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Biogeography: the nature of the subject, its history and its applications

1.1 Introduction

In 1994, an article in the journal *New Scientist* proclaimed that 'Since biogeography holds the key to the survival of life, it deserves more attention' (Bowman, 1994). That statement is a very fitting opening to this first chapter.

Biogeography is about the geography of plants, animals and other organisms, that is, the study of the geographical distribution of plants, animals and other organisms. Biogeographical research helps us to understand the patterns and processes of distribution and the factors that cause and maintain those patterns and processes. The patterns of distribution that we find today amongst living organisms have been determined by many things, including the following:

Evolution
Physiological and behavioural adaptations
Dispersal mechanisms and levels of dispersal abilities
Competition between species
Ecological succession
Climate change
Sea level changes
Moving continents through a process called plate tectonics
Direct and indirect impact of humans

The distribution and abundance of plants (phytogeography) and animals (zoogeography) have been the two main divisions of biogeography. Both those divisions embrace elements of several disciplines including biology,

geography, taxonomy, geology, climatology and ecology. Many biologists, taxonomists, geologists, climatologists and ecologists have interests in various aspects of biogeography and indeed some have particular views as to the precise nature of biogeography. Those differences in views are based partly on differences of scale, be it in time or spatially. For example, a geologist's view might be particularly biased by an interest in evolutionary processes over very long periods of time (millions of years) perhaps in relation to plate tectonics. Geographers might take a special interest in researching the distribution of plants and animals over the last few thousand years, perhaps in relation to the post-glacial periods. An ecologist's view of biogeography might be dominated by those factors which determine and maintain the distribution of plants and animals within certain localities and over much shorter periods of time (perhaps in relation to the reduction and fragmentation of habitats in the last few decades). These different views contribute to the rich and varied nature of biogeographical research and its many important, practical applications. The common theme in all approaches to the study of biogeography is the study of the geographical distribution of groups of plants, animals and other organisms from a spatial or space perspective (that is, over land, in the soil, in water and in the air) and a temporal or time perspective (that is changes in distribution that occur over time). Biogeography provides a valuable link between traditional single disciplines (such as ecology, taxonomy and conservation biology) and a focus for interdisciplinary studies. That is important because many if not all environmental problems facing us today require an interdisciplinary approach (that is an integration of several disciplines, including ecology, geology, economics, policy and sociocultural factors).

Biogeography is more than about mapping the geographical distribution of organisms (present and past) at different spatial scales or merely dividing the land and sea into regions which are based on groups of characteristic organisms. Once a predominantly descriptive discipline, biogeography is now a quantitative science. It has applications in conservation, helping to establish a strategy for the location, extent and management of protected areas. It has applications in trying to achieve sustainable use of living resources and in environmental assessment by helping to ensure the least impact on the natural environment. It has applications in helping to tackle many aspects of environmental change, whether it be modelling the effects of changing weather patterns on agriculture or those of introduced and invasive species on native (indigenous) commercial fish species.

Before we can look in more detail at biogeography we need to know what we are dealing with and thus a brief introduction to the classification of organisms is helpful. We then go on to introduce the subject of biogeography and the

history of biogeography. The relation between ecology and biogeography is then discussed and finally we look at some applications of biogeography.

1.2 An introduction to plants, animals and other organisms

There are approximately 1.7 million named species of living oganisms. The total number of living species is of course not known and we can only estimate what the figure might be. Estimates range from about 11 to 30 million or more. What is certain is that human impacts are causing species to become extinct faster than they can be named. Also of concern is our lack of knowledge about the named species. Scientists have intensively investigated only 10 per cent of plant species and a far smaller proportion of animal species (information from the World Commission in Environment and Development 1987 publication *Our Common Future*, Oxford University Press).

There are many terms used to refer to different groups of animals, plants and other kinds of living organism such as fungi, bacteria and viruses. The classification of biota (living organisms) has been reviewed and changed many times as a result of new information. In 1969, R. H. Whittaker of Cornell University suggested five groups of living organisms (Box 1.1). More recently, new taxonomic levels and regrouping of major taxa have been proposed as a result of studies in molecular biology.

Commonly used terms for living organisms include 'wildlife' and more recently the widely misunderstood term 'biological diversity' (often abbreviated to biodiversity). Wildlife is often used only with reference to mammals and birds. In this book it refers to any kind of wild organism (plants, animals, fungi and other groups) and therefore not to domesticated animals or plants.

