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A PRELIMINARY CLASSIFICATION OF COASTAL AND MARINE ENVIRONMENTS

The attached document, which was prepared by G. Carleton Ray for the International Union for the Conservation of Nature and Natural Resources with support from the World Wildlife Fund, is distributed to participants for their information.

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by
G. Carleton Ray

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INTERNATIONAL UNION FOR CONSERVATION OF NATURE AND NATURAL RESOURCES
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FOREWORD

IUCN has been concerned with the development of a system for defining and classifying natural regions for purposes of conservation which uses regional divisions of biomes based on Wallace's faunal regions and further subdivision into biotic provinces distinguished by their vegetation, flora or fauna (see IUCN Occasional Paper No. 9, Morges, 1974). This system has been adopted by UNESCO as the basis for the Man and the Biosphere Programme, Project 8: "Conservation of Natural Areas and the Genetic Material they Contain". The classification at present covers only the land areas of the world.

There is a need for a similar classification for marine areas. A study to define critical marine habitats that should be conserved is being carried out for IUCN by Dr. G. Carleton Ray at The Johns Hopkins University, Baltimore, Maryland 21205, U.S.A., in collaboration with associates elsewhere. As part of that study Dr. Ray has prepared the tentative classification of marine ecosystems set out in this paper. As Dr. Ray points out in his preface, classifying marine habitats presents formidable problems. It is hoped that through comments received on the present draft, it will be possible to develop the classification further and eventually to make it analogous in approach and detail to the above-mentioned classification of terrestrial biotic provinces.

The work has been carried out with support from the World Wildlife Fund as part of IUCN/WWF Project No. 1037.

PREFACE

It has been said that if man had first looked at this planet from space, he might have named it "Sea", rather than "Earth". No other planet, as far as we know, has a sea. Indeed, the land areas of Earth could be dumped into the oceans and still the waters would cover this whole planet to a depth of two to three kilometres! It is, in fact, the waters of Earth which gave it life and which stabilize climate.

Man is a giant, terrestrial animal and his perspectives remain so, though the despoiliation of the land is causing him to turn to the seas increasingly. Conservationists are no less human. For example, IUCN (1974) has described the "Biotic Provinces of the World", but there is no consideration of that marine 70% of Earth therein! This classification responded in large part to the immediate requirements of the Man and the Biosphere (MAB) Programme and states (UNESCO, 1974: p. 7):

> "Since biosphere preserves are to include representative and unique areas of the world's biomes and their subdivisions, it is essential that their establishment be based on a knowledge of the nature and extent of the important biotic communities of the biosphere. This involves international and national support for development of mutually acceptable classifications of the world's biomes and for the required surveys and inventories of biotic communities to determine their nature and extent."

This statement is applicable to both land and sea!

This paper is a preliminary effort to come to grips with the difficult problem of classifying marine ecosystems biologically and geographically. It is a companion paper to "Critical Marine Habitats" (Ray, 1975). There are several classifications of the coasts and open seas, none of them truly holistic, as ecosystem description requires. The greatest reason for this is that description of marine habitats is much more difficult than that for terrestrial or freshwater areas. The sea's complexity, in terms of dynamism, life forms and species diversity (if one eliminates insects), is greater and the logistics problems are formidable. We must recall, for instance, that it has been less than two decades since man first gazed at the deep sea in person and found that life does indeed exist to the very bottom, twelve kilometres down!

The stakes in the effort to preserve the sea's productivity are high, no less than the preservation of the life support system for man himself. A classification scheme is the basis for the establishment of a system of preserves by means of which marine ecosystems will eventually be conserved, studied, and monitored. No matter how preliminary the present effort may appear to be, it is vital that we indulge in the classification task. It is my hope that this beginning matrix, which is not entirely original, but is derived from several other sources, will invite

revision through critical and constructive comment. At this stage, maps (properly speaking, "charts") of marine provinces are perhaps premature. Their addition awaits development of further knowledge and/or collation of present knowledge by scientists presently at work on this problem.

G. Carleton Ray

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INTRODUCTION

Given our ignorance of the ecosystems of the seas, we must seek now to evolve a practical, working classification of provinces and habitats which will serve as a basis from which to judge the comprehensiveness and extent of preservation. Habitats are expressive of processes which occur within ecosystems. Inclusiveness of habitat diversity within preserves to some extent serves to tell us, therefore, how well ecosystems themselves might be protected or, at least, may tell us of the effects of man's perturbations if our research and monitoring efforts within preserves are well enough designed and supported.

