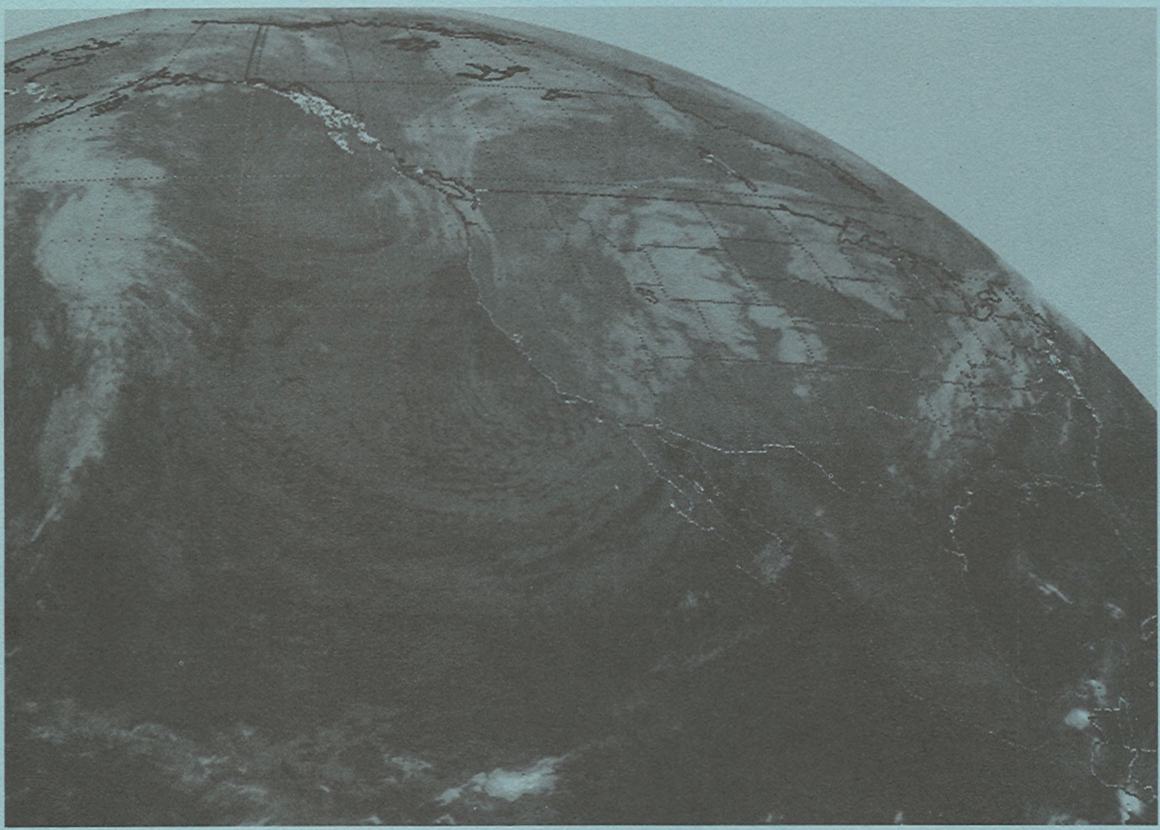
Biological Services Program

FWS/OBS-78/80
MARCH 1979

PHYSICAL REGIONALIZATION OF COASTAL ECOSYSTEMS OF THE UNITED STATES AND ITS TERRITORIES



Interagency Energy-Environment Research and Development Program

OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY

Fish and Wildlife Service

U.S. Department of the Interior

The Biological Services Program was established within the U.S. Fish and Wildlife Service to supply scientific information and methodologies on key environmental issues that impact fish and wildlife resources and their supporting ecosystems. The mission of the program is as follows:

- To strengthen the Fish and Wildlife Service in its role as a primary source of information on national fish and wildlife resources, particularly in respect to environmental impact assessment.

- To gather, analyze, and present information that will aid decisionmakers in the identification and resolution of problems associated with major changes in land and water use.

- To provide better ecological information and evaluation for Department of the Interior development programs, such as those relating to energy development.

Information developed by the Biological Services Program is intended for use in the planning and decisionmaking process to prevent or minimize the impact of development on fish and wildlife. Research activities and technical assistance services are based on an analysis of the issues a determination of the decisionmakers involved and their information needs, and an evaluation of the state of the art to identify information gaps and to determine priorities. This is a strategy that will ensure that the products produced and disseminated are timely and useful.

Projects have been initiated in the following areas: coal extraction and conversion; power plants; geothermal, mineral and oil shale development; water resource analysis, including stream alterations and western water allocation; coastal ecosystems and Outer Continental Shelf development; and systems inventory, including National Wetland Inventory, habitat classification and analysis, and information transfer.

The Biological Services Program consists of the Office of Biological Services in Washington, D.C., which is responsible for overall planning and management; National Teams, which provide the Program's central scientific and technical expertise and arrange for contracting biological services studies with states, universities, consulting firms, and others; Regional Staff, who provide a link to problems at the operating level; and staff at certain Fish and Wildlife Service research facilities, who conduct inhouse research studies.

Cover photo is from a

Synchronous Meteorological Satellite (SMS-2)

located at the equator and 135°W.

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402

Stock No. 024-010-00511-4

FWS/OBS-78/80
March 1979

PHYSICAL REGIONALIZATION OF COASTAL ECOSYSTEMS OF THE UNITED STATES AND ITS TERRITORIES

by

Terry T. Terrell
U.S. Fish and Wildlife Service
Office of Biological Services
Western Energy and Land Use Team
National Habitat Assessment Group
2625 Redwing Road
Fort Collins, Colorado 80526

Project Officer

James B. Johnston
National Coastal Ecosystems Team
U.S. Fish and Wildlife Service
National Space Technology Laboratories
NSTL Station, Mississippi 39529

This study was conducted
in cooperation with the
Environmental Protection Agency
Office of Research and Development

Performed for

Coastal Ecosystems Project
Biological Services Program
Fish and Wildlife Service
U.S. Department of the Interior

PREFACE

This report presents a hierarchical regional classification scheme for coastal ecosystems of the United States and its territories based on physical characteristics of those areas. It is designed to answer the question, "How can the coastline of the United States be partitioned to best separate ecosystems?" The purpose for defining these ecosystems is to make predictions about how specific types of perturbations in specific geographical areas will affect the ecosystems hydrologically, structurally, functionally, and biologically.

Funding for this study was provided through the Interagency Energy/Environment Research and Development Program, which is planned and coordinated by the Office of Energy, Minerals, and Industry within the Environmental Protection Agency's Office of Research and Development. Inaugurated in FY 1975, this program brings together the coordinated efforts of 77 Federal agencies and departments. The goal of the program is to ensure that both environmental data and technology are available to support the rapid development of domestic energy resources in a manner which is most compatible with the protection of the environment.

Comments are solicited. Any suggestions or questions regarding this publication should be directed to:

Information Transfer Specialist
National Coastal Ecosystems Team
U.S. Fish and Wildlife Service
National Space Technology Laboratories
NSTL Station, Mississippi 39529

This report should be cited as follows:

Terrell, T. T. 1979. Physical regionalization of coastal ecosystems of the United States and its territories. U.S. Fish and Wildlife Service, Biological Services Program. FWS/OBS-78/80. 30 pp.

ACKNOWLEDGMENTS

The author would like to acknowledge the assistance and advice of those persons listed in the Appendix, and personnel from State Coastal Zone Management programs; State planning and natural resources management agencies; Bureau of Land Management Outer Continental Shelf Office; National Marine Fisheries Service; and U.S. Fish and Wildlife Service Regional, Area, and Field Offices. Several members of the staff of the National Coastal Ecosystems Team, especially Dr. James Johnston, deserve special thanks for the many suggestions offered. The author is responsible for any errors or misstatements of fact contained in this work.

TABLE OF CONTENTS

LIST OF FIGURES

PHYSICAL REGIONALIZATION OF COASTAL ECOSYSTEMS OF THE UNITED STATES AND ITS TERRITORIES

INTRODUCTION

OBJECTIVES AND PURPOSES

The objective of this project is to formulate a hierarchical regional classification scheme for partitioning coastal ecosystems of the United States and its territories, based on the physical (mainly hydrological and geological) characteristics of those areas. The geographical area covered by this classification is the continental United States, Alaska, Hawaii, and all other United States claimed, governed, and administered territories and areas. The classification is based on physical criteria rather than biotic criteria because the objective is to define whole ecosystems, which are constrained by their physical components, rather than to define the distribution of one or a few species. (See the discussion of the differences between biogeographical and physical regional classifications in the following subsection, Review of Existing Coastal Classifications).

This classification should serve two purposes. It should first provide a data collection structure for organizing the storage of data and for demonstrating areas where additional data should be collected. Second, and perhaps more important, it should delineate geographical zones about which predictions on the structure and functioning of ecosystems within these zones may be made at various levels of resolution. These geographical areas are analogous to the ecological land and ecological water units of the Wildland Planning Glossary (Schwartz et al. 1976) and should be regarded as operational definitions of the boundaries of ecosystems or clusters of similarly functioning ecosystems. Thus, predictions within any given division[1] of the regional classification should be more reliable than predictions spanning divisions (ecosystems or clusters of ecosystems).

[1] The term division is used in the same sense as the word taxonomy; i.e., any one of the categories such as Level I, Level II, etc., into which coastal ecosystems are classified.

This classification system should be useful to a broad range of users for the above reasons. Two primary users are the National Coastal Ecosystems Team and Ecological Services, both within the U.S. Fish and Wildlife Service (FWS), for the delineation of study boundaries of their Ecological Characterization Studies, and Profiles (see Glossary).

REVIEW OF EXISTING COASTAL CLASSIFICATIONS

It is appropriate to review several existing coastal classifications, and to explain why these were not suitable to answer the stated objective of this work. It should be noted, however, that numerous ideas and pieces of information used in this classification were borrowed from many of those classifications reviewed.

There are a number of existing classifications of coastal areas, each serving a different purpose. They fall into three categories: structural, functional, and regional (geographical). While these may not be totally mutually exclusive types of classification, each has very specific characteristics. Following are descriptions of each category of classification, and several examples of each.

Structural classification schemes classify the coastline on the basis of the structural components of the area; for example, geological structure (rocky beach, sandy beach) or surface cover or structure (seagrass beds, kelp beds). Examples of this type of classification are the main body of the Cowardin et al. (1977) wetlands classification system (exclusive of the regional portion), as it applies to estuarine and marine systems, Ray's (1975) classification by habitat, and Hedgpeth's (1957) discussion of classifications. The Cowardin et al. (1977) system is a structural classification because it classifies substrate type, bottom cover, and/or surface cover. An example of a unit in this classification would be a marine, subtidal bedrock bottom dominated by *Strongylocentrotus*. Ray's (1975) classification deals mainly with geological structure. An example of a unit in this classification would be a coastal area with exposed rocky shore with a slightly or noncalcareous substrate.

Functional classifications separate systems on the basis of functional processes such as energy inputs, stratification and circulation patterns, or geological processes forming the coastline. Examples of functional classifications are those by Shepard (1937), Hansen and Rattray (1966), Glenne (1967), Inman and Nordstrom (1971), and Odum et al. (1974). Shepard's (1937) classification and that of Inman and Nordstrom (1971) are geological ones addressing the processes which form the shoreline. An example of a unit in Shepard's classification would be a glacially deposited coast with partially drowned drumlins. Inman and Nordstrom use first order effects of plate tectonics and coastal morphology as criteria for separating units in their classification. An example unit in their classification would be an island arc collision coast with mountains.

Hansen and Rattray's (1966) classification addresses mixing and stratification in estuaries. A unit in this classification would be a mathematical description of the salinity and circulation within the estuary. Glenne (1967) also addresses mixing and stratification in estuaries from a mathematical perspective. An example of a unit in his classification would be a mathematical description of the tidal effects, frictional effects, choking effects, stratification effects, and other effects in the estuary itself. Odum et al. (1974) address in their classification the stresses and energy sources of systems; e.g., turbid outwash fjords in natural Arctic ecosystems with ice stress.

A regional classification system is one based primarily on geography. Areas which are contiguous may be in the same region, but those some distance apart, though they may be quite similar structurally or functionally, cannot be classified together regionally. Secondary attributes used in the classification may be biotic or physical, and thus a biogeographic (or zoogeographic or phytogeographic) regionalization or a physical regionalization would be produced.

