole Oceanographic Institution. He has made numerous dives in Alvin and other submersibles.



A shark swimming through the earth's magnetic field induces electric fields giving the animal's compass heading (the horizontal component of the earth's magnetic field and the induced electrical currents are indicated). (From Kalmijn, 1974)

The Electric and Magnetic Sense of Sharks, Skates, and Rays

by Adrianus J. Kalmijn

Scientists must know the sensory world of an animal if they are to understand its behavior. Certainly most aquatic vertebrates have good eyesight, hear well, and are endowed with a sharp sense of smell and taste. Yet the physical characteristics of underwater light, sound, and odor fields are quite different from those on land. Moreover, animals use the sensory information in a variety of ways, depending on the particular interest of the species. Therefore, scientists cannot infer from man's own sensory experience how an animal perceives its environment but have to learn through behavioral tests and field observations. This point is dramatically emphasized by animals that have sensory capabilities that stretch man's imagination. One of the most interesting examples of this is the electromagnetic sensory performance of marine sharks, skates, and rays, commonly referred to as elasmobranch fishes.

In predation, sharks, skates, and rays cunningly cue in on the weak, bioelectric fields of their prey, even though it may be hiding under sand. These well-aimed feeding responses clearly demonstrate the remarkable acuity of the elasmobranchs' electric sense and testify to its biological significance in the animals' daily life. Recent research indicates that the elasmobranchs also detect the electric fields they induce when swimming through the earth's magnetic field, and thus sense their compass heading. Obviously, the electric sense of these ancient fishes has reached a high degree of sophistication.

Last year, the author and his student collaborators initiated field experiments in Vineyard Sound off Cape Cod, Massachusetts, to verify the results of earlier laboratory studies on the electrical aspects of predation. After chumming with chopped herring, we observed the smooth dogfish *Mustelus canis* search the bottom and viciously attack a current source simulating the bioelectric fields of the shark's prey. Although attracted and motivated by odor, the predators made their final approach exclusively relying on their electric sense. Coming in with the sharks, the American eel *Anguilla rostrata* paid no attention to the fields, whereas in comparative tests the catfish *Ictalurus nebulosus* repeatedly dug at a current source hidden in the mud along the banks of a local freshwater pond.

The magnetic orientation studies have been conducted on the stingray *Urolophus halleri* at our land facilities, set up in the woods of the quiet Quissett Campus of the Woods Hole Oceanographic Institution. The stingrays were trained to seek reward and avoid punishment by orienting to the earth's magnetic field. Between trials, the horizontal component of the magnetic field was reversed in a random order to eliminate the use of alternative orientational cues. These experiments have conclusively demonstrated the elasmobranchs' magnetic sensory abilities, which the author predicted on the basis of their acute electric sense.

Previous Studies

In 1917, G. H. Parker and A. P. Van Heusen published a historic paper on the curious behavior of *Ictalurus,* the common brown bullhead, with regard to metallic and non-metallic objects. They noticed that blindfolded specimens responded to the approach of metallic rods at distances of several centimeters, whereas a glass rod did not elicit a reaction until it actually touched the skin of the animals. In a series of simple but convincing experiments, Parker and Van Heusen demonstrated that these distant responses were due to galvanic currents generated at the interface between metal and aquarium water. Though very close to discovering the catfish's electric sense, these scientists did not realize the biological implications of their remarkable results.

In 1934, the Dutch biologist S. Dijkgraaf also observed a great sensitivity to metallic objects in the small shark *Scyliorhinus canicula.* A quarter of a century later, he suggested that the author, then his student in the Netherlands, investigate the possibility of electrical stimulation, as in the case of the catfish, and evaluate the biological significance of the response. A few years earlier, H. W. Lissmann in England had discovered that certain knife-fishes produce weak electrical discharges to probe their environment. Sharks, however, lack electrogenic organs; therefore, the main questions were: what might be the fields in nature that the sharks detect, and what could be the role of these fields in the animals' daily life?

Subsequent research soon revealed that marine sharks, skates, and rays are indeed extremely sensitive to weak electric fields. By recording the heartbeat of free-swimming specimens with implanted electrodes, the author established transient cardiac decelerations when applying electric fields of voltage gradients as low as 0.01 microvolt per centimeter, which represents the highest electrical sensitivity known in the animal kingdom. In later behavioral tests, the frequency range of the animals' response appeared to extend from direct current (DC) up to about 8 hertz. Reception of these low-frequency, low-level electric fields was shown to take place by means of the ampullae of Lorenzini, delicate sensory structures in the protruding snout of the elasmobranch fishes (Figure 1).

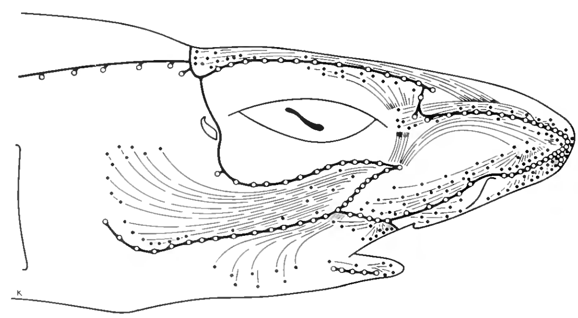


Figure 1. Ampullae of Lorenzini and mechanical lateral-line system in head region of the shark Scyliorhinus canicula. *(Solid dots: skin pores of electroreceptors. Small circles: openings of lateral-line canals) (From Dijkgraaf and Kalmijn, 1963)*

By measuring the electric fields in the laboratory habitat of the sharks and skates, it was found that aquatic animals produce direct-current and low-frequency electric fields in the water, which stem mainly from potential differences at the skin/water interface. In fish, for example, the mucous membranes lining the mouth and the gill epithelia in the pharynx give rise to steady DC fields, usually modulated by ventilatory movements. Externally, the bioelectric fields are of distributed dipole* configuration and, accordingly, fall off steeply with increasing distance. Yet the DC voltage gradients emanating from small fish and wounded crabs often measured over 0.01 microvolt per centimeter at distances up to 25 centimeters, which suggested the role of the elasmobranchs' electric sense in predation.

To elucidate the electrical aspects of predation, the author decided to analyze the feeding responses of the shark *Scyliorhinus*

*A field produced by equal but opposite electrical poles, usually separated by a small distance.

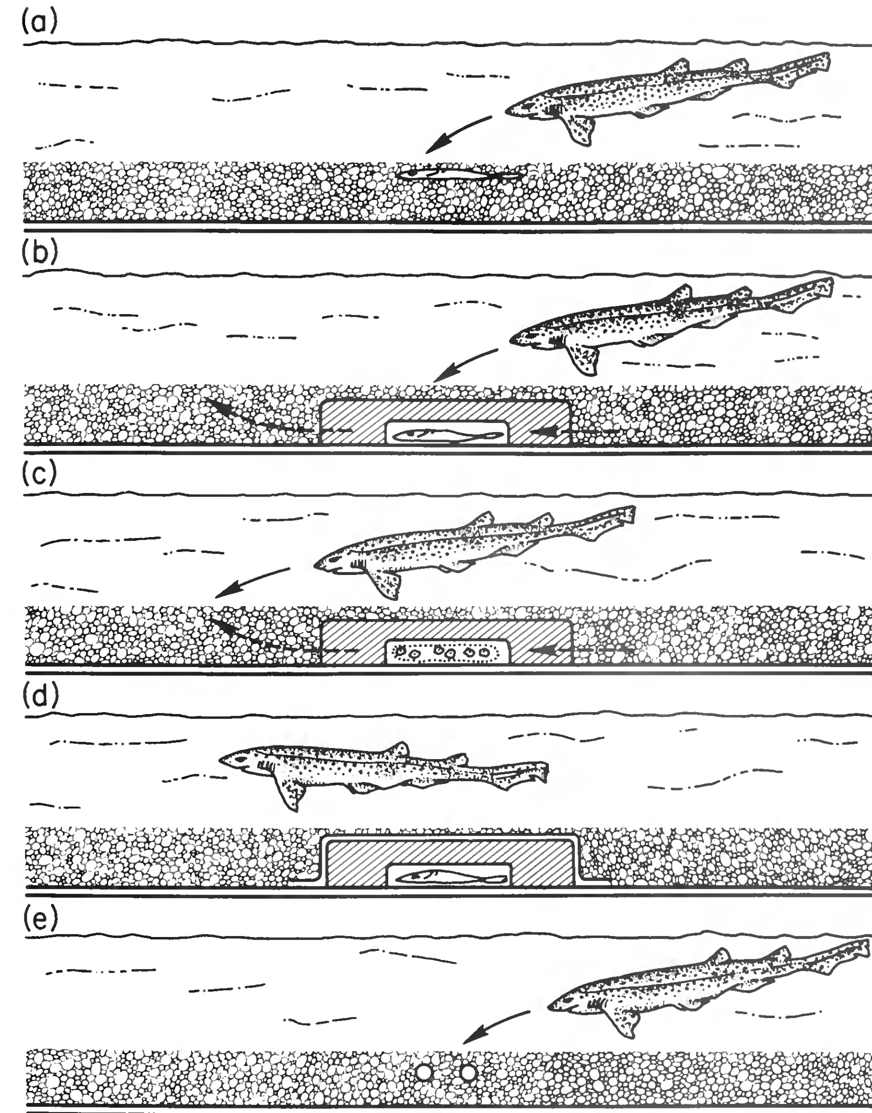


Figure 2. Feeding responses of the shark Scyliorhinus canicula *to: (a) flounder under sand, (b) flounder in an electrically transparent agar chamber, (c) pieces of whiting in an agar chamber, (d) flounder in an agar chamber covered with an electrically insulating plastic film, and (e) electrodes simulating the bioelectric field of a flounder. Agar chamber not to scale. Solid arrows: responses of shark; dashed arrows: flow of seawater through agar chamber. (From Kalmijn, 1971)*

