A Classification System and Map of the Biotic Communities of North America

David E. Brown, Frank Reichenbacher, and Susan E. Franson[1]

Abstract.—Biotic communities (biomes) are regional plant and animal associations within recognizable zoogeographic and floristic provinces. Using the previous works and modified terminology of biologists, ecologists, and biogeographers, we have developed an hierarchical classification system for the world's biotic communities. In use by the Arid Ecosystems Resource Group of the Environmental Protection Agency's Environmental Monitoring and Assessment Program, the Arizona Game and Fish Department, and other Southwest agencies, this classification system is formulated on the limiting effects of moisture and temperature minima on the structure and composition of vegetation while recognizing specific plant and animal adaptations to regional environments. To illustrate the applicability of the classification system, the Environmental Protection Agency has funded the preparation of a 1:10,000,000 color map depicting the major upland biotic communities of North America using an ecological color scheme that shows gradients in available plant moisture, heat, and cold. Digitized and computer compatible, this hierarchical system facilitates biotic inventory and assessment, the delineation and stratification of habitats, and the identification of natural areas in need of acquisition. Moreover, the various categories of the classification are statistically testable through the use of existing climatic data, and analysis of plant and animal distributions. Both the classification system and map are therefore of potential use to those interested in preserving biotic diversity.

Numerous classifications have been created in an attempt to assess and depict our natural resources. In North America, these efforts have resulted in classification systems and maps of potential natural vegetation (e.g., Shantz and Zon 1924; Küchler 1964, 1967; Flores et al. 1971), forest types (Society of American Foresters 1954, Rowe 1972), wetlands (Ray 1975, Zoltai et al. 1975, Cowardin et al. 1979, Hayden et al. 1984), land use (Anderson et al. 1972, 1976), land cover (Loveland et al. 1991), and vegetation change (Eidenshink 1992). These efforts, including "ecological" maps of states, provinces, regions, and even sub continents, have proven useful to those interested in land use planning and the sampling and stratification of large scale ecological units (see e.g., Holdridge 1959, 1969; Bailey 1976; Garrison et al. 1977; Bailey and Cushwa 1981; Wiken 1986; Wiken et al 1986; Omernik 1987; Wickware and Rubec 1989). Although based primarily on various types of vegetation, these classifications also often incorporate physiographic, climatic, soil, and chemical criteria. Moreover, some of these classifications are hierarchical, thus facilitating land use mapping at various scales. Several recent maps also have the advantage of being derived from high altitude imagery so that they are able to show vegetative and other changes over time. Indeed, the only criticism of these maps and classifications is that their usefulness depends on the designing agency's mission, objectives, and budget. That, and the fact that none of the recent systems is world wide in scope or universal in its application.

Biologists, unfortunately, have also yet to agree on a universal classification system to inventory plant and animal communities. Systems

[1]*Department of Zoology, Arizona State University, Tempe; Southwestern Field Biologists, Tucson, AZ; Environmental Monitoring and Assessment Program (EMAP), Environmental Protection Agency, Las Vegas, NV.*

and maps currently in use at national scales are either based entirely on potential or dominant vegetation without regard to plant and animal associates, or depend upon one or more land use systems employing anthropogenic and other "non evolutionary" criteria. Furthermore, several recent classifications are non hierarchical or only partially hierarchical. As such, these systems and maps are frequently one dimensional and are not readily subject to user modification when higher or lower levels of assessment are desired. These limitations have caused resource management agencies to combine, create, and adapt a variety of classification systems in their attempts to inventory biotic resources. The result has been a proliferation of large and small scale maps depicting either only limited areas (e.g., Brown and Lowe 1982), or employing classifications that are too broad for detailed biological inquiry (e.g., Bailey and Cushwa 1981). Nonetheless, these efforts, coupled with the accelerated inventory of the world's biota and the development of high quality aerial imagery, now make a biologically universal classification system possible from both a theoretical and practical perspective.

That a national need for a standardized taxonomic system for biotic communities exists is obvious from the requirements of the National Environmental Policy Act of 1969, the National Resource Planning Act of 1974, the Environmental Monitoring and Assessment Program, and numerous other governmental policies and programs. Nor should such a system be confined to the United States and its territories. The present and increasing emphasis on endangered species residing within and outside the U. S. as prescribed in the Endangered Species Act of 1973, the North American Waterfowl Plan and the Neotropical Migratory Bird Inventory now being undertaken by the U. S. Fish and Wildlife Service, and the Biosphere Reserve Program being fostered by the International Union for the Conservation of Nature, dictate a world wide approach to biotic assessment. Clearly, the time has come for a universal classification system for biotic resources.

THE CLASSIFICATION SYSTEM

On two main points every system yet proposed, or that probably can be proposed, is open to objection; they are, — 1stly, that the several regions are not of equal rank; 2ndly, that they are not equally applicable to all classes..." Alfred Russell Wallace, 1878

Modifying the existing works and terminology of other biologists, ecologists, and biogeographers, Brown, Lowe, and Pase(1979, 1980) developed an hierarchical classification system for the biotic communities of North America. This classification system was formulated on natural criteria and recognizes the limiting effects of moisture and temperature minima as well as evolutionary origin on the structure and composition plant and animal communities. The system was originally developed for southwestern North America where its adaptability was demonstrated for both natural and human altered communities (Brown and Lowe 1974a, 1974b, 1980, 1982; Brown 1980. Because the classification system is both parallel and hierarchical (fig. 1), it is adaptable for use at various levels of detail. Mapping can therefore be at any scale or unit of resolution. Moreover, the hierarchical sequence allows for the incorporation of existing vegetation classification taxa in use by federal, state, and private agencies into an appropriate biotic community level within the classification system. The Brown, Lowe, and Pase classification system, however, is not an "ecosystem" classification. Except for their influences on regional climate, evolution, and biota, abiotic factors such as soil, chemistry, and geology are not used as determining criteria. It is intended to be an entirely biological system.

The numerical coding of the hierarchy also makes the classification system computer compatible, thereby readily allowing for the storage and retrieval of information. The Brown, Lowe, Pase system for the North American Southwest is currently in use in the RUN WILD program developed for use on remote terminals by the USDA Forest Service's Southwestern Region and Rocky Mountain Forest and Range Experiment Station (Patton 1978). This classification is similarly incorporated within the files of the Arizona and New Mexico game and fish departments, and is used by industry in environmental analysis procedures as required by the National Environmental Policy Act (e.g., Reichenbacher 1990). Recently this classification has been adopted by the Arid Ecosystems Resource Group of the U. S. Environmental Protection Agency for their environmental monitoring and assessment program (EMAP).

As such, this classification system facilitates biotic inventory and assessment, the delineation and stratification of habitats, resource planning, the interpretation of biological values, and other activities pertaining to natural history inquiry. It has proven especially useful for environmental