Examples of zoogeographic regionalizations are Ekman (1953), Briggs (1974), Ray (1975), and Smith (1976). Ekman (1953), Briggs (1974), and Ray (1975) all use the distribution of both vertebrates and invertebrates to fashion their zoogeographic regionalizations. Ray's is adapted directly from Ekman, and an example unit in both regionalizations would be Indo-West-Pacific. An example unit in Brigg's classification would be Northern Hemisphere Warm-Temperate Regions. Smith (1976) uses fish distribution in his regionalization of the Eastern Gulf of Mexico, and an example unit in his classification would be Northeastern Gulf of Mexico.

Examples of phytogeographic regionalizations are Earle (1969) and Humm (1969). Earle (1969) uses distribution of the Phaeophyta to separate regions in the eastern Gulf of Mexico. An example of a unit in her regionalization would be Subregion E, Cape Romano to Florida Bay. Humm (1969) uses distribution of algae to regionalize the Atlantic coast. An example of a unit in his classification would be a distributional group of species extending from Arctic waters south to Cape Cod.

Examples of regionalizations which include some physical factors, but which are chiefly biotic regionalizations, are Ketchum (1972), Cronin (1974), Ray (1975), and the coastal regionalization of wetlands in Cowardin et al. (1977). Ketchum (1972), Cronin (1974), and Ray (1975) use the distribution of biota, circulation, and geology to separate units in their classifications. Both Ray's and Cronin's classifications are adopted from Ketchum's, and the units are identical. An example unit would be West Indian. The Cowardin et al. (1977) classification which relates to marine and estuarine systems is based mainly on distribution of biota, but also on coastal geology and tides. The names of the units are the same as those used by Ketchum (1972), Cronin (1974), and Ray (1975). West Indian would also be an example of a unit in the Cowardin et al. (1977) regionalization.

Examples of regionalizations which include some biotic factors, but which are chiefly regionalizations based on physical parameters, are Wastler and de Guerrero (1968), U.S. Fish and Wildlife Service (1970), U.S. Senate (1970), and Lynch et al. (1976). Wastler and de Guerrero (1968) use water pollution and resource management aspects to separate units in their classification; e.g., the South Central Coastal Region. The U.S. Fish and Wildlife Service (1970) classification is one using both biotic and physical factors though the criteria used to separate units are not expressed. The criteria appear to be coastal geology, tidal information, water chemistry, climate, water input, sediment input, and the biota present. An example unit would be the North Atlantic Estuarine Zone. The U.S. Senate

289-605 O - 79 - 2

classification (1970:83) separates categories by "combinations of environmental conditions characteristic of various parts of the coastline." An example unit is the Pacific Southwest. Lynch et al. (1976) do not explicitly describe the criteria they use to separate units, but the criteria appear to be geological history, tidal amplitude, weather, currents, latitude, and estuarine environments. An example of a unit in the Lynch et al. classification would be the Columbia-North Pacific Region.

An excellent example of classification of coastal areas on purely physical (chemical, geological, etc.) attributes is Dolan et al. (1972). They use atmospheric and marine climates (currents) as well as coastal materials and configuration to separate units. An example of a unit in the Dolan et al. (1972) classification would be Regime VII: Subdominant-Maritime Polar-Marine-Divergent/Convergent.

Each of the above types of classification may be put to a number of uses, and each is well suited to answering certain types of questions. However, information obtained by applying one type of classification may be useless in trying to solve problems best addressed by application of another type of classification system. A few examples will clarify this. If all coastal areas of the United States were classified according to Odum et al. (1974), then the question, "What is the mixing pattern of estuary X?", could not be answered because their classification only considered energy inputs. If all coastal areas of the United States were classified according to Inman and Nordstrom (1971), then the question, "How many surface hectares of coastline are covered by kelp beds?", also could not be answered because Inman and Nordstrom only considered geological processes. The information collected for either classification would not be incorrect, but would be inappropriate to answer the types of questions being asked. Thus it is obviously necessary to select a classification which best answers the question or questions being asked.

The objective of this project is to formulate a hierarchical regional classification scheme for coastal ecosystems of the United States and its territories, based on the physical characteristics of those areas. The question the classification is designed to address is the following: "How can the coastline of the United States be partitioned to best separate ecosystems, when the purpose of defining these ecosystems is to understand and subsequently to make predictions about how specific types of perturbations in specific geographical areas will affect those ecosystems hydrologically, structurally, functionally, and biologically?" Structural and functional classifications do not adequately address the above stated problem because they are not geographically oriented. The geographic orientation is essential to making predictions about a specific estuarine or marine system. Thus, a regionalization is necessary.

Since delineation of ecosystems is the primary interest, a regionalization based on physical parameters is more appropriate than a biogeographical regionalization. Although the argument is frequently made that the biota integrate all the physical attributes of their environment, two factors argue against a biotic regionalization for answering the objective of the study. The first is historical accident of distribution and/or extinction. For example, a group of organisms might be absent from an area which they could inhabit simply because they were never distributed there or had become extinct in that area because of environmental or man-induced perturbations. Regionalization with respect to ecosystems should not be determined by historical accident.

The second factor supporting an argument against biogeographical regionalization is the difficulty of selecting the group or groups to represent the whole ecosystem. Questions have to be answered if benthic or motile forms, plants or animals, vertebrates or invertebrates, or vascular or nonvascular plants are the appropriate organisms to consider. A regional scheme based on physical parameters eliminates these problems since physical factors constrain the distribution of ecosystems. Thus a regionalization is most appropriate to answer the originally stated objective.

The above argument should not be construed to mean that the distribution of biota should not reflect the distribution of coastal ecosystems. If the theory that biota integrate their physical environment is correct, then they should reflect, though perhaps imperfectly by their own distribution, the distribution of coastal ecosystems. In fact, the distribution of biota would provide an excellent method for testing a regionalization based on physical parameters.

The classification proposed by Dolan et al. (1972) is extremely well done and well documented. It was not used to satisfy the objective of this study because the elemental units in some cases are of inconvenient size for the purpose of characterization. A great deal of information obtained from Dolan et al. (1972) was used in preparing this document.

A limitation of classification of coastal areas which should be briefly mentioned is the restriction to that which specifically is being classified. Classifications have addressed only beaches (Shepard 1937), estuaries (Hansen and Rattray 1966), coastal waters including or excluding estuaries (Lynch et al. 1976), coastal ecosystems (Odum et al. 1974), or coastal and estuarine species associations (Briggs 1974). Only one example of each is cited for the sake of brevity, although many more exist. As mentioned previously, the classification presented in this paper is concerned with coastal ecosystems in estuarine and coastal waters and associated wetlands.

The major problem with this proposed scheme or any other classification scheme is that of drawing boundaries somewhere along what is all too frequently a continuum. All natural ecosystems are "open ended" and have no fixed boundaries. Where there may be a distinct boundary between geological units along a coast, climate may well be continuous. When geology intergrades, climate may fall into distinct units. No clear boundary may be definable. Compounding this problem are those of shifting current, rainfall, and temperature patterns during the year, and the very nature of the coastal zone itself as an ecotone between the land and sea. Thus, while some of the different divisions specified may represent fairly distinctive ecosystems or clusters of similar ecosystems, others may be less distinctive. Some divisions may be different from other divisions only because they are intermediate. This paper presents an attempt to regionalize and separate into similarly functioning ecosystems the coastal areas of the United States, using the available ecological information and the expert opinion of numerous resource managers who work along the coast.

METHODS

In order to formulate a hierarchical regional classification scheme for coastal ecosystems, criteria were established which allow inspection of the characteristics of coastal ecosystems or clusters of ecosystems at various levels of resolution. Those criteria are:

Level I: These divisions are the largest in geographical area and represent clusters of similarly functioning ecosystems. The main criteria for separating the different divisions of Level I are ocean or lake systems upon which the coastline abuts, or the major ocean current or currents which wash the shore, or major differences in climate. Ocean currents and climate are the main forcing functions of ecosystems along the coastline and are appropriate criteria for separating these ecosystems.

Level II: These divisions are geographically smaller than Level I divisions, and represent a small number of interrelated and similarly functioning ecosystems. They are separated chiefly by geological structural properties of the coast, both above and below the waterline, with consideration given to hydrological, physical, and chemical properties. The structural geology of the coastal area is a major constraining factor on ecosystems and thus is an appropriate second level criterion for separation of these ecosystems.

Level III: For the purposes of this study, Level III divisions have not been delineated, but may be required in the future. A detailed study would be required to properly delineate Level III divisions. The following are the recommended methods for determining such divisions. Level III divisions would be the smallest divisions of the classification. Each should represent a logical unit or ecosystem. The primary criterion for separation should be the homogeneity of response, considering the forcing functions and constraints, of the division to perturbation.

At the first, most general level, the forcing functions of the systems are the chief criteria. At the second level, the major constraints on the system are the chief criteria. At the third, most specific level, the homogeneity of the response of the system to the forcing functions and constraints is suggested as the criterion for separation. Thus the criteria are: what makes the system work, what determines how the system can work, and how does the system respond.

To separate divisions, boundary lines were drawn perpendicular to the coast using the listed criteria and manual overlay of maps exhibiting the necessary information. The units delineated by this study are described under the heading Level I and II Descriptions in the following subsection, Results. The Level I description lists the factor used to separate that unit from others. For example, unit A (the U.S. North Atlantic Coast) is different from unit B (the U.S. Middle Atlantic Coast) because the former is affected by the Labrador Current, whereas the Middle Atlantic Coast is affected by both the Labrador Current and the Gulf Stream.

The Level II descriptions list those criteria used to separate Level II units, plus some additional information. For example, A1 (the Northern Gulf of Maine) differs from A2 (the Southern Gulf of Maine) because it is rockier, has fewer sand and/or cobble areas, and has less extensive marshes.

The information used in the Level I and II descriptions came mainly from Sverdrup et al. (1942), U.S. Geological Survey (1954), Earle (1969), U.S. Geological Survey (1970), Dolan et al. (1972), Brooks (1973), Joint Federal-State Land Use Planning Commission for Alaska (1973), Selkregg (1974a, 1974b, 1974c, 1974d, 1974e, 1974f), Adams et al. (1975), Bureau of Land Management (1975a, 1975b, 1975c, 1975d), Great Lakes Basin Commission (1975), Bureau of Land Management (1976a, 1976b, 1976c, 1976d, 1976e), General Land Office of Texas (1976), Weaver et al. (1976), and Bureau of Land Management (1977a, 1977b).

Lateral boundary demarcations and descriptions were examined critically by the reviewers (see Appendix for list) of the first draft and other staff members in their respective offices. In many cases the opinion of these reviewers was used to modify both boundaries and descriptions.

Possible options for landward and offshore boundaries are listed in the following subsection. A recommendation is made about which option to select based on both ecological and practical considerations.

RESULTS

The results of this project are the options for landward and offshore boundaries (below), the coastal regionalization Level I and Level II boundaries (Table 1, page 18), the Level I and II descriptions (page 7), and the figures located at the back of this report. (Maps shown are Albers conical equal area projections; letters and numbers labeling divisions on the figures correspond to those of Table 1.) The figures are visual delineations of the divisions described in Table 1 and in the Level I and II descriptions. The Level II divisions represent what are judged to be, in most cases, units which are individual coastal ecosystems or clusters of closely related coastal ecosystems.

A major portion of the ideas and information used for the list of options for landward and offshore boundaries is derived from papers by Robbins and Hershman (1974) and McIntire et al. (1975). The information sources used in the Level I and II descriptions are listed in the Methods section.

OPTIONS FOR LANDWARD AND OFFSHORE BOUNDARIES

Landward Boundary Options

1. Seaward boundary of Bailey's (1977) regionalization.

   Pro—The regionalization is extant. Many Federal agencies and States are committed to its use.

   Con—Not at all designed to give indications of coastal areas. No clear indication of seaward boundary. Does not include in coastal ecosystems Cowardin et al.'s (1977) emergent wetland class (marshes, swamps, etc.). Emergent wetlands would be included in uplands.

2. Coastal Zone Management (CZM) inland boundaries.

   Pro—Most boundaries extant, information collected for characterizations would be directly applicable to CZM problems.

   Con—Not uniform around the country, thus problems of comparability of data.

3. Mean high water mark, high high tide, etc.

   Pro—Easy to determine.

   Con—Obviously leaves out a lot of what has traditionally been considered coastal.

4. One-hundred-year flood and tidal innunda-

tion level.

Pro—Fairly easy to determine.

Con—May include large areas not normally considered coastal or exclude those which are.

5. A fixed distance from some tidal line, such as 300 m from mean high tide.

Pro—Easy to determine.

Con—May include or exclude inappropriate areas.

6. Some contour line such as the 10-m contour.

Pro—Easy to determine.

