28 June 1974, Volume 184, Number 4144 SCIENCE

Marine Science and the 1974 Law of the Sea Conference

Science faces a difficult future in changing law of the sea.

John A. Knauss

The nations of the world are slowly negotiating a multipurpose treaty on the law of the sea. In terms of numbers of issues it is perhaps as complex as any multinational treaty negotiation ever attempted by the United States. Military and economic interests are considerable, and these dominate the negotiating postures of the 90 nations who have recently completed 3 years of preparation for the full conference of plenipotentiaries that is scheduled to take place in Caracas, Venezuela, 20 June to 29 August 1974 (*1*). Scientific research in the ocean is also on the agenda of the forthcoming Law of the Sea Conference and, based on the deliberations to date, the prospects are that the treaty will impose severe restrictions on future marine scientific research. The time is long since past when marine science was treated as a harmless amusement of the rich nations. To many countries there is a direct tie between the establishment of a major basic research program and the development of offshore oil, distant water fishing fleets, sophisticated military weapons systems, and the emergence of a deep-sea mining industry. These countries are convinced that knowledge is power and that even the most fundamental oceanographic studies are of potential economic value. This article reviews briefly the present status of the law of the sea negotiations and discusses in more detail those parts of the negotiations that concern marine scientific research.

The author, who is provost for marine affairs at the University of Rhode Island, Kingston 02881, is a member of the State Department Advisory Committee on the Law of the Sea and has served as a member of the United States delegation to meetings of the United Nations Seabed Committee.

Background

The 1970 United Nations General Assembly called for a conference in 1973 on the law of the sea that would deal with "the establishment of an equitable international régime including an international machinery for the area and the resources of the seabed and the ocean floor and the subsoil thereof, beyond the limits of national jurisdiction" (*2*). The committee charged with preparing for this conference was the Committee on the Peaceful Uses of the Seabed and the Ocean Floor Beyond the Limits of National Jurisdiction. However, the interests of the seabed committee were not limited to seabed resources. The operative paragraph of the U.N. resolution charged the committee with "a broad range of related issues including the régimes of the high seas, the continental shelf, the territorial sea (including the question of its breadth and international straits) and contiguous zone, fishing and the conservation of the living resources of the high seas (including the question of preferential rights of coastal States), the preservation of the marine environment (including, *inter alia*, the prevention of pollutants) and scientific research" (*2*). In effect, the United Nations was opening the door to a reconsideration of all items of the law of the sea now codified in the four conventions resulting from the first Law of the Sea Conference held in Geneva in 1958.

During the years 1971 through 1973, the Seabed Committee has met twice a year in New York and Geneva for periods ranging from 3 to 8 weeks. The final list of subjects and issues to be discussed at the Caracas conference has 25 headings, most of which have anywhere from 3 to 19 subheadings, and carries the caveat, "The list is not necessarily complete nor does it establish the order of priority for consideration of the various subjects and issues" (*3*). In addition to the more obvious subjects of boundaries and resource exploitation, the list includes such diverse topics as "the rights and interests of landlocked countries," "the development and transfer of technology [to developing countries]," "the régime of islands," "archaeological and historical treasures on the seabed and ocean floor beyond the limits of national jurisdiction," and "archipelagos." An additional dimension is provided by the large number of new nations. As many as 150 will be present in Caracas at the conference of plenipotentiaries, compared to 86 which attended the 1958 conference.

The Issues

The central problem facing the conference is to reconcile traditional use and practice with the increasing demands upon ocean resources as evidenced by the development of offshore oil, the exploitation of manganese nodules, the use of 300,000-ton tankers, and a growing fishing fleet which will soon be capable of fishing most commercial species to near extinction. The requirements of minimum inter-

ference with the traditional uses of the sea as enunciated by military and shipping interests, and by nations highly dependent upon trade, must be balanced against the requirements of those countries that want an orderly régime for the exploitation of the mineral and fishing resources. Except for the geographically disadvantaged, such as landlocked states or those with minimal coastlines, the development of an orderly régime for resource exploitation is often expressed as a demand for exclusive coastal state jurisdiction over the resources to a distance of some 200 nautical miles (362 kilometers) or more offshore.

Although there has been some effort to make law of the sea negotiations a classic confrontation between the developed and developing world, this effort has been only partially successful. Geography is at least as important in deciding positions on issues as is the stage of a nation's development. Thus one sees position papers submitted by landlocked nations, by nations bordering important international straits, and by archipelago nations. The development of positions and consequent negotiations have been slow. In part, this lack of speed may have been deliberate strategy by certain nations such as Peru and Brazil who are among the strongest advocates of extended coastal state jurisdiction, and who apparently believe that time is on their side on this issue. However, this lack of speed must also be due to many nations being unable to see clearly wherein their own interests lie and their not wanting to be rushed. Considering the difficulty the United States has had in enunciating a common policy (*4*), one can sympathize with the plight of many developing nations with limited resources to draw upon, and with little maritime history but perhaps a big future.