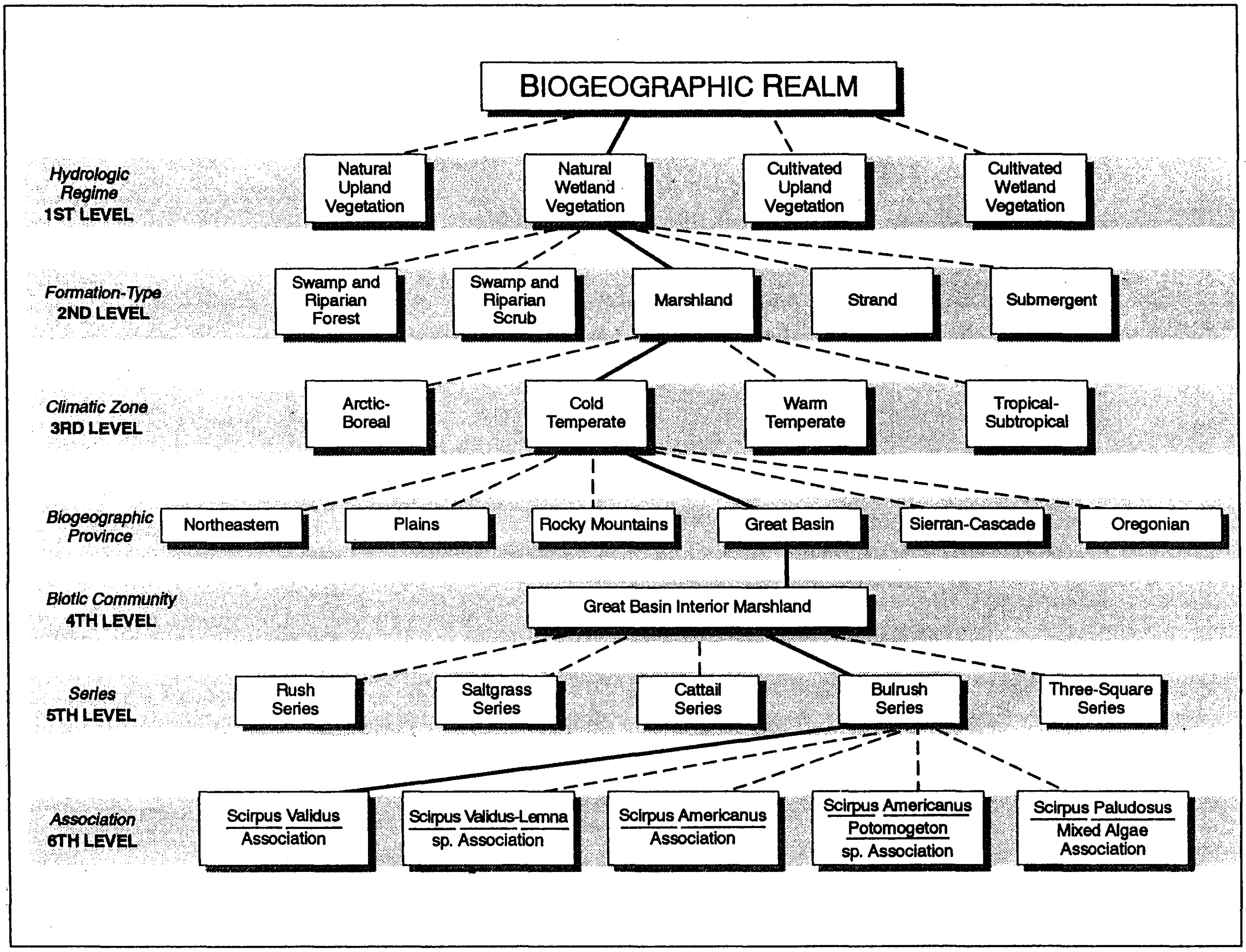

Figure 1.—Hierarchy of a bulrush marsh in Great Salt Lake, Utah, to the association (sixth) level of the classification system.

analysis where the comparison of biological units is desired by governmental, scientific, educational, and other institutions. In short, the classification system is of particular use for those interested in inventorying biotic diversity for resource management, vegetation change, biological study, natural area preservation and habitat acquisition. Moreover, because the system is hierarchical and universal, earlier inventory efforts can usually be accommodated into the system at some level.

The most important value of a natural hierarchical classification system based on biotic criteria is the meaningful assignment of plant and animal habitats. Although most of the classification's categories are determined primarily on the basis of observable vegetation, the inclusion of biotic provinces and biotic communities automatically incorporates the less visible animal components within the hierarchy. The system therefore allows for a meaningful delineation and inventory of specific plant and animal habitats. For example, because biotic provinces are included in the system, a resource manager can determine which marshlands are likely to include nesting black ducks *(Anas rubripes)* as opposed to similar appearing wetlands within other biotic provinces inhabited by Florida ducks (*A. fulvigula fulvigula*), mottled ducks (*A. f. maculosa)*, and Mexican ducks (*A. platyrhynchos diazi*). Such separations of plant and animal habitats are important in fulfilling the requirements of the Endangered Species Act, for evaluating the North American Waterfowl Plan, for monitoring warblers and other migratory birds of recent concern, and for following numerous other governmental directives. The inclusion of biogeographic criteria is also of primary importance in the world biosphere reserve program (see e.g. Franklin 1977; McNeely and Miller 1983; Udvardy 1984a, 1984b; IUCN 1974, 1992).

Presented below is a computer compatible hierarchy of the world's biological systems with representative examples of the classification to the series (5^{th}) level for North America. Neither the biotic community (4^{th}) level, nor the series level examples of the classification are complete or final. Similarly, representative examples of the association (6^{th}) level of the system are given only for the Rocky Mountain Montane Conifer Forest biotic community. Unlike previous presentations of the classification system (Brown and Lowe 1974a, 1974b, Brown, Lowe and Pase, 1979, 1980, Brown 1980), in which North America's biotic communities were all contained within the Nearctic biogeographical realm, the classification presented here properly separates the continent into Nearctic and Neotropical realms (fig. 2).

The hierarchy presented below is neither rigorously scientific nor rigidly systematic. Our only intention is to present an hierarchical synthesis of existing biogeographical concepts to aid in the development of a world wide classification system for the world's biota. Neither is it proposed that this system replace existing classifications, or be officially adopted at a national or any other level where workable classification systems have been developed. We also recognize that portions of the classification system are dated or incomplete and require additional work. For example, easily retrievable climatic data from a great variety of stations are now available, and we are currently refining the temperature parameters of the climatic zones to make them more precise and meaningful. Nonetheless, the integrity of the most important levels of the classification are already testable through scientific methodologies. For example, we are now evaluating the reality of the various biotic communities through a statistical analysis of seasonal climatological data. This analysis, and the recent acceleration in floristic and faunistic inventories will help determine the endemic reality of these and possibly other biotic communities.

Table 1.—Summary of world natural vegetation to the first level.

	Biogeographic Realm Natural	1. Upland Natural Vegetation	2. Wetland Vegetation
1,000	Nearctic	1,100	1,200
2,000	Palaearctic	2,100	2,200
3,000	Neotropical Antartican	3,100	3,200
4,000	Indomalayan (Oriental)	4,100	4,200
5,000	African (Ethiopian)	5,100	5,200
6,000	Australian	6,100	6,200
7,000	Oceanic	7,100	7,200

Where:

1,000 = Biogeographic Realm
1,100 = Hydrologic Regime (Upland, Wetland, Cultivated, or Urban)
1,110 = Formation type
1,111 = Climatic Zone
1,111.1 = Biotic Community (= Regional Formation)
1,111.11 = Series (Biociation of Generic Dominants)
1,111.111 = Association (Plant community of specific taxa)
1,111.1111 = Plant and Animal Composition, Age Class, Density,

In previous publications (Brown 1980, 1982; Brown and Lowe 1980; Brown et al. 1979, 1980), we have shown the usefulness of the Series and Association levels of the classification. For the purposes of this publication, discussion will focus on the Biome and above. Here, we present only those North American biomes mapped on the 1:10,000,000 map soon to be released by the Environmental Protection Agency (Reichenbacher and Brown 1994).

The number preceding the comma (e.g., 1,000) differentiates the hierarchy on the basis of the world's biogeographic realms (Table 1). Origin and evolutionary history are thus recognized as being of primary importance in the determination and classification of biotic entities. The mappable reality of the world's biogeographical realms is, as in all natural evolutionary taxonomy, interpretive and dependent on the criteria used. The following seven realms are adapted from Sclater (1858), Wallace (1876), Allen 1878, Sharpe 1893, Hesse et al. (1937), Darlington (1957), Dansereau (1957), Walter (1973), the International Union for Conservation of Nature and Natural Resources (1974), DeLaubenfels (1975), Cox et al. (1976), Udvardy (1975, 1984a).

- 1,000 Nearctic—Continental North America exclusive of the tropics including most of the highland areas of Mexico and parts of Central America (fig. 2).
- 2,000 Palaearctic—Eurasia exclusive of the tropics; Africa north of the Sahel.
- 3,000 Neotropical and Antarctican—South America, most of Central America, and Mexico south of the Tropic of Cancer; Antarctica.