canicula and the skate *Raja clavata* to small specimens of the flounder *Pleuronectes platessa*. The prey was cautiously introduced into the seawater habitat, and after it had hidden itself in the sand, a few drops of liquified whiting were diffusely spread throughout the water. Motivated by the odor, the sharks and skates began randomly searching the bottom of the pool. When coming within a distance of 10 to 15 centimeters from the flounder, they made well-aimed dives at their prey, uncovered it from under the sand, and devoured it voraciously (Figure 2a). Subsequently, the flounder was placed in a flat chamber made out of 3 percent agar in seawater, and positioned under the sand on the bottom of the pool. The chamber was aerated by a steady flow of seawater to keep the prey alive. The purpose of the agar chamber was to conceal the flounder visually, chemically, and mechanically without impeding the animal's bioelectric field. Again, after odor motivation, the sharks and skates made their well-aimed feeding attacks from the same distance and in the same frenzied manner, as if the prey were not screened by agar at all (Figure 2b).

To prove that the 1-centimeter-thick roof of the agar chamber was really effective in attenuating odor stimuli, the live flounder was exchanged for pieces of whiting that had been frozen for several days (whiting was the regular food for the experimental animals). In this case, the predators did not show the slightest response to the food when swimming over the agar chamber, although they were strongly motivated by the odor of the seawater flow ventilating the chamber (Figure 2c). Whether the agar was adequate to mechanically shield the live flounder was indirectly tested by repeating the original experiment, this time, however, with a thin, electrically insulating polyethylene film covering the agar chamber. Now, the sharks and skates no longer responded to the prey, although they eagerly searched about and often passed directly over it (Figure 2d). This drastic effect could not conceivably be due to the mechanical properties of the thin (10 micrometer) and extremely pliable polyethylene film, since even the stiff, 1-centimeter-thick agar roof to which the film was added did not noticeably weaken the feeding responses. Hence, the sharks and skates evidently were able to attack a flounder hiding in the sand without the aid of visual, chemical, or mechanical cues.

The results of these behavioral tests suggested that the sharks and skates *electrically* located the agar-screened prey. This would also explain the all-or-none effect of the polyethylene film, which offered an extremely high electrical resistance, whereas the agar layer did not distort the bioelectric field of the flounder to any extent. To provide direct evidence for the electrical hypothesis, the presence of the flounder was simulated by passing electrical current between two salt-bridge electrodes buried in the sand. After odor motivation, the predators displayed the same characteristic feeding responses to the electrodes (whether or not covered with agar) as they did to the actual prey (Figure 2e). They dug tenaciously at the source of the field, responding again and again when coming across the electrodes. These results proved that the electric sense of sharks and skates plays an important role in the animals' lives.

Field Observations on Cape Cod Sharks

Following the studies on captive sharks, we have sought to verify the results in tests on wild specimens, roaming freely in their natural habitat. The main problem, however, has been approaching the animals without introducing galvanic fields or other perturbations into the environment that might interfere with the fishes' normal behavior. Remember that the electrical sensitivity of catfish and sharks first revealed itself through the animals' unusual responses to metallic objects.

During the summer of 1976, we learned from longline fishing off Cape Cod that the smooth dogfish *Mustelus* regularly frequents the shallow, inshore waters of Vineyard Sound on its nightly feeding excursions. This predatory shark is a warm-season visitor, arriving at Woods Hole in May and leaving for the South again in late October or shortly thereafter. It is an active bottom hunter, preying on small fish as well as crustaceans and other invertebrate animals. The females reach an average length of 115 centimeters; the males are slightly smaller. The smooth dogfish is truly live-bearing; the new-born measure 29 to 37 centimeters.

To observe the sharks' feeding behavior, we worked from an inflatable rubber raft (Zodiac Mark II) free of any metal under the waterline. On station in 2.5 to 3.0-meter-deep water over a sand patch devoid of seaweed, we attracted the sharks by squeezing liquified herring through a long Tygon tube that ran from the raft to the bottom of the sea. The Tygon chumming tube was attached to a polypropylene line, suspended from a Styrofoam float and stretched over the ocean floor between two polyvinyl pipes anchored in low-profile cinder blocks (Figure 3). Starting after dark, we illuminated the area with a 100-watt, battery-operated underwater light. To break the water surface, we used a glass-bottom viewing box secured behind the stern of the raft.

Two pairs of agar-filled, salt-bridge electrodes were tied to the polypropylene line and positioned on the sand, one on either side of the odor source and 30 centimeters from it. Mekka underwater plugs with stainless steel pins and integral cables connected the thin, 30 to 90-centimeter-long Silastic salt-bridge tubes to the electrical equipment set up in the rubber raft. The use of a constant-current source virtually eliminated the adverse effects of polarization at the stainless steel/seawater interfaces. From the raft, we could conveniently vary the strength of the field and select the pair of electrodes to be energized, the other pair functioning as the control. The applied direct-current dipole moments ranged from 1 to 8 microamperes x 5 centimeters (dipole current x distance between electrodes), roughly corresponding to the bioelectric fields of small prey at a seawater resistivity of 20.0 to 20.5 ohm·centimeters and

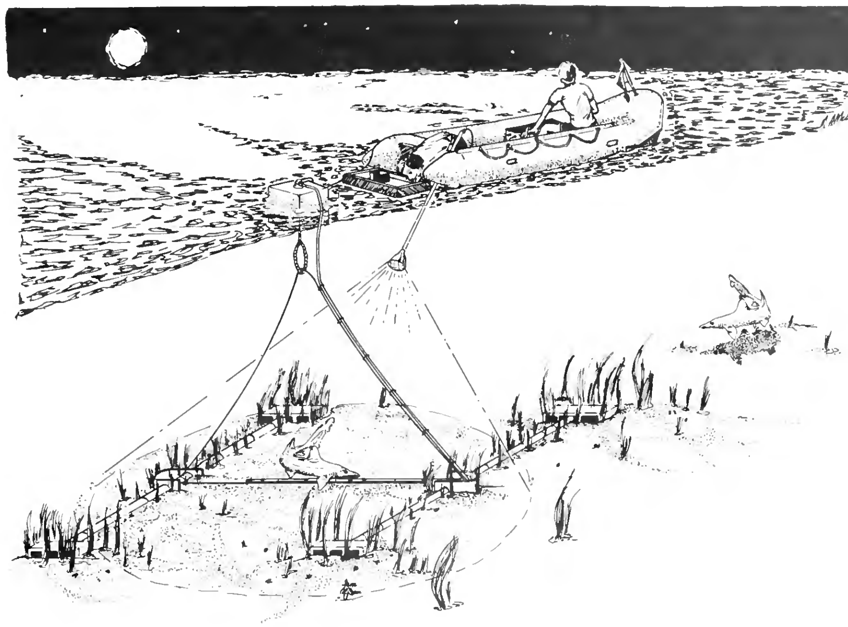


Figure 3. Field setup for observing the feeding responses of sharks to electrically stimulated prey. Though attracted by fish extract exuding from chumming tube, the shark Mustelus canis *zeroes in on electrical dipole field in Vineyard Sound.*

a temperature of 19 to 22 degrees Celsius.

After entering the area, the smooth dogfish began frantically searching over the sand, apparently trying to locate the odor source. Both young and mature sharks were observed, sometimes alone, sometimes in groups of two to five. Neither the raft nor the underwater light appeared to bother them. Most interestingly, when nearing the odor source, the animals did not bite at the opening of the chumming tube but from distances up to 25 centimeters turned sharply to the current-electrodes, viciously attacking the electrically simulated prey. After snapping the line with their teeth right at the position of the electrodes, the sharks usually attempted to rip them apart — and one night they succeeded. When the current was switched to the other pair of electrodes, the animals let go, circled around for awhile, and attacked again, but at the electrodes on the other side of the odor source. At the lower current levels, the sharks kept responding, though from increasingly shorter distances.

These observations convincingly demonstrate that odor-motivated sharks are capable of detecting and taking prey by the exclusive use of their electric sense, not only under well-controlled laboratory conditions, but also in their electrically more noisy, ocean habitat. Of course, other sense organs, in particular the fish's lateral-line mechanoreceptors, also can play an important part in predation. At short range, the electric fields appear to dominate in our experiments over the much vaguer odor cues that initially attracted the sharks from a distance. Since the odor of wounded prey lingers long after the animal is gone, the sharks obviously need more precise directional cues to locate their prey accurately, enabling them to seize it with one quick move.