The classification scheme presented here is an adaptation derived mostly from three previous efforts: (1) zoogeographic regions adapted from Ekman (1953) serve to identify biotic provinces in the very broadest sense, and perhaps they identify ecosystems in that faunal associations are expressive of ecosystem processes from the evolutionary and adaptive points of view; (2) a regional classification of coastal zones, after Ketchum, ed. (1972) and Cronin (1974) is expressive of the interface between coastal features, both emergent and submerged, and marine biotic associations and is presented here, as a model, for North America only; and (3) a habitat classification as conceived originally by The Symposium on the Classification of Brackish Waters (1959) and extended by the USIBP/CE Programme emphasizes geological, aquatic, and biotic features which define habitats.

I wish to emphasize that this classification scheme is fraught with problems. Clearly, zoogeographic provinces are not really "biotic" and need further elaboration in order to incorporate flora and advances in knowledge since Ekman's work. Unfortunately, most classifications are heavily weighted towards certain taxa: Abbott (1968, pp. 34-37) gives one for Mollusca of North America in attractive, simple, and concise form, presented for non-scientists; Briggs (1974) presents a new scheme which is, however, heavily weighted towards fish fauna; Miller, ed. (1974) proposes that open ocean systems can be defined by a consideration of both zooplankton and water mass characteristics, but mechanisms are not known to the extent that ecosystem processes can be defined with precision. The latter two works have not been incorporated into the present scheme, and it remains to be seen to what extent they are compatible with each other or with Ekman's broader review.

The coastal zone scheme is probably sufficient for North America, but needs expansion to include other coasts the world over. Its emphasis may, indeed, be more terrestrial than marine, and its relationships to zoogeographic regions of the sea is far from clear. The habitat classification has been well thought out previously and has been only slightly expanded here. Nevertheless, it will no doubt prove to be inadequate for many local situations, as each habitat is indeed "unique" and any effort to generalize must not lose sight of this. Thus, this tripartite scheme is presented to provoke critical comment as well as to

serve as a preliminary basis for the judgement of inclusiveness of preservation.

If such a tripartite scheme appears to be overly complex, we must respond that it is probably not complex enough. The mobility of large components of aquatic systems, the great seasonal and annual changes, the lack (except inshore) of rooted biomass (like trees) by which to characterize marine systems, and their almost incomprehensible size do indeed introduce a few problems, for which the answer could easily be to sigh and relinquish the job of classification entirely.

Dasmann (1972) speaks for many in warning that whole segments of biota and genetic resources could be lost through the failure to establish reserves. This is even more true of the seas than for the land, for representation and extent of reserves is so much less there. The seas are largely a "commons" (cf. Hardin, 1968), the only present protection for which is international treaty and which remains highly unsatisfactory (cf. Ray, 1970; Ray and Norris, 1972). Perhaps a classification scheme will highlight the nakedness of the sea when those who create international law compare its diversity with the paucity of reserves which purportedly protect it.

Problems of "Ecosystem" Definition

IUCN (1974) states that the term ecosystem "is now used in a wide variety of senses." This is, unfortunately, true, but it should be apparent by now what it is we mean by "ecosystem" in terms of processes and structure (cf. Van Dyne, ed. 1969; Odum, 1973; Steele, 1974). So let us build our terms from the species level upward. A species' "niche" is its "way of life". The place where this way of life is carried out is a species' "habitat". Habitats have certain characteristics which cause "communities" of animals and plants to assemble there, so we speak of the community as being a "centre of action". We now need to add the abiotic component to derive "ecosystem" and some would say that the biotic community plus non-living elements becomes the centre of action called an "ecosystem". Not quite so! The problem is larger than a simple add-on.

Ecosystems are functional units with properties of homeostasis, that is, they exhibit stability which in turn may relate to species diversity. Ecosystems evolve so as to maximize stability but to reduce net community productivity through efficient recycling of materials. The exercise of modelling must be employed to determine the extent of these essential features, though attempts to do this are fraught with great problems.

Diversity and stability have been much discussed in the ecological literature lately and this is no place for assessment of that discussion. But I do wish to bring to the forefront the important principles stated by Woodwell (1974):

(1) The stability of the biosphere is related in large degree to the total amount of life.