This article gives an admittedly personal view of the present stage of the negotiations, but provides a necessary prelude to understanding the situation in which marine science finds itself (*5*).

Territorial sea. The present convention on the territorial sea is silent on the question of breadth. Nations now claim anywhere from 3 to 200 miles (*6*). There appears to be an emerging consensus on a 12-mile territorial sea, but the final decision will depend upon whether or not agreement can be reached on transit through international straits and an economic zone.

Straits. The U.S. Department of State lists 116 straits which are more than 6 and less than 24 miles wide, passage through which would be effected by a change from a 3- to a 12-mile territorial sea (*7*). Included are the Straits of Gibraltar and of Malacca. The United States and Soviet Union, among other countries, are insistent that any agreement on a 12-mile territorial sea be coupled with the concept of free passage through straits. The limits of free passage have yet to be negotiated, but free passage differs from the right of innocent passage within territorial seas in that the former includes the submerged passage of submarines, the overflight by military airplanes, and very limited jurisdiction, if any, for pollution regulations affecting passing ships.

Economic area. There is a trend toward recognition that the coastal nation has at least preferential rights to all living and mineral resources for some distance beyond a 12-mile territorial sea, a region variously referred to as an economic zone, resource zone, or patrimonial sea. To balance the interests of the international community with those of the coastal nation in the economic area is not easy. For many nations, including most, if not all, Latin American and African nations, satisfactory resolution of the economic area is a prerequisite to agreement on a 12-mile territorial sea. The outer boundary of the economic area may be geographic (for example, 200 miles from shore) or functional (the offshore range of a particular coastal fish). If functional, the economic area would be different for different resources. Limited sharing of revenue with the international community has been suggested since, in the view of some, these are "international resources." The rights of the coastal nation to establish special regulations are also in question; for example, should such a nation be able to impose stricter pollution laws than required by international standards? The major disagreements on control of scientific research are in this area with many nations proposing that the coastal nation has the right to control scientific research in its economic area.

Archipelagoes and islands. Clipperton Island is about 6 miles long and sits between Mexico and the Galápagos islands some 600 miles from the nearest land. Assuming there is an agreement on a 200-mile economic zone, should the same rule apply to Clipperton and similar isolated islands? Suppose that a nation could claim a full 200-mile economic zone only if there were at least 400 miles of clear water between it and its nearest neighbor with its own 200-mile economic zone. In cases where the distance was less than 400 miles, as between countries bordering the Baltic and Mediterranean seas, a median line drawn between shorelines of the countries might be acceptable; but what role would islands play, as, for example, the Danish island of Bornholm in establishing Denmark's economic zone, the Italian Pelagie islands in the Mediterranean, or the French islands of St. Pierre and Miquelon which are less than 20 miles off the coast of Newfoundland?

The case of archipelago nations is similarly complicated. Can one draw a perimeter around the outermost islands in the group and claim the area within as internal waters, drawing the territorial sea and economic zone seaward of this perimeter? If not, what special rights, if any, can the archipelago nation establish in the waters between its various islands? These, and similar questions, have yet to be resolved.

International seabed. Mineral resource exploitation of the deep seabed will be regulated by an International Seabed Authority (ISA). The geographic bounds of its jurisdiction await resolution of the economic zone boundary. The political organization as well as its power are in question, but at least the range of alternatives are becoming clearer. Probably there will be a two-tiered organization of an assembly and a council. The council representation will be heavily weighted toward those nations investing heavily in deep-sea mining operations. These nations want stronger representation than is available in the assembly on which all nations will be represented and which will be governed by the principle of one nation, one vote. The alternatives suggested for the delegation of powers between council and assembly range between the extremes of making one group or the other all-powerful and the other nearly impotent. Suggestions concerning the power granted the council or assembly, or both, range from limiting the ISA to establishing limited safety, pollution, licensing, and procedural regulations to giving it power to establish production quotas and its own exploration and production company. Some have proposed that the ISA should have the power to regulate

all scientific research on the deep seabed and in the waters above. As a minimum it may be empowered to establish regulations for drilling in the deep seabed to depths greater than a few hundred meters such as done by the Deep Sea Drilling Project.

Other issues. Some issues await further discussion, or have not yet been brought up. For example, the nature of the regulation concerning highly mobile pelagic species, such as tuna, is dependent in part on the resolution of the economic zone issue, as are the regulations concerning anadromous fish (salmon).

It has been generally agreed that this conference is not prepared to cope comprehensively with land-based pollution. For marine-based pollution (that is, ships and offshore structures) the issue is which international authority, or authorities, should establish regulations and what residual rights, if any, does the coastal nation have to establish additional regulations? This latter point has become a potentially explosive one since the unrestricted right to establish local pollution regulations in an economic zone could result in inconsistent shipping regulations and similar constraints to other international uses of economic zones. The economic zone could thus be reduced to the status of an extended territorial sea.