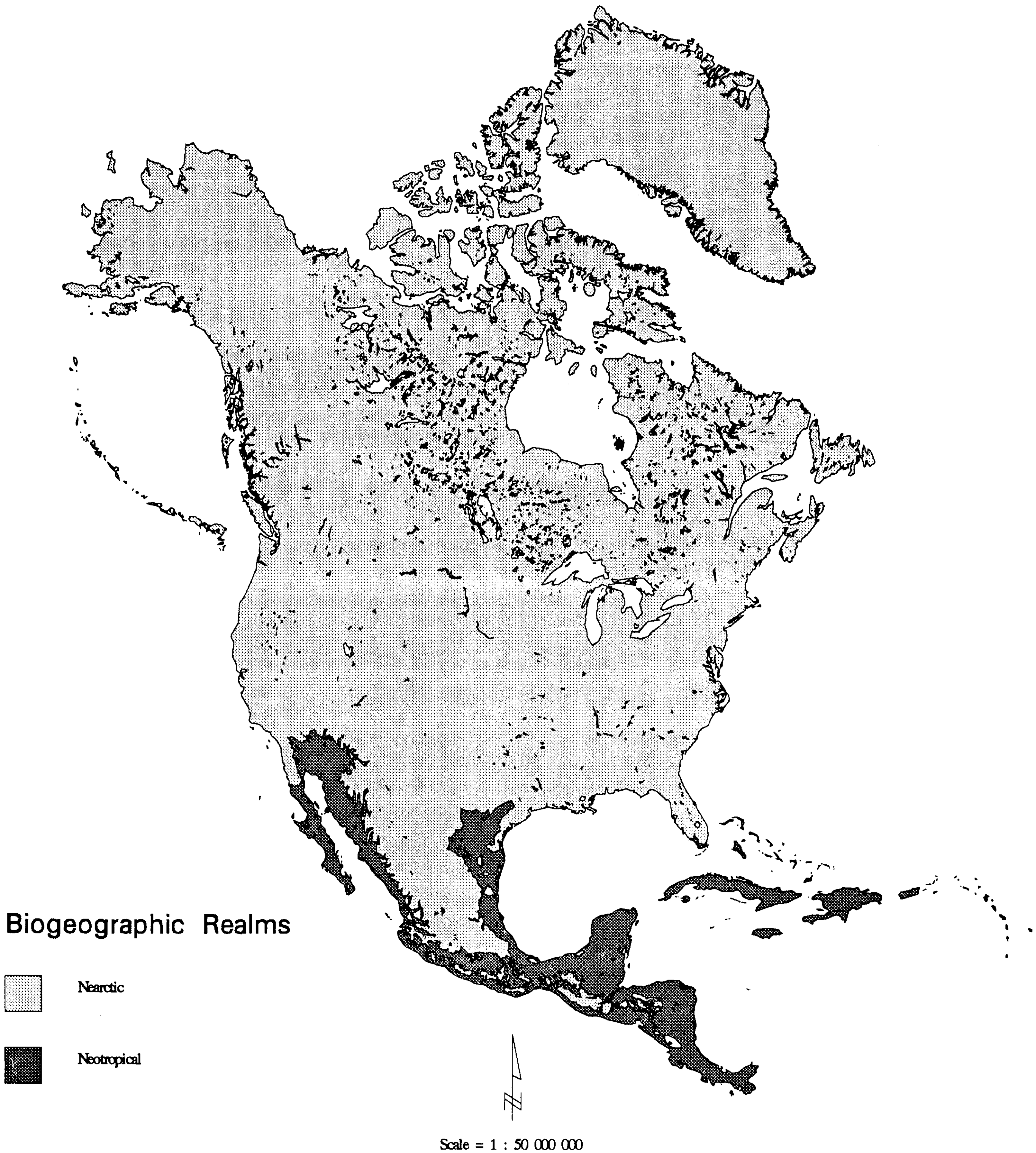

Figure 2.–Biogeographic realms of North America.

- 4,000 Indomalayan (Oriental)—Southeast Asia, the Indian subcontinent, Indonesia, the Phillipines, etc.
- 5,000 African (Ethiopian)—Africa south of the Sahara, Malagasy, and parts of the Arabian peninsula.

- 6,000 Australian—Australia and Tasmania.
- 7,000 Oceanian—Oceanic islands displaying a high degree of endemism.

First Level

The first digit *after* the comma (e.g., 1,1̲00) refers to one of *four hydrologic* regimes including all upland (1,100) and wetland (1,200) communities existing under natural conditions. The important adaptations of plants and animals to terrestrial ecosystems, as opposed to aquatic systems, is thus recognized early in the classification system. The classification of submerged freshwater (e.g. 1,300) and marine (e.g. 1,400) environments is as yet in a tentative stage (see e.g. Ray 1975 and Maxwell et al. (1994). Although accommodated in the system, the classification of these aquatic communities is outside the scope of the present work and will not be elaborated on further. Because almost all "natural communities" are now more or less influenced by human activity, we include all terrestrial and wetland vegetation communities composed of native, naturalized, or adventive plants as belonging to either the natural upland regime or a natural wetland regime (Table 1).

In this classification system, wetlands include all periodically, seasonally, or continually submerged lands populated by species and/or life forms different from the immediately adjacent upland vegetation (see also e.g., Martin et al. 1953, Lowe 1964, and Cowardin et al. 1979). Hence, riparian communities containing both upland and wetland components are included here in the natural wetland regime (1,200, Table 1). Only a few wetland biomes are included because most would not appear on the 1:10,000,000 map (Reichenbacher and Brown 1994) we produced to illustrate the application of the classification. Coastal wetlands, in partiucular, are difficult to map at this scale and are grouped into a 1,200. Undifferentiated Nearctic Wetland and a 3,200. Undifferentiated Neotropical Wetland category.

Second Level

The second digit *after* the comma, e.g.(1,11̲0) refers to one of the following recognized plant formations, or as they are called on a worldwide basis, *formation types* (Table 2). Formation types are vegetative responses to integrated environmental factors, most importantly, available soil and plant moisture.

Upland Formations

- Tundra—Communities existing in an environment so cold that moisture is unavailable during most of the year, precluding the establishment of trees, and in which the maximum development is perennial herbaceous plants, shrubs, lichens, and mosses, with

Table 2.–Summary for the natural upland and wetland vegetation of the world to the second level.

	Biogeographic Realm	Formation-type 1. Tundra	2. Forest and Woodland	3. Scrubland	4. Grassland	5. Desert-land	6. Non-Vegetated
UPLAND							
1,100	Nearctic	1,110	1,120	1,130	1,140	1,150	1,160
2,100	Palearctic	2,110	2,120	2,130	2,140	2,150	2,160
3,100	Neotropical-Antarctican	3,110	3,120	3,130	3,140	3,150	3,160
4,100	Indomalayan (Oriental)	4,110	4,120	4,130	4,140	4,150	4,160
5,100	African (Ethiopian)	5,110	5,120	5,130	5,140	5,150	5,160
6,100	Australian	6,110	6,120	6,130	6,140	6,150	6,160
7,100	Oceanic	7,110	7,120	7,130	7,140	7,150	7,160
		1. Wet Tundra	2. Forest*	3. Swamp-Scrub	4. Marshland	5. Strand	6. Non-Vegetated
WETLAND							
1,200	Nearctic	1,210	1,220	1,230	1,240	1,250	1,260
2,220	Palearctic	2,210	2,220	2,230	2,240	2,250	2,260
3,200	Neotropical-Antarctican	3,210	3,220	3,230	3,240	3,250	3,260
4,200	Indomalayan (Oriental)	4,210	4,220	4,230	4,240	4,250	4,260
5,200	African (Ethiopian)	5,210	5,220	5,230	5,240	5,250	5,260
6,200	Australian	6,210	6,220	6,230	6,240	6,250	6,260
7,200	Oceanic	7,210	7,220	7,230	7,240	7,250	7,260

*Swamp-forests, bog forests, and riparian forests.

grasses poorly represented or at least not dominant.

- Forests and Woodlands—Communities dominated principally by trees potentially over 10 meters in height, and characterized by closed and/or multi layered canopies (forests); or, communities comprised principally of trees with a mean potential height usually under 10 meters, the canopy of which is usually open, interrupted, and singularly layered (woodlands).
- Scrubland—Communities dominated by sclerophyll or microphyll shrubs and/or multistemmed trees generally not exceeding 10 meters in height, usually presenting a closed physiognomy, or if open, interspaced with other perennial vegetation.
- Grassland—Communities dominated actually, or potentially by grasses and/or other herbaceous plants.
- Desertland—Communities in an arid environment (usually less than 300 millimeters precipitation per annum) in which plants are separated by significant areas devoid of perennial vegetation.

Wetland Formations

- Wet Tundra—Wetland communities existing in an environment so cold that plant moisture is unavailable during most of the year, precluding the establishment of trees and all but a low herbaceous plant structure in a hydric matrix.
- Swamp and Riparian Forests—Wetland communities possessing an overstory of trees potentially more than 10 meters in height and frequently characterized by closed and/or multi layered canopies.
- Swamp and Riparian Scrub—Wetland communities dominated by short trees and/or woody shrubs, generally under 10 meters in height and usually presenting a closed physiognomy.
- Marshland—Wetland communities in which the principal plants are herbaceous emergents having their basal portions annually, periodically, or continually submerged.
- Strand—Beach and river channel communities subject to regular to infrequent submersion, wind driven waves or spray. Plants are separated by significant areas devoid of perennial vegetation.

Some upland and wetland communities, e.g. dunes, lava flows, salt lakes, etc., are essentially without vegetation and are populated only by one cell organisms. For purposes of classification, these areas can be considered as belonging to a non vegetated or a "non vascular formation" if a desertland or strand formation type is considered inappropriate (Table 2).

Third Level

The third digit beyond the comma (e.g., 1,11<u>1</u>) refers to one of the four world *climatic zones* (see e.g. Walter 1973, Ray 1975, Cox et al. 1976) in which minimum temperatures are recognized as a major evolutionary control of and within formation types (Table 3, fig. 3):

- Arctic Boreal (Antarctic–Austral)—Lengthy periods of freezing temperatures with the coldest month isotherm -3 degrees C (Köppen 1931); growing season generally averaging less than 100 days, occasionally interrupted by nights of below freezing temperatures.
- Cold Temperate—Freezing temperatures usually of moderate duration, although of frequent occurrence during winter months. Potential growing season generally from 100 to 200 days and confined to late spring and summer when freezing temperatures are infrequent or absent.
- Warm Temperate—Freezing temperatures of short duration but generally occurring every year during winter months. Potential growing season over 200 days with an average of less than 150 days a year subject to temperatures below 0 degrees C or chilling fogs.
- Tropical Subtropical—Infrequent or no 24 hour periods of freezing temperatures, cold fogs, or chilling winds.