(2) Disturbance causes a systematic and predictable pattern of degradation of life that has profound importance for man.

Woodwell emphasized the disastrous results of the philosophy of compromise of system integrity (for instance, our dependence on the "assimilative capacity" of environments) when he says: "Clearly the continued development of leaky, man-dominated systems is out . . . the natural systems, dominant on earth throughout human history, are the proper objective of conservation . . . the world is run by living systems that operate under discoverable laws that compromise does not repeal." I have underlined the word "leaky" to emphasize the functional nature of ecosystems with respect to efficiency and recycling. I have also underlined "discoverable" to counter the oft-said jargon that "ecosystems are not only more complex than we think they are, but also more complex than we can think." Such a tidy thought is no reason not to be clear as to the definition of the word and not to emphasize that their features may be discoverable by paying great heed to habitat diversity and its inclusion in protected areas.

These theoretical considerations contribute to formidable practical problems in classification. For instance, Dunbar (1968) examines the relatively simple polar regions in detail, emphasizing that the polar regions are not as diverse as tropical regions, but their fewer species are present in greater relative biomass, and that the reason may simply be that polar ecosystems are young, not that cold somehow induces lack of diversity. The question arises as to how to classify evolving systems and to differentiate between evolutionary and successional phenomena and the perturbations of man.

The important conclusion here is that surely we cannot presently define marine ecosystems with great precision. Nevertheless, zoogeographic and habitat diversity exemplifies processes, and long-term research and monitoring within reserves can serve to tell us of general ecosystem characteristics and health.

Contrast--Terrestrial vs. Marine

IUCN (1974) describes biotic provinces by vegetation, floristics and faunistics. It points out that one difficulty is that in many areas climax or natural vegetation no longer exists. This is one problem that some marine systems have escaped. Surely, inshore habitats have been perturbed by pollution, dredging, and other causes, but at least man is not yet very much the agriculturist in the sea. He is still the "hunter-gatherer", and he does not live in the water. So, though his effects are severe at the edges (coasts), the open sea remains more intact than the land, at least in outward appearance.

Formidably, marine systems are vastly larger than land systems. Between the two is that huge "ecotone" or transition zone, the coastal zone, only parts of which may have ecosystem properties. These features mean that the establishment of "core" reserves of moderate size will not, in all probability, preserve marine or coastal ecosystems. "Buffer zones" must usually encompass huge areas incorporating land drainages, coastal cir-

culation cells, and oceanic regions. Thus, each "core" reserve on land may contain many features of a whole ecosystem or even be a natural self-sustaining unit. However, in the sea, size and complexity will usually defeat this goal and each "core" reserve will usually be analogous to a block or work gate of an ecosystem model. The reserve system is to be emphasized over the individual reserve itself, in order that preservation of habitat diversity incorporate complete representation for ecosystem process protection.

Contrast between Disciplines

We must clearly separate in our minds three phases of ocean science: marine biology, oceanography and fisheries. Of the three, the first has been the most ecologically oriented, but there are healthy signs now of confluence of them all. Oceanography began with the voyages of the HMS Challenger about a century ago. The oceanographic approach has led to a classification of the sea according to water masses. This has been a major contribution, but the great failing has been a lack of consideration of total biota and an incomplete approach to living resources: for instance, primary productivity has been emphasized practically to the exclusion of consumers.

Fisheries studies have dominated thinking in terms of larger economic species. The single-species, "yield" approach is autecological at best and in marked contrast with the more biological "carrying capacity" approach to terrestrial game management (cf. Wagner, 1969). Fisheries studies thus have little potential for classification schemes. Some use may be made of them in terms of distribution of species, but fisheries biologists have not been much concerned with the relationship between their few species of concern and whole biota. A partial breakthrough is that some fisheries embody "regional management" (cf. Ray and Norris, 1972) towards exploitation, witness treaties for the North Atlantic and elsewhere in which whole faunal regions rather than single species are emphasized.

Marine biologists, by contrast, have long been concerned with faunal zonations and distributions. Hesse, Allee, and Schmidt (1937) contributed important early descriptions, and recently many works have appeared containing a huge amount of important information on marine ecology. The work of Ekman (1953), however, remains the most comprehensive zoogeography of the sea. The important contribution of plant geography remains potential rather than accomplished. Hopes are high that the sea grass ecosystem programme of The International Decade of Ocean Exploration will produce a world habitat map for spermotophytes as at least a partial answer to this need.