Con—May include or exclude inappropriate areas.

7. Peak of the coastal mountain range.

Pro—Easy to determine.

Con—Many coasts do not have mountain ranges.

8. Inland boundaries of coastal counties or parishes.

Pro—Easy to determine.

Con—May include or exclude inappropriate areas.

9. Man-made structures such as roads, canals, etc.

Pro—Easy to determine.

Con—May include or exclude inappropriate areas.

10. Pleistocene/Recent contact.

Pro—Some areas recently built are obviously coastal, and may be easy to discern.

Con—Not appropriate on beaches which are not aggrading.

11. Maximum inland or seaward range of any one species.

Pro—Should be fairly easy to determine.

Con—No species is distributed along entire United States coastline. Historical accidents of distribution can cause erroneous results. Plasticity of the response of an organism to its environment and synergisms among environmental inputs may allow an organism to occur in a variety of coastal and noncoastal areas.

12. Wetland/nonwetland soils.

Pro—Fairly easy to determine.

Con—Wetland soils may occur in areas which are no longer wetlands.

13. Wetland/nonwetland vegetation.

Pro—Fairly easy to determine.

Con—Large number of species needed for coastal delineation of the entire United States. Not appropriate for unvegetated coast.

14. Salinity intrusion.

Pro—Fairly easy to determine.

Con—Salinity is not the only factor which determines the inland extent of coastal ecosystems, nor is salinity restricted to the seacoast.

15. Tidal influx.

Pro—Fairly easy to determine.

Con—Tidal influx is not the only factor which determines the inland extent of coastal ecosystems.

16. Inland boundaries for marine and estuarine in the Cowardin et al. (1977) system which has been adopted by the National Wetlands Inventory. These boundaries are based on vegetation, soils, and salinity.

Pro—Will be mapped for the entire United States, large amounts of information already on this framework, will probably be updated regularly.

Con—No information yet on how this applies to coastal processes. Updates will certainly change inland boundaries.

17. Determine the major coastal influences and make an inland boundary determination for each Level I, II, or III division based on the extent of the influences.

Pro—Would most accurately reflect the functioning of coastal ecosystems in area of interest.

Con—Would not be uniform around the coastline and would cause problems of comparison of information among divisions. Extremely difficult to determine.

Offshore Boundary Options

1. Territorial sea boundary.
   Pro—Easy to define. The United States controls this area, so management would be simplified.
   Con—It is an artificial boundary having no demonstrable relationship to coastal ecosystem processes.

2. Two-hundred-mile (322-km) "economic zone."
   Pro—Easy to define. United States has some management control.
   Con—Artificial boundary having no demonstrable relationship to coastal ecosystem functioning.

3. Line marking the 30-m (or any) depth contour.
   Pro—Fairly easy to define. Is somewhat more related to functioning of ecosystems.
   Con—Line is still very artificial and data would not always be comparable along the coast.

4. Seaward boundary of the Cowardin et al. (1977) classification scheme, which has been adopted by the National Wetlands Inventory. This is the edge of the continental shelf.
   Pro—Fairly easy to determine. Much more related to ecosystem processes than above options.
   Con—May not include all the important processes. Is not completely controlled by the United States.

5. Line demarking the limit of the important processes in ecosystem functioning.
   Pro—Would best relate to and allow for modeling of coastal ecosystems.
   Con—Would be very difficult to delimit; this would have to be done for every level I, II, and III division along the coast. Might cause problems of comparability.

LEVEL I AND II DESCRIPTIONS

A U.S. North Atlantic Coast. This division is affected by the Labrador Current.

A1 Northern Gulf of Maine. Rocky, deeply incised "drowned" coastline with numerous bays, estuaries, and islands. High tidal range, creating an abundance of intertidal pool communities. Small areas of mudflats and marshes, few shallow areas.

A2 Southern Gulf of Maine. Some rocky shores from Cape Elizabeth to Cape Ann, mainly sandy beaches south of Cape Ann. Sandy or cobble beaches with high energy except those sheltered within Cape Cod Bay. Marshes more extensive than those in A1, but smaller than marshes further south; some mudflat areas.

B Middle Atlantic Coast. This division is affected by both the Labrador Current and the Gulf Stream.

B1 Southern New England. Fairly irregular coastline with several large islands, two large bays, and two sounds (Long Island Sound very large, protected). Mainly sandy beaches, some high energy, with marsh areas behind; some barrier islands, some with dune systems.

B2 New York Bight. Coastline dominated by wide, sandy, high-energy beaches, often with dune systems on extensively developed barrier islands protecting bays and large areas of marshes. Hudson River estuary included.

B3 Delaware Bay. Large embayment semiprotected from ocean. Extensive marshes on both sides of Bay as far as Philadelphia. Tidal energy twice that of Chesapeake Bay.

B4 Delmarva Shore. Dominated by series of barrier islands with some dune systems and high-energy, wide, sand beaches. Extensive marsh systems in protected shallow waters behind islands.

B5 Chesapeake Bay. Very large, "drowned coastline" estuary with several riverine subestuary systems. Largely protected from high-energy ocean influence but with pronounced influence by saline waters, marine organisms, etc., on declining gradient northward into

Bay. Extensive marsh systems, especially on eastern shore. Some oyster reefs.

C South Atlantic Coast. The Florida Current and the Antilles Current fuse to form the Gulf Stream in this division.

C1 Pamlico Sound Complex. Wide, sandy beaches with extensive marshy areas, but mostly characterized by very extensive outer bank and barrier island system which protects the sound complex. Reasonably high amount of freshwater inflow.

C2 North Carolina Coast. Broad white quartz sand beaches, smaller estuary systems than Pamlico Sound Complex, protected by long, narrow barrier islands and numerous smaller ones. Also includes marine systems seaward of barrier islands from Cape Hatteras to Cape Fear.

C3 Sea Islands. Barrier islands much smaller and more numerous, coastline less protected, fairly highly dissected coastline with high freshwater inflow, gently sloping, wide quartz sand beaches, and very extensive marshes.

C4 East Florida. Low-lying beaches of calcareous sand, extensive marshy areas, some areas of very extensive barrier islands, freshwater inflow only from coastal plain.

D Southern Florida. This division is affected by the main branch of the Florida Current.

D1 Biscayne Bay. Extremely low-lying swampy coastline, generally with mangroves (*Rhizophora mangle* L.), hard bottom, marine influence from Atlantic Ocean, freshwater inflow extremely variable.

D2 Florida Keys. Low limestone islands with pinnacle rock coasts or very narrow shell beaches bordered with mangroves, extensive shallow areas with soft marl or shell fragment bottoms extending out to coral reefs, very extensive seagrass and algal beds.

D3 Florida Bay. Coastline part of Everglades National Park, area of numerous mangrove-covered islands and very extensive swamps covering entire southern tip of Florida. Marine influence from Gulf of Mexico, but area is fairly protected.

D4 Ten Thousand Islands. Coastline dominated by a multitude of small mangrove islands and tidal channels, extremely complex, direct marine action on the coast.

E Atlantic Insular. The Antilles Current affects this division on the east, the Florida Current on the west.

E1 Puerto Rico. Consists of the large, rugged island of Puerto Rico and several smaller islands. Faces both Atlantic and Caribbean but receives much greater wave action from Atlantic. Coastline mostly steep and rocky, but some areas have coral reefs and islands sheltering lagoons, with some mangrove swamp development.

E2 Virgin Islands. Numerous islands mostly of volcanic origin, but a few of marine sediments. Areas of steep rocky cliffs, some areas with small sandy bays and rocky headlands, some areas of wide low coastal plain and wide shallow area covered by algae and turtle grass or mangrove swamps. Beaches mainly rocky or composed of calcareous sand. Well developed coral reefs.

E3 Navassa Island. Small island of about 2.6 sq km (1 sq mi) located between Jamaica and Haiti in Caribbean Sea. Volcanic origin.

E4 Serrana Bank and Roncador Bank. Coral reefs 352 km (220 mi) east of Nicaragua in the Caribbean Sea.

F Gulf of Mexico. The North and South Equatorial Currents join to form the Florida current at the Yucatan Channel. Most of the water goes directly to and out of the Straits of Florida, but a small branch of the Florida current circulates in the Gulf of Mexico and affects this division.

F1 Central Barrier Coast. Sandy beaches with a few rocky areas, extensive marshy and swampy areas present, narrow shallows area; *Juncus*, *Spartina*, or mangroves characteristic, depending on latitude.

F2 Big Bend Drowned Karst. Rugged shoreline, rocky bottoms, very wide shallows area, clear water, extensive seagrass beds and marshes, high fish production, extensive oyster bars.

F3 Apalachicola Cuspate Delta. Smooth sand beaches, mud-bottomed bays, turbid water, barrier islands present, little or no seagrass.

F4 North Central Gulf Coast. White sand beaches, clear water, extensive dune system, and barrier island system. High-energy beaches compared to others of the Gulf Coast.

F5 Mississippi Delta. Extensive marsh systems, barrier island system, sediments silty, silt terrigenous, water turbid, very extensive shallows area, extensive influence from Mississippi River.

F6 Strandplain-Chenier Plain System. Extensive marsh system, freshwater inflow from several small river systems, but lacking direct influence from Mississippi; cheniers present.

F7 Texas Barrier Island System. Extensive lagoon system formed by drowned rivermouths and barrier islands, freshwater inflow regular on upper coast to limited with hypersaline condition on lower coast, marshes common along upper coast, submerged grass beds common along lower coast, barrier islands of sand.

G U.S. Southwest Pacific Coast. This division is affected by the California Current.

G1 Southern California. Fairly smooth coastline with a few large islands, both low and high-cliffed beaches which are mainly sandy with a few rocky promontories, sporadic seasonal high freshwater inflow, but generally low to no freshwater inflow, extensive algal communities, kelp beds.

G2 Central California. High-cliffed beaches, mostly rocky but some sandy with a high frequency of pocket beaches in some areas, moderate freshwater inflow, extensive algal communities, kelp beds.

G3 San Francisco Bay. Highly protected from marine influence, some low-cliffed beaches, but mostly low-lying mudflats with a few pocket beaches and marshes, moderate freshwater influence.

H U.S. Northwest Pacific Coast. The branching of the Aleutian Current into the Alaska and California Currents occurs off this portion of the coast.

H1 Pacific Northwest. High-cliffed beaches mainly with numerous pocket beaches but a few extensive sandy or rocky beaches; in the northern part are lower rocky coastal flats, moderately dissected coastline, cool water temperatures, high freshwater inflow, numerous rocky islands, small bays, and estuary systems with mudflats and eelgrass beds.

H2 Columbia River Estuary. Separated mainly due to high freshwater inflow generated far inland, extensive inland marsh complex.

H3 Puget Sound. Relatively protected from direct marine influence by Olympic Peninsula, highly complex coastline with numerous islands, high freshwater inflow.

I Pacific Insular. This division is affected by the North and South Equatorial Currents and by the Equatorial Counter Current.

I1 Hawaii. Tropical volcanic islands rising sharply from ocean, coral reefs, high wet islands and low dry islands, several species of endemic fauna and flora.

I2 Guam, the Pacific Trust Territories, and Other U.S. Claimed and Administered Islands. Tropical islands, some having mountains, some with upthrust limestone plateaus, and several with wide sandy beaches and extensive coral reefs, or some combination of the above, all lying north of the equator; includes high wet islands and low dry islands, some of which receive very intense storm activity.

I3 American Samoa and Other U.S. Claimed and Administered Islands. Tropical and subtropical islands south of the equator, a few with mountains, but most with low sandy beaches with extensive coral reefs; includes high wet islands and low dry islands.

J Panama Canal Zone. This division is affected along the Gulf of Panama coast by the Equatorial Counter Current and on the Caribbean coast mostly by the South Equatorial Current.

J1 Canal Zone, Caribbean. Faces Caribbean Sea, receives high-energy wave action; coastal plain with high relief, cliffed, with sand beaches.

J2 Canal Zone, Gulf of Panama. Abuts the Gulf of Panama; receives lower energy wave action than J1; coastal plain with high relief, mostly composed of recent fluvial and deltaic rocks, and sand beaches.

J3 Canal Zone, Gatun Lake. Highly disturbed area due to the Canal itself. Receives freshwater influence from Gatun and Madden Lakes and marine influence from the Caribbean Sea and the Gulf of Panama.

K Pacific Alaska. This division is affected by the Alaska Current.

K1 Alexander Archipelago. Extremely complex shoreline due to glacier-formed fjords. In numerous cases glacial formation of coastline presently occurring. Shoreline may receive direct wave action from Pacific Ocean or may be protected and facing one of numerous straits and passages.