The Marine Science Issue

Control and regulation of scientific research beyond the territorial sea began with the Convention on the Continental Shelf, ratified in 1964 (*8*). This convention gave to the coastal nation "sovereign rights for the purpose of exploring it and exploiting its natural resources." The *it* of the above clause is "the seabed and subsoil of submarine areas adjacent to the coast but outside the territorial sea to a depth of 200 meters or beyond that limit to where the depth of the superjacent waters admit of the exploitation of the natural resources of the said area."

The Continental Shelf Convention represents a compromise between the rights of coastal states and the interests of science. It states in paragraph 1 of article 5 that exploration and exploitation should not result in *any interference* with fundamental oceanographic research. Later, in paragraph 8, it provides that consent must be obtained from the coastal state for research concerning the shelf and undertaken there. It seeks to protect science from arbitrary refusal of consent by providing that consent shall not normally be withheld if certain conditions are met.

The experience of U.S. scientists attempting to conduct research under the Continental Shelf Convention has been frequent refusals of consent even though all the conditions of the convention have been met. In addition to denials, U.S. oceanographers have frequently received no response whatsoever, or responses have been received so late that the research programs have already been altered. Daily costs for operation of an average research vessel range upwards of $3000.

There is a growing feeling in the oceanography community that it is becoming increasingly difficult to secure permission to conduct scientific research (*9*). Although there are records of refusals and delays, there is no way to determine how many research programs have been designed to avoid potential problem areas.

As a result of its experience with the 1958 Continental Shelf Convention, the oceanographic community views the probable outcome of the forthcoming Law of the Sea Conference with considerable dismay. A 200-mile economic zone encompasses about 37 percent of the world ocean (*10*), an area comparable to the total land area of the earth. Figure 1 illustrates what a 200-nautical-mile economic zone might look like. It includes the entire Mediterranean and Caribbean and large areas of the North Atlantic and South Pacific. We have calculated that our research vessel *Trident*, of the University of Rhode Island, has averaged 45 percent of her time during the past 5 years in the proposed 200-mile zone of other countries, and *Trident* is not the most far-ranging of U.S. research vessels.

Unless the scientists can prevail, the most likely outcome of the Law of the Sea Conference will be that permission will be required to conduct scientific research in the economic zone of foreign countries. Those who have followed the debate on the issue to date are not optimistic that scientific interests will be protected. Some might consider scientists lucky if they can escape with the language of the Continental Shelf Convention applied to the economic zone. There is a real possibility that regulations of some kind may be imposed by the ISA for the area under its jurisdiction, and the régime for the economic zone may be considerably more restrictive than that in the 1958 Continental Shelf Convention. The delegation of the Peoples Republic of China proposed that in regions of national jurisdiction (that is, an economic zone), "[t]he publication and transfer of such data and results are subject to the prior consent of the coastal state concerned" (*11*).

The United States has accepted the proposition that science and scientists have certain obligations to the coastal nation while conducting research in the economic zone, but the United States proposes that scientists not be denied access to these vast ocean areas as long as they abide by rules designed to protect coastal state interests. The key to the U.S. proposal (*12*) is article 7 which reads:

> In areas beyond the territorial sea where the coastal State exercises jurisdiction pursuant to Articles ——— over seabed resources and coastal fisheries, States and appropriate international organizations shall ensure that their vessels conducting scientific research shall respect the rights and interests of the coastal State in its exercise of such jurisdiction, and for this purpose shall:
>
> a. provide the coastal State at least ——— days advance notification of intent to do such research, containing a description of the research project which shall be kept up-to-date;
>
> b. certify that the research will be conducted in accordance with this Convention by a qualified institution with a view to purely scientific research;
>
> c. ensure that the coastal State has all appropriate opporunities to participate or be represented in the research project directly or through an appropriate international institution of its choice; the coastal State shall give reasonable advance notification of its desire to participate or be represented in the research within ——— days after it has received notification;
>
> d. ensure that all data and samples are shared with the coastal State;
>
> e. ensure that significant research results are published as soon as possible in an open readily available scientific publication and supplied directly to the coastal State;
>
> f. assist the coastal State in assessing the implications for its interests of the data and results directly or through the procedures established pursuant to Article 5;
>
> g. ensure compliance with all applicable international environmental standards, incuding those established or to be established by [insert name or names of appropriate organizations].