The conclusion is that any classification scheme we may now devise must be fraught with both incompleteness and the difficulty of blending these very separate approaches.

Legal Problems

There remains the legal classification embodied in the law of the sea and by which the seas are divided into the high seas, territorial seas, continental shelf, and fisheries. Should management of ocean resources continue to be promulgated during the "marine revolution" (Ray, 1970), according to this scheme, the continual threat to ocean ecosystems is assured! It is a scheme dominated by a history of law according to exploitive and nationalistic thinking, thoroughly out of tune with ecosystem reality. The thinking currently goes that "patrimonial" seas (which at least should worry the feminists) is a partial solution, but I doubt that legal-economic solutions will solve ecological problems. Surely, ecological thought must precede legalistic compartmentalization. The danger is that it will not!

CLASSIFICATION

As stated above, this scheme is tripartite and derived from existing schemes in the interests of precedent and practicality. It is not an ecosystem classification, though potentially and with revelation of the relationship between process and structure, it has that potential.

By Zoogeographic Regions

The following is an adaptation of Ekman (1953). Marine regions are delineated more strongly by current structure and hydrological conditions than by geographical landmarks, and therefore the geographical limits given below are to be viewed with flexibility. It remains to be seen how these regions may be made more truly biotic. Further, zoographical features are presently more useful than floral classifications, as used for terrestrial regions, except immediately adjacent to coasts.

I. Tropical Warm Water Shelf Provinces. Less than 200 m in depth. Dominated by mangroves and coral reefs and their associated biota. Tropical and subtropical regions included: tropical between the 20°C isotherms and subtropical extending to about 16-18°C. Barriers between provinces and subregions are land masses and pelagic water masses. In the past, i.e., Mesozoic through early Tertiary, the entire area was joined by the great Tethys Sea, hence certain faunistic similarities throughout.

   A. Indo-West Pacific. Red Sea south to about Durban, South Africa, east to the Korean Strait, southern Japan, Hawaii, the Marquesas, Tuomatus and Northern Australia.

      1. Indo-Malayan. The centre of the Indo-West Pacific region; biota becoming relative depauperate outwards. Possibly the most varied of the world's biota is found here. From Indo-Malay Archipelago north to the Ryukyus and south to between the Kei and Aru Islands.

      2. Central Pacific Islands. Somewhat impoverished in biota, the more so as one goes east from the Indo-Malayan centre. Includes all the tropical islands of the central West Pacific except as noted for other regions below.

      3. Hawaiian Archipelago. The number of endemics distinguishes this region.

      4. Subtropical Japan. Impinges on the temperate fauna to the north at about 36°N Lat., i.e., at about Tokyo and the Korean Strait.

5. Tropical-Subtropical Australia. South to about Perth on the west coast and about 32°-34° on the east coast, i.e., near the southern limits of coral reefs.

6. Indian Ocean. Generally more depauperate biota the farther one goes west from the Indo-Malayan centre. The Persian Gulf is included, as is the Red Sea, but there is some justification for separating out the latter due to distinctive high salinity, high temperature, and a considerable number of endemics.

B. Atlantic-East Pacific. The Isthmus of Panama separated the two American coasts relatively recently in geologic time so that considerable similarities exist between them. The West African region does not exhibit the same degree of difference as that between the Indo-West Pacific and American regions, so it is included here.

1. Tropical-Subtropical America. Atlantic and Pacific sides were joined in Tertiary times. The great Pacific pelagic-abyssal water mass separates the region from the Indo-West Pacific.

(a) American Pacific. High degree of endemism. Gulf of California and the southern tip of Baja California south to about 3-4° S Lat. The subtropical region extends north to central Baja California. The entire region is characterized by upwelling, meaning that only shallow waters rather close to the continents are included. Southern border especially subject to change by reason of north-south current shifts. Galapagos are included. Subregions are Panamanian, Gulf of California, and Galapagos.

(b) American Atlantic. Second in richness only to the Indo-Malayan, but not nearly so rich in corals as the latter. Cape Hatteras and Bermuda south to southern Brazil. Cape Hatteras to Florida transitional. Subregions are Antillean, Bermudian, Brazilian, northern Gulf of Mexico.