K2 Wave-Beaten South Central Alaska Coast. Receives wave action from Pacific Ocean, as well as a large amount of glacial action on shoreline. Much of the shoreline has exposed sand beaches which receive strong onshore currents and a lot of drift.

K3 Prince William Sound. Fjord-type shoreline protected from Pacific Ocean by Montague and Hinchinbrook Islands. Extensive glacial action presently occurring on coastline.

K4 Cook Inlet. Tide-mixed estuary, extensive marshy lowlands, water very salty, little glacial action on shoreline. Tide very dominant with tidal bore exceeding 9 m (30 ft) in some places, currents up to 12 knots.

K5 Kodiak Island and Protected Coast. Unit contains three types of coastline: that which is wave-beaten by the Pacific, that which faces the Shelikof Strait and has fjords, and that which faces the Shelikof Strait and is protected from direct Pacific wave action but not greatly affected glacially.

K6 Wave-Beaten Southwest Alaska Coast. Rugged, mountainous coastline of the Alaska Peninsula, little glacial activity, direct wave action from Pacific. Large numbers of small islands and rocks with numerous small areas of protected coast.

L Aleutian Islands. This division is affected by the Aleutian Current.

L1 Aleutian Islands. Island chain receiving direct wave action from both Pacific and Bering Oceans; wave action much greater from Pacific.

M Bering Alaska. This division is affected by a branch of the Aleutian Current which enters the Bering Sea via passes between the Aleutian Islands.

M1 South Bristol Bay. Coast may or may not be ice-locked during winter, receives wave action from Bering Sea; beaches of black volcanic sand, interspersed with dune-type headlands, backing onto low-lying wet tundra, flanked by mountainous volcanic terrain.

M2 North Bristol Bay. Coast ice-locked in winter and subject to ice-scouring; area adjacent to coast either mountainous or low-lying wet tundra, with black volcanic mud beaches; receives direct wave action from the Bering Sea, but more protected than South Bristol Bay.

M3 Yukon-Kuskokwim Delta. Very extensive marsh systems extending hundreds of miles inland, receiving varying amounts of freshwater and saltwater influence; coastline ice-locked during winter, water turbid.

M4 Norton Sound Coast. Coastline mainly mountainous, but a few low-lying areas present; icebound in winter, receives wave action from Bering Sea but somewhat protected.

M5 Bering Sea Islands. Volcanic-type islands with pocket beaches, precipitous cliff-type shoreline, backing onto grassy highlands often rising to volcanic peaks of 3,050 m (10,000 ft), but may have extensive areas of marshy lowlands and well-developed barrier islands and spits, receiving wave action on all sides from Bering Sea. Ice-influenced in all cases, islands may be ice-locked up to half the year, with extensive ice-scouring.

N Arctic Alaska. This division is affected by the North Atlantic Littoral Current and the Arctic Basin Gyre.

N1 Chukchi Coast. Receives wave action from Chukchi Sea, some mountainous coastline, but mostly low-lying, marshy areas, with some areas having extensive barrier islands. Some sounds and inlets protected from wave action. Ice-locked during winter, ice-free during summer, receives extensive ice-scouring.

N2 Beaufort Coast. Receives wave action from Beaufort Sea, ice-locked during winter, usually ice-free in summer, very extensive ice-scouring. Coastline very low with extensive marshy areas. Some barrier islands.

O Great Lakes. This division is a freshwater area not affected by marine currents. Each lake, however, has complex current patterns of its own.

O1 Lake Superior. Has the most rugged uninhabited and inaccessible shorelands of all the Great Lakes. The shore type of Lake Superior and the St. Marys River varies from the steep rock cliffs of the Pictured Rocks National Lakeshore Area to the sandy beaches of White Fish Bay, Michigan, to the low-lying clay and gravel bluffs near Duluth, Minnesota, and in Wisconsin to the marshlands of Munuscong Bay, Michigan. Lake Superior and St. Marys River contain major islands and island groups.

O2 Lake Michigan. Large expanse of sand dunes extending almost continuously from the Indiana Dunes National Lakeshore northward to the tip of the Leelanau Peninsula in Michigan. They result from the prevailing westerly winds that cause an almost continuous washing and separation of shore soil material by wave action. Wide, sandy beaches are often associated with the dune areas, especially during years of low water levels on the Great Lakes.

O3 Lake Huron. Mainly a rock and boulder shore in the northern area with some high bank beaches extending landward into a rolling upland area. From Sand Point in outer Saginaw Bay to the most northern part of Huron County, the shore is composed of sandy beaches backed by low dunes and bluffs. This shore type also predominates in Sanilac County. From northern Huron County east and south approximately to the Huron-Sanilac County line, exposed bedrock and very rocky shorelands replace the sandy shore type. The shorelands of Lake St. Clair are predominantly artificial fill, erodible low plain, and a smaller wetland contingent.

O4 Lake Erie. Eastern Lake Erie has glacial till and raft-shale bluffs. The Pennsylvania portion comprises shore bluffs of 15 to 30 m (50 to 100 ft). Bluffs are composed of clay, silt, and granular material with shale bedrock occurring about water level. To the east of Erie Harbor, the shale bedrock is frequently 5 to 11 m (15 to 35 ft) above lake level and the upper part of the bluff is composed of silt, clay, and granular material. Sand and gravel beaches up to 46 m (150 ft) wide extend along the toe to the bluffs. The shoreline of western Lake Erie consists mainly of wetlands, low plains, artificial shore types, and low rocky bluffs. Lake Erie is subject to impressive seiches.

O5 Lake Ontario. The U.S. shoreline consists generally of bluffs of glacial material ranging from 6 to 18 m (20 to 60 ft) high. Narrow gravel beaches border the bluffs, which are subject to erosion by wave action. The bluffs are broken in several places by low marshes. The shore in the vicinity of Rochester and Irondequoit is marshy, with sand and gravel barrier beaches separating the marshes and open ponds from the lake. The shoreline from Sodus Bay east to Port Ontario is a series of drumlins and dunes separated by marsh areas. North of the Oswega-Jefferson

289-605 O - 79 - 3

County line for a distance of 16 km (10 mi), the shorelands are composed of dunes and barrier beaches. At this point the shore type changes abruptly to rock outcrop at the water's edge. This rock shore extends north to the St. Lawrence River interrupted only by a few pockets of beaches and marshes at the inner end of the deep bays.

RECOMMENDATIONS

A list of options for landward and seaward boundaries of Level I, II, and III divisions, along with the pros and cons of adopting each option, was presented in the Results section. The ideal landward and seaward boundaries of divisions would be those which delimit the major coastal processes which occur in each division. This would most accurately reflect functioning of real-world ecosystems. Unfortunately, these are extremely difficult to delimit. In actual practice the landward and seaward boundaries described by the Cowardin et al. (1977) classification, as described in Results, are probably as close to these ideal boundaries as can be drawn. The real advantages to adopting the boundaries used by the National Wetlands Inventory are that they are being mapped presently and that a large amount of data are being stored in this format. All other options listed are unacceptable due to the problems inherent in each, as previously described.

Concerning lateral (perpendicular to the shoreline) boundaries of Level I and II divisions, those which end at the political boundaries of the United States are obviously artificial. They were delineated in that manner due to the scope of the study. It is obvious, however, that the boundaries of coastal ecosystems logically should not resemble political boundaries. Thus Table 2 lists more rational boundaries for Level I and II divisions which abut the political boundaries of the United States and overlap into other countries.

In some instances it may be necessary or useful to lump or further subdivide Level II divisions for the purpose of producing Characterizations or Profiles. For example, one might lump the North and South Bristol Bay divisions into a Bristol Bay Characterization. In the case of lumping, it is advisable to lump Level II divisions which are within a Level I division, rather than those from two different Level I divisions. Level II divisions within a Level I division are by definition more similar and, thus, may have predictions made about them which are more reliable than predictions made about Level II divisions drawn from different Level I divisions. Thus, lumping should occur only within Level I divisions.

Criteria for separating Level III divisions are suggested in the Methods section. Because of the detailed information which would be needed to accurately delineate the Level III divisions, it is recommended that such divisions, if they are needed, be products of either a characterization or some special study on a specific Level II division.

SUMMARY

The objective of this project is to formulate a hierarchical regional classification scheme for coastal ecosystems of the United States and its territories based on the physical characteristics of those areas. The classification is designed to address the following: "How can the coastline of the United States be partitioned to best separate ecosystems, when the purpose of defining these ecosystems is to make predictions about how specific types of perturbations in specific geographical areas will affect the ecosystems hydrologically, structurally, functionally, and biologically?" Two primary users of this classification are the National Coastal Ecosystems Team and Ecological Services, both within the FWS, who will use the classification for determining locations and boundaries of subject areas for their Characterization Studies, and Profiles (see Glossary).

Existing coastal classification schemes were examined to determine if any were suitable for fulfilling the above stated objective. Coastal classifications were found to fall into essentially three types—structural, functional, and regional. Structural and functional classifications do not address geographical problems and are thus not appropriate; only regional classifications address the question being asked.

There are two types of regionalizations—one based on biogeography and one based on physical (chemical, geological, etc.) parameters. Biogeographical regionalizations are based on the actual distribution of one or a few groups of organisms and do not address distribution of coastal ecosystems per se; regionalizations based on physical parameters do address ecosystems. The only regionalization found which is based on physical parameters (Dolan et al. 1972) was rejected because of the size of its Elemental Units. Thus it was appropriate to develop a classification scheme

to answer the question stated.

The criteria used for separation of Level I and II divisions are as follows:

Level I The forcing functions of the system
Level II The major constraints of the system

The lateral (i.e., perpendicular to the shore) boundaries of Level I and II divisions, determined by the above criteria, and descriptions of these divisions are given. Level III division separations are not made. If Level III divisions are needed, they should be the products of a special study on a specific Level II division, and the homogeneity of the response by the system should be the chief criterion used for separation. A list of options for landward and seaward boundaries of Level I, II, and III divisions is given with the pros and cons of using each of the options.

The most appropriate landward boundaries for Level I, II, and III divisions are either the marine and estuarine landward boundaries, as defined by the National Wetlands Inventory classification scheme (Cowardin et al. 1977), or the landward limit of the major coastal processes which occur in each division. In some cases these two boundaries are the same.

Seaward boundaries should be set as either the edge of the continental shelf (as indicated by Cowardin et al. 1977) or at the seaward boundary of the major coastal processes which are occurring in each division. For landward and seaward boundaries, the lines delimited by the National Wetlands Inventory classification system (Cowardin et al. 1977) are the more practical option.

In some cases the political boundaries of the United States are regarded as boundaries of coastal ecosystems because of the chief use of the regionalization. These boundaries are highly artificial. A list is given of more practical lateral boundaries of coastal ecosystems which do cross political boundaries of the United States.

LITERATURE CITED

Adams, J. B., L. C. Gerhard, J. C. Ogden, and J. Bowman. 1975. Potential national natural landmarks, U.S. Virgin Islands. West Indies Lab., Fairleigh Dickinson Univ., for the Natl. Park Serv. 82 pp.

Bailey, R. G. 1977. Ecosystems and ecoregions of the United States. Map, Scale 1:7,500,000, U.S. Forest Serv.

Briggs, J. C. 1974. Marine zoogeography. McGraw-Hill, New York. 475 pp.

Brooks, H. K. 1973. Geological oceanography: Historical background and regional relationships. Pages IIE-1 to IIE-49 *in* J. J. Jones, R. Ring, M. Rinkel, and R. Smith, eds. A summary of knowledge of the eastern Gulf of Mexico: 1973. State Univ. System, Fla. Inst. Oceanogr., St. Petersburg, Florida.

Bureau of Land Management. 1975a. Visual graphics, offshore southern California, Outer Continental Shelf lease sale 35.

______. 1975b. Visual graphics, northern Gulf of Alaska, Outer Continental Shelf lease sale 39.

______. 1975c. Visual graphics, Gulf of Mexico and Atlantic Ocean, Outer Continental Shelf lease sale 41.

______. 1975d. Visual graphics, eastern Gulf of Mexico, Outer Continental Shelf lease sale 41.

______. 1976a. Visual graphics, offshore the Mid-Atlantic States, Outer Continental Shelf lease sale 40.

______. 1976b. Visual graphics, Cape Hatteras Planning Unit, Outer Continental Shelf lease sale 43.

______. 1976c. Visual graphics, western and central Gulf of Mexico, Outer Continental Shelf lease sale 47.

______. 1976d. Visual graphics, lower Cook Inlet, Outer Continental Shelf lease sale.

______. 1976e. Visual graphics, western Gulf of Alaska, Outer Continental Shelf lease sale 46.

______. 1977a. Visual graphics, offshore the North Atlantic states, Outer Continental Shelf lease sale 42.

______. 1977b. Visual graphics, Blake Plateau Planning Unit, Outer Continental Shelf lease sale 43.

Corliss, J. F. 1974. Ecoclass: A method for classifying ecosystems. Pages 264-271 *in* Foresters in land-use planning. Proc. Natl. Conv. Soc. Am. Foresters, Portland, Oregon. 1973.