Behaviorally, elasmobranchs readily respond to direct-current fields. Electrophysiologically, however, the ampullae of Lorenzini are not true DC receptors, although they do detect frequencies as low as 0.1 hertz. That is, to sense a prey's DC field, elasmobranch fishes have to move relative to their prey, or *vice versa.* Alternatively, they may detect the low-frequency components that accompany the prey's ventilatory and body movements. Odor-motivated sharks and skates do zero in on DC, as well as low-frequency dipole fields of biological strengths. In their final approach, they aim directly at their prey, deriving its location from the spatial configuration of the animal's bioelectric field.

The American eels that visited our test area often nibbled at the opening of the chumming tube, but they *did not* pay any attention to the current-passing electrodes. The eels' behavior was particularly noteworthy because the fish had been reported to exhibit similar cardiac decelerations when subjected to weak electric fields, as previously observed in elasmobranch fishes. The eels' responses, however, have not been independently confirmed, nor are these fish known to have specific electroreceptors. In predation at least, they evidently are more chemically inclined.

Toward the end of the season, we conducted comparative tests on the common brown bullhead, which is endemic to the Cape's freshwater ponds. With small pieces of beef liver, we lured the fish into shallow water, and offered them direct-current dipole fields of 0.5 to 4.0 microamperes passed between two salt-bridge electrodes with openings 1 centimeter apart buried in the mud. Along the banks of the pond, the resistivity of the water measured 19 kiloohm·centimeters at a temperature of 20 degrees Celsius. As with the sharks, the catfish repeatedly dug at the source of the field in apparent attempts to devour the electrically simulated prey.

Although we primarily conceived this field work with the undisturbed bioelectric sensory world of the sharks in mind, the results of our tests also indicated that attacks on humans and underwater gear may be elicited and guided by electric fields resembling those of regular prey. The human body, especially when the skin is damaged, creates DC bioelectric fields that sharks in the ocean may detect from distances up to 1 or 2 meters. The galvanic fields of metallic objects on the body may be even stronger. In this connection, we expect that the U.S. Navy's polyvinyl anti-shark bag, which is suspended from an inflatable floatation collar and designed to visually and olfactorily conceal a mariner in distress, electrically screens the person as well. Sidetracking the sharks to alternative sources of electricity that secondarily release a discouraging agent may, under certain circumstances, be another means of warding off electrically evoked shark bites. It should be emphasized here that the electrical aspects of the animals' environment should be taken into account in all behavioral studies on elasmobranchs and, if possible, left undisturbed.

Evidence of Geomagnetic Orientation

When cruising through the earth's magnetic field, marine sharks, skates, and rays induce electric fields that are well within the dynamic range of their highly-sensitive electroreceptor system. As the induced voltage gradients depend on the direction in which the animals are heading, they may form the physical basis of an electromagnetic compass sense in these fishes. To substantiate the biological feasibility of this novel orientation mechanism, the author has endeavored to collect hard experimental evidence of the elasmobranchs' magnetic abilities predicted from the animals' known electric sense and the theory of electromagnetic induction.

Our first, most simple magnetic tests were performed on the leopard shark, *Triakis semifasciata,* in outdoor, all-fiberglass pools on the bluffs of Scripps Institution of Oceanography's campus at La Jolla, California. With the fish swimming steadily along the circumference of their circular habitat, we introduced a local magnetic field by passing an electrical current through a small induction coil (20 centimeters in diameter) held external to the tank. The field was switched on when the sharks were at the far side of the pool. Then, seconds later, upon completing their lap and swimming into the imposed field, the sharks suddenly veered off to the center of the tank, although the coil current did not distort the earth's ambient magnetic field by more than 25 percent.

Next, we noticed that the leopard sharks each morning before dawn gathered in the northern area of the tank. To eliminate the possibility of visual orientation, we covered their pool with a large sheet of black plastic. We also took all objects out of the water and even rotated the whole tank. Surprisingly, this did not change the sharks' early-morning orientation. However, when we roughly neutralized the earth's ambient magnetic field by passing electrical current through two large induction coils diametrically attached to the outside of the tank, the animals lost their positional preference and distributed randomly.

Although the outcome of these preliminary tests was consistent with the idea of geomagnetic orientation, none were fully conclusive. The avoidance reactions proved the sharks' sensitivity to fields of geomagnetic strength but were not of obvious biological significance. The spontaneous orientation was biologically more interesting, but at that time we were not technically prepared to reverse the field in order to verify the magnetic nature of the response.

In the meantime, the author moved to Massachusetts to pursue his magnetic studies at the Woods Hole Oceanographic Institution. To scale down the technical problems of controlling the ambient magnetic field, we

(a)

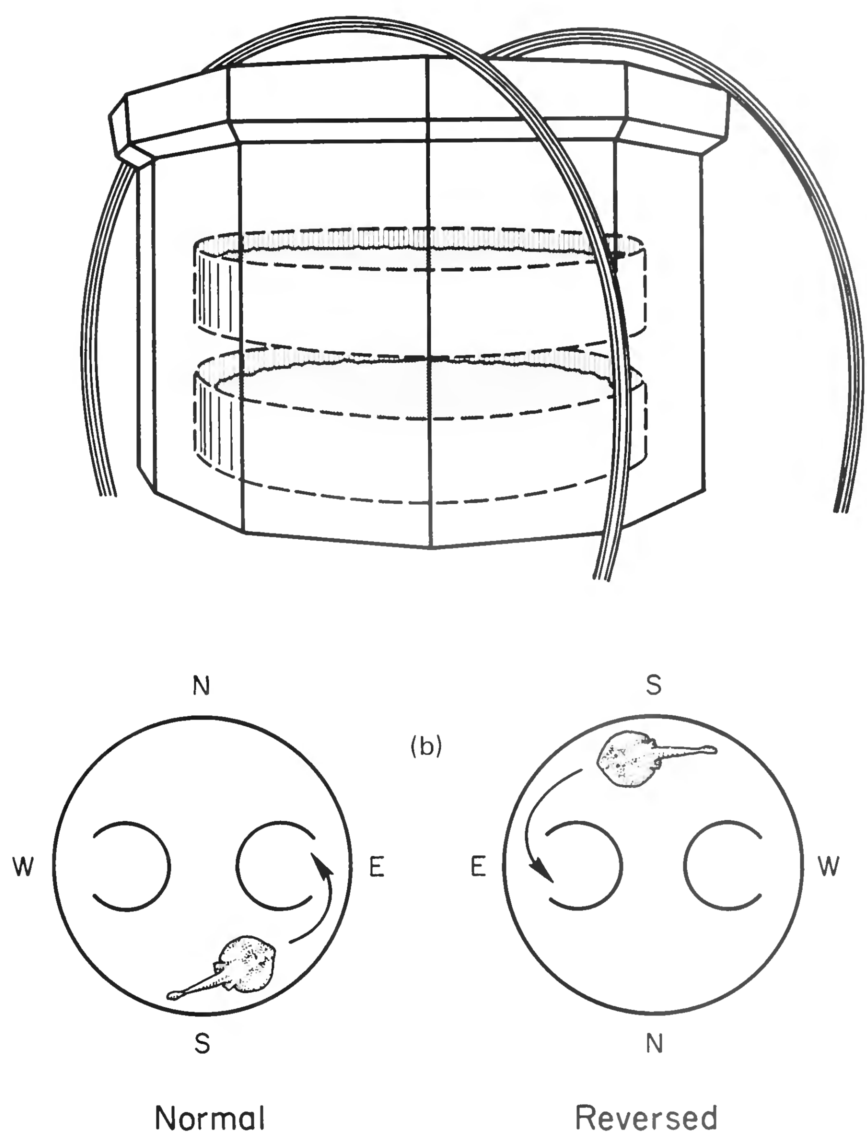


Figure 4. Magnetic test facility on the Quissett campus of the Woods Hole Oceanographic Institution (a). The round stingray Urolophus halleri, *swimming toward the east enclosure to secure food, under normal and reversed field conditions (b).*

looked for a good experimental animal of smaller size, which one of the students found in the round stingray *Urolophus halleri*. The round stingray is a hardy, very alert and active elasmobranch of subtropical and tropical seas, reaching an average span of 25 centimeters. To fit our tanks, we selected five specimens measuring only 15 to 20 centimeters.

The stingrays were tested in a circular, fiberglass pool, 1.8 meters in diameter, which rested on Teflon blocks to insulate it from ground. The pool was filled with natural seawater to a depth of 15 centimeters. Coarse sand covered the bottom, and two airlifts maintained a slow, internal circulation. We surrounded the pool with a lighttight, twelve-sided hut devoid of any ferromagnetic materials. The seawater was kept at 20 degrees Celsius by regulating the air temperature in the hut. Outside the hut, two large Helmholtz coils, each 5 meters in diameter, were mounted along the north-south axis to control the horizontal component of the earth's magnetic field in the tank (Figure 4a). We chose for our tests a magnetic induction of 0.34 gauss, corresponding to the horizontal component of the Southern California region from where the animals were taken.

During the 1 to 2-hour training sessions, twelve concealed lights illuminated the ceiling over the tank to produce an even, low-level light distribution. For the rest of the day, the lights were programmed to simulate the sunshift and daily variation in brightness of the sky in accordance with the direction of the ambient magnetic field. Lights, heaters, and coils were DC-powered from distantly located voltage and current sources. The wiring was tightly twisted and judiciously installed to prevent unwanted electric and magnetic fields from straying into the animals' habitat.