2. Tropical-Subtropical West Africa. Centres on the Gulf of Guinea. Poorest of the tropical faunas. Tropical north to Cape Verde. Subtropical north to Cape Blanco and the Cape Verde Islands and south to southern Angola. Like American Pacific, a shallow and variable region, particularly at the southern border, because of upwelling and of shifts of the Benguela Current.

II. North Temperate and Boreal-Austral. Temperate regions are the most variable of all seas, being tropical in temperature in summer and falling to almost polar temperature in winter, especially inshore. Thus, the biota varies seasonally and boundaries are extraordinarily hard to define.

A. Mediterranean-Atlantic and Samartic. Warmer temperate regions of Europe.

1. Mediterranean-Atlantic. A warm temperate region which forms a gradient to the neighbouring boreal region. Called Lusitanean from Gibraltar north to the western entrance of the English Channel and Mauritanean south to Cape Blanco. These and the Mediterranean are subregions.

2. Black Sea Pelagic. Related to both the Mediterranean and Samartic, but relatively depauperate in species of both regions, i.e., transitional between the two regions. Characterized by low salinity throughout and low oxygen/high hydrogen sulphide deeper than 125-175 m.

3. Samartic. Resulted from the West Asian-East European portion of the Tethys Sea which became separated from the Mediterranean region in the Miocene. Once the richest Brackish water biota known.

   (a) Sea of Azov-Black Sea estuaries. Remains from the Samartic brackish water after the Mediterranean reconnection with the Black Sea in the Tertiary. Very shallow, brackish, and with fluctuating temperatures.

   (b) Caspian Sea. Low oxygen/high hydrogen sulphide in waters over 600-730 m in depth. Greatly fluctuating salinity, especially at the mouths of large rivers; brackish to mesohaline. Practically a pure Samartic fauna.

B. Warm Temperate Atlantic North American. Very complex hydrology and currents make boundaries hard to define; roughly Cape Hatteras to about Cape Cod, but neither is a precise boundary. Extremely variable seasonally. Cape Hatteras to Florida transitional. Coastal Labrador Current forms a "cold wall" between much of the coast north of Cape Hatteras and the Gulf Stream.

C. Cold Temperate and Boreal North Atlantic. Transitional to the Arctic.

1. European. Centered on the North Sea. Intensively studied; however, boundaries hard to define. Widely fluctuating temperatures. Dominated by North Atlantic Current, part of which is originated in the Gulf Stream.

   (a) Sea water of ordinary salinity. From the Lusitanean subregion of the Mediterranean-Atlantic to the southwest Barents Sea, shallow areas of the White Sea, northeast Iceland and southwest Greenland.

   (b) Baltic and neighbouring brackish. Largest brackish region on earth. Biota largely derived from North Sea. Fauna composed of euryhaline species, brackish water animals, and glacial relicts. Encompasses the entire Baltic and the Gulfs of Finland and Bothnia.

2. North American. Complex and fluctuating interrelationships between the Labrador Current and Gulf Stream make boundaries difficult to delineate. Cape Cod to Newfoundland appears to be boreal-transitional to the Arctic, but neither is a precise boundary.

D. Temperate North Pacific. Incorporates a vast area of the North Pacific.

1. Northwest American. Very uniform cool temperature from southern California to the Gulf of Alaska and into the southern Bering Sea leaves hardly any room for a warm temperate biota. The latter exists only from southern California to central Baja California and may be considered a subregion.

2. Northeast Asian. Similar to the Northeast American in that the south-flowing Liman and Oyashio Currents cool the coasts to make northern Japan and the northwest Sea of Japan colder than the southeast seas off Japan. Southern border at about 36° on the east side of Japan and the Straits of Korea on the west.

3. Boreal/Arctic. Ice-stressed over shelf regions of the Okhotsk and Bering Seas in winter. Currents warm the eastern Bering Sea more in summer than they do the western Bering Sea and the Okhotsk Sea. Northern boundary uncertain, but possibly near Bering Strait.

E. South Temperate. Shelf areas separated by great expanses of abyssal pelagic seas and the regions are consequently quite different in distributional features from the northern hemisphere.

1. Southern African. Durban west to the Cape of Good Hope. Area warmed by arms of the south-flowing Mozambique Current. A warm temperate region.