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1977. Classification of wetlands and deep-water habitats of the United States (an operational draft). U.S. Fish and Wildl. Serv., Office Biol. Serv., Washington, D.C. 100 pp.

Cronin, L. E. 1974. Scientific workshop summary. Pages 165-185 *in* M. P. Lynch, B. L. Laird, and T. F. Smolen, eds. Marine and estuarine sanctuaries. Proc. Natl. Workshop on Sanctuaries. Nov. 1973. Washington, D.C., Va. Instit. Marine Sci., Spec. Sci. Rep. 70.

Dolan, R., B. Hayden, G. Hornberger, J. Zieman, and M. Vincent. 1972. Classification of the coastal environments of the world. Part 1. The Americas. U.S. Office Naval Res., Geogr. Programs Tech. Rep. 1 Natl. Tech. Inf. Serv. Dept. Commerce, Springfield, Virginia. 163 pp.

Durrenberger, R. W. 1973. Dictionary of the environmental sciences. Natl. Press Books, Palo Alto, California. 282 pp.

Earle, S. A. 1969. Phaeophyta of the eastern Gulf of Mexico. Phycologia 7 (2):71-254.

Ekman, Sven. 1953. Zoogeography of the sea. Sidgwick and Jackson, Ltd., London, England. 417 pp.

Ford-Robertson, F. C., ed. 1971. Terminology of forest science, technology, practice and products. Soc. Am. Foresters, Washington, D.C. 349 pp.

General Land Office of Texas. 1976. Texas coastal management program hearing draft. 114 pp.

Glenne, B. 1967. Classification system for estuaries. Am. Soc. Civ. Eng. J. Waterw. Harbors Div. 93:55-59.

Gove, P. B., 1963. Webster's third new international dictionary of the English language. Unabridged. G. and C. Merriam Co., Springfield, Massachusetts. 2,662 pp.

Great Lakes Basin Commission. 1975. Appendix 12: Shore use and erosion. *In* Great Lakes basin framework study. Public Inf. Office, Great Lakes Basin Comm., Ann Arbor, Michigan.

Hansen, D. V., and M. Rattray, Jr. 1966. New dimensions in estuary classification. Limnol. Oceanog. 11(3):319-326.

Hanson, H. C. 1962. Dictionary of ecology. Philos. Libr. New York. 382 pp.

Hedgpeth, J. W. 1957. Classification of marine environments. Geol. Soc. Am. Mem. 67(1):17-28.

Humm, H. J. 1969. Distribution of marine algae along the Atlantic Coast of North America. Phycologia 7(1):43-53.

Inman, D. L., and C. E. Nordstrom. 1971. On the tectonic and morphologic classification of coasts. J. Geol. 79(1):1-21.

Joint Federal-State Land Use Planning Commission for Alaska. 1973. Major ecosystems of Alaska. Map, Scale 1:2,500,000.

Ketchum, B. H., ed. 1972. The water's edge: critical problems of the coastal zone. MIT Press, Cambridge, Massachusetts. 303 pp.

Lynch, M. P., B. L. Laird, N. B. Theberge, and J. C. Jones, eds. 1976. An assessment of estuarine and nearshore marine environments. SRAMSOE 93, U.S. Fish and Wildl. Serv., Office Biological Serv., Washington, D.C. FWS/OBS-76/5. 132 pp.

McIntire, W. G., M. J. Hershman, R. D. Adams, K. D. Midboe, and B. B. Barrett. 1975. A rationale for determining Louisiana's coastal zone. La. State Univ., Cent. for Wetland Resour., Baton Rouge. Sea Grant Publ. LSU-Y-75-006. 91 pp.

Odum, E. P. 1971. Fundamentals of ecology. 3rd ed. W. B. Saunders Co., Philadelphia, Pennsylvania. 574 pp.

Odum, H. T., B. J. Copeland, and E. A. McMahan, eds. 1974. Coastal ecological systems of the U.S. Conservation Foundation, Washington, D.C. 4 vols.

Ray, G. C. 1975. A preliminary classification of coastal and marine environments. IUCN Occas. Paper 14, Morges, Switzerland. 26 pp.

Reid, J. E. 1972. The resource capability system. Pages 145-152 *in* Proceedings, symposium on watersheds in transition. Fort Collins, Colorado, 1972. Am. Water Resour. Assoc. and Colo. State Univ., Urbana, Illinois.

Robbins, J. M. and M. J. Hershman. 1974. Boundaries of the coastal zone: A survey of state laws. Coastal Zone Management J. 1(3):305-331.

Schwartz, C. F., E. C. Thor, and G. H. Elsner. 1976. Wildland Planning and Range Exp. Stn., General Tech. Rep. PSW-13/1976. 252 pp.

Selkregg, L. L., ed. 1974a. Alaska regional profiles: southcentral region, State of Alaska in cooperation with the Joint Federal-State Land Use Planning Comm. for Alaska, Anchorage. 255 pp.

______. 1974b. Alaska regional profiles: Arctic region, Vol. II. Univ. Alaska, Arctic Environ. Inf. and Data Cent. for the State of Alaska in cooperation with the Joint Federal-State Land Use Planning Comm. for Alaska, Anchorage. 218 pp.

______. 1974c. Alaska regional profiles: Southwest region, Vol. III. Univ. Alaska, Arctic Environ. Inf. and Data Cent. for the State of Alaska in cooperation with the Joint Federal-State Land Use Planning Comm. for Alaska, Anchorage. 313 pp.

______. 1974d. Alaska regional profiles: Southeast region, Vol. IV. Univ. Alaska, Arctic Environ. Inf. and Data Cent. for the State of Alaska in cooperation with the Joint Federal-State Land Use Planning Comm. for Alaska, Anchorage. 233 pp.

______. 1974e. Alaska regional profiles: Northwest region, Vol. V. Univ. Alaska, Arctic Environ. Inf. and Data Cent. for the State of Alaska in cooperation with the Joint Federal-State Land Use Planning Comm. for Alaska, Anchorage. 265 pp.

______. 1974f. Alaska regional profiles: Yukon region, Vol. VI. Univ. Alaska, Arctic Environ. Inf. and Data Cent. for the State of Alaska in cooperation with the Joint Federal-State Land Use Planning Comm. for Alaska, Anchorage. 346 pp.

Shepard, F. P. 1937. Revised classification of marine shorelines. J. Geol. 45(6):602-624.

Smith, G. B. 1976. Ecology and distribution of eastern Gulf of Mexico reef fishes. Fla. Marine Res. Publ. 19. 78 pp.

Sverdrup, H. U., M. W. Johnson, and R. H. Fleming. 1942. The oceans: Their physics, chemistry, and general biology. Prentice-Hall, Inc., New York, New York. 1,087 pp.

U.S. Fish and Wildlife Service. 1970. National estuary study. U.S. Department of the Interior, Bur. Sport Fisheries and Wildl. and Bur. Commercial Fisheries, U.S. Govt. Printing Office, 7 vols.

U.S. Geological Survey. 1954. Alaska, Map E. Map, scale 1:2,500,000.

______. 1970. The national atlas of the United States of America. 417 pp.

U.S. Senate. 1970. The national estuarine pollution study. Rep. of the Sec. of Interior to the U.S. Congr. Pursuant to Public Law 89-753, The Clean Water Restoration Act of 1966. U.S. Senate Doc. 91-58. U.S. Govt. Printing Office, Washington, D.C. 633 pp.

Wastler, T. A., and L. C. deGuerrero. 1968. National estuarine inventory—Handbook of descriptors. U.S. Dept. of Interior, Fed. Water Pollution Control Adm. 77 pp. + A22 pp.

Weaver, J. D., B. Beck, G. Drewry, N. Schneidermann, and R. Woodbury. 1976. Inventory of potential national natural landmarks in Puerto Rico. Geol. Soc. Puerto Rico for Natl. Park Serv. 141 pp.

GLOSSARY

Biogeographic regionalization—A regional classification based secondarily on the distribution of some group or groups of organisms. Ekman's (1953) zoogeographical regional classification of marine areas is an example.

Coastal biotic province—Delineations of associations based on biotic components, water mass characteristics, and coastal geomorphology, with emphasis on the biotic components (Ray 1975).

Division—Used in the same sense as the word taxon is used in taxonomy; i.e., any one of the categories such as Level I, Level II, etc., into which coastal ecosystems are classified.

Ecological characterization studies—Studies being performed by the National Coastal Ecosystem Team of the U.S. Fish and Wildlife Service which provide a description of the important resources and processes comprising a coastal ecosystem. They also provide an understanding of the functional and dynamic relationships in coastal ecosystems through integration of existing environmental and socioeconomic resource data into an ecological unit. These studies follow a holistic approach (J. Johnston, NCET, pers. comm.).

Ecological land unit (ELU)—1. "U.S. Forest Service usage. One of the lowest levels of the Ecoclass system of classifying ecosystems into subdivisions for forest description and management. An ELU is a composite of elements from the land subsystem and vegetation subsystem which together define a homogeneous unit (after Corliss 1974)."

2. "U.S. Forest Service Resource Capability System (RCS) usage. Units of land having strong uniformity in slope steepness, aspect, microclimate, rock types and conditions, geomorphology, soil characteristics and productive capabilities, type, density and age of vegetation and ground cover, and drainage characteristics."

"The basic physical unit of land that scientific disciplines agree must be delineated and examined as a separate entity (for use-evaluation or management purposes)."

"The basic unit that is used in the anlaysis of on site potentials, capabilities, and limitations. The most significant level of land stratification which best communicates the basic (inherent) capabilities and limitations (Reid 1972)."

"Land (or water) units which because of their strong uniformity in physical and biological characteristics respond similarly to management activities or other stimuli. Sometimes called response units." (Schwartz et al. 1976:64-65).

Ecological water unit (EWU)—"U.S. Forest Service usage. One of the lowest levels of the Ecoclass system of classifying ecosystems into subdivisions for forest description and management. An EWU is a composite of elements from the land and aquatic subsystems, where aquatic type and adjacent land types together define a homogeneous unit (after Corliss 1974)" (Schwartz et al. 1976:65).

Ecosystem—1. "The system formed by the interaction of a group of organisms and their environment (Durrenberger 1973)."

2. "A complete, interacting system of organisms considered together with their environment, e.g., a marsh, a watershed, a lake, etc. (after Hanson 1962)."

3. "An ecological community considered together with the nonliving factors of its environment as a unit" (Gove 1963).

4. "Any spatial unit that includes all of the organisms (i.e., the biotic community) in a given area interacting with the physical environment so that a flow of energy leads to clearly defined food and feeding relationships, biologic diversity and biogeochemical cycles (i.e., exchange of materials between living and nonliving parts) operating as an integrated system."

"Ecosystem is the preferred term in English while biocoenosis or biogeocoenosis is preferred by writers using or familiar with the Germanic and Slavic languages (after Odum 1971)."

"Some (Ford-Robertson 1971, Hanson 1962) make a distinction between the two terms by using bio(geo)coenosis to refer to actual biological units (such as a certain bog) and ecosystem when referring to conceptual units. Others (Odum 1971) make no such distinction. We prefer Odum's lumping of the terms, while recognizing that in some technical, ecological literature the distinction is significant (C.F.S.)."

5. "Any complex of living organisms taken together with all the other biotic and abiotic factors which affect them, that are mentally isolated for purposes of study. (after Ford-Robertson 1971, citing Tansley)" (Schwartz et al. 1976:67).

Functional classification—A classification of sytems based on some aspect of the functioning of the system. An example would be the system of Odum et al. (1974) which classifies coastal ecosystem by energy inputs.

Physical regionalization—A regionalization based secondarily on some physical feature or features of the environment. The classification by Dolan et al. (1972) of coastal areas by climate, water mass, and geology is an example of a physical regionalization.

Phytogeographic regionalization—A regional classification based secondarily on the distribution of some group of plants. Humm (1969) presents a regionalization based on the distribution of marine algae along the Atlantic coast of North America.