Each morning, two observers ran a series of 15 to 20 trials after first turning on the lights, shutting off the airlifts, and checking the direction of the horizontal component of the magnetic field (either normal or reversed). Then, they simultaneously introduced two circular enclosures into the pool, one with the opening to magnetic East, the other with the opening to magnetic West (Figure 4b). After positioning the enclosures, the observers stepped back to watch the behavior of the animals from behind a black, felt screen. When one of the three participating stingrays entered either the east or west enclosure, both observers blocked off the openings by lowering a gate. If the animal entered the east, by definition the correct enclosure, it was rewarded with a small piece of herring; if the animal entered the west or incorrect enclosure, it was gently prodded with a blunt Plexiglas rod as a form of punishment. Eventually, the enclosures were moved to the magnetic North and South of the pool, and the animal was set free for the next trial.

Although it took the animals awhile before they learned to rely on the magnetic field in deciding which side to avoid and where to go for food, after catching on, two of the stingrays made the highly significant scores of 56 and 164 correct choices out of 78 and 248 trials, respectively ($P<0.001$). The third ray was disqualified because it was not fast enough to compete and was actually losing weight. After the initial training, the stingrays' orientational performances did not significantly change further, either during individual sessions, or from day to day. This, we felt, allowed us to treat the trials as independent choices, despite the fact that the field was reversed only once a day; that is, after each series of 15 to 20 trials. In a follow-up series, we changed the direction of the field again on a daily basis, but this time in random order. Under this regime, our most active stingray, without further training, made 120 correct choices out of 184 trials ($P<0.001$) within a period of 15 days.

In earlier tests, frequent field reversals appeared to confuse the animals. Yet we recently began a series in which we randomly reversed the horizontal component of the magnetic field from trial to trial so as to provide the strongest possible evidence. In these experiments, the field is set by a third person, while the two observers do not know whether to feed or punish until after the animal has made its choice. At this writing, our fastest performing stingray has scored 101 out of 154 correct choices, which proves our case ($P<0.001$) and makes the magnetic orientation of *Urolophus halleri* a fact. Since these results were anticipated as a logical consequence of the animals' keen electric sense, it seems justified to assume that the proposed electromagnetic detection mechanism holds true.

Usually, animals are magnetically tested to explain such remarkable performances as long-distance migration and homing. Thus, a magnetic sense has been established in migratory birds and homing pigeons, though without any indication of the underlying physical principles. In our case, however, we started with sensory structures of unknown function — the ampullae of Lorenzini — and inched our way to discover the electric and subsequently the magnetic sensory world of the elasmobranch fishes.

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Geosecs and Tritium Tracers

by Claes H. Rooth

If you ever have had the experience of luxuriating in a bathtub that is slowly filling with warm water, when suddenly, the supply runs out — then you have noticed how hard it is to get rid of that cool water down by your feet. As a child, I developed elaborate schemes of thrashing with my legs to mix the water, while at the same time using my hands to generate a large-scale horizontal circulation in the bathtub. Little did I know then that similar combinations of locally intense vertical mixing and large-scale horizontal circulation cells or gyres are important in a much larger tub — the world ocean. Nor did I dream that my games at a later time and in different circumstances would become an avocation.

Let us briefly consider the apparent similarities between the oceans and the poorly-mixed bathtub. More than half of the surface area of the oceans lies in the tropics and subtropics, where high insolation leads to intense warming and permanently high surface temperatures. The subpolar seas, on the other hand, are permanently cold — to the extent that ice survives there year 'round, at least in some parts. It is not surprising then that early studies of the interior temperature distribution in the oceans showed that the warm surface layers are quite thin and underlain by very cold waters, apparently of high latitude origin. Plots of the distributions with depth and latitude of various chemical parameters, such as those in Figure 1, show that tongue-like intrusions of water apparently extend from near the surface at high latitudes into the interior and toward the equator.

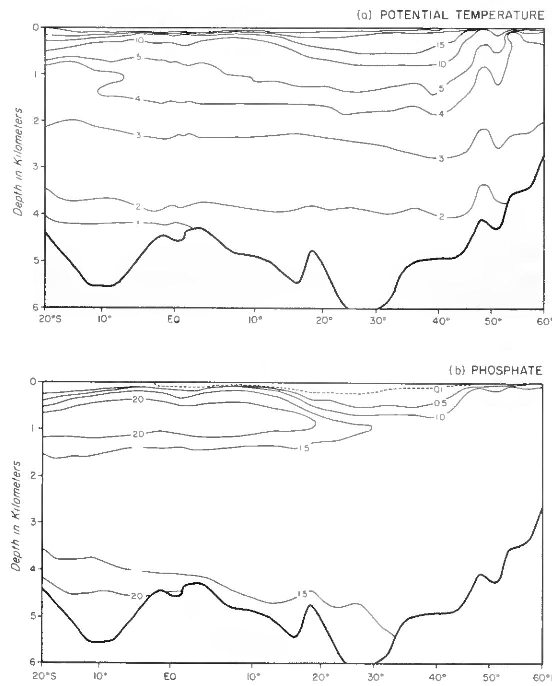

Figure 1. Latitude-depth distributions of (a) temperature and (b) dissolved phosphate in the western part of the Atlantic Ocean. The temperatures shown have been adjusted for pressure effects at depth, and are therefore denoted at potential temperature values.

The question of interpreting geochemical data in relation to large-scale ocean circulation was debated at the Woods Hole Oceanographic Institution in the summer of 1968. Leading marine geochemists and other scientists actively working on deep-ocean circulation patterns participated in these week-long discussions, which represented the highlight of a summer-long seminar in Geophysical Fluid Dynamics. The participants were brought together both by the need for chemical data on the part of the physical oceanographers, and by the need among chemists for adequate information about deep-ocean circulation in the construction of dynamic models for the chemical evolution of the oceans and their bottom sediments. During the discussions, it became clear that many of the inferences that could be drawn from chemical data might be considerably strengthened if a uniform set of such data could be made available from all the major oceans, based on new instrumentation methods and on a careful reevaluation of how to interpret the resulting data, with respect to the new information available on the physical chemistry of seawater. The concept of the Geochemical Ocean Sections program, or Geosecs, was thus born.

A consortium of marine chemists and geochemists (a delicate distinction at times) took on the challenge of making an authoritative baseline study of the distribution of chemical constituents in the world oceans. Nearly forty major and minor constituents of seawater were selected for surveying. From the beginning, it was clear that the task would require a long-term commitment of money and manpower by many of those in the field of chemical oceanography. No single institution was in a position to mount such a program, nor could the funding be handled through the normal support channels of the 1960s without seriously draining the nation's oceanographic research institutions. Coincidentally, a new program concept came into being at the National Science Foundation — the International Decade of Ocean Exploration. Special funding for this program was made available through congressional appropriations, and Geosecs became a natural and successful candidate for support.

The years 1970 and 1971 were devoted to preparing for the Atlantic and Pacific expeditions that occurred in 1972 and 1973, respectively. The data from these expeditions, which include information on radioactive and chemical pollutants, have been made widely available only within the last year. Some 7,000 separate water samples were collected in the Atlantic Ocean alone at 110 stations, ranging from the Arctic to Antarctica. As many as 50 depths were sampled at each station, using 30-liter sampling bottles clustered in "rosettes." On the rosettes were instruments which continuously monitored temperature, pressure, salinity, dissolved oxygen, and particulate matter. One major phase of this work still remains to be completed — the Indian Ocean, which is scheduled to be surveyed in 1978.

The Geosecs program included measurements of the distribution of the radioactive isotope tritium, a heavy form of hydrogen. These data show how such an atmospheric pollutant — the tritium was produced by the testing of nuclear weapons by the United States and the Soviet Union in the 1950s and early 1960s — penetrates the oceans. During the test explosions, the tritium that was produced combined with atmospheric oxygen to form heavy water which was then in part transformed into rainfall and in part injected into the ocean by direct vapor exchange.

Thus with the start of the nuclear age, man introduced a number of radioactive substances into his environment. Of particular interest to oceanographers are carbon (^{14}C or radiocarbon) and hydrogen (^{3}H or tritium). Both are produced in nature by cosmic ray-induced nuclear modifications. Both decay by means of beta particle (electron) emission. Their half-lives are 5,700 and 12.3 years, respectively. This implies that a 1‰ concentration drop occurs in about eight years for radiocarbon, and in just over two months for tritium.

Ocean Mixing Rates Traced

Radiocarbon has been extensively used to date archeological finds and to establish time scales for recent geological processes. This dating process, however, has been affected by man's increased burning of fossil fuels, which dilutes radioactive carbon dioxide by adding old carbon (from the fossil fuels) that is effectively free of radioactivity. There also has been an opposite tendency which is the result of nuclear testing and industrial activities — that of adding to the natural sources of radiocarbon to the point where modern carbonates, or wood, can appear to have "negative ages" of several thousand years. Our best estimates of the "ventilation time scales" for the deep-ocean basins — close to 2,000 years for the abyssal North Pacific — are derived from observations of the natural radiocarbon distributions in areas not yet affected by the influences of man.