Fourth Level

The fourth level (e.g., 1,111.<u>1</u>) refers to a regional formation or *biotic community* within a biogeographic region or province (Clements and Shelford 1939; Pitelka 1941; Dice 1943; Goldman and Moore 1945; Odum 1945; Blair 1950; Webb 1950; Miller 1951; Kendeigh 1952; Aldrich 1967; Franklin 1977; Udvardy 1975a, 1975b, 1984a, 1984b). Each biogeographic province is characterized by a particular precipitation pattern and other climatic regimen so that the plant and animal species found therein share a more or less distinctive evolutionary history. Hence, each biogeographic province comes with a name that describes its geographic center or an important

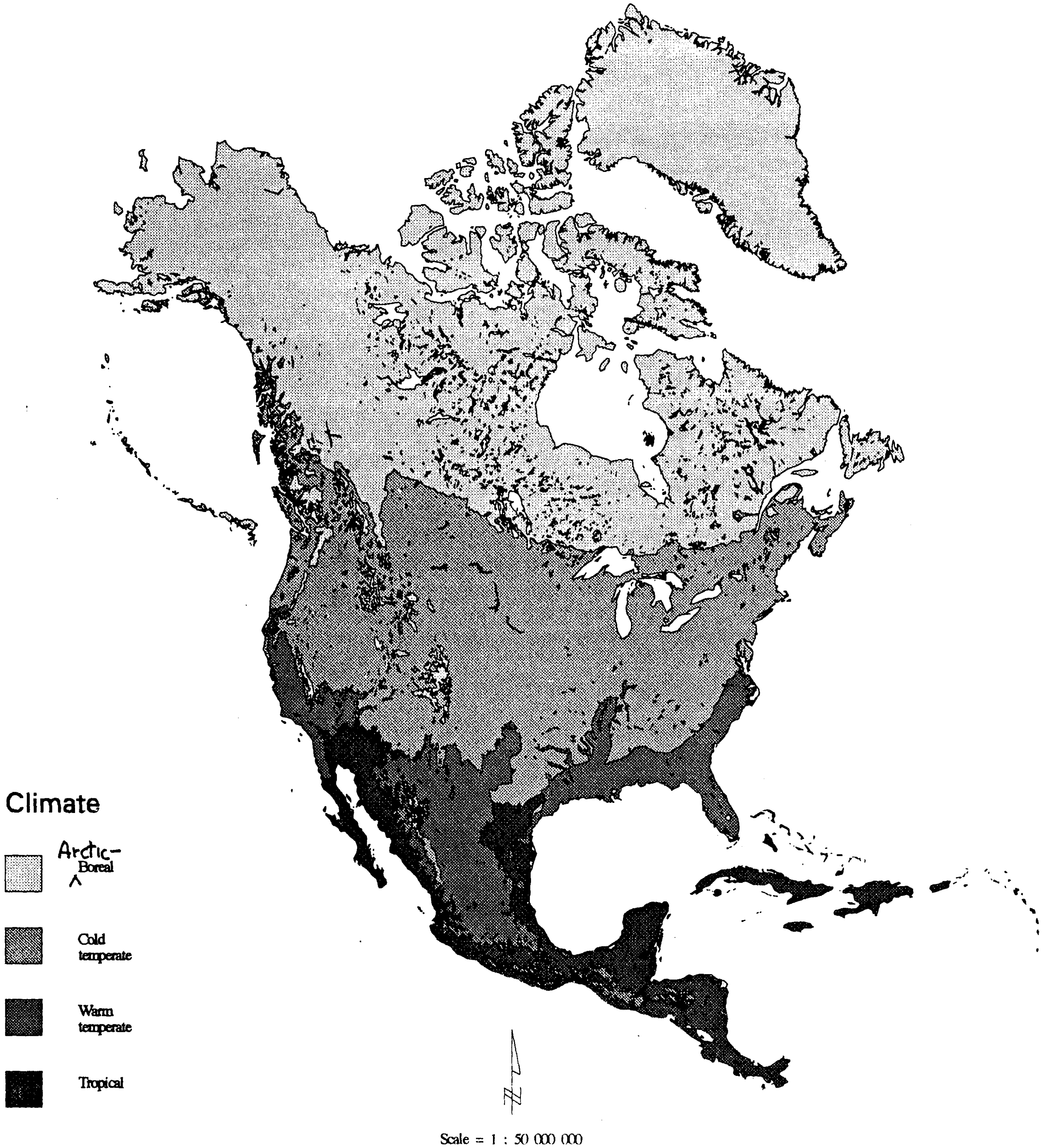

Figure 3.—Climatic zones of North America.

Table 3.—Summary for the natural upland and wetland vegetation of Nearctic and Neotropical North America to the third level.

Formation		1. Arctic Boreal	2. Cold Temperate	3. Warm Temperate	4. Tropical-Subtropical
		Climatic (thermal) Zone			
		NEARCTIC			
UPLAND					
1,110	Tundra	1,111			
1,120	Forests and Woodland	1,121	1,122	1,123	1,124
1,130	Scrubland	1,131	1,132	1,133	1,134
1,140	Grassland	1,141	1,142	1,143	1,144
1,150	Desertland	1,151	1,152	1,153	1,154
1,160	Nonvegetated	1,161	1,162	1,163	1,164
WETLAND					
1,210	Wet Tundra	1,211			
1,220	Swamp and Riparian Forests	1,221	1,222	1,223	1,224
1,230	Swamp and Riparian Scrub	1,231	1,232	1,233	1,234
1,240	Marshland	1,241	1,242	1,243	1,244
1,250	Strand	1,251	1,252	1,253	1,254
1,260	Nonvegetated	1,261	1,262	1,263	1,264
		NEOTROPICAL			
UPLAND					
3,110	Tundra and Paramo	3,111			
3,120	Forest and Woodland	3,121	3,122	3,123	3,124
3,130	Scrubland	3,131	3,132	3,133	3,134
3,140	Grassland	3,141	3,142	3,143	3,144
3,150	Desertland	3,151	3,152	3,153	3,154
3,160	Nonvegetated	3,161	3,162	3,163	3,164
WETLAND					
3,210	Wet Tundra	3,211			
3,220	Swamp and Riparian Forest	3,221	3,222	3,223	3,224
3,230	Swamp and Riparian Scrub	3,231	3,232	3,233	3,234
3,240	Marshland	3,241	3,242	3,243	3,244
3,250	Strand	3,251	3,252	3,253	3,254
3,260	Nonvegetated	3,261	3,262	3,263	3,264

physiographic feature that importantly contributes to its ecological isolation (fig. 4). In the West, as in Mexico and Central America, where topography, altitudinal, and climatic influences are extremely complicated, biotic provinces diminish in size and increase in number, and their boundaries, following certain topographical features, become highly complex (Udvardy 1969). Although the delineation of biogeographic provinces is interpretive in part and often arbitrary, the identification of biotic communities only requires the assignation of recognizable communities of plant dominants (5th level of the classification system) and their known animals to the province in which these species are known to be important constituents.

Biotic communities are characterized by distinctive plants and animals living within a single formation type (third level of the classification system) and commonly called "indicator species" (Merriam 1890, Clements 1920, Shelford 1963). Because each biotic community is a complete ecosystem of plants, animals,and their habitat, this level is the natural unit for studying the interrelations of plant and animal species (Odum 1945, Shelford 1945, Kendeigh (1952). Although the original concept of "ecosystems" involved the exchange of chemical energy within a given community (Odum 1945), this term, as it is often presently used, is equivalent to biotic community. As ecological units of regional isolation, the reality of biotic communities can be tested statistically through the analysis of climatic data and the presence and distributions of endemic species and/or subspecies.

It is this fourth (biotic community) and the fifth (series) levels that have been most often used to map regions, states, and countries (e.g., Bruner 1931; Rasmussen 1941; Hayward 1948; Webb 1950; Allred et al. 1963; Aldrich 1967; Küchler 1964, 1977; Franklin and Dyrness 1973; Brown 1973, Brown and Lowe 1982). Biogeographic provinces and biotic communities are also the bases for biosphere reserve programs in the United States and elsewhere(I.U.C.N. 1974, Franklin 1977, Udvardy 1984b).

Tables 4 and 5 list those biotic communities shown on the 1:10,000,000 color map (Reichenbacher and Brown 1994). Present plans are to describe each of these biotic communities in detail in a publication similar to one for the southwest United States and northwest Mexico (Brown 1982). Neither the classification nor the map is meant to be final. Additional biotic communities will undoubtedly be identified, and others may be deleted, upon further analysis and consideration.