Profiles—Studies being performed by Ecological Services of the U.S. Fish and Wildlife Service which review and synthesize the existing information into a compendium of information on a coastal area. In some cases the information is restructured into a format which will facilitate the making of use decisions about land and water (L. Goldman, ES, pers. comm.).

Regional classification—A classification of systems based primarily on geography. Areas which are contiguous may be in the same region, but those some distance apart, though they may be quite similar structurally or functionally, cannot be classified together regionally. Secondary attributes used in the classification may be biotic or physical. Briggs' (1974) book on marine zoogeography features a regional classification based secondarily on zoogeographic features.

Structural classification—A classification of systems based on some structural feature such as geology or surface cover. Ray's (1975) classification "by habitats" of coastal environments is an example of a structural classification. It includes such classes as exposed environments with highly calcareous, rocky substrate..

Zoogeographic regionalization—A regional classification based secondarily on the distribution of some group or groups of animals. See the discussion of Briggs (1974) under Regional Classification in this glossary.

Table 1. Coastal regionalization Level I and II lateral boundaries.

Level I	Level II	Lateral boundaries
A. U.S. North Atlantic Coast		A. Maine-Canada border to Cape Cod
	1. Northern Gulf of Maine	1. Maine-Canada border to Cape Elizabeth
	2. Southern Gulf of Maine	2. Cape Elizabeth to Cape Cod at Monomoy Island
B. U.S. Middle Atlantic Coast		B. Cape Cod at Monomoy Island to Cape Hatteras, but not including Pamlico, Currituck, or Albermarle Sound
	1. Southern New England Coast	1. Cape Cod at Monomoy Island to Montauk Point, including Long Island Sound
	2. New York Bight	2. Montauk Point to Cape May
	3. Delaware Bay	3. Cape May to Cape Henlopen
	4. Delmarva Shore	4. Cape Henlopen to Cape Charles, plus seaward shore from Cape Henry to Cape Hatteras
	5. Chesapeake Bay	5. Cape Charles to Cape Henry
C. U.S. South Atlantic Coast		C. Cape Hatteras to Fort Lauderdale plus Pamlico, Albermarle, and Currituck Sounds
	1. Pamlico Sound Complex	1. Pamlico, Albermarle, and Currituck Sounds
	2. North Carolina Coast	2. Seaward coast of Outer Banks from Cape Hatteras to Cape Lookout and both estuarine systems and seaward islands from Cape Lookout to Winyah Bay
	3. Sea Islands	3. Winyah Bay to St. Johns River
	4. East Florida	4. St. Johns River to Fort Lauderdale
D. Southern Florida		D. Fort Lauderdale to Cape Romano including Florida Keys
	1. Biscayne Bay	1. Fort Lauderdale and Biscayne Bay including Biscayne Bay National Monument
	2. Florida Keys	2. From Biscayne Bay National Monument to Key West and to include Dry Tortugas
	3. Florida Bay	3. South tip of Biscayne Bay to Cape Sable
	4. Ten Thousand Islands	4. Cape Sable to Cape Romano
E. Atlantic Insular		E. Puerto Rico and Virgin Islands
	1. Puerto Rico	1. Puerto Rico
	2. Virgin Islands	2. Virgin Islands
	3. Navassa Island	3. Navassa Island
	4. Serrana Bank and Roncador Bank	4. Serrana Bank and Roncador Bank[a]
F. Gulf of Mexico		F. Cape Romano to Texas-Mexico border
	1. Central Barrier Coast	1. Cape Romano to Tarpon Springs
	2. Big Bend Drowned Karst	2. Tarpon Springs to Light House Point
	3. Apalachicola Cuspate Delta	3. Light House Point to Cape San Blas
	4. North Central Gulf Coast	4. Cape San Blas to Pascagoula-Horn Island
	5. Mississippi Delta	5. Pascagoula-Horn Island to, and including, Vermilion Bay
	6. Strandplain-Chenier Plain System	6. Vermilion Bay to Galveston Bay
	7. Texas Barrier Island System	7. Galveston Bay to Texas-Mexico border (including Galveston Bay)

continued

Table 1. (continued)

Level I	Level II	Lateral boundaries
G. U.S. Southwest Pacific Coast		G. California-Mexico border to Cape Mendocino
	1. Southern California	1. California-Mexico border to Point Conception
	2. Central California	2. Point Conception to Cape Mendocino
	3. San Francisco Bay	3. San Francisco Bay
H. U.S. Northwest Pacific Coast		H. Cape Mendocino to Washington-Canada border
	1. Pacific Northwest	1. Cape Mendocino to the Straits of Juan de Fuca
	2. Columbia River Estuary	2. Columbia River Estuary from Cape Disappointment to Clatsop Spit
	3. Puget Sound	3. Puget Sound and the Straits of Juan de Fuca and Georgia
I. Pacific Insular		I. Hawaii, Guam, Samoa, Pacific Trust Territories, and other Pacific islands, administered, claimed, or in trust to the United States
	1. Hawaii	1. State of Hawaii
	2. Guam, the Pacific Trust, and Other U.S. Claimed and Administered Islands	2. Guam, the Carolines, the Marianas, the Marshalls, Wake, Midway Island, Johnston Atoll, Kingman Reef, Palmyra Atoll, Howland Island, Baker Island
	3. Samoa and Other U.S. Claimed and Administered Islands	3. Samoa, Jarvis Island, Canton Island, Enderbury Island, the Line Islands[b], Phoenix Islands[b], Ellice Islands[b], Northern Cook Islands[c], Tokelau (or Union) Islands[c]
J. Panama Canal Zone		J. Panama Canal Zone
	1. Canal Zone, Caribbean	1. That portion of the Canal Zone which faces the Carribbean
	2. Canal Zone, Gulf of Panama	2. That portion of the Canal Zone which faces the Gulf of Panama
	3. Canal Zone, Gatun Lake	3. That portion of the Canal Zone which faces the Canal itself, including the shorelines of Gatun and Madden Lakes
K. Pacific Alaska		K. Alexander Archipelago to Unimak Island at Unimak pass, including Cook Inlet
	1. Alexander Archipelago	1. Alexander Archipelago to Cape Spencer
	2. Gulf of Alaska Coast	2. Cape Spencer to Kenai Peninsula at Cape Elizabeth, except Prince William Sound but including the outer or Gulf of Alaska facing coasts of Montague and Hinchinbrook Islands
	3. Prince William Sound	3. Cape Hinchinbrook to San Juan-Latouche, including the inner or lee coasts of Montague and Hinchinbrook Islands
	4. Cook Inlet	4. Cape Elizabeth to Cape Douglas
	5. Kodiak Island and Protected Coast	5. Kodiak Island, coast from Cape Douglas to Cape Providence, and Chirikof Island
	6. Wave-Beaten Southwest Alaska Coast	6. Cape Providence to Unimak Pass

continued

Table 1. (concluded)

Level I	Level II	Lateral boundaries
L. Aleutian Islands		L. Aleutian Islands
	1. Aleutian Islands	1. Aleutian Islands
M. Bering Alaska		M. Unimak Island at Unimak Pass to Cape Prince of Wales, including Pribilof Islands, Nunivak Island, St. Matthew Island, and St. Lawrence Island
	1. South Bristol Bay	1. Unimak Island at Unimak Pass to Cape Greig
	2. North Bristol Bay	2. Cape Greig to Jacksmith Bay
	3. Yukon, Kuskokwim Delta	3. Jacksmith Bay to Point Romanof, including Nunivak Island
	4. Norton Sound Coast	4. Point Romanof to Cape Prince of Wales
	5. Bering Sea Islands	5. Pribilof Islands, St. Lawrence Island, St. Matthew Island, and Diomedes Islands
N. Arctic Alaska		N. Cape Prince of Wales to Alaska-Canada border east of Demarcation Point
	1. Chukchi Coast	1. Cape Prince of Wales to Barrow
	2. Beaufort Coast	2. Barrow to Alaska-Canada border east of Demarcation Point
O. Great Lakes		O. Great Lakes
	1. Lake Superior	1. Lake Superior and the St. Marys River
	2. Lake Michigan	2. Lake Michigan and the Mackinac Straits
	3. Lake Huron	3. Lake Huron and the St. Clair River
	4. Lake Erie	4. Lake Erie and the Niagara River
	5. Lake Ontario	5. Lake Ontario and the St. Lawrence River

[a]Both claimed by the United States and Colombia.

[b]Claimed by the United States and the United Kingdom.

[c]Claimed by the United States and New Zealand.

Table 2. Proposed actual boundaries of Level I and II divisions which abut U.S. political boundaries.

Level I	Level II	Lateral boundaries
A. North Atlantic		A. Cape Cod to St. Johns, Newfoundland, including Nova Scotia and the Bay of Fundy
	1. Gulf of Maine	1. Cape Elizabeth to Lancaster, New Brunswick, and the east coast of Nova Scotia, but not including the Bay of Fundy
F. Gulf of Mexico		F. Cape Romano to the cape off Matamoras, Mexico
	7. Texas Barrier Island System	7. Galveston Bay to the cape off Matamoras, Mexico
G. Southwest Pacific		G. Cape Mendocino to Cabo San Lucas
	1. Southern California	1. Point Conception to the coast of El Rosario
H. Northwest Pacific		H. Cape Mendocino to and including Vancouver Island
	3. Puget Sound	3. Puget Sound and the Straits of Juan de Fuca and Georgia (already included in definition)
K. Pacific Alaska		K. From, but not including, Vancouver Island to Unimak Island at Unimak Pass, including Cook Inlet
	1. Alexander Archipelago	1. Queen Charlotte Island and the Alexander Archipelago to Cape Spencer
N. Arctic Alaska		N. Cape Prince of Wales to Cape Bathurst
	2. Beaufort Coast	2. Barrow to Demarcation Point