In the prenuclear era, tritium was not a very useful geophysical tracer because of its low natural abundance. It has been estimated that only a few kilograms of this isotope existed naturally in the entire hydrosphere, whereas testing thermonuclear fusion devices in the early 1960s produced about a hundred times the background (natural) amount. Even so, the resulting surface concentrations in the oceans amount to only one tritium atom for every 10^{17} to 10^{18} ordinary hydrogen atoms. This kind of tracer concentration is detectable, although with considerable effort.

The low natural background concentrations make tritium a very attractive tracer for determinations of oceanic mixing rates. Wherever it can be effectively measured, we know that at least some of the water in our sample is under the influence of near surface processes that took place later than the year 1960. Although between 80 and

90 percent of the world ocean volume is excluded by the relatively short time scale of tritium, its use as a tracer in identifying precisely those areas of the ocean that are significantly influenced by surface processes within about a decade of their occurrence represents a valuable contribution to the understanding of ocean mechanics.

As a way of understanding the level of radioactivity involved, let us consider a fairly high surface concentration of one tritium atom for every 10^{17} hydrogen atoms in the water. This concentration is denoted as 10 tritium units (10 TU), based on the convention that one tritium unit represents a concentration fraction in hydrogen of $1{:}10^{18}$. Since 18 grams of water (one gram-molecule) contain 6×10^{23} molecules, we can compute that 1 cubic centimeter (1 milliliter) of water at 10 TU contains about 7×10^{5} tritium atoms. Based on the known half-life of 12.3 years, we can then deduce that in such a water volume tritium atoms undergo radioactive decay at a rate of one every 800 seconds. The decay of a tritium atom produces a beta particle (an energetic electron), and an atom of light helium of atomic weight 3 (normal helium has an atomic weight of 4). Either of these decay products can be used for determining the tritium concentration in the sample.

New Analysis Method

All the Geosecs tritium analyses were performed at the University of Miami in Florida. The direct counting method of the beta particle production was employed, after first subjecting the samples to approximately one-hundredfold enrichment in tritium concentration by a chemical process known as controlled electrolysis, or conversion of the remaining enriched water to hydrogen and the "counting" of the gas in a device similar to a Geiger detector. In this process, a 300-milliliter sample is used, leading to a counting rate of about 23 decay events per minute for a 10 TU original concentration of tritium. The practical detection limit with this technique is about 0.1 TU, or a concentration fraction $1{:}10^{19}$.

A new analysis method is currently in use at the Woods Hole Oceanographic Institution. In this method, the water sample is first subjected to a careful degassing to remove any dissolved helium. Then, it is stored in a gas-tight container for several months. The decay-produced light helium is then determined mass spectrometrically, and the original tritium concentration is calculated. By also analyzing the helium composition initially in the water (prior to degassing), one has the additional advantage of getting an estimate of the total amount of tritium decay that has occurred in the water since it was last in a position of near surface exposure to the atmospheric helium gas: hence "tritium-helium dating." This can be used to measure in situ rates of chemical reaction, such as oxygen utilization.

The most complete Geosecs data at the present time come from an Atlantic section that extends from the Greenland Sea in the north, to the edge of the Antarctic continent in the south. The ship track is shown in Figure 2, and a presentation of the data appears in Figure 3, which is plotted in a reference frame of latitude and depth. One notes a very large difference in tritium concentration values between the northern and the southern hemispheres. This is due to the fact that the largest portion of the tritium contamination was a result of the high-yield hydrogen bomb tests conducted in the Arctic by the Soviet Union. The relatively short lifetime of water vapor in the atmosphere (due to rain-out) led to the tritium's penetration into surface waters before it could spread to the southern hemisphere.

In the northern hemisphere, where the higher tritium concentration allows a greater resolution, we note the pronounced differences in depth penetration with latitude, and in particular the occurrence of a near-bottom tritium concentration maximum north of 40^{0} latitude. This near-bottom tongue of "tagged" water represents the primary southward spreading of water that has been cooled at high latitudes, hence sinking along the bottom contours in a path that is basically southward, but which leans on the western side of the ocean basin because of the effects of the earth's rotation. The effects of this rotation, together with the influences of global wind and weather patterns, are important factors in explaining the distribution of tritium in the upper 2,000 meters. Note how the distributions in the two hemispheres in the mid- and tropical latitudes show substantial similarity, both with each other and with the distribution patterns of other chemical constituents, as shown in Figure 1.

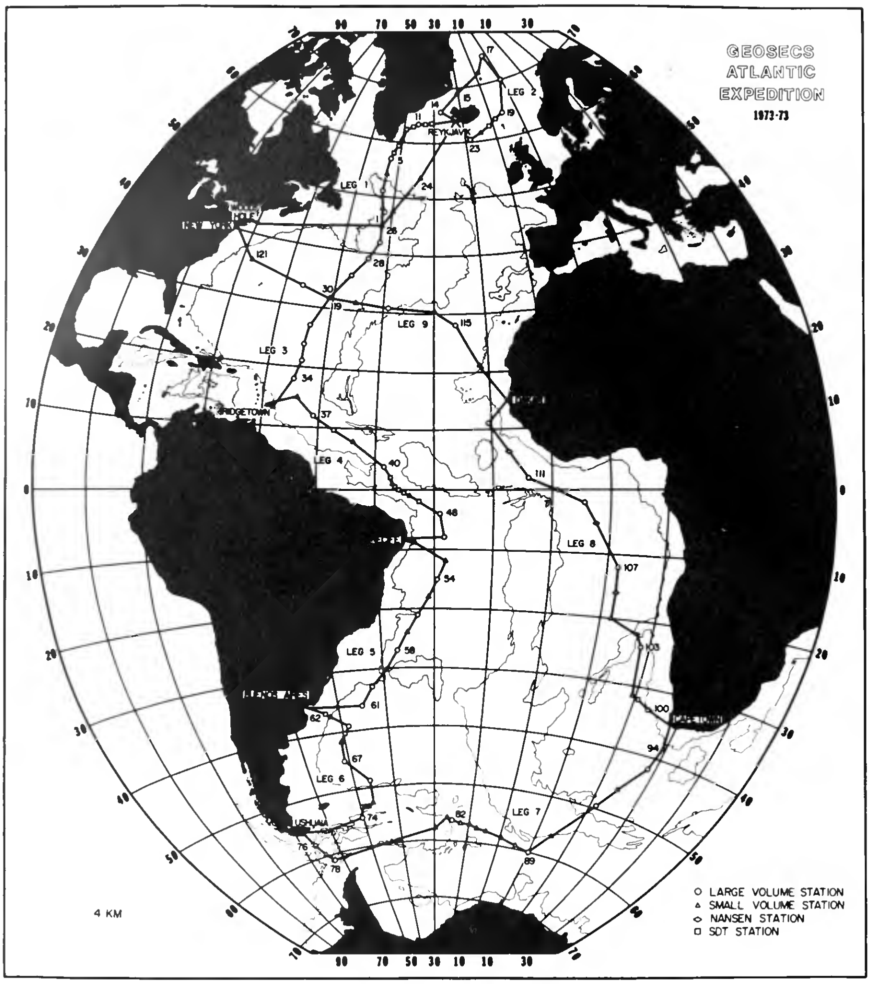

Figure 2. The Geosecs Atlantic ship track. This project phase was carried out on the R/V Knorr of the Woods Hole Oceanographic Institution.

The combination of mainly westerly winds with maximum strength somewhat poleward of 40° latitude and easterly trades in the tropics produces a set of subtropical ocean gyres which are then distorted toward the west and poleward, due to the earth's rotation effect. This phenomenon is the essence of the mechanics of major currents, such as the Gulf Stream in the western Atlantic Ocean (see *Oceanus,* Spring 1976, Ocean Eddies). For our purpose here, it is enough to understand that the dynamics of the upper ocean current patterns lead to a pushing away from the equator of much of the heated surface waters, with a maximum accumulation in the western gyre around 35° latitude. The dips in the concentration patterns away from the equator in Figure 1 can therefore be understood in terms of upward or downward sliding paths of water as they move in a meridional direction.

Figure 4 is a redrawing on a larger scale of the upper northern quarter of Figure 3, with the temperature pattern superimposed on the tritium concentration. Looked at in the context of data on late winter temperatures in the North Atlantic, it is not difficult to imagine that surface outcroppings of water in wintertime are related to the interior tracer distributions. The basic wind-driven circulation in the North Atlantic leads to a relatively fast gyre-wide redistribution of properties roughly above the level where the water is at a temperature of 10 degrees Celsius. Different spreading processes, perhaps dominated by mid-ocean eddy systems, prevail below this temperature and down to the near-bottom current regime. The possible validity of these conjectures is the subject of present research; their resolution will help us understand many aspects of ocean physics, chemistry, and biology, since the distribution and recirculation of seawater properties, such as heat content, nutrient concentrations, and manmade contaminants of diverse kinds affect all factors in the oceans.