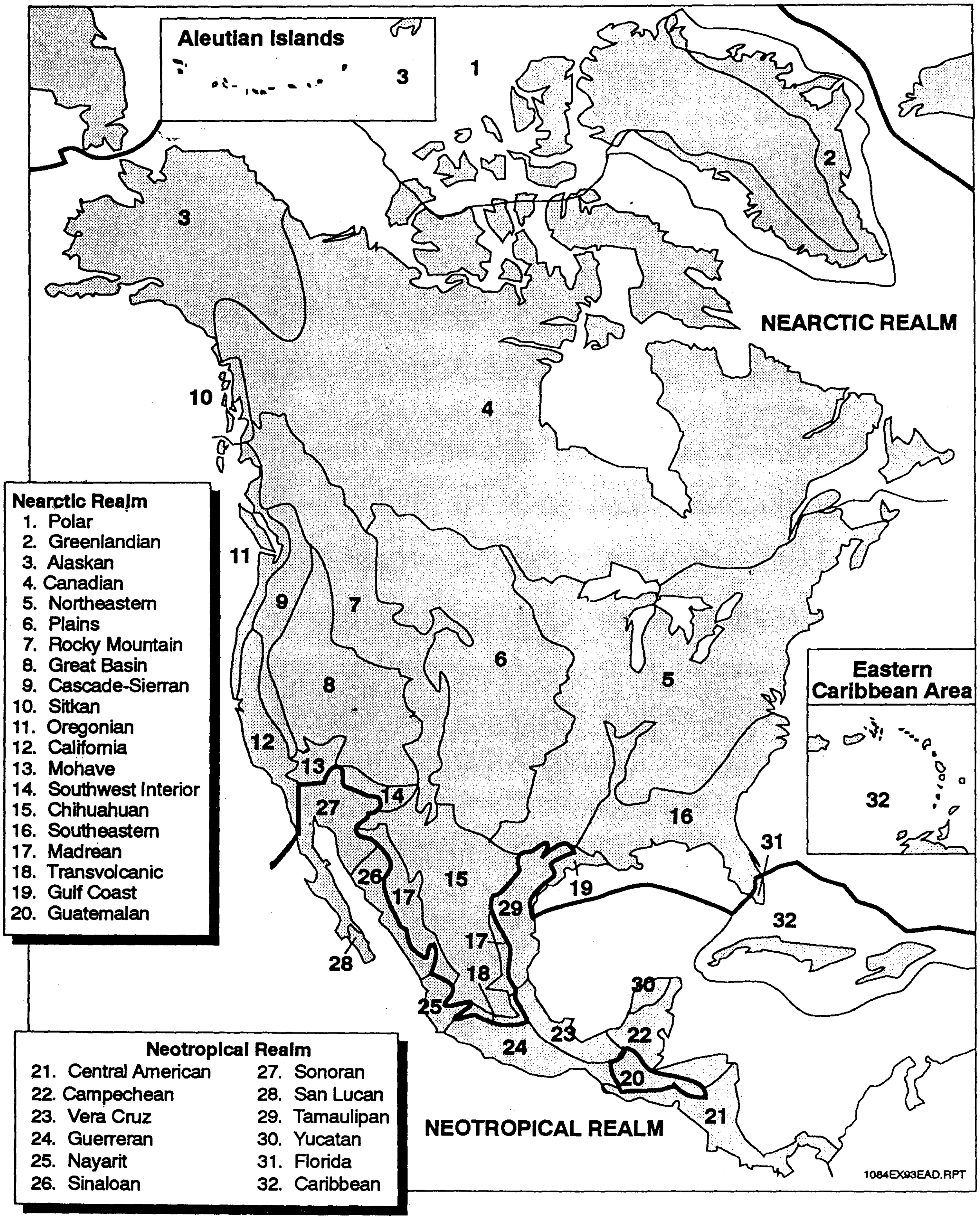

Figure 4.—Biogeographic Provinces of North America.

Fifth Level

The fifth level beyond the comma (e.g., 1,111.11) provides the principal plant animal communities within the biotic communities, each recognized by one or more indicator plants, and called a *series*. These generic series, sometimes referred to as cover types (Society of American Foresters 1954), are in turn composed of one or more plant associations within the same biotic community (Oosting 1956, Lowe 1964, Braun 1967, Franklin and Dyrness 1973, Pfister et al. 1977). For example, a yellow pine series would include all plant associations within a biotic community in which *Pinus ponderosa* was a dominant component (table 4). Because the number of series

Table 4.—Nomenclature of upland biotic communities (fourth level) of Nearctic and Neotropical North America. A more complete list is presented in Brown et al. (1982). The list of biomes presented here includes only those illustrated on the 1:10,000,000 map of the biotic communities of North America (Reichenbacher and Brown 1994).

1,000. NEARCTIC REALM
1,100. Natural Upland Vegetation
1,110. Tundra Formation
1,111. Arctic-Boreal Tundras
1,111.1 Polar (High Arctic) Tundra
1,111.2 Alaskan Coastal Tundra
1,111.3 Canadian (Low Arctic) Tundra
1,111.4 Greenlandian Coastal Tundra
1,111.5 Arctic-Alpine Tundra
1,111.6 Rocky Mountain and Great Basin Alpine Tundra**
1,111.7 Cascade-Sierran Alpine Tundra
1,111.8 Adirondack-Appalachian Alpine Tundra
1,111.9 Transvolcanic Tundra
***120. Forest and Woodland Formation
121. Boreal and Subalpine Forests and Woodlands
121.1 Alaska-Yukon Subarctic Conifer Forest
121.2 Canadian Taiga
121.3 Rocky Mountain Subalpine Conifer Forest
121.4 Cascade-Sierran Subalpine Conifer Forest
121.5 Adirondack-Appalachian Subalpine Conifer Forest
121.6 Transvolcanic Subalpine Conifer Forest
122. Cold Temperate Forests and Woodlands
122.1 Northeastern Deciduous Forest
122.2 Sitka Coastal Conifer Forest
122.4 Cascade-Sierran Montane Conifer Forest
122.5 Rocky Mountain Montane Conifer Forest
122.6 Great Basin Conifer Woodland
122.7 Madrean Montane Conifer Forest
122.8 Transvolcanic Montane Conifer Forest
123. Warm Temperate Forests and Woodlands
123.1 Southeastern Deciduous and Evergreen Forests
123.2 Oregonian Deciduous and Evergreen Forests
123.3 California Evergreen Forest and Woodland
123.4 Madrean Evergreen Forest and Woodland
123.5 Transvolcanic Evergreen Forest and Woodland
123.7 Guerreran Evergreen Woodland
123.8 Guatemalan Cloud Forest
123.9 Guatemalan Evergreen Forest and Woodland
123.1a Vera Cruz Cloud Forest
123.1b San Lucan Evergreen Forest and Woodland
130. Scrubland Formation
131. Arctic-Boreal Scrublands
131.1 Alaskan Coastal Scrub
132. Cold Temperate Scrublands
132.1 Great Basin Montane Scrub
133. Warm Temperate Scrublands
133.1 California Chaparral
133.2 California Coastalscrub
133.3 Southwestern (Arizonan) Interior Chaparral
133.4 Chihuahuan Interior Chaparral
140. Grassland Formation
142. Cold Temperate Grasslands
142.1 Plains Grassland
142.2 Great Basin Shrub-Grassland
143. Warm Temperate Grasslands
143.1 Semidesert Grassland
143.2 California Valley Grassland
143.3 Gulf Coastal (Tamaulipan) Grassland
150. Desertland Formation
152. Cold Temperate Desertlands
152.1 Great Basin Desertscrub
153. Warm Temperate Desertlands
153.1 Mohave Desertscrub
153.2 Chihuahuan Desertscrub
3,000. NEOTROPICAL REALM
3,100. Natural Upland Vegetation
3,110. Tundras and Paramo Formation
3,111. Alpine Paramos
3,111.1 Central American Paramo
***120. Forest and Woodland Formation
124. Tropical-Subtropical Forests and Woodlands
124.1 Central American Cloud Forest
124.2 Central American Evergreen Rain Forest
124.3 Central American Semi-evergreen Forest
124.4 Central American (Guanacaste) Dry Forest
124.5 Campechian Evergreen Rain Forest
124.6 Campechian Semi-evergreen Forest
124.7 Yucatan Semi-deciduous Forest
124.8 Yucatan Dry Deciduous Forest
124.9 Guerreran Dry Deciduous Forest
124.1a Vera Cruz Evergreen Rain Forest
124.1b Vera Cruz Semi-evergreen Forest
124.1c Nayarit Semi-evergreen Forest
124.1d Sinaloan Dry Deciduous (Monsoon) Forest
124.1e Tamaulipan Semi-deciduous Forest
124.1f San Lucan Dry Deciduous Forest
124.1g Caribbean Cloud and Montane Forest
124.1h Caribbean Coastal Evergreen and Semi-evergreen Forest
124.1i Caribbean Dry (Monsoon) Forest
124.1j Floridian Evergreen Forest
130. Scrubland Formation
134. Tropical-Subtropical Scrublands
134.1 Guerreran Thornscrub
134.2 Sinaloan Thornscrub
134.3 Tamaulipan Thornscrub
134.4 San Lucan Thornscrub
134.5 Caribbean Thornscrub
133.6 Central American Thornscrub
140. Grassland Formation
144. Tropical-Subtropical Grasslands
144.1 Central American Savanna Grassland
144.2 Campechian Savanna Grassland
144.3 Vera Cruz Savanna Grassland
144.4 Caribbean Savanna Grassland
144.5 Sonoran Savanna Grassland
144.6 Tamaulipan Savanna Grassland
150. Desertland Formation
154. Tropical-Subtropical Desertlands
154.1 Sonoran Desertscrub

*** The first "1" (in front of the comma and representing the Nearctic realm) is understood and dropped for tabular convenience only from this point onward.
*** The first "3" in front of the comma and representing the Neotropical Realm is dropped for tabular convenience from this point onward.

within any given biotic community may be large, and because some biotic communities are as yet little studied and imperfectly known, only illustrative examples of the fifth level are given for the biotic communities listed in Tables 4 and 5. For these same reasons, the numerical prefix given for a particular series is also illustrative only and may be modified at will for regional studies.

It should be noted that tropical and subtropical series are inherently more diverse than those in arctic boreal and temperate biotic communities. Series in tropical and subtropical biotic communities frequently contain dozens, if not hundreds, of competing species of plants and animals per acre; arctic boreal series typically contain only one or two plant dominants. Series in arctic boreal and temperate environments also tend to be larger in extent and fewer in number than those in the tropics. For these reasons the identification and classification of fifth level communities is more easily determined in Canada and the United States than in Mexico or Central America (compare e.g., Halliday 1937, Küchler 1964, Braun 1967 and Franklin and Dyrness 1973 with Tosi 1969 and Rzedowski 1978).