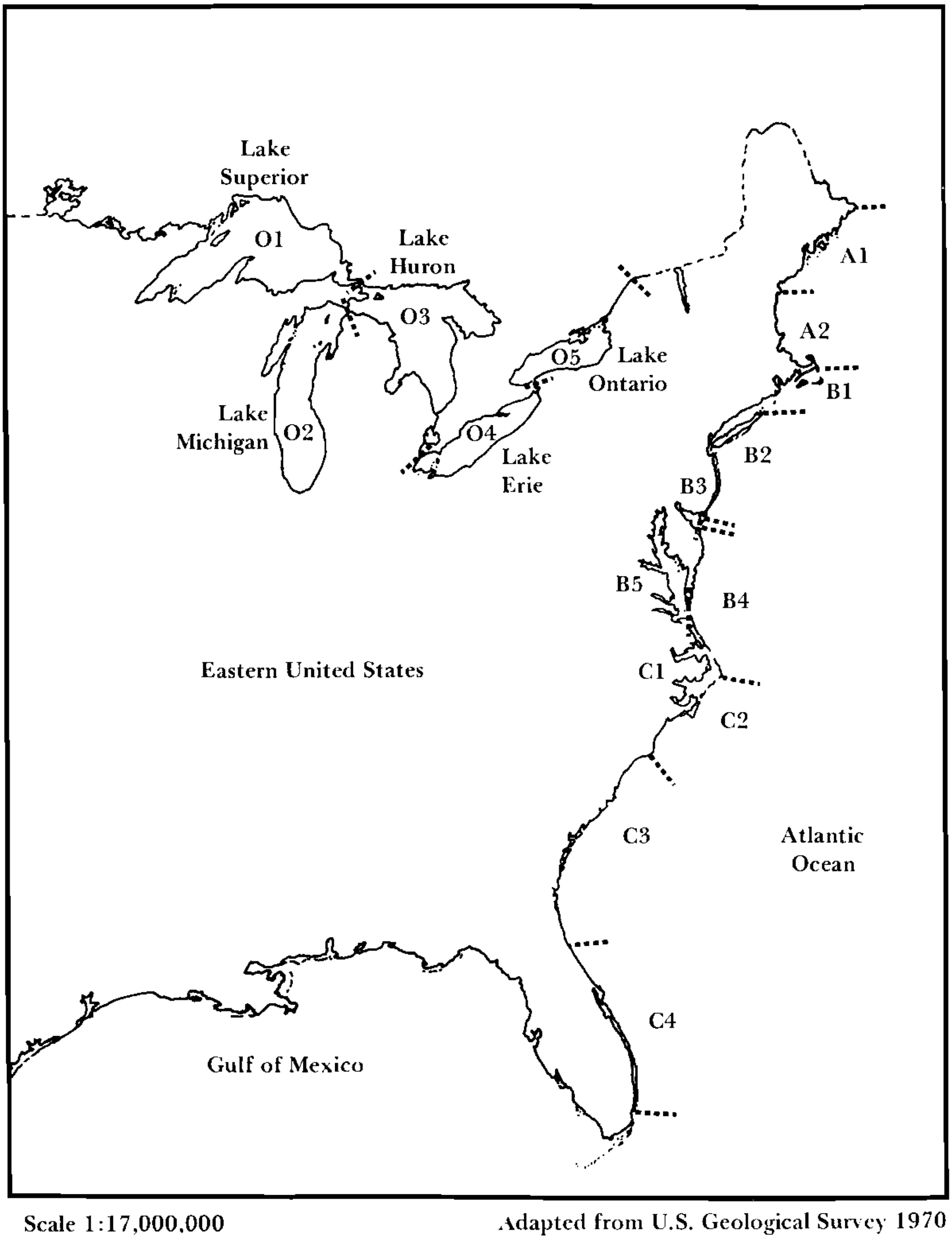
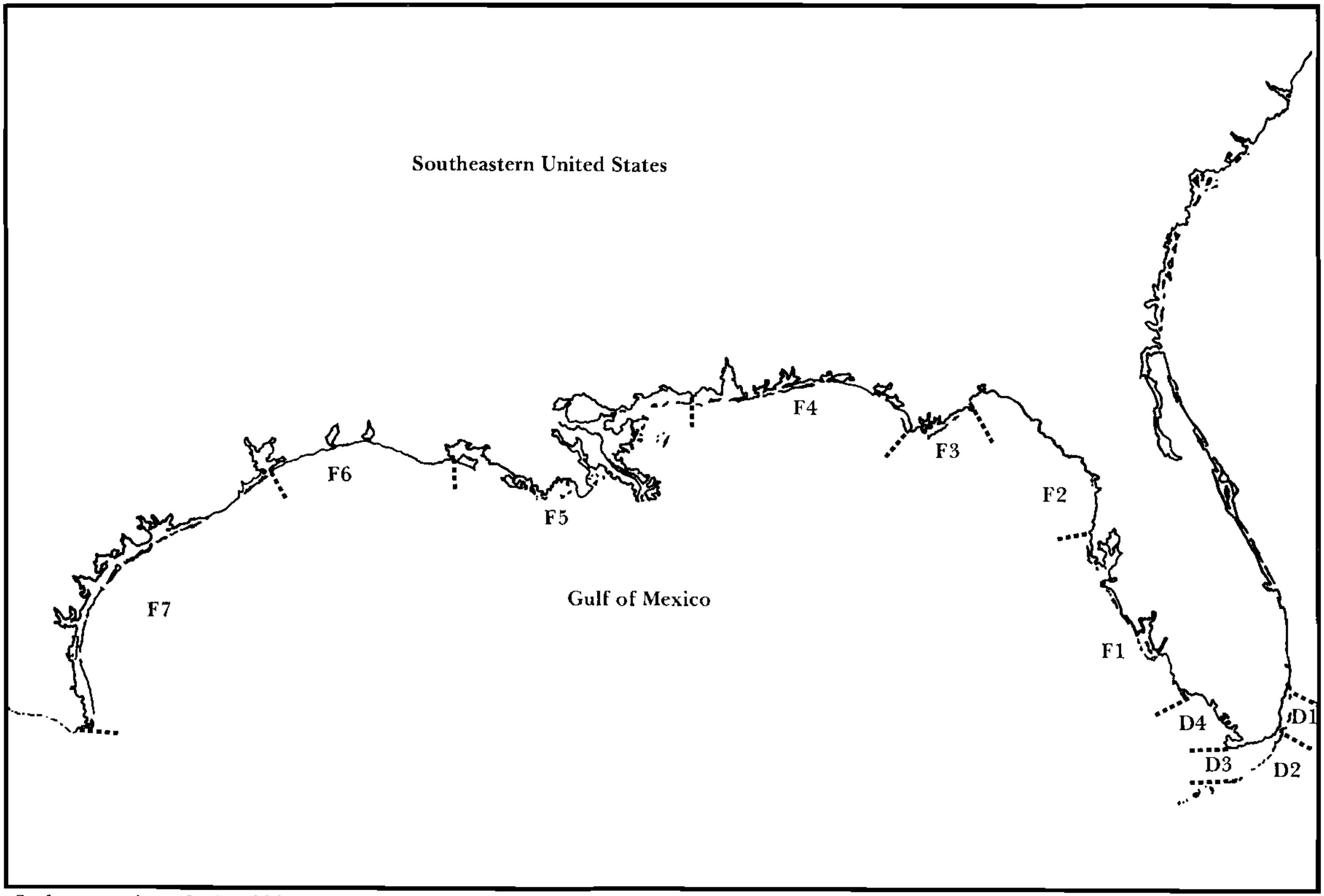


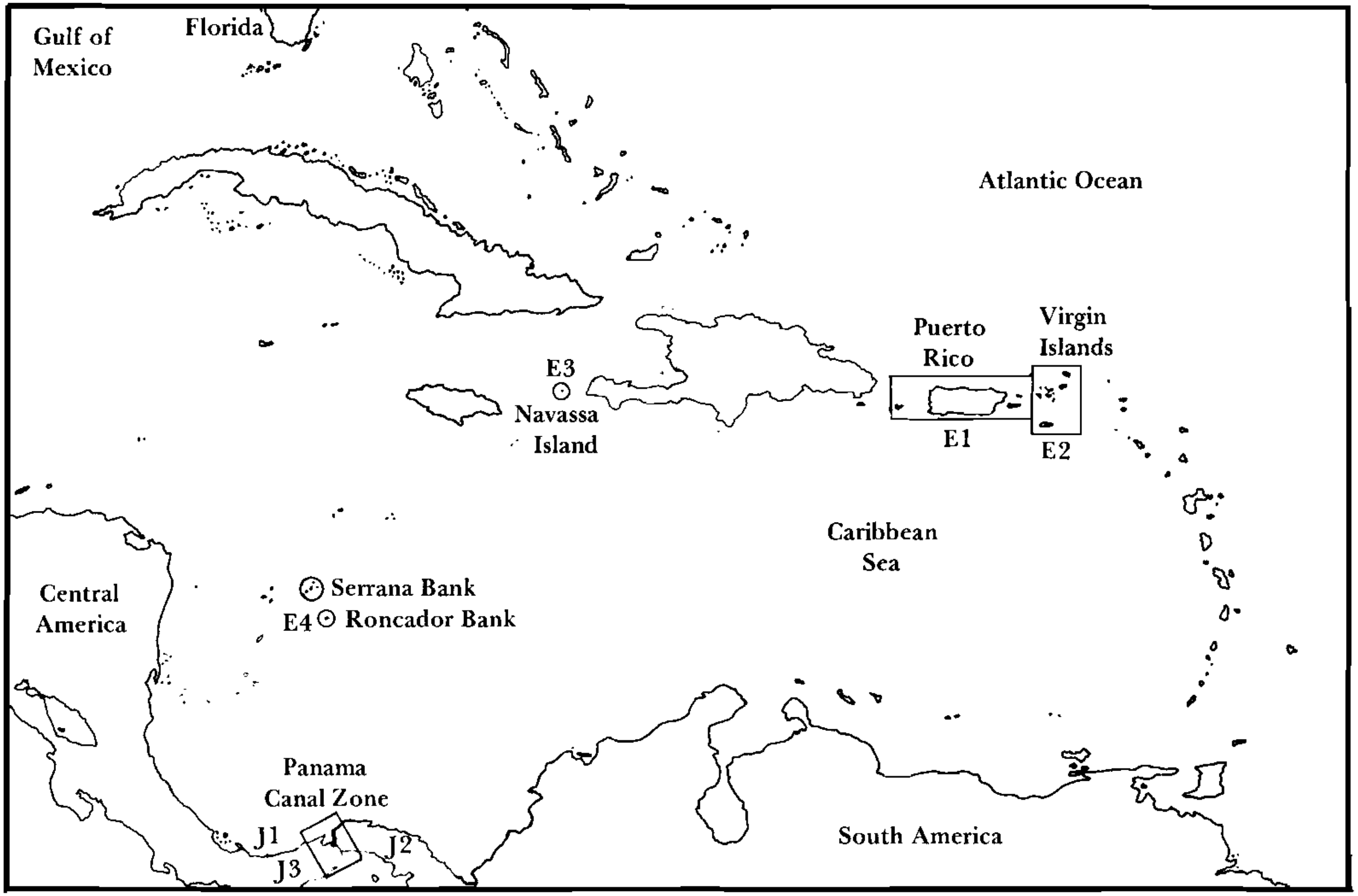
Figure 1. Great Lakes and Atlantic coast of United States showing coastal regionalization Level I and II divisions.



Scale approximately 1:9,200,000

Adapted from U.S. Fish and Wildlife Service 1970

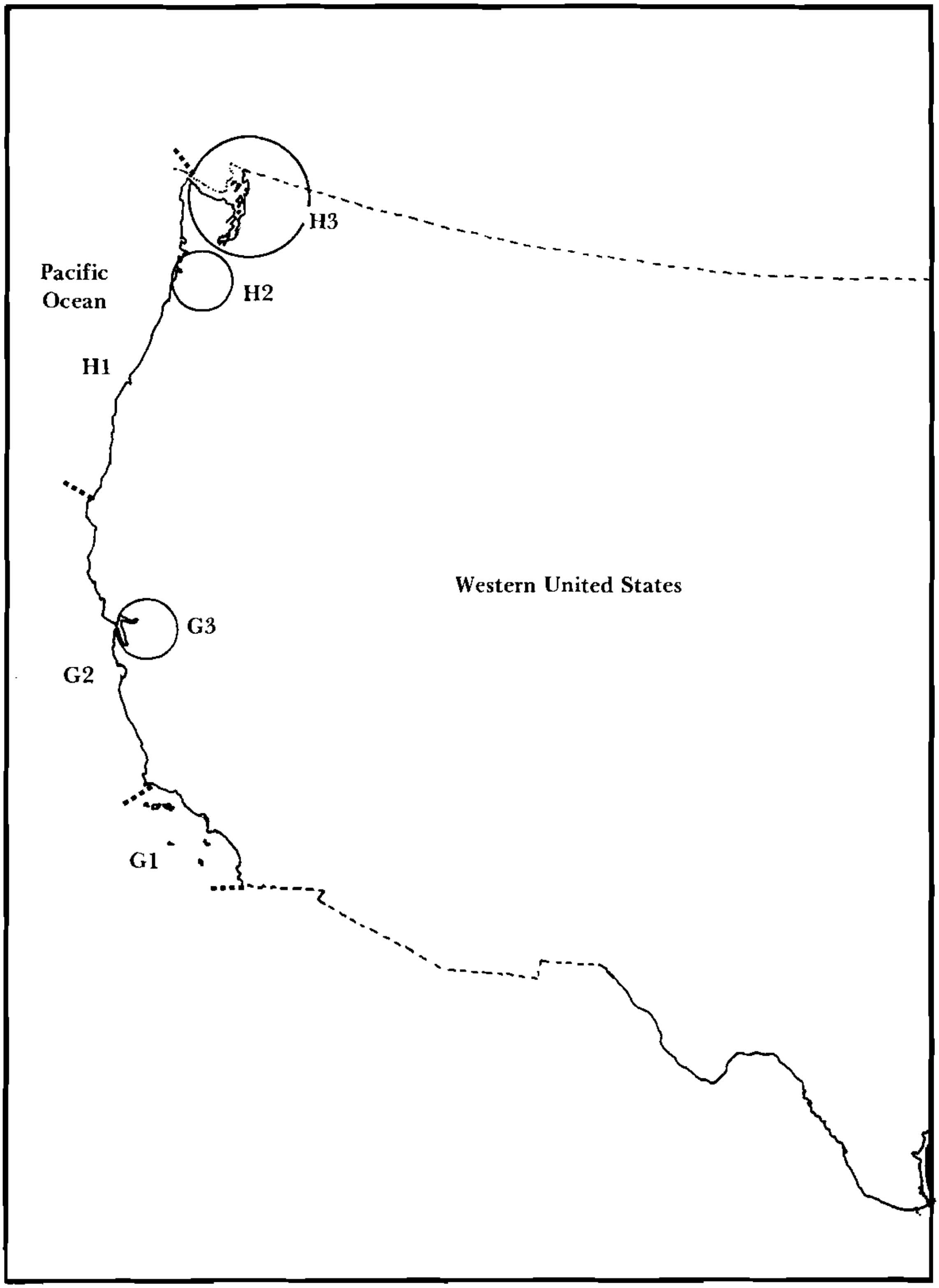
Figure 2. Gulf coast of United States showing coastal regionalization Level I and II divisions.