The rationale behind the U.S. proposal is that the provision of article 7 should satisfy the legitimate concerns of the coastal nation about any scientific research in its area of economic jurisdiction (other articles address themselves to safeguarding the marine

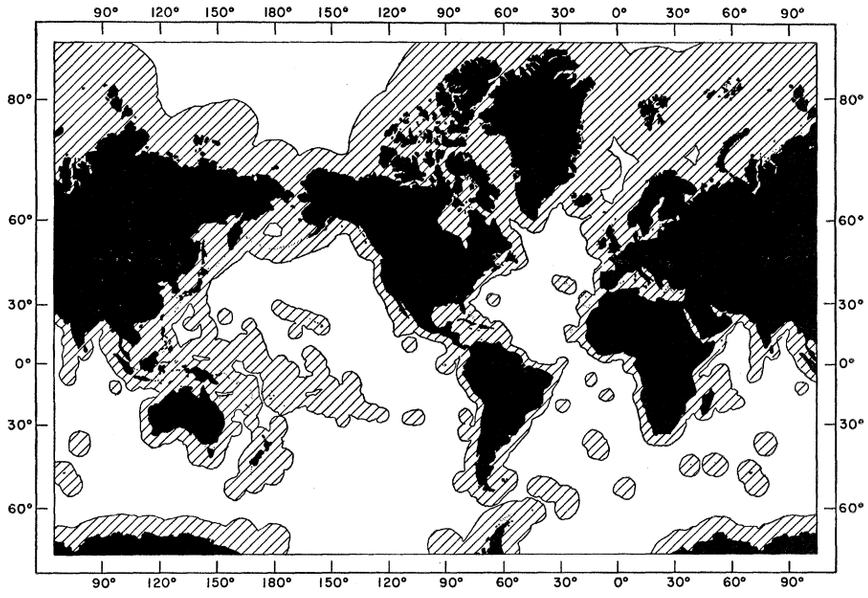

Fig. 1. The area of the oceans encompassed by a 200-nautical-mile economic zone. Redrawn from a chart published by the Office of the Geographer, U.S. Department of State.

environment and assuring that scientific research will not form the basis for a claim to the natural resources in the area). The U.S. position is that if these concerns are met, the coastal nation should not be in a position of controlling research by requiring explicit permission. Although a number of oceanographers feel the stipulations of article 7 have gone too far in compromising the interests of the science community, there appears to be a consensus that the proposed obligations are "livable" and that they are preferable to a régime in which the "consent requirement" of article 5, paragraph 8, of the Continental Shelf Convention applies to the entire economic area shown in Fig. 1.

To most of the Seabed Committee, however, the U.S. proposition is a radical one. They wish to start with the "consent requirement" of the Continental Shelf Convention and negotiate further restrictions from that point. Some have suggested that the U.S. article 7 provisions might be the minimum requirements to ensure consent. At the moment, the concept of substituting an explicit set of obligations for consent has found few adherents. On the basis of what was said (and not said) by delegations of the Seabed Committee in Geneva last summer one can only conclude that it is not only the developing nations that are concerned about substituting an obligation régime for consent régime. The same apparently holds true for the United Kingdom, France, Canada, and Australia, with Canada being by far the most outspoken. The positions of Japan and the Soviet Union are less clear, but neither spoke in favor of the U.S. proposal. These are all nations with highly developed oceanographic programs.

Coastal State Concerns

The oceanographic community is deeply concerned about the course of events in the law of the sea negotiations. Even if oceanographers in the major maritime nations such as Canada, France, United Kingdom, and the Scandinavian countries can eventually prevail upon their governments to adopt a more positive attitude toward facilitation of marine science, there remains the very large problem of convincing the developing nations, most of whom have but a limited oceanographic capability at present. The task is not an easy one. One element underlying all negotiations is the large emotional issue of nationalism of the newly emerging nations. How large a role this plays in the attitude of some Latin American and African nations is a matter of speculation, but it cannot be assumed that logical arguments will automatically prevail in the Law of the Sea Conference any more than they do in Congress, state assemblies, corporate board rooms, or faculty senates.

The explicit stated concerns of the coastal state revolve about the relationship between research and economic development. The United States has attempted to show the long and often tortuous path between bona fide basic research and resource exploitation, such as the many steps between the discovery of manganese nodules 100 years ago on the *Challenger* expedition and the present efforts by a number of mining companies to develop an economically efficient method of collecting and processing them (*13*). Although the techniques used by marine geologists to study a continental shelf are similar to those used by oil exploration companies, the amount of data and the kind of detail required for each kind of investigation are entirely different. Figure 2 is an example of the detailed seismic profiling lines run by oil prospectors in an oil field in the Gulf of Mexico. No oil company would make the necessary investment in drilling without the information provided by such detailed profiling. I am not aware of any geological investigation that has required more than one or two such lines in an area of comparable size.

The United States has also argued that the information collected by scientists should be of benefit to the coastal nations, even if it is also of interest to oil companies. For example, it is difficult to see how the information about the diapir field off Angola reported by Emery from a cruise of the Woods Hole ship, R.V. *Atlantis II*, in 1972 can do any economic harm (*14*). To the contrary, it may encourage oil companies to negotiate exploration rights earlier than might otherwise have happened.