2. Southwest African. Also called the Namaqua Fauna. Coldest region on the coasts of Africa due to upwelling of the Benguela Current. North from Cape of Good Hope to about Great Fish Bay where temperatures reach 17-20°C.

3. Southern Australian-Tasmanian. South of about Perth on the west coast and south of about Sydney on the east (32-34°C). Influenced by the West Wind Drift to the south.

4. New Zealand. Isolated and covering warm temperate to cold temperate waters. Subregions are the warm Aupourian, the central Cookian, and the southern Forsterian.

5. Chatham, Auckland, Campbell, and Macquarie Islands. Not well known. Sub-Antarctic, New Zealand-dominated islands.

6. Peru and northern Chile. Under the influence of upwelling of the Peru (Humboldt) Current. From about 3-4° south to Chiloe Island is warm temperate where region probably intergrades with South American Austral. Juan Fernandez is a subregion.

F. Austral (Anti-Boreal). Strongly influenced by the West Wind Drift, the largest ocean current, being circumpolar and giving rise to the northward-flowing Benguela, Peru, Falklands and Australian Currents. North boundary of West Wind Drift at 38-40°S; southern boundary at about 65°S (70°S between 90 and 120°W), i.e., at the boundary with the East Wind Drift. The Antarctic Convergence lies within the West Wind Drift and is the northern boundary of Antarctic surface water; its limit between 50-60°S forms the southern boundary of the Austral region.

1. South American. Contains the only Austral coastal fauna. South from Chiloe Island on the west coast and La Plata on the east coast of South America.

2. Oceanic Islands. Poorly known. May include Auckland, Campbell, and Macquarie Islands as well as Gough, Prince Edward, Marion, Crozet, Tristan de Cunha, Saint Paul, and New Amsterdam. Some of these are on the border of the Anti-Boreal Convergence between 35 and 45° South.

3. Kerguelan Island. Includes Heard and MacDonald which may be purely Antarctic. Kerguelan lies on the Antarctic Convergence and exhibits a high degree of endemism.

III. Polar

A. Arctic. From the northeast Barents Sea between North Cape and Bear Island to the interior of the White Sea which is a high Arctic relict, west to east Greenland north of 68°, west Greenland north of 73°, and including the entire Canadian Archipelago. Extends northeast of Spitzbergen, including the Kara Sea, the Siberian Arctic, and the Chukchi and Beaufort Seas. Influenced on all fronts by Boreal and Boreal/Arctic regions.

B. Antarctic. The area south of the Antarctic Convergence. Includes the oceanic islands of Bouvet, South Georgia, South Shetlands, South Orkneys, and South Sandwich. No other region has such sharp boundaries partly because there is no shelf connection to other regions northward and also because of the abrupt temperature difference at the sea's surface at the Convergence. Never higher than 4.5°C the year around at the water's surface.

IV. Oceanic, Bathypelagic, and Benthic Deep Sea. These are regions mostly outside our immediate perview though we must be conscious of them. Included are: warm water and northern and southern cold water oceanic regions; the Bathypelagic seas, mostly poorly lit; and the archibenthal and abyssal benthic deep sea. In the deeper regions lives a partly architypal and peculiarly specialized biota, highly dependant on surface phenomena for its continued existence. Water mass characteristics, more than any other features, delimit regions and the nature of the benthic sediments has a powerful influence on the benthic forms.

By Coastal Biotic Provinces

These regions are essentially coastal associations, as the names imply. The classification is mostly by criteria of coastal geomorphology, water mass characteristics, and biotic associations. It has already been stated that coastal regions have characteristics of ecotones or transition zones. Their relationship to the IUCN (1974) biotic provinces is unclear. For example, the Mediterranean may be divided roughly into eastern and western basins with a transition zone between (the Italy-Malta-Tunisia region). Each of these regions may be subdivided; for example, the western Mediterranean has subregions which may be described as Gulf de Lion, Mer Ligure, Spanish Coast and Balearic, Gibraltar to Mer Alboran, the Magreb Coast, and Corsica-Sardinia. There appears to be almost no relationship between this marine regional or subregional classification and floristic terrestrial biotic provinces.