Some plant dominants are highly facultative, and the same species may be dominant in more than one formation type. As an extreme example, mesquite (*Prosopis juliflora*) may be the dominant life form in forest and woodland, scrubland, desertland, and even disclimax grassland formations. The distributions of some plant dominants also span more than one climatic zone, e.g., mesquite, creosote bush (*Larrea tridentata*), and the introduced saltcedar (*Tamarix chinensis*). The plant and animal associates of these sometime dominants differ when passing from one formation type or climatic zone to another, however. These and other generic dominants and some of their associates may also occur in more than one biotic community (e.g., *Larrea, Populus, Salix, Quercus*, etc.). Nonetheless, further investigation should show a significant change in plant and animal species when passing from one biotic community to another. Furthermore, when the same species is present in more than one biotic community, the different populations exhibit genetic and other differences (Yang 1970).

Table 5.—Nomenclature of wetland biotic communities (fourth level) of Nearctic and Neotropical North America. A more complete list is presented in Brown et al. (1982). The list of biomes presented here includes only those illustrated on the 1:10,000,000 map of the biotic communities of North America (Reichenbacher and Brown 1994).

1,000. NEARCTIC
- 1,200. Natural Wetland Vegetation
  - *** 220. Forest Formation
    - 223. Warm Temperate Swamp and Riparian Forests
      - 223.1 Southeastern Swamp and Riparian Forest
  - 230. Swamp-Scrub Formation
    - 231. Arctic Boreal Swamp-Scrubs
      - 231.3 Alaskan Swamp Scrub
  - 240. Marshland Formation
    - 243. Warm Temperate Interior Marshland
      - 243.8 Everglades Interior Marshland

3,000. NEOTROPICAL REALM
- 3,200. Neotropical Natural Wetland Vegetation

*** The first "1" (in front of the comma and representing the Nearctic realm) is understood and dropped for tabular convenience only from this point onward.

Sixth Level

The sixth level after the comma (e.g., 1,111.111) refers to a distinctive *association* which has been defined by the International Botanical Congress as a plant community having a certain floristic composition, uniform habitat conditions, and uniform physiognomy (see also eg., Braun Blanquet 1932). Plant associations are therefore more or less local in distribution, and as used here, generally equivalent to niches (Pitelka 1941) and habitat types as outlined by Daubenmire and Daubenmire (1968), Layser (1974), and Pfister et al. (1977). Although we provide plant association examples for two 5th level series within one 4th level biotic community (Douglas fir and Yellow Pine series within Rocky Mountain Montane Conifer Forest), the enormous numbers of possible sets preclude presentation for the continental treatments in tables 4 and 5.

This level of the classification emphasizes actual vegetation. As a working system, it accommodates, but does not stress, both subclimax and disclimax plant associations (and associes) as well as potential natural vegetation (see e.g., Clements 1916, Weaver and Clements 1938, Clements and Shelford 1939, Oosting 1956, Küchler 1964). Those plant associations judged to be subclimax or seral in nature can be indicated by an "a" in the numerical code, e.g. 111.111a. Similarly, those series and associations considered to be in a disclimax condition can be indicated by a "D" at the series (5th) level or a "d" at the plant association level. Plant associations may therefore be expanded to any length for regional studies.

Seventh Level

The seventh level (e.g., 1,111.1111) accommodates detailed assessment of *composition, structure, density*, or other quantitative determinations for plant and animal species within a plant association. In that implementation of this level in the system is intended for intensive studies of limited areas (e.g., Dick Peddie and Moir 1979), no examples are provided in Tables 4 and 5.

THE BIOTIC COMMUNITIES OF NORTH AMERICA MAP

The 1:10,000,000 color map (Reichenbacher and Brown 1994) depicts the continent's major upland biotic communities (4^{th} level of the classification system) using Gaussen's (1953) ecological color scheme that illustrates gradients in available plant moisture, heat, and cold. The base map was reproduced at scale on an acetate overlay of a 1:8,000,000 Kummerly and Frey stereographic chart, and the biotic communities delineated in 83 vinyl colors using as source data the maps, terminology, and descriptions found in the Literature cited and. Because of the limitations of scale, upland biotic communities such as Relict Conifer Forests and Central American Thornscrub, which occupy areas less than 10 km^2 in extent, are omitted from the map. Their enormous diversity, dynamic nature, and generally limited area, also preclude all but the highest level illustration of the largest wetland communities. Nonetheless, the biogeographic affiliation of a particular wetland can be readily determined by referring to the biotic community in which it occurs. It is expected that further research and peer review will result in improvements in the nomenclature and delineation of the biotic communities depicted, particularly those in Latin America.

The biotic communities shown depict regional formations within recognized biotic or floristic regions as modified from Dice (1943), Goldman and Moore (1945), Shreve (1951), Rzedowski(1978), and other biogeographers. The boundaries and terminology are importantly based on the system developed by the IUCN and UNESCO and proposed for use in the International Biosphere Reserve program (Udvardy 1974, 1984b). Neither the biotic community designations, nor their delineations, however, need to be considered as final. Indeed, it is hoped that the use of high altitude imagery and other recently developed techniques (see e.g., Loveland et al. 1991) will result in an improved understanding and depiction of the continent's biota.

Even a cursory examination of the map shows some portions of the North American continent to be more biotically homogeneous than others. Of particular concern to some users will be the large uniform areas of Northeastern Deciduous Forest, Canadian Taiga, and Plains Grassland as compared to the smaller, more numerous biotic communities in Mexico and the American Southwest. This apparent discrepancy at the biotic community level is real, however, and reflects an increasing biotic diversity as one travels westward and southward across the North American continent—a phenomenon long recognized by biologists (e.g., Simpson 1964, Kiester 1971, and Wilson 1974). Mexico, despite only having 11% of the land area of Canada and the U. S., has more species of mammals, more species of birds, and more reptiles and amphibians than the two northern countries combined. One Mexican state, Chiapas, has 8,250 known species of plants compared to the twice as large (115,719 km^2 vs. 74,000 km2) and botanically rich American state of Ohio's 2700 species (Ramamoorthy et al. 1993). The large number of Mexican species is the result of Mexico's and the American Southwest's great topographic and climatic diversity. Climatic variation and evolutionary isolation are the two primary factors in the determination of biotic communities. Hence, these parts of North America possess a greater degree of endemism at both the species and community levels than areas to the north and east (Klopfer and MacArthur 1960, Wilson 1974).

Nonetheless, further research may show that one or more of the biotic communities depicted are not sufficiently distinct to warrant separation at the biotic community level. Future investigators, for example, may conclude that the Neotropical Realm's Yucatan Dry Deciduous Forest is not sufficiently different from Central American Dry Forest to justify separate biotic community status. Similarly, additional study may support the division of Plains Grassland or other fourth level community into one or more biotic communities as was suggested by Dice (1943). In either event, biotic communities can easily be deleted or added in the classification system. Also, should additional biotic detail be desired within a biotic community, future editions of the map can provide series or fifth level community designations as was done for the Northeastern Deciduous Forest by Braun (1967) and for Sonoran Desertscrub by Brown and Lowe (1980, 1982).

The map has been digitized by the Environmental Protection Agency's Environmental Monitoring Systems Laboratory in Las Vegas, Nevada. Digitization will facilitate modifying the biotic communities based on peer review along with the overlay of land use data. It will also facilitate the division of the larger biotic communities such as the Northeastern Deciduous Forest and Plains Grassland into large general series should such a subdivision be desired. Also, by using the map as a sample frame, EMAP can stratify the various biotic communities for conducting wildlife surveys and other monitoring activities. And finally, the map permits those interested in biological diversity to determine the percentage of each biotic community remaining in a natural state and/or having protected status.

In summation, the purpose of the map is to illustrate the applicability of the classification system for inventorying the continent's biotic resources and to provide a sample frame for those interested in stratifying natural history information. With the recent availability of highly detailed aerial imagery, one could feasibly now also overlay land use, thus evaluating the extent of those biotic communities remaining in a natural state. National park boundaries and other enhancements would also enable resource managers to identify those biotic communities having protected status and determine which ones are in need of additional protection. A biotic communities map also facilitates the evaluation of candidate areas for biosphere reserves and wilderness status. Enhanced with land use information, such a map can also assist in the interpretation of environmental change and the gathering of base data for the environmental monitoring and assessment program (EMAP) currently underway by the U. S. Environmental Protection Agency (Kepner and Fox 1991).

ACKNOWLEDGEMENTS

We wish to express our appreciation to Thomas R. Loveland, U. S. Geological Survey, Sioux Falls, South Dakota; James M.Omernik, U. S. Environmental Protection Agency, Corvallis, Oregon;Jan W. van Wagtendonk, Research Scientist with the National Park Service, Yosemite National Park, California and Denis White, Oregon State University, Corvallis, Oregon for their editorial comments and review of the manuscript. Their helpful comments and suggestions were thought provoking and greatly improved the manuscript. NOTICE: Although the research described herein has been funded in part by the U. S. Environmental Protection Agency through Purchase Requisition Numbers 1V 0703 and 2V 0295 to David E. Brown, it does not necessarily reflect the views of the Agency.