From my personal point of view, the most exciting prospect is that the geochemical data, including the tritium distributions and their evolution in time, will provide important

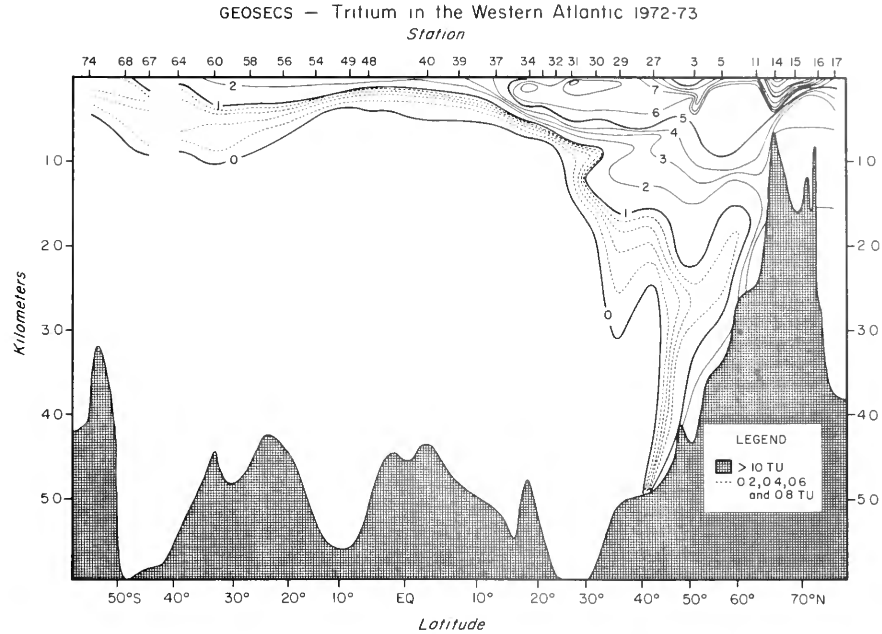

Figure 3. The tritium concentrations observed along the Western Atlantic Geosecs track.

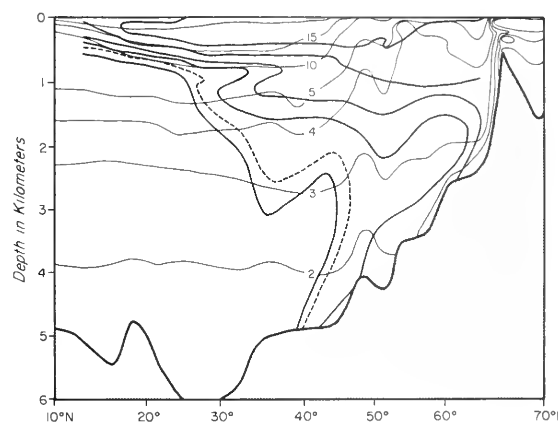

Figure 4. The northern portion of Figure 3 redrawn with potential temperature contours superimposed.

clues to the mechanics of oceanic heat transport and storage. These processes are an important part of global climate dynamics, both in its current state and in the long-term variations, such as ice age development. The question of what paths are followed in the oceanic redistribution of pollutants (of which manmade tritium is only one example) also has great significance for assessing the possible impact of an accelerated program for burning fossil fuels. It has been suggested by some researchers that the adding of carbon dioxide to the atmosphere might create a thermal radiation blanket that would cause a lot of the inland ice masses to melt. This would cause extensive flooding of low-lying areas, such as in Bangladesh, where tens of millions of people would be displaced without food sources. The ocean's capacity for absorption of added carbon dioxide in the atmosphere is an important aspect of the assessment of risks engendered by various global energy policy options. The answers to questions like these will largely come from programs such as Geosecs and from new research projects inspired by them.

Claes H. Rooth is Professor of Meteorology and Physical Oceanography at the University of Miami in Florida.

Nitrogen Fixation in Salt Marshes—A Built-In Plant Fertilizer

by Charlene D. Van Raalte

Despite the fact that approximately 80 percent of the atmosphere is made up of nitrogen (N_2), our world food production is limited by a lack of this element. The reason for this apparent contradiction is that most organisms cannot assimilate gaseous nitrogen. Plants take up nitrogen in the inorganic form as nitrate (NO_3^-) or ammonia (NH_3), and animals absorb nitrogen in the organic form as amino acids and proteins (the nitrogen is bound to carbon and hydrogen).

Certain bacteria and blue-green algae are able to take gaseous nitrogen from the atmosphere and incorporate it into their chemical pools. This process is called nitrogen fixation because the nitrogen gas is "fixed" (or bound) into a stable and utilizable form: first as ammonia, and then as amino acids and proteins. All other organisms, therefore, are dependent on the fixers for the biological conversion of nitrogen to a form that can be generally used. The enzyme that catalyzes the reaction ($N_2 \rightarrow NH_3$), called nitrogenase, is common to the many different bacterial types that fix nitrogen.

Sergei N. Winogradsky first isolated the nitrogen-fixing bacteria at the turn of the century, and since then, the biology and chemistry of fixation has interested scientists of various disciplines. The process by which the tightly bound nitrogen atoms ($N \equiv N$) are cleaved and reduced with hydrogen is of basic interest to the biochemists. In addition, nitrogen fixers provide many fascinating examples of symbioses ("living together"). This pairing of two dissimilar organisms is generally of mutual benefit to both partners. For example, the organisms may trade chemicals that each has in abundance for others in low supply. In these relationships, the nitrogen-fixing organisms exchange reduced nitrogen (a growth-limiting nutrient) for other needed factors (often energy sources, such as sugars). Blue-green algae/fungi (lichens) and root bacteria/plants (legumes) are examples of such symbioses.

The High Cost of Fertilizer

Nitrogen-fixing bacteria can form several types of relationships with the roots of plants. In general, the location of the bacteria and the rigidity of the association distinguishes the various types. Free-living fixers growing in soil are loosely associated with the rhizosphere (root zone) of many plants, such as *Typha* (cattail) and *Ammophila* (sand dune grass). Nitrogen-fixing bacteria also can grow within the root cortex of some grasses. In the leguminous plants (peas, soybeans, clover), the nitrogen-fixing bacteria live in root swellings called nodules. Since an understanding of the interaction between the bacterial symbiont and the host plant in the legumes is of obvious agricultural importance, these plants have received considerable study. Scientists have learned that bacteria of the genus *Rhizobium* invade the roots of the legumes; that the bacteria are deformed inside the nodules; that the plant manufactures a hemoglobin-like chemical (leghemoglobin), which protects oxygen-sensitive nitrogenase from this gas; and that the amide asparagine is the major form of nitrogen transported from the nodules to the aerial part of the plant.

Due to their internal nitrogen source, legumes require little nitrogen fertilizer. In contrast to the leguminous plants, other food crops show a marked response to nitrogen application and, largely because of this, there has been a sharp rise in the production of these crops during the last 30 years. Corn yields, for example, have increased 240 percent from 1945 to 1970. Of the nonbiological inputs responsible for these greater yields, the increased use of nitrogen fertilizer is probably the most important factor. In 1974, 40×10^6 tons of nitrogen fertilizer (costing $8 billion) were used, compared to 3.5×10^6 tons applied in 1950.

Of course, the impressive increase in agricultural yields has been accompanied by a large output of energy. Unfortunately, most of the energy used in mechanized agricultural production — transportation machinery, irrigation, pesticides, and fertilizer — is derived from fossil fuels. As seen in Table 1, the production of nitrogen in the United States requires the largest input of energy. (Nitrogen is commercially converted to NH_3 under conditions of high temperature and pressure). Because fossil-fuel resources are being depleted, agricultural researchers are looking for ways to reduce crop nitrogen requirements without reducing crop yields. Some think that nitrogen fixation may be the answer to this problem.

These scientists have attempted to encourage nitrogen-fixing *Rhizobium* strains to cohabit with the roots of other plants, such as wheat and corn, that lack such an association. If this research is successful, the cost of fertilization will be greatly reduced. The difficulty with this approach, however, is that the *Rhizobium* strains are very specific to the parent plant species and seem untransferable to another type of plant.

Encouraged by the work of Johanna Döbereiner of Brazil, some scientists are beginning to work with less rigid nitrogen-fixing bacterial/root symbioses — where the bacteria are promiscuous and can be encouraged to associate with other plants. Döbereiner has found that nitrogen fixers commonly form loose symbioses with the roots of many tropical forage grasses. In *Paspalum* (elephant grass), for example, the fixers are of the genus *Azotobacter,* and in *Digitaria* (crab grass), *Spirillum lipoferum* is the bacterial symbiont.Since the rates of nitrogen fixation compare favorably with those of the legumes, the success of this approach seems plausible (Table 2).

Similar plant-bacterial associations can be found in other environments. We have been working in one of these habitats — a salt marsh — with the salt marsh cord grass, *Spartina alterniflora. Spartina* roots fix nitrogen at high rates, and the bacterial symbiont within the root is strikingly similar to that of *Digitaria.* Because of this similarity, the *Spartina* fixation research is of interest to the agriculturalists. However, little is known about the interactions between the *Spartina* and the nitrogen fixers. How do the bacteria invade the roots? Do the bacteria grow in the salt marsh sediment? Is there only one type of bacteria or more? What is the carbon subsidy provided by the plant to the bacteria? In what form is the nitrogen fixed by the bacteria transferred to the plant? All of these questions and others need to be answered before we can seriously consider the agricultural application of these symbioses (Figure 1).