Scale approximately 1:15,000,000

Adapted from U.S. Geological Survey 1970

Figure 3. Atlantic outlying areas showing coastal regionalization Level I and II divisions.



Scale 1:17,000,000 Adapted from U.S. Geological Survey 1970

Figure 4. Pacific coast of the United States showing coastal regionalization Level I and II divisions.

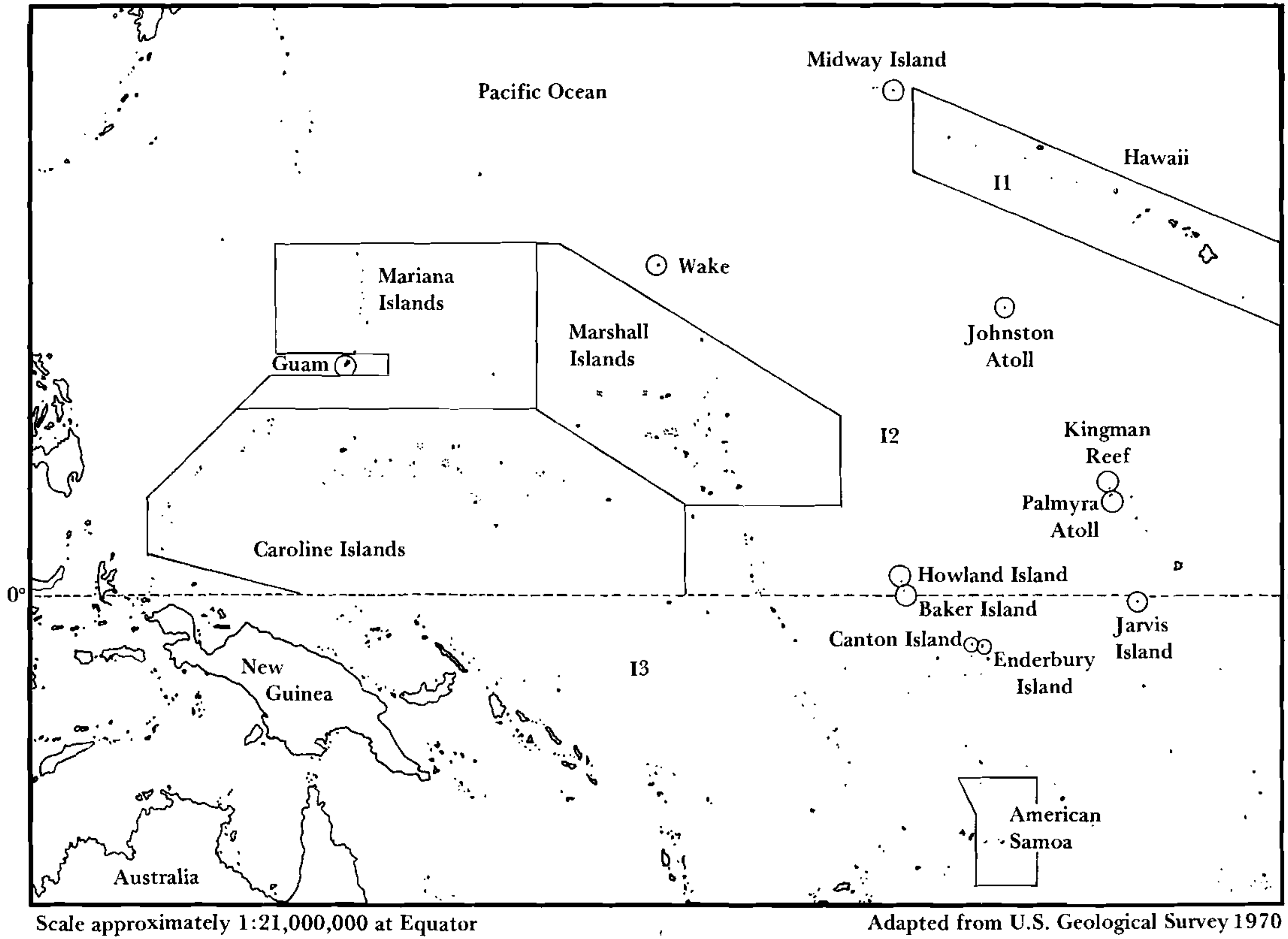
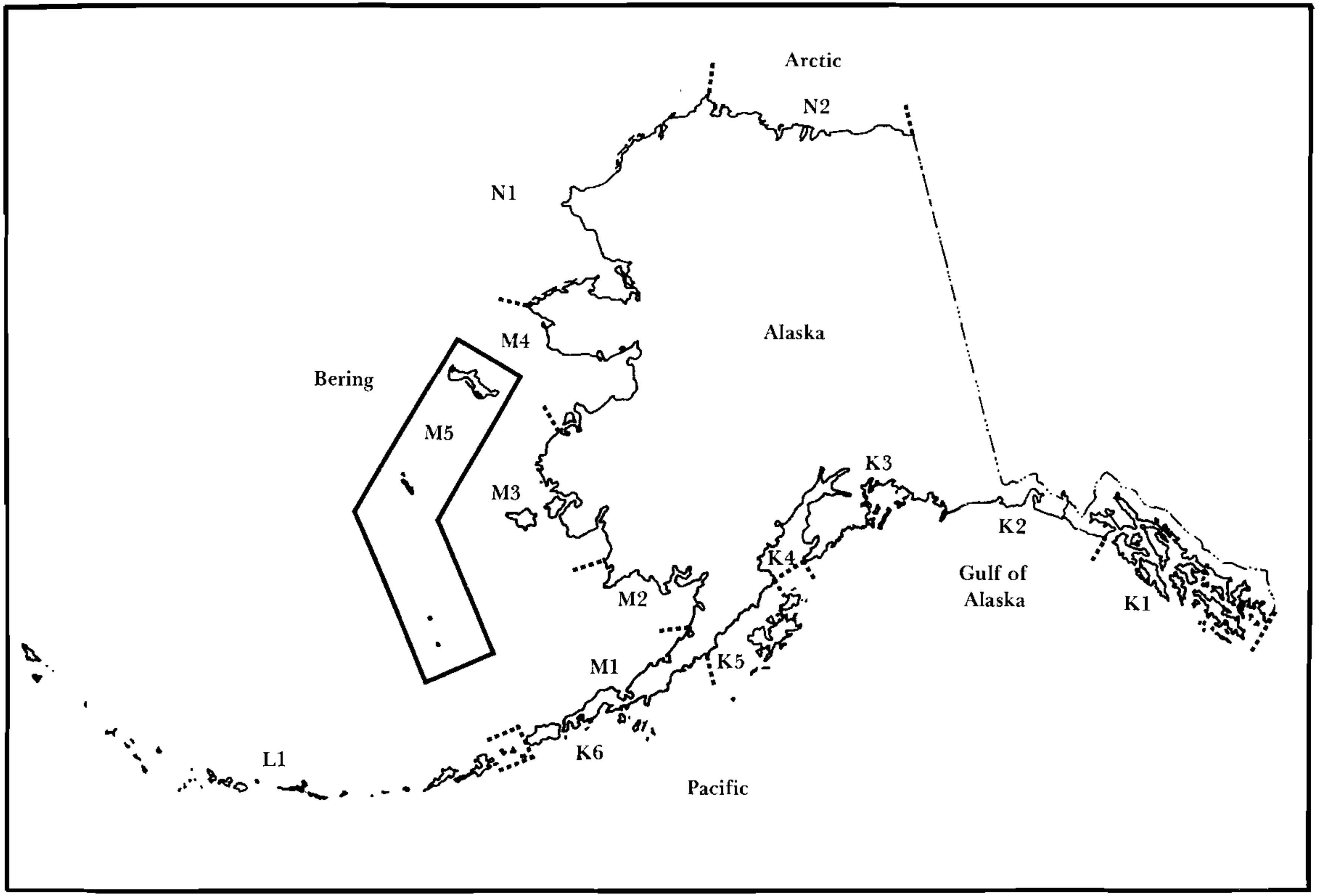


Figure 5. Pacific outlying areas showing coastal regionalization Level I and II divisions.



Scale approximately 1:15,000,000

Adapted from U.S. Fish and Wildlife Service 1970

Figure 6. Alaska coast showing coastal regionalization Level I and II divisions.

APPENDIX

The following persons provided comments on the first draft of the regionalization presented in this paper:

Name	Affiliation	Commented on
R. Andrews	U.S. Fish & Wildlife Service Regional Activity Leader Coastal Ecosystems Region 5 Newton Corner, MA	Atlantic, Great Lakes, Alaska
L. Barclay	U.S. Fish & Wildlife Service Asst. Regional Activity Leader Outer Continental Shelf Region 4 Charleston, SC	Atlantic coast
J. Barkuloo	U.S. Fish & Wildlife Service Asst. Regional Activity Leader Coastal Ecosystems Region 4, Panama City, FL	Florida, Gulf coast
B. Brun	U.S. Fish & Wildlife Service Asst. Regional Activity Leader Coastal Ecosystems Region 5 Newton Corner, MA	Atlantic coast
J. Byrne	U.S. Fish & Wildlife Service Asst. Regional Activity Leader Coastal Ecosystems Region 1 Portland, OR	Pacific insular, Pacific northwest, California
J. Carrol	U.S. Fish & Wildlife Service Supervisory Fish & Wildlife Biologist Vero Beach Field Office, FL	Florida
V. Carter	U.S. Geological Survey Wetlands Ecologist Reston, VA	Classification in general, Atlantic coast
R. Chabreck	Louisiana State University Professor Baton Rouge, LA	Regionalization in general, Gulf coast
H. Coulombe	U.S. Fish & Wildlife Service Leader, National Habitat Assessment Group Fort Collins, CO	Panama Canal Zone

Name	Affiliation	Commented on
D. Dobel	U.S. Fish & Wildlife Service Supervisory Fish & Wildlife Biologist Galveston Field Office, TX	Texas coast
R. Folker	U.S. Fish & Wildlife Service Fish and Wildlife Biologist Laguna Niguel Field Office, CA	California coast
L. Goldman	U.S. Fish & Wildlife Service Wildlife Biologist Ecological Services Washington Office, D.C.	Regionalization in general
R. Hays	U.S. Fish & Wildlife Service Plant Ecologist National Habitat Assessment Group Fort Collins, CO	Classification in general
H. Hyatt	U.S. Fish & Wildlife Service Regional Activity Leader Coastal Ecosystems Region 3 Twin Cities, MN	Great Lakes, Alaska, Pacific coast
J. Johnston	U.S. Fish & Wildlife Service Wetlands Ecologist National Coastal Ecosystems Team NSTL Station, MS	Regionalization in general, Gulf coast
J. Kirkwood	U.S. Fish & Wildlife Service Regional Activity Leader Coastal Ecosystems Region 4 Atlanta, GA	Classification in general
G. Kline	U.S. Fish & Wildlife Service Fish & Wildlife Biologist Olympia Field Office, WA	Pacific coast
C. Laffin	U.S. Fish & Wildlife Service Asst. Regional Activity Leader Outer Continental Shelf Region 5 Newton Corner, MA	Atlantic coast, Florida, Atlantic insular
E. LaRoe	State of Oregon Coastal Specialist	Regionalization in general, Florida, Texas, Alaska

Name	Affiliation	Commented on
	Department of Land Conservation and Development Salem, OR	
C. Lensink	U.S. Fish & Wildlife Service Regional Activity Leader Coastal Ecosystems Anchorage Area Office, AK	Alaska coast
P. Lent	U.S. Fish & Wildlife Service National Petroleum Reserve Alaska Coordinator Anchorage Area Office, AK	Alaska coast
F. Smith	U.S. Fish & Wildlife Service Supervisory Fish & Wildlife Biologist Sacramento Field Office, CA	California coast
R. Swanson	U.S. Fish & Wildlife Service Fish & Wildlife Biologist Mayaguez Field Office, PR	Atlantic insular
T. Talley	U.S. Fish & Wildlife Service Supervisory Fish & Wildlife Biologist Panama City Field Office, FL	Florida coast
R. Wade	U.S. Fish & Wildlife Service Regional Activity Leader Coastal Ecosystems Region 2 Albuquerque, NM	Gulf coast
J. Watson	U. S. Fish & Wildlife Service Regional Activity Leader Coastal Ecosystems Region 1 Portland, OR	Pacific coast
B. Wilen	U.S. Fish & Wildlife Service Asst. Project Leader National Wetland Inventory St. Petersburg, FL	Regionalization and classification in general

U.S. GOVERNMENT PRINTING OFFICE : 1979 O—289-605