LITERATURE CITED

Agassiz, L. 1854. Sketch of the natural provinces of the animal world and their relation to the different types man. In J. C. Nott and G. R. Glidden. Types of mankind. Philadelphia.

Aldrich, J. W. 1967. Biomes of North America (map). In O. H.Hewitt (ed.). The wild turkey and its management. Wild.Soc., Washington, D.C. and elsewhere.

Allen, J. A. 1878. The geographic distribution of mammals. Bull. Amer. Mus. Nat. Hist. 4:199 242

Allred, D. M., D. E. Beck, and C. D. Jorgensen. 1963. Biotic communities of the Nevada test site. Brigham Young Univ. Biol. Sci. Bull. 2:1 52.

Anderson, J. R., E. E. Hardy, and J. T. Roach, 1972. A land use classification system for use with remote sensor data. U.S. Geological Survey Circ. 671:1 15.

Anderson, J. R., E. E. Hardy, J. T. Roach, and R. E. Witmer. 1976. A land use and land cover classification system for use with remote sensor data. U. S. Geological Survey Professional Paper 964:1 28.

Bailey, R. G. 1976. Ecoregions of the United States. Map (scale 1:7,500,000). USDA Forest Service, Inter-mountain Region, Ogden Utah.

Bailey, R. G., and C. T. Cushwa. 1981. Ecoregions of North America. Map (scale 1:12,000,000). USDI, Fish and Wildl. Serv., Office of Biological Services, Eastern Energy and Land Use Team.

Beard, J. S. 1953. Savanna vegetation types of northern tropical America. Ecol. Monog. 23:149 215.

Billings, W. D. 1973. Tundra grasslands, herblands and shrublands and the role of herbivores. In Grassland Ecology. R. H. Kessel, ed. Louisiana State Univ. Press, Baton Rouge

Blair, W. F. 1950. The biotic provinces of Texas. Texas J.Sci. 2:93 117.

Braun, E. L. 1967. Deciduous forests of eastern North America. Hafner Publ. Co., New York, NY, and London, England. 596p.

Braun Blanquet, J. 1932. Plant sociology: the study of plant communities. McGraw Hill, New York. 439p.

Brown, D. E. 1973. The natural vegetative communities of Arizona. (map, scale 1:500,000). State of Arizona, Arizona Resources Information System, Phoenix.

__________. 1980. A system for classifying cultivated and cultured lands within a systematic classification of natural ecosystems. J. Ariz. Nev. Acad. Sci. 15:48 53.

__________. 1982. The biotic communities of the American Southwest—United States and Mexico. Desert Plants (1 4):1 341.

__________, and C. H. Lowe. 1974a. A digitized computer compatible classification for natural and potential vegetation in the Southwest with particular reference to Arizona. J. Ariz. Acad. Sci. 9, Supple. 2:1 11.

__________, and __________. 1974b. The Arizona system or natural and potential vegetation—illustrated summary through the fifth digit for the North American Southwest. J. Ariz. Acad. Sci. 9, Supple. 3:1 56.

_________, and _________. 1980, 1982. Biotic communities of the Southwest, map (1:1,000,000)). Gen. Tech. Rep. RM 78, U. S. D. A. Forest Service, Fort Collins, CO.

_________, _________, and C. P. Pase. 1979, 1982. A digitized classification system for the biotic communities of North America, with community (series) and association examples for the Southwest. J. Ariz. Nev. Acad. Sci. 14, Supple. 1:1 16. Reprint. as an appendix in *Biotic Communities of the Southwest—U. S. and Mexico*, D. E. Brown, ed. Desert Plants 4(1 4).

_________, _________, and _________. 1980. A digitized systematic classification for ecosystems with an illustrated summary of the vegetation of North America. Gen. Tech. Rep. RM 73, Rocky Mt. Forest and Range Exp. Sta., Ft. Collins, CO. 93p.

Bruner, W. E. 1931. The vegetation of Oklahoma. Ecol. Monogr. 1:99 188.

Clements, F. E. 1916. Plant succession. Carnegie Instit., Washington, D.C. Publ. 242:1 512.

_________. 1920. Plant indicators. Carnegie Instit., Washington D. C. Publ. 290:1 388.

_________, and V. E. Shelford. 1939. Bio ecology. John Wiley and Sons, New York. 425p.

Cooper, J. G. 1859. On the distribution of the forests and trees of North America, with notes on its physical geography. Smithsonian Instit. Ann. Rep. to the Board of Regents: 246 280.

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. Laroe. 1979. Classification of wetlands and deep water habitats in the United States in the United States. USDI Fish and Wildlife Serv., Office of Biological Services, Washington D.C. FWS/OBS 79/31:1 103.

Cox, B. C., I. N. Healy, and P. D. Moore. 1976. Biogeography, an ecological and evolutionary approach. 2nd. ed. Blackwell Science Publ., Oxford and London England; Edinburgh, Scotland; Melbourne, Australia. 194p.

Dansereau, P. 1957. Biogeography. 394p. Ronald Press, New York, NY. 394p.

Darlington, P. J., Jr. 1957. Zoogeography. John Wiley and Sons, Inc., New York, NY. 675p.

Daubenmire, R. F. 1946. The life zone problem in the north intermountain region. Northwest Sci. 20:28 38.

_________, and J. Daubenmire. 1968. Forest vegetation of eastern Washington and northern Idaho. Washington Agric. Exp. Sta. Tech. Bull. 60:1 104.

DeLaubenfels, D. J. 1975. Mapping the world's vegetation. Syracuse Univ. Press, NY, Geographical Series 4:1 246.

Dice, L. R. 1943. The biotic provinces of North America. Univ. of Michigan Press, Ann Arbor. 78p.

Dick Peddie, W. A., and W. H. Moir. 1970. Vegetation of the Organ Mountains, New Mexico. Range Sci. Dept., Colorado State Univ., Fort Collins, Science Series 4:1 28.

Dyksterhuis, E. J. 1957. The savannah concept and its use. Ecology 38:435 442.

Eidenshrink, J. C. 1992. The 1990 conterminous U. S. AVHRR data set. Photogrammetric Engineering and Remote Sensing, 58:809 813.

Fleming, T. H. 1973. Numbers of mammal species in North and Central American forest communities. Ecol. 54:555 563.

Flores, M. G., J. Jiminéz L., X. Madrigal S., F. Moncayo Ruiz, and F. Takaki T. 1971. Memoria del mapa de tipos de vegetación de la República Mexicana. SRH, Subsec. de Planeacion, Direccion de Agrologia, Mexico, D. F. 59p. + map, scale 1:2,000,000.

Franklin, J. F. 1977. The biosphere reserve program in the United States. Science 195:262 267.

_________, and C. T. Dyrness 1973. Natural vegetation of Oregon and Washington. USDA Forest Service Gen. Tech. Pacific Northwest Forest and Range Exper. Sta., Portland OR, Report PNW 8:1 417.

Garrison, G. A., A. J. Bjugstad, D. A. Duncan, M. E. Lewis, and D. R. Smith. 1977. Vegetation and environmental features of forest and range ecosystems. USDA, Washington, D.C., Agric. Handbook 475:1 68.

Gaussen, H. 1953. A proposed ecological vegetation map. Surveying and Mapping: 13:168 173.

Goldman, E. A., and R. T. Moore. 1945. Biotic provinces of Mexico. J. Mammal. 26:347 360.

Halliday, W. E. D. 1937. A forest classification for Canada. Canada Dept. Mines Res., Forest Service Bull. 89:1 189.

Hayden, B. P., G. C. Ray, and R. Dolan. 1984. Classification of coastal and marine environments. Environ. Conserv. 11:199 207.

Hayward, C. L. 1948. Biotic communities of the Wasatch chaparral, Utah. Ecol. Monog. 18:473 506.

Hesse, R., W. C. Allee, and K. P. Schmidt. 1937. Ecological animal geography. John Wiley and Sons, New York, NY. p.597.

Holdridge, L. R. 1959. Mapa ecologico de Central America. Según publicaciones de Unidad de Recursos Naturalos, Dept. de Asuntos Económicos, Union Panamericana.

_________. 1969 (and elsewhere). Diagrama para la clasificacion de zonas de vida o formaciones vegetales del mundo. In J. A. Tosi, Republica de Costa Rica mapa ecologico (scale 1: 750,000). Centro Cientifico Tropical, San Jose, Costa Rica.

Huxley, T. H. 1868. On the classification and distribution of the Alectoromorphae and Heteromorphae. Proc. London Zool. Soc.: 294 319.

International Union for Conservation of Nature and Natural Resources. 1974. Biotic provinces of the world—Further development of a system for defining and classifying natural regions for purposes of conservation. Occas. Paper 9:1 57.

Kendeigh, S. C. 1952. History and evaluation of various concepts of plant and animal communities in North America. In K. B. Sterling. 1974. Selections from the literature of American biogeography. Arno Press, New York.

Kepner, W. G., and C. A. Fox 1991. Arid ecosystems strategic monitoring plan, 1991. Environmental Monitoring and Assessment Program (EMAP), U. S. Environmental Protection Agency, Environmental Monitoring Systems Laboratory, Las Vegas, NV. Peer Review Draft.