Similarly, there is only a vague relationship between the terrestrial provinces of North America and the agreed-upon coastal regions given below which are adopted from Ketchum, ed. (1972) and Cronin (1974). Yet common sense tells us that there must and should be a greater degree of agreement, particularly along the sloping coastal plains and shallow coastal marine waters of the east and Gulf coasts. One can only conclude that not enough attention has been paid towards convergence of terrestrially and aquatically-oriented interests.

Therefore, as an example towards future expansion only, the North American classification is presented here. Similar coastal schemes for the rest of the world must be developed and/or incorporated.

1. Arcadian--Northeast coast of North America (from Newfoundland and southern Greenland to Cape Cod). Rocky, glaciated shoreland and submarine topography; shoreline subject to winter icing; large attached algal species important producers; biota essentially boreal. Within the North American Boreal-Transitional Province.

2. Virginian--Coast of middle Atlantic states (from Cape Cod to Cape Hatteras). Climate, topography, and biota transitional between Regions 1 and 3; lowland streams, coastal marshes, and muddy bottoms becoming prominent; biota primarily temperate with some boreal components. Within the Warm Temperate North American Province.

3. Carolinian--Coast of south Atlantic states (from Cape Hatteras to Cape Kennedy). Extensive marshes and cypress swamps; muddy bottoms predominate; waters turbid and highly productive; biota temperate with some subtropical elements. Within the American Atlantic Tropical-Subtropical Province.

4. Floridan--Cape Kennedy south to Key West and the Tortugas. Coasts dominated by calcareous sands and coral reef formation. Within the American-Atlantic Antillean Subprovince, though there may be justification for erecting a Floridan Subprovince to account for a continental influence.

5. Louisianian--Northern coast of Gulf of Mexico (from west central Florida to Tuxpan, Mexico). Quite similar to Region 3, but more tropical in environmental conditions and in biotic composition; bottoms mostly terrigenous. Within the American-Atlantic northern Gulf of Mexico Subprovince.

6. Vera Cruzian--Eastern coast of Mexico (from Tuxpan to the base of the Yucatan Peninsula). Diverse shoreland (hills and volcanic mountains grading southward to extensive low plains, marsh, and swampland); bottoms mostly terrigenous; biota - distinctly tropical, but with some temperate elements. Within the American-Atlantic Antillean Subprovince.

7. West Indian--Eastern coast of tropical America (southern tip of Florida, Yucatan Peninsula, Caribbean coast of Central America, West Indian islands). Shoreland low-lying limestone varying to mountainous, but distinctly calcareous and often of biological origin; foreshore and seabed with calcareous marls, sands and coral reefs; biota tropical. Within the American-Atlantic Antillean Subprovince.

8. Californian--Western coast of North and Middle America (from southern California through Mexico and Central America). Shoreland generally mountainous (often volcanic); rocky coasts with volcanic sand; marshes, swamps, calcareous bottoms not predominant; biota subtropical to tropical. Within the Tropical-Subtropical American Pacific Province

9. Columbian--Northwestern coast of North America (from southern Bering Sea to southern California). Shoreland predominently mountainous; rocky shores prevalent; extensive algal communities, especially nearshore kelp beds; biota boreal to temperate. Within the Temperate Northwest American Province.

10. Pacific Subarctic-Arctic--Ice-stressed coasts, (south central Bering Sea to western Arctic Ocean). Shoreline subject to icing, biota Arctic and Subarctic. Within both the Pacific-Boreal-Arctic and Polar Arctic Provinces.

11. Atlantic Subarctic-Arctic--Similar to Pacific in ice-stressed nature, but fauna and flora quite different in species compo-

sition. North of Hudson Bay, Baffin Island, and Davis Strait. Within North American Boreal and Polar Arctic Provinces.

12. Pacific Fiords--Tidal, glacial and turbid backwash. Alaska and British Columbia. Precipitous mountains, deep estuaries often with glacial moraines. Within the Temperate Northwest American Province.

13. Atlantic Fiords--Similar in character to those of the Pacific, Greenland and Northeastern Canada.

14. Tropical Insular-Hawaiian. Precipitous mountains, considerable wave action, endemic tropical and subtropical fauna. Within the Indo-West Pacific Hawaiian Subprovince.

15. North Pacific Insular-Aleutian. Precipitous shorelines dominated by North Pacific weather and oceanic influences. North Pacific to Boreal-Beringean biota. Probably should be a subprovince of the Temperate North Pacific Province.