The term biological diversity is often used in connection with conservation, not because it is fashionable to do so but because of the important concept embodied in its use. Conservation of wildlife conjures up lists of species which are endangered. There is nothing wrong with that but biological diversity draws attention to the need to conserve variety at different levels of biological organisation (from the genetic level to ecosystem levels). Biological diversity is an all-embracing term that means the variety of life at all levels of biological organisation, including 'diversity within species, between species and of ecosystems' (from the 1992 Convention on Biological Diversity). There is biological diversity at different levels of ecological organisation, genetic organisation and taxonomic organisation.

Box 1.1. The diversity of life. Classifications and definitions of biological diversity (see also Table 5.1)

In this five-kingdom system (developed primarily by R. H. Whittaker of Cornell University) living organisms are arranged on the basis of level of biological complexity and mode of nutrition. This is merely a summary of what is a much more detailed classification and it omits many groups within the major taxonomic levels of phylum, class, order, family, genus and species.

The numbers in brackets are the approximate number of named species (numbers are in thousands and are given only where there is good agreement about the number).

Kingdom Monera: Bacteria and blue-green algae.
Kingdom Protista: Primitive fungi, slime moulds, green algae, etc.
Kingdom Fungi: (mode of nutrition by absorption) three main groups of fungi (40).
Kingdom Plantae: (mode of nutrition photosynthesis):
Division Bryophyta: Mosses and liverworts.
Division Tracheophyta: This division includes the most complex and advanced plants such as the three classes – ferns, conifers and flowering plants.
Class Filicineae: Ferns (10).
Class Gymnospermae: Conifers (0.6).
Class Angiospermae: Flowering plants (286).
Subclass: Monocotyledonae: Grasses, lilies, palms, orchids, etc.
Subclass: Dicotyledonae: e.g. Rose Family, . . . Genera in other families such as *Fagus* (northern beech) and *Nothofagus* (Southern beech).

Kingdom Animalia: (mode of nutrition ingestion):
Phylum Porifera: Sponges (10).
Phylum Coelenterata: Sea anemones, corals, jellyfish, etc. (10).
Phylum Platyhelminthes: Flatworms, tapeworms, flukes, etc. (125).
Phylum Nematoda: Roundworms (30).
Phylum Mollusca: Shellfish or molluscs, squid, snails, etc. (110).
Phylum Annelida: Earthworms, leeches, etc. (15).
Phylum Onychophora: Velvet worms, e.g. the genus *Peripatus.*
Phylum Arthropoda: Insects (800), spiders (130), crustacens (30), etc.
Phylum Echinodermata: Starfish, sea urchins, sea lilies, etc. (6).
Phylum Hemichordata: Acorn worms.
Phylum Chordata: The vertebrates including fish (20), amphibians (2.5), reptiles (6.3), birds (8.5) and mammals (4).

This table indicates the variety of known life in terms of taxonomic diversity. However, this is only one aspect of biological diversity.

Box 1.1 (*cont.*)

The 1992 Convention on Biological Diversity defines Biological diversity 'the variability among living organisms from all sources including, amongst other things, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems'.

Biological Diversity occurs at different levels of organisation (after Angermeier & Karr, 1994):

Taxonomic	Genetic	Ecological
Species	Gene	Population
Genus	Chromosome	Community
Family etc.	Genome	Ecosystems

Plants, animals and other organisms are collectively known as biota or organisms. Aggregations of the same kind of organisms are known as populations, for example trout populations, or oak tree populations. A population of organisms such as trout lives in a habitat; a habitat is usually linked to a population and is the locality or area occupied by the populations. Habitats can be characterised by the physical features, soil conditions, and by the other kinds of organism found in the area. Biological communities are made up of different kinds of populations of organisms; for example a coral reef community consists of coral populations, fish populations, crustaceans, algae and other marine life. Different kinds of community have sometimes been classified on the basis of recognisable mixes or assemblages. Different kinds of woodland or grassland can be recognised by the different composition of the species; for example, we could refer to the mixed-species deciduous woodlands of the temperate climate region.

At a higher level of ecological organisation there are ecosystems. An ecosystem has no boundaries and is characterised by cycles and flows of water, energy, minerals and other elements through both the living components and physical components of the ecosystem. Ecosystems comprise three categories: individual organisms, species etc.; processes such as energy flow or ecological succession; and properties such as fragility and condition.

Biota, living and extinct, have long been classified into different groups; the science of classifying organisms and the study of relationships between those groups is systematics. The science of taxonomy is the oldest of all biological sciences and is about the study and description of the diversity of organisms and how that diversity arose. Living organisms include more than just plants and animals (Box 1.1).