Kiester, A. R. 1971. Species density of North American amphibians and reptiles. System. Zool. 20:127 137.

Klopfer, P. H., and R. H. MacArthur. 1960. Niche size and faunal diversity. Amer. Nat. 94:293 300.

Köppen, W. 1931. Gundriss der Klimakunde. Walter de Gruyter Co, Berlin, Germany.

Küchler, A. W. 1964. The potential natural vegetation of the conterminous United States. American Geographical Soc. Special Publ. 361:1 116 + map, scale 1:7,000,000.

_________. 1977. Natural vegetation of California map. In M. G. Barbour and J. Major (eds.), Terrestrial vegetation of California. John Wiley and Sons, New York. 1002p.

Layser, E. F. 1974. Vegetative classification: its application to forestry in the northern Rocky Mountains. J. of Forestry 72:354 357.

Loveland, T. R., J. W. Merchant, D. O. Ohlen, and J. F. Brown. 1991. Photogrammetric Engineering and Remote Sensing. 57:1453 1463.

Lowe, C. H., Jr. 1964. Arizona's natural environment: landscapes and habitats. Univ. of Arizona Press, Tucson. p. 136.

MacArthur, R. H. 1964. Environmental factors affecting bird species diversity. Amer. Nat. 98:387 398.

Martin, A. C., N. Hotchkiss, F. M. Uhler, and W. S. Bourn. 1953. Classification of wetlands of the United States. USDI Fish and Wildlife Service Spec. Science Report on Wildl. 20:1 14.

Maxwell, J. R., C. Deacon Williams, C. J. Edwards, M. E. Jensen, H. Parrott, S. J. Paustian, and K. Stein. 1994. A hierarchical framework of aquatic ecological units in North America. Draft ECOMAP, USDA Forest Service. 73+p.

Maycock, P. F. 1979. A preliminary survey of the vegetation of Ontario as a basis for the establishment of a comprehensive Nature Reserve system. Provencial Parks Branch, Ontario Ministry of Natural Resour., Toronto, Ontario.

McNeely, J. A., and K. R. Miller. 1983. IUCN National Parks and protected areas: priorities for action. Environ. Conserv. 10:13 21.

Merriam, C. H. 1892. The geographic distribution of life in North America with special reference to the Mammalia. Ann. Pres. Address to the U. S. Biol. Surv. 12:365 415 (also 1891. Ann. Rep. Board of Reg. Smithsonian Instit., Washington D.C. 1891.

__________, V. Bailey, E. W. Nelson, and E. A. Preble. 1910. Zone map of North America. USDA Biol. Surv., Washington D.C.

_________, and L. Stejneger. 1890. Results of a biological survey of the San Francisco Mountain region and desert of the Little Colorado in Arizona. No. Amer. Fauna 3:1 136.

Odum, E. P. 1945. The concept of the biome as applied to the distribution of North American birds. Wilson Bull. 57:191 201.

Omernik, J. M. 1987. Ecoregions of the conterminous United States. Map Suppl. Annuals of the Assoc. of Amer. Geographers. 77:118 125.

Oosting, H. J. 1956. The study of plant communities. 2nd. ed. W. H. Freeman and Co., San Francisco, CA. 440p.

Patton, D. R. 1978. RUN WILD: A storage and retrieval system for wildlife habitat information. USDA Forest Service Rocky Mountain Forest and Range Exp. Sta., Fort Collins, CO, Gen. Tech. Report RM 51:1 8.

Pfister, R. D., B. L. Kovalchik, S. F. Arno, and R. C. Presby. 1977. Forest habitat types of Montana. USDA Forest Service Intermountain Forest and Range Exp. Sta., Ogden UT, Gen. Tech. Report INT 34:1 174.

Pitelka, F. A. 1941. Distribution of birds in relation to major biotic communities. American Midland Nat. 25:11 137.

Rasmussen, D. I. 1941. Biotic communities of Kaibab Plateau, Arizona. Ecol. Monog. 11:229 275.

Ramamoorthy, T. P., R. Bye, A. Lot, and J. Fa, eds. 1993. Biological diversity of Mexico—origins and distributions. Oxford Univ. Press, New York.

Ray, G. C. 1975. A preliminary classification of coastal and marine environments. IUCN Occas. Pap. No. 14:1 26.

Reichenbacher, F. W. 1990. Tumamoc globe berry studies in Arizona and Sonora, Mexico. U. S. Bureau of Reclamation Phoenix Office Contract Report BR8802 FR:1 109

Reichenbacher, F. W., and D. E. Brown 1994. Biotic communities of North America, map (1:10,000,000). Environmental Protection Agency, EMAP, Las Vegas, NV.

Rowe, J. S. 1972. Forest regions of Canada. Canadian Forest Service, Ottawa. Publ. 1300.

Rzedowski, J. 1978. Vegetación de Mexico, Editorial Limosa S.A., Mexico, D.F. p. 432.

Sclater, P. L. 1858. On the general geographical distribution of the members of the class Aves. J. Proc. Linn. Soc. (Zool.). 2:130 145.

Shantz, H. L., and R. Zon. 1924. Natural vegetation. USDA, Washington, D.C., Atlas of American agriculture plot 1, Section E (map).

Sharpe, R. B. 1893. On the zoo geographical areas of the world, illustrating the distribution of birds. Nat. Sciences 3:100 108.

Shelford, V. E. 1945. The relative merits of the life zone and biome concepts. Wilson Bull. 57:248 252.

_________. 1963. The ecology of North America. Univ. Illinois Press, Urbana. 610p.

_________, and F. Shreve, eds. 1926. Naturalists guide to the Americas. Wilkins and Wilkins, Baltimore, MD. 761p.

Simpson, G. G. 1964. Species density of North American recent mammals. Syst. Zool. 13:57 73.

Society of American Foresters. 1954. Forest cover types of North America (exclusive of Mexico). Society of American Foresters, Washington, D.C.

Stejneger, L., and G. S. Miller, Jr. 1903. Plan for a biological survey of the

Palearctic Region. Carnegie Instit. Washington Yearbook 1:240 266.

Takhtajan, A. 1986. The floristic regions of the world. Univ. of Calif. Press, Berkeley.

Tosi, J. A., Jr. 1969. Republica de Costa Rica mapa ecologico. map, scale 1:750,000.

Udvardy, M. D. F. 1969. Dynamic zoogeography. Van Nostrand Reinhold Co., New York, Cincinnati, Toronto, London, and Melbourne.

_________. 1975a. World biogeographical provinces (map, scale 1:39,629,000). The CoEvolution Quarterly, Sausalito, CA.

_________. 1975b. A classification of the biogeographical provinces of the world. IUCN Occas. Paper No. 18:1 48.

_________. 1984a. The IUCN/UNESCO system of biogeographical provinces in relation to the biosphere reserves. pp. 16 19 In Conservation, science and society: contrib. to the first Intern. Biosphere Reserve Congress, Minsk, Byelorussia/U.S.S.R, 26 Sept. 2 Oct., 1983. UNESCO UNEP.

_________. 1984b. A biogeographical classification system for terrestrial environments. pp. 34 38 In national parks, conservation and development, J. A. McNeely and K. R. Miller, eds., Smithsonian Instit. Press, Washington, D. C.

_________. 1987. The biogeographical realm Antarctica: a proposal. In Forum on the biogeographical classification of New Zealand. J. Royal Soc. New Zealand 17:187 200.

Wallace, A. R. 1876. The geographical distribution of animals, with a study of the relations of living and extinct faunas and as elucidating the past changes of the earth's surface. MacMillan and Co., London, England.

Walter, H. 1973. Vegetation of the earth in relation to climate and the eco physiological conditions. English Univ. Press, Ltd., London, England. 237p.

Weaver, J. E., and F. E. Clements. 1938. Plant ecology. McGraw Hill Book Co., New York, NY. 237p.

Webb, W. L. 1950. Biogeographic regions of Texas and Oklahoma. Ecology 31:426 443.

Wickware, G. M., and C. D. A. Rubec. 1989. Terrestrial ecoregions and ecodistricts of Ontario, Map, scale 1:2,000,000, and descriptive table. In Ecoregions of Ontario, Environment Canada, Sustainable Development Branch, Ottawa, Ontario. Ecol. Land Class. Ser. 26:1 37.

Wiken, E. B. 1986, (compiler). Terrestrial ecozones of Canada. Environment Canada, Ottawa, Ontario. Ecol. Land Class. Ser. 19:1 26.

_________, C. D. A. Rubec, and G. R. Ironside. 1989. Terrestrial ecoregions of Canada. Provisional map, scale 1:7,500,000. Environment Canada, Sustainable Develop. Branch, Ottawa, Ontario.

Wilson, J. W. III. 1974. Analytical zoogeography of North American mammals. Evol. 28:124 140.

World Conservation Monitoring Centre. 1992. Protected areas of the world. IUCN. Gland, Switzerland and Cambridge, U.K.

Yang, T. W. 1970. Major chromosome races of Larrea divaricata in North America. J. Arizona Acad. Sci. 6:41 45.

Zoltai, S. C., F. C. Possett, J. K. Jeglum, and G. D. Adams. 1975. Developing a wetland classification for Canada. Proc. of the North American Soils Conference 4:497 511.