By Habitats

This scheme is to be used to designate specific characteristics of reserves. Often more than one category will apply to a particular area. It is an expansion of the salinity classification of The Symposium on the Classification of Brackish Waters (1959), refined largely through the efforts of the USIBP/CE Program and incorporated also by Cronin (1974). A few further extensions are provided here.

A. Coastal Environments

1. Exposed

   (a) with rocky substrate
      (i) highly calcareous
      (ii) weakly or non-calcareous
   (b) with unconsolidated substrate
      (i) with low organic content
         1) gravels
         2) sands
         3) silts
         4) clays
      (ii) with high organic content

2. Protected

   (a) with rocky substrate
      (i) highly calcareous
      (ii) weakly or non-calcareous

(b) with unconsolidated substrate
  (i) with low organic content
    1) gravels
    2) sands
    3) silts
    4) clays
  (ii) with high organic content

3. Deltas

B. Coast-Associated Environments

1. Submarine vegetation beds

(a) dominated by algae
(b) dominated by vascular plants

2. Estuaries

(a) mixoeuhaline (30.0 - 35.0 o/oo salinity)
(b) polyhaline (18.0 - 30.0 o/oo)
(c) mesohaline (5.0 - 18.0 o/oo)
(d) oligohaline (0.5 - 5.0 o/oo)

3. Lagoons

(a) hyperhaline (over 40.0 o/oo salinity)
(b) euhaline (30.0 - 40.0 o/oo)
(c) mixoeuhaline (30.0 - 35.0 o/oo)
(d) polyhaline (18.0 - 30.0 o/oo)
(e) mesohaline (5.0 - 18.0 o/oo)
(f) oligohaline (0.5 - 5.0 o/oo)

4. Tidal salt marshes

5. Nontidal salt marshes and flats

6. Mangrove swamps

7. Drainage basins

(a) extent (size)
(b) type (agriculture, industrial)

C. Offshore Environments

1. Kelp beds

2. Coral reefs (active) bordering continents

(a) algal
(b) coral

3. Coral reefs bordering oceanic islands and atolls

   (a) algal
   (b) coral

4. Drowned reefs (on subsiding shorelines)

5. Insular environments

6. Continental shelf areas

7. Submarine canyons

8. Ice

   (a) shore-fast
   (b) pack
   (c) shelf
   (d) glacial and berg

9. Continental slope environments

10. Offslope environments

   (a) abyssal plains
   (b) submarine trenches
   (c) seamounts
   (d) submarine ridges

D. Man-Made Environments

1. Spoil

2. Reefs

3. Maricultural

E. Special Interest

1. Sea bird rookeries and waterfowl moulting sites

2. Sea turtle rookeries

3. Sea mammal rookeries

4. Seasonal fish concentrations

F. Water Circulation Bodies

1. Inshore circulation cells

2. Larger scale circulation cells

3. Upwelling systems

CONCLUSION

Obviously, the three schemes presented here are related. Equally, none really describes ecosystems; perhaps zoogeographic regions are not true biotic provinces. The clearest need is to describe the floristic characteristics of coastal zones in more detail, with particular reference to relating terrestrial and aquatic biota.

Nevertheless, this should be a workable scheme. There is no harm in describing environments in more than one way. And if acceptance of this approach is forthcoming, then we must commence to refine the scheme in accord with the latest scientific knowledge and to work towards description of all coastal zones of the world along the lines of that for North America given here.

Note that the scheme is computer-compatible. Description of a particular area, let us say a rocky shore of the south tip of Greenland, would be as follows:

Zoogeographic Region	II. C. 2.	North Atlantic, North American Boreal
Coastal Biotic Province	1.	Arcadian
Habitat	A. 1. (a) (ii)	Coastal, exposed with rocky, weakly or non-calcareous substrate.

Other notations peculiar to the site may be made on the Area Description as outlined in Ray (1975).

A classification is at the heart of the work of marine conservation, research, and monitoring. It is to be highly recommended that a workshop be convened in the very near future for the purpose of refining this scheme or replacing it with another which is more reflective of marine ecosystems.

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This objective can be achieved through active conservation programmes for the wise use of natural resources in areas where the flora and fauna are of particular importance and where the landscape is especially beautiful or striking, or of historical, cultural or scientific significance. IUCN believes that its aims can be achieved most effectively by international effort in co-operation with other international agencies, such as UNESCO, UNEP and FAO.

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