The counterarguments of the coastal nations are several. Some are based on the underlying suspicion of superpowers such as the United States. Many suspect that there is more to oceanographic research cruises than is apparent. Perhaps there is an additional research component of a military or economic classification associated with the advertised open research program. The fact that the U.S. oceanographic community has been less than perfect in following through in providing results makes the U.S. position more difficult (*15*).

A major element must be the fact that most nations have insufficient local scientific talent to participate in these programs, evaluate their content, and provide assurance to the government that such programs are not harmful and indeed, in the long run, are beneficial. The United States has suggested a program "to strengthen scientific research capabilities of developing

countries, including assistance in assessing the implication for their interests of scientific research data and results, education and training of their personnel" (*16*). Presumably the financing of such a program could be done through direct contributions of nations such as the United States, a suggestion presented by the United States to the Seabed Committee in 1972, or through "revenue sharing" from the resources of the deep seabed. To date there has been little meaningful discussion of either proposal.

The Importance of Marine Research

The importance of science to resource development is apparent, although direct relationships are often difficult to find, and scientists can argue that open publication of data and results does not give the sponsoring state any economic advantage (*17*). However, if science is to receive special treatment in the law of the sea negotiations it will probably require something more than such negative arguments. It is necessary to develop the case that science contributes to other socially important goals of man and that scientific contributions benefit everyone. Some potential contributions are more problematic than others. It is suggested that the following are sufficiently obvious as to have some value in attempting to convince nonscientist representatives at the Law of the Sea Conference about the importance of oceanographic research and the needs to minimize restraints on oceanographic research activities.

Long-range weather forecasting. Only the most rudimentary ocean-atmosphere interactions need be used for making forecasts up to 10 days in advance. Longer forecasts, such as the 30-day forecast or predictions of seasonal variations from the mean, are dependent upon a better understanding of the ocean-atmosphere interaction. Although the atmospheric winds determine the primary ocean currents, most of the heat that drives the atmosphere does not come directly from the sun, but from the surface of the ocean by direct long-wave radiation and by heat released by evaporation. Most experts are convinced that the difference in "climate" from one year to the next is related to small changes in the average ocean from year to year (*18*), and the key to prediction is better ocean monitoring of these variations and understanding the apparently very complex interactions between ocean and atmosphere. There are many economic benefits of successfully predicting a "cold winter," a "wet spring," or an "extra long growing season."

Ocean pollution. The evidence that ocean pollution has had significant effects beyond coastal areas is slight, although there is no lack of evidence of the products of man being found far from shore, as witness the reports of tar balls (*19*), polychlorobiphenyls (PCB's) (*20*), and lead (*21*) in the central North Atlantic. Although relatively few oceanographers would go so far as to claim "the oceans are dying," there is an increasing concern about their condition. One basis of concern is our lack of knowledge. Our level of understanding of ecological relationships in the open ocean is probably more rudimentary than in any other large ecosystem on this earth, including desert and rain forest ecosystems. Another concern is our lack of information concerning pollutants reaching the ocean and what happens to them after they get there. For example, there is evidence that PCB's are more prevalent in the ocean than DDT and that they are potentially a more serious problem (*20*). It seems possible that the PCB data would be missing were it not for the concern over DDT in oceans, since the PCB's were essentially "discovered" because they were originally confused with DDT.

A second basis for concern is the fact that if the oceans ever do become polluted, cleaning them up as one does a river, lake, or estuary is probably not feasible. Polluted water runs from rivers or estuaries to the ocean.