Table 1: Average energy per acre of some inputs in the production of corn during different years. In the United States, corn is the most important grain crop. (From Pimentel, et al., 1973)

Inputs	1945	1954	1970
Labor (hrs. crop acre $^{-1}$)	23	17	9
Machinery (Kcalx10^3)	180	300	420
Nitrogen (lbs.)	7	27	112
Phosphorous (lbs.)	7	12	31
Insecticides (lbs.)	0	0.3	1.0
Transportation (Kcalx10^3)	20	45	70
Corn yields (bushel)	34	41	81

The Salt Marsh Research

Actually, our work on nitrogen fixation in *Spartina* was not begun with the idea that the findings would be agriculturally important. The research had quite a different beginning in Great Sippewissett Marsh on Cape Cod in Massachusetts, and only recently have the paths of several marine laboratories converged at this common point. The nitrogen fixation story in Great Sippewissett Marsh is an interesting example of an unforeseen spin-off from another research project: studies of the structure of salt marsh ecosystems, and the effect of pollutants on these ecosystems.

In 1970, Dr. Ivan Valiela, an Associate Professor in the Boston University Marine Program at the Marine Biological Laboratory in Woods Hole, Massachusetts, and Dr. John

Table 2: A comparison of the nitrogen-fixing potential of several systems.

Nitrogen-Fixing System	KgN hectacre^{-1}yr.$^{-1}$	Reference
Clover	250	Postgate, 1974
Blue-green algae	25	Postgate, 1974
Paspalum-Azotobacter	15-93	Döbereiner, et al., 1972
Digitaria-Spirillum	100	Hardy and Havelka, 1975

Figure 1. Spartina alterniflora, *Sippewissett salt marsh, Falmouth, Massachusetts. Research on the nitrogen-fixing bacteria in the roots of this grass may be of agricultural importance. (Photo by Dr. Ivan Valiela)*

Teal, a Senior Scientist at the Woods Hole Oceanographic Institution, began a new research project. They wanted to determine how the interactions of the components of a salt marsh ecosystem would be affected by additions of a fertilizer containing sewage sludge. This study is of practical value because marshes are being considered as sites for sewage disposal.

This large-scale operation involved technicians, students, and other researchers, who examined the effects of the fertilizer on many aspects of the marsh ecosystem. One of the most obvious effects was the increased growth of the *Spartina* grass. In plots fertilized with sewage and in those plots fertilized with only nitrogen, the grass grew taller, looked greener, and was higher in nitrogen. Other plots were only fertilized with phosphate, and in these areas there was no change in grass growth or chemistry, compared to unfertilized areas. Since the effect of the nitrogen-only fertilizer was the same as that of the sewage fertilizer, nitrogen was presumed to be the component in the sewage sludge that increased grass growth.

Nitrogen increases grass production (and that of other components of the marsh, such as algae). Since the grasses are the major photosynthesizers in marshes, and the bases of the food web, we can generally say that the marsh ecosystem is "nitrogen limited" or lacking in nitrogen. (The study of factors that "limit" the growth of organisms in ecosystems is a basic approach of ecological research.) This is where nitrogen fixation enters our story. The determination of nitrogen limitation was a basic step in our realization that nitrogen fixation must be important in salt marshes. It turned out that the rates of fixation were very high.

Nitrogen fixation only occurs in nitrogen-limited habitats because, in terms of energy, it is an expensive process. A great deal of energy is needed to break apart the three chemical bonds that hold the two nitrogen atoms together. When nitrogen is readily available, as in the fertilized marsh plots, where we measure availability by the concentration of ammonia nitrogen (NH_4-N) in sediment water, nitrogen fixation is greatly reduced (Figure 2). Nitrogen fixers will absorb the nitrogen from their external environment rather than wasting their energy to fix it. The same relation holds in

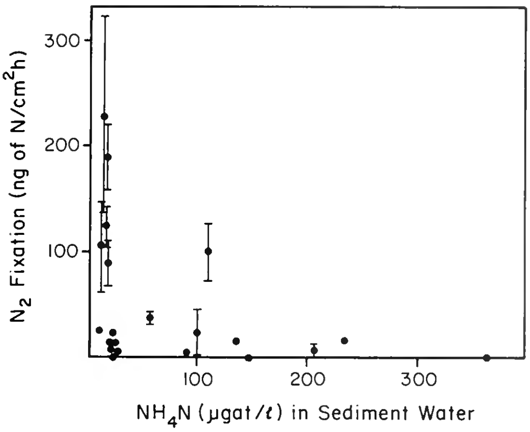

Figure 2. Nitrogen fixation by surface-living blue-green algae plotted against NH_4-N concentration in the sediment water in Great Sippewissett Marsh. (From Van Raalte, et al., 1974)

farm fields, the more fixed nitrogen (ammonia or nitrate) available, the lower the rate of fixation.

Other Nitrogen Fixers

There are several types of nitrogen fixers in the salt marsh. In addition to the bacteria living inside the *Spartina* roots, other nitrogen-fixing organisms grow on the surface of the marsh. The blue-green algae, also called blue-green bacteria, are found in the greatest abundance. (These organisms are called "algae" because they photosynthesize and therefore are pigmented, as are true algae. Structurally, however, the blue-greens are bacteria because they lack the internal membrane structure of the algae.) The blue-greens live on the marsh surface beneath the canopy of marsh grasses. They also are found in wet, flat areas behind sand dunes where they form thin, compact growths called "algal mats" that look somewhat like pieces of a black asphalt parking lot. Algal mats fix nitrogen at high rates (Figure 3).

In addition to the blue-greens, the photosynthetic bacteria also have the potential for nitrogen fixation. These bacteria are found in pannes that are bare, waterlogged depressions that dot the surface of the marsh. The photosynthetic bacteria, lovely scarlet or pink in color, often proliferate due to their nitrogen-fixing ability. The pannes then become brightly colored, and the slashes of scarlet contrast vividly with the swards of green marsh grasses.

Life Below the Surface

One can imagine the microscopic activity of the marsh surface: bacteria absorbing and excreting nutrient chemicals and gases; protozoan animals sliding over clay particles, ingesting the bacteria; blue-green algae and

Figure 3. An algal mat, containing nitrogen-fixing blue-greens, mainly of the genus Calothrix. *(Photo by Dr. Ivan Valiela)*

diatom cells gliding over invisible slimes; and huge invertebrates, such as snails and insects, dining on the microbial feast with the towering grass stalks standing sentinel above.

Less easily imagined, though equally interesting, is life beneath the surface — deep within the salt marsh mud and peat. Life is dark and slower there, but no less fascinating to the microbiologist than that on the surface. Below a depth of about 5 millimeters, the marsh sediments become anaoxic, or lacking in oxygen. Oxygen diffuses slowly down from the marsh surface, and it is quickly burned by all the metabolic activity occurring there. The organisms that live within the sediments have adjusted to this seemingly inhospitable environment. Bacteria that thrive in this environment — the anaerobes — use molecules other than oxygen to accept the electrons spent during respiration (Figure 4).

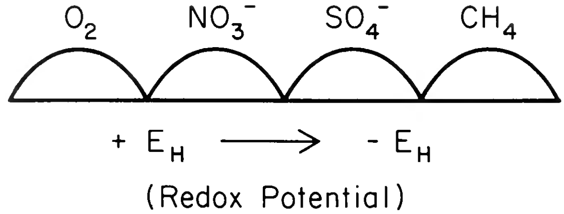

Figure 4. A simplified diagram of the shift in terminal electron acceptors from aerobic to increasingly anaerobic conditions — as occurs in salt marsh sediments.

The area directly surrounding the roots of the marsh grass, the rhizosphere, is particularly active. The roots themselves absorb nutrients from the water contained in the sediment. The root cells respire, excrete wastes, and slough off their dead cells. Many bacteria in the rhizosphere take advantage of these products exuded from roots. Some of the rhizosphere bacteria are nitrogen fixers, but the most significant site of nitrogen fixation (at least in *Spartina)* is within the root (Figure 5).

According to observations by Dr. David Patriquin of Dalhousie University, Halifax, Nova Scotia, the predominant fixers appear to occur directly beneath the epidermis of the roots in the outer cortex. This site seems ideal for the bacteria. Here within the root, the energy substrates that are needed for nitrogen fixation are readily available. The photosynthesizing *Spartina* manufacture energy-rich carbon compounds and probably shunt them down from the leaves to the roots through phloem tubes. The nitrogen fixers burn these rich substrates, fix nitrogen, and somehow transfer the fixation products to the root cells. The fixed nitrogen then is transported to the rest of the plant.