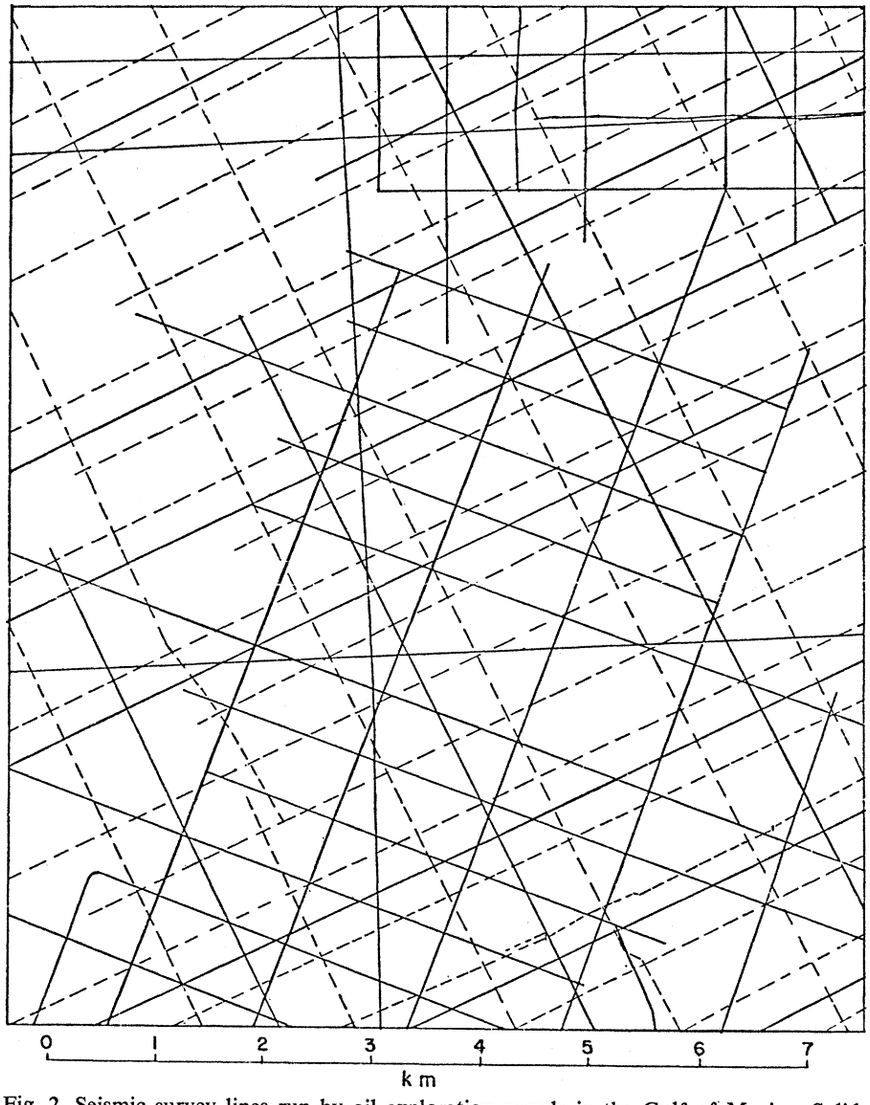

Fig. 2. Seismic survey lines run by oil exploration vessels in the Gulf of Mexico. Solid and dashed lines represent different surveys. Redrawn from a chart furnished by the Amoco Production Company.

There the water evaporates and rains on the land to begin the cycle again; but most of the material brought to the ocean remains, either to be deposited on the bottom, broken down by biological or chemical action, or to remain dissolved in seawater. For those worried about oceanwide pollution, there is the additional concern that monitoring river outfalls does not give a true indication of the amount of pollutants entering the oceans. A large percentage of the pollutants of most concern, including lead, mercury, DDT, and PCB's, apparently reach the ocean by atmospheric transport and are thus much more difficult to monitor (*22*).

These and other factors have convinced many oceanographers that the possibility of significant ocean pollution cannot be ignored. More important, we cannot allow ourselves the luxury of waiting for a pollution problem to appear: it is unlikely that we could ever "clean up" the ocean in any time scale meaningful to man. Thus, it is important that ocean processes relating to these problems be intensely studied so that mankind will have sufficient warning, if possible, concerning significant pollution.

Fisheries management. It has become fashionable in recent years to argue that many of the problems of fisheries management are institutional rather than scientific (*23*). Granted there are major problems associated with limiting the entry of new fishermen into a mature fishery, controlling the harvesting of fish, and inducing investors to place their capital in a somewhat risky, labor-intensive industry. But even if we could solve all such institutional problems, there remains the fundamental fact that we probably do not have the scientific basis for managing a complex fishery. The recent example of the Peruvian anchoveta fishery is an example. This single-species fishery is the largest fishery in the world with a harvest of about 10×10^6 to 12×10^6 tons per year. Because it is controlled by the Peruvian government it does not suffer from many of the institutional problems that plague the U.S. industry. The anchoveta's diet consists primarily of phytoplankton, and the species reaches sexual maturity at the age of about 1 year. Superficially, at least, it presents a relatively simple system for ecosystem modelers.

About every decade there is shift in the winds and currents which causes a condition called El Niño off the coast of Peru, and this results in a warming of the surface water, a decrease in phytoplankton, and a disappearance of the anchoveta (*24*). The period and intensity of the El Niño condition varies but, until recently, the anchoveta population reestablished itself after each El Niño. The first major occurrence of El Niño since the anchoveta harvest reached its present level was in 1972. The El Niño condition has receded since then, but the anchoveta population has been slow to reestablish itself, and fisheries biologists are uncertain about what is happening.

Our fishery models are essentially steady-state models; fisheries dynamics are insufficiently understood even in a "simple system" such as the Peruvian anchoveta fishery to allow for significant environmental perturbations. The modeling difficulties are even more acute in a fishery where there is believed to be important species-species interaction such as with the demersal fish populations in the northeast Atlantic region.

One result of the Law of the Sea Conference is that a régime will probably be established which will make it easier for nations to attack the many institutional problems that plague fisheries management. However, a strong case can be made for the proposition that any resolution of the institutional problems will only highlight the fact that we lack the scientific base for rational fisheries management if our goal is to maximize the sustainable harvest of the oceans.