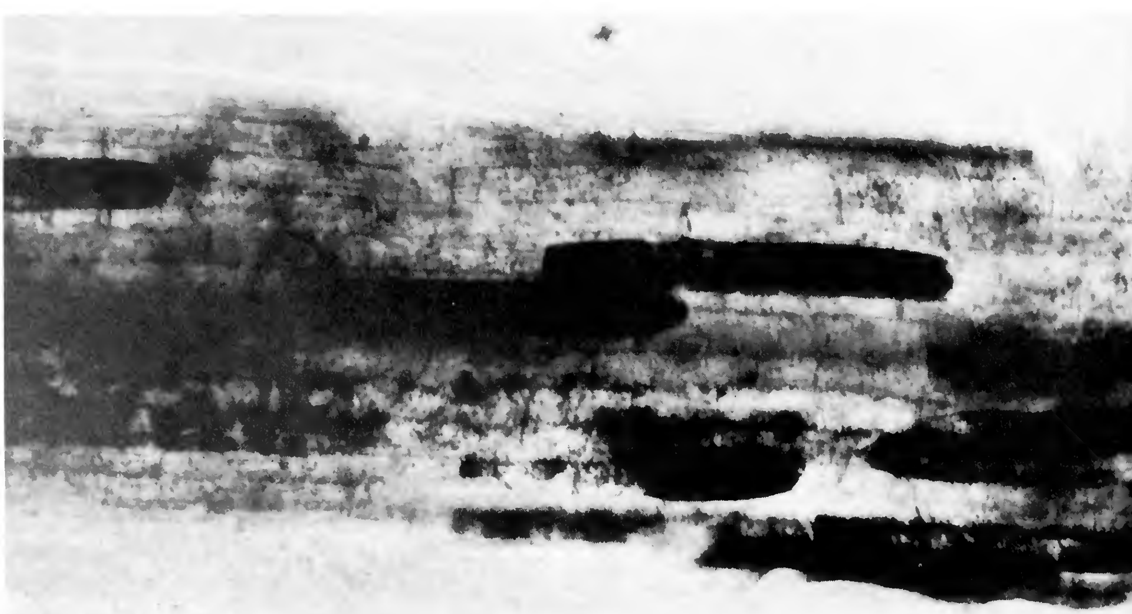

Figure 5. Longitudinal section of the roots of Spartina alterniflora *X225, illustrating cells of the outer cortex packed with bacteria, possibly nitrogen fixers. The roots were preincubated in tetrazolium; high reducing enzyme systems, such as nitrogenase, reduce tetrazolium, producing dark formazam crystals around the bacteria. (Photograph by Dr. David Patriquin, Dalhousie University, Halifax, Nova Scotia)*

The Road Ahead

After several years of research, we now have a better understanding of nitrogen fixation in salt marshes. We have identified the major sites of fixation and have determined seasonal rates and the environmental factors controlling these rates. The interest that agricultural researchers have shown toward our work at recent scientific meetings assures us that our study of the comparison and contrast between the two systems — the marsh and the farm field — will provide a better comprehension of both.

Last year, several research teams published some exciting results on the potential for induction of nitrogen fixation in crops. A group in Oregon measured fixation in roots of corn that had been inoculated with a nitrogen-fixing strain of *Spirillum*. Another group in Lethbridge, Canada, isolated nitrogen-fixing bacteria from the rhizosphere of a chromosome substitute of a common wheat. While these findings are preliminary, they provide a beginning. In addition, another approach — the genetic transfer of nitrogen-fixing capacity to bacteria already associated with plant roots — is being investigated.

It is difficult to say whether crops with "built-in fertilizers" will be growing in our fields a few decades from now. The concept has potential, but there is a great deal of basic research still to be done. In the past, farmers have used *Spartina* marshes as grazing pastures. Perhaps through our work on nitrogen fixation in *Spartina*, this grass will benefit the farmers of the future in a very different fashion.

Charlene D. Van Raalte is an Assistant Professor at Hampshire College, Amherst, Massachusetts.

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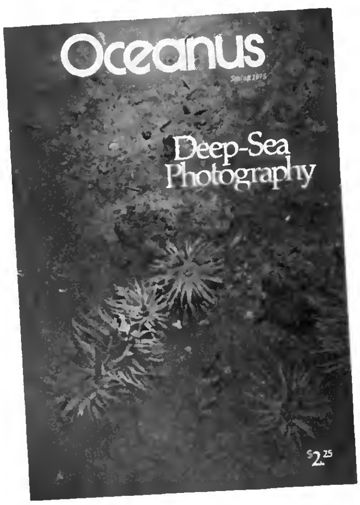

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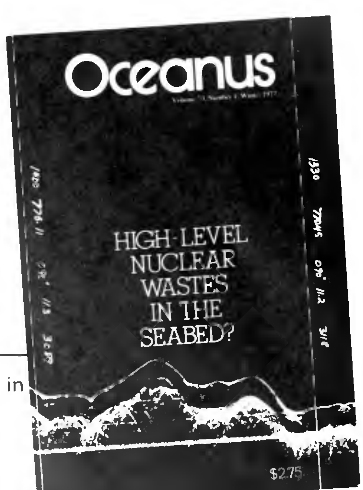

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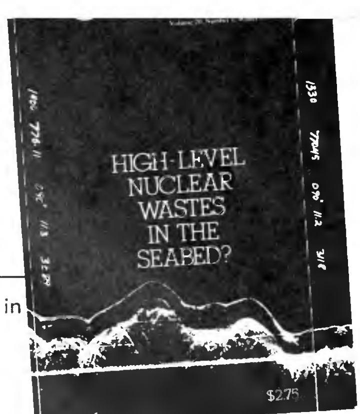

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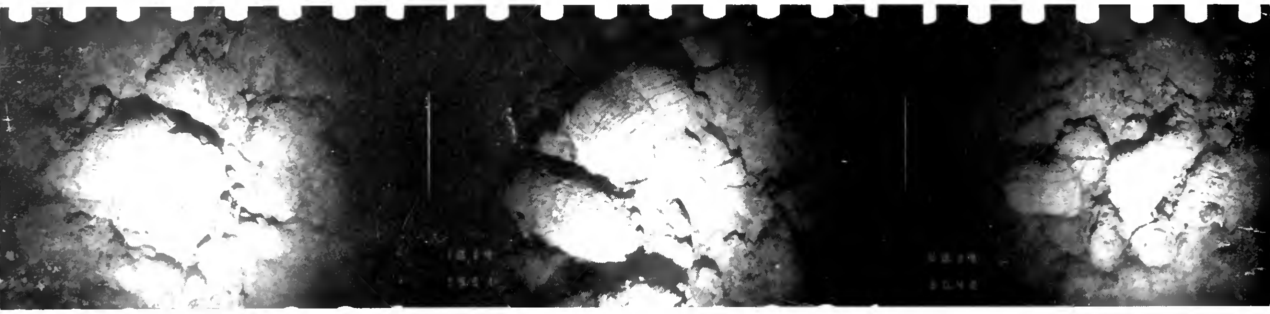

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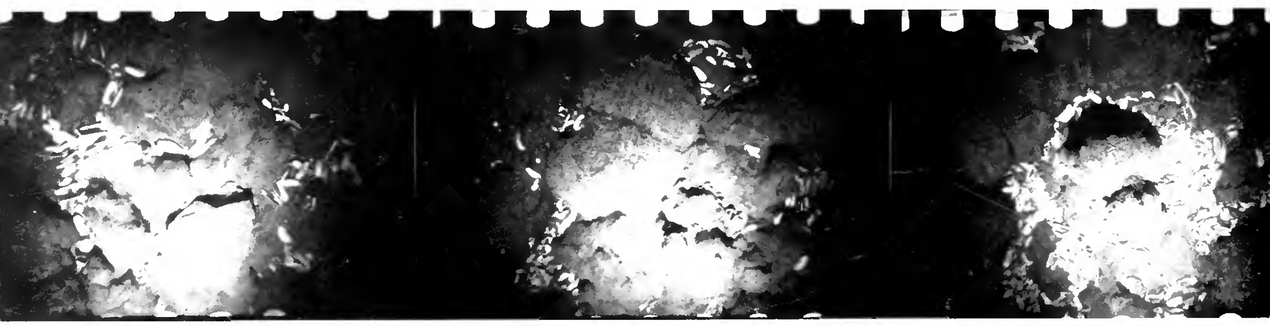

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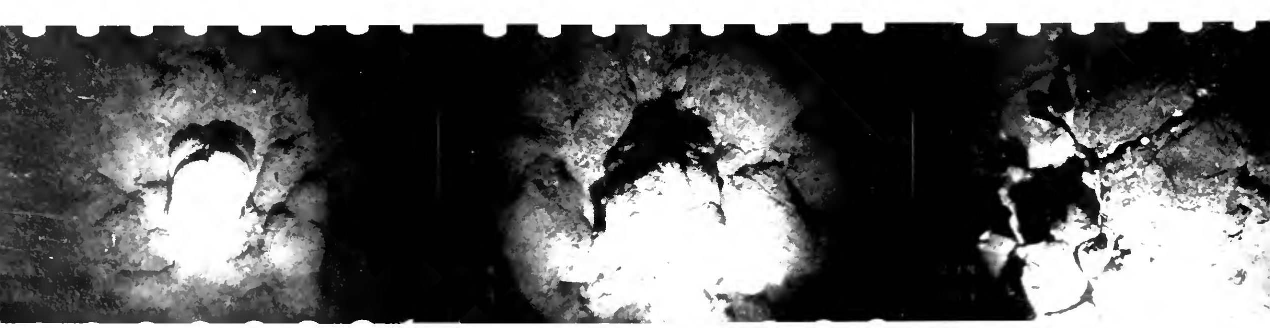

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