Conclusion

More intensive and varied use of the oceans and their resources requires a more comprehensive legal régime than previously. Three years of preparatory work have been completed leading toward the Law of the Sea Conference that opened on 20 June in Caracas, Venezuela. Although the details of the new régime are still to be negotiated, it appears certain that the coastal nations will gain some form of jurisdiction over the fisheries and mineral resources off their shores. It is probable that a new "economic zone" will be established between a relatively narrow (12-mile) territorial sea and the international ocean space beyond. If, as seems likely, this economic zone is 200 miles wide, it will encompass some 37 percent of the ocean as shown in Fig. 1.

Unless the scientific community can gather more support than it has to date, it seems probable that scientific research within this economic zone will only be possible with the consent of the coastal nation. The United States has proposed a compromise solution which attempts to balance the interests of the scientific community with those of the coastal state. Under the U.S. proposal, a research group abiding by certain specific obligations to the coastal state would be free to carry out its research activities without obtaining explicit consent from the coastal state. To date the U.S. proposal has received little official support from any nation, even from nations with major oceanographic interests.

References and Notes

1. U.N. General Assembly Resolution 3067, 28th session (1973).
2. U.N. General Assembly Resolution 2750, 25th session, suppl. No. 21, A/8721 (1972)].
3. *Report of the Committee on the Peaceful Uses of the Sea-bed and the Ocean Floor Beyond the Limits of National Jurisdiction* [U.N. General Assembly Official Records, 27th session, suppl. no. 21, A/8721 (1972)].
4. Hammering out a single U.S. policy has been the job of an interagency task group chaired by the State Department. In addition, the State Department has an 84-man advisory committee of private citizens broken into eight subgroups representing petroleum, fishery, hard minerals, marine environment, international law, marine science, international finance and taxation, and marine industry. Congress and state governments are also represented. Individuals from this group have served as "experts" on the U.S. delegation at all LOS preparatory meetings in New York and Geneva since 1971.
5. The source of the official records are the *Report of the Committee on the Peaceful Uses of the Sea-bed and the Ocean Floor Beyond the Limits of National Jurisdiction* to the 25th (1970), 26th (1971), 27th (1972), and 28th (1973) U.N. General Assembly.
6. According to the latest State Department compilation, there are 29 nations claiming 3 miles, 10 claiming 6 miles, 53 claiming 12 miles, and 8 claiming 200 miles, with additional scattered claims of 4 to 130 miles. All miles are nautical miles.
7. U.S. Department of State, *World Straits Affected by 12 Miles Territorial Sea* (Office of the Geographer, U.S. Department of State, Washington, D.C., 1971).
8. The first U.N. Conference on the Law of the Sea in 1958 was primarily an attempt to codify existing law and practices. It resulted in four conventions: Convention of the High Seas Convention on the Territorial Sea and Contiguous Zone, Convention on the Continental Shelf, and Convention on Fishing and Conservation of the Living Resources of the High Seas. The second U.N. Conference on the Law of the Sea in 1960 attempted, but failed, to resolve the issue of the breadth of the territorial sea and control over fisheries.
9. J. Kildow, in *Freedom of Oceanic Research*, W. S. Wooster, Ed. (Crane, Russak, New York, 1973).
10. U.S. Department of State, "Theoretical Areal Allocation of Seabeds to Coastal States based on Certain U.N. Sea-bed Committee Proposals" *Int. Boundary Study, Series A, Limits in the Sea*, No. 46 (Office of the Geographer, U.S. Department of State, Washington, D.C., 1972).
11. U.N. General Assembly Document A/Ac.

138/SC. III L. 42, in *Report of the Committee on Peaceful Uses of the Sea-bed and the Ocean Floor Beyond National Jurisdiction* (U.N. General Assembly Officials Records, 28th session, 1973).
12. U.N. General Assembly Document A/Ac. 138/SC. III L. 44, in *ibid.*
13. One such attempt was made by the author before Subcommittee III of the Seabed Committee in August 1972.
14. K. O. Emery, *Science* **178**, 298 (1972).
15. At least one institution found to its chagrin that telling a foreign colleague what you are planning and inviting him to come along is not the same as securing formal permission from the government. Scientists may send reprints and data reports to colleagues in foreign countries, but in the office that gives permission there may be nothing in the file. In connection with a recent request, the Scripps Institution of Oceanography was queried by the Peruvian foreign office concerning results of a previous study in the area. For further discussion, see W. S. Wooster, Ed., *Freedom of Oceanic Research* (Crane, Russak, New York, 1973).
16. Article 5 of U.S. draft articles, see (*12*).
17. G. Cadwalader, *Science* **182**, 15 (1973); J. A. Knauss, *Ocean Dev. Int. Law J.* **1**, 93 (1973).
18. National Science Foundation, *International Decade of Ocean Exploration, Second Report* (National Science Foundation, Washington, D.C., 1973), p. 55.
19. B. F. Morris, *Science* **173**, 430 (1971).
20. G. R. Harvey, W. G. Steinhauer, J. M. Teal, *ibid* **180**, 643 (1973).
21. C. Patterson, in *Impingment of Man on the Oceans*, D. W. Hood, Ed. (Wiley-Interscience, New York, 1971).
22. *Marine Environmental Quality* (National Academy of Sciences, Washington, D.C., 1971).
23. G. L. Kesteven, in *World Fishery Policy*, B. J. Rothschild, Ed. (Univ. of Washington Press, Seattle, 1972), pp. 229–261.
24. C. P. Idyll, *Sci. Am.* **228**, 22 (June 1973).

The Pineal Gland: A Neurochemical Transducer

Chemical signals from nerves regulate synthesis of melatonin and convey information about internal clocks.

Julius Axelrod

The pineal gland has become the subject of considerable investigation during the past decade because it provides a productive experimental model for studying circadian rhythms and regulation of end organs by nerves. In the mammal, the pineal gland rests between the two cerebral hemispheres and weighs about 100 milligrams in man and 1 mg in the rat (*1*). The pineal gland originates in the brain of the developing mammalian embryo, but it loses direct nerve connection with the brain soon after birth. The pineal parenchymal cells are innervated by sympathetic nerves (noradrenaline-containing) whose cell bodies lie in the superior cervical ganglia (*2*). Amphibian pineals have photoreceptive cells that can generate nerve impulses in direct response to environmental light (*3*). Photoreceptor elements, however, are not found in the mammalian pineal cells.

The beginning of the modern era in pineal research stemmed from the isolation and identification of the indoleamine melatonin (5-methoxy-*N*-acetyltryptamine) from bovine pineals by Lerner *et al.* (*4*). It then became possible to examine its localization, physiologic properties, formation, and metabolism. Melatonin is the most potent agent for causing contractions of melanophores in frog and fish skin. When treated with melatonin at concentrations of 10^{-13} gram per milliliter, the skin of many fish and amphibians rapidly blanches (*5*). The amphibian pineal contains melatonin and the enzymes that make it (*6*). These results indicate that melatonin causes changes in skin pigmentation in fish and amphibians when it is released from pineal organs. In the mammal, melatonin is synthesized mainly in the pineal (*1*), and it exerts inhibitory effects on gonads. When injected into birds, it causes a decrease in weight of the ovaries, testes, and oviduct (*1*). It delays vaginal opening and reduces ovary weight in young rats (*7*). When melatonin is implanted in the median eminence, the elevation in the content of leutinizing hormone (LH) in the pituitary following castration is blocked, and plasma LH concentration is lowered (*8*). Blinding of male hamsters causes a fall in the weight of testes, but when pineals are removed or when nerves to the pineal are cut the reduction in testicular weight is prevented. During proestrus in rats, melatonin inhibits ovulation by preventing the release of LH (*9*). The early morning elevation in plasma prolactin in male rats is mediated by increased release of a pineal hormone (*10*). In the sparrow, the pineal serves as a time-measuring system (*11*). The physiological aspects of the pineal have been reviewed recently (*12*).

Melatonin is synthesized almost exclusively within the pineal cell as follows (Fig. 1): tryptophan → 5-hydroxytryptophan → serotonin → *N* acetylserotonin → melatonin. Tryptophan is hydroxylated to 5-hydroxytrytophan by tryptophan hydroxylase (*13*). The latter amino acid is then decarboxylated by *l*-aromatic amino acid decarboxylase to form the biogenic amine serotonin. Serotonin then undergoes a complex fate. One portion is deaminated to 5-hydroxyindoleacetic acid by monoamine oxidase, and another portion leaves the pineal cell and is taken up by the sympathetic nerve terminal and stored together with the neurotransmitter noradrenaline (*1*) (Fig. 1). A third portion is acetylated to *N*-acetylserotonin by the enzyme serotonin *N*-acetyltransferase (*14*). This is a critical regulatory step, as will be shown later. *N*-Acetylserotonin is then *O*-methylated by hydroxyindole *O*-methyltransferase to form melatonin, *S*-adenosylmethionine serving as the methyl donor (*15*).

Hydroxyindole *O*-methyltransferase is highly localized in the pineal glands of mammals and birds. Small amounts of the enzyme are also present in the retina of the rat. In other classes (reptiles, amphibia, and fish), hydroxyindole *O*-methyltransferase is also found in the eye and brain as well as the pineal region (*16*). Although indirect, the evidence that the frog pineal blanches skin by secreting melatonin is compelling.

The author is chief of the pharmacology section, Laboratory of Clinical Science, National Institute of Mental Health, Bethesda, Maryland 20014.