Taxonomic classifications have a hierarchical structure, in which the basic unit is the species (see also Table 5.1). A species is a group of organisms that are recognised as being distinct (in form and reproductively) from other groups. When a species is identified or named, it is typically given a binomial (Latin) name which includes a generic and a specific component. The designation of a binomial name follows an agreed convention and is the same when used within any language. An example of a binomial name is that used for beech trees, of which there are many kinds or species. In northern temperate climate regions, species belong to the genus *Fagus* whereas in southern temperate climate regions there is a different genus, *Nothofagus*. Note the convention of putting the scientific names in italics. There are different species within each of the genera; for example, in the genus *Nothofagus* there are the species *Nothofagus fusca*, *Nothofagus menziesii* and *Nothofagus solandri*.

In much of this book we consider the biogeography of species – the distribution patterns and the reasons for those patterns. This does not mean that biogeography is concerned only with one level of taxonomic organisation, the species. It deals with other levels such as genera and families.

1.3 A history of biogeography

The presence and distribution of plants and animals has been recorded by humans for many thousands of years. Cave drawings of animals could be said to be the beginning of biogeography. The earliest written records and books mention the occurrence, abundance and absence of various plants and animals. Similarly, maps depicting plants, animals, dragons and other creatures have been made for centuries. Until early this century, many of these maps depicted actual organisms rather than indicating their distribution. However, as early as 1697, animals were drawn on an economic map of Hungary and later, in 1845, Heinrich Berghaus's *Physikalischer Atlas* has animal distribution maps (George, 1969). Throughout the 20th century there has been an ever-growing interest in how best to map, survey, record and distribute information about the distribution of plants, animals and natural biological communities. The books listed in Table 1.1 are testament to the varied nature of that mapping, etc. In recent years, the interest in mapping has been greatly facilitated and enhanced by developments in computer and satellite technologies (see Chapter 6).

Biogeography, in the sense of identifying geographical faunal and floral characteristics, probably emerged from early attempts to classify organisms

Table 1.1. *One hundred years of biogeography books*

Charles Darwin's *The Origin of Species* was the first great landmark in books that greatly influenced subsequent writing on biogeography. This table is a list of books or chapters in books (in English or translated into English) published during the 100 years following 1859 and which have been relevant to the advancement of biogeography. This list excludes those publications which specialise on island biogeography (see Section 3.2).

These books represent a history of literature on biogeography which has brought the subject to a wider audience. Underlying these books is a wealth of material from expeditions and research, most of which is published in scientific journals.

1859. *On The Origin of Species by means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life*, by C. Darwin. London, John Murray.

1869. *The Malay Archipelago*, by A. R. Wallace. London, Macmillan. (Wallace dedicated this book to Charles Darwin with whom he had shared thoughts about the theories of natural selection.

1876. *The Geographical Distribution of Animals*, by A. R. Wallace. London, Macmillan.

1887. *The Geographical and Geological Distribution of Animals*, by A. Heilprin. London, Kegan Paul, Trench & Co.

1911. *Atlas of Zoogeography*, by J. G. Bartholomew, W. E. Clarke & P. H. Grimshaw. Edinburgh, J. Bartholomew and the Edinburgh Geographical Institute.

1913. *The Wanderings of Animals*, by H. Gadow. London, Cambridge University Press.

1934. *The Life Forms of Plants and Statistical Plant Geography*, by C. Raunkiaer. Oxford, Clarendon Press.

1935. *Zoogeography of the Sea*, by S. Ekman. German edition first published in 1935 and translated into English in 1953. London, Sidgwick and Jackson.

1936. *Plant and Animal Geography*, by M. I. Newbigin. London, Methuen.

1937. *Ecological Animal Geography*, by R. Hesse, W. C. Allee & K. P. Schmidt, New York and London, John Wiley.

1944. *Foundations of Plant Geography*, by S. A. Cain. New York and London, Harper & Bros.

Table 1.1. *(cont.)*

1951. *Zoogeography of the Land and Inland Waters*, by L. de Beaufort. London, Sidgwick & Jackson.

1953. *Zoogeography of the Sea*, by S. Ekman. London, Sidgwick & Jackson (originally published in Germany in 1935).

1953. *Evolution and Geography*, by G. G. Simpson. Eugene, Oregon State System Higher Education.

1954. *The Distribution and Abundance of Animals*, by H. H. Andrewartha & L. C. Birch. Chicago, University of Chicago Press.

1957. *Zoogeography: The Geographical Distribution of Animals*, by P. J. Darlington. New York and London.

1957. *Biogeography: An Ecological Perspective*, by P. M. Dansereau. New York, Ronald Press.

1958. *Panbiogeography or An Introduction Synthesis of Zoogeography, Phytogeography, and Geology; with notes on Evolution, Systematics, Ecology, Anthropology* etc. by L. Croizat. Caracas, published by the Author.

and in the origins of taxonomy and systematics. Georges Louis Leclerc, Comte de Buffon (1707–1788), a wealthy French nobleman had, as early as 1761, observed that the Old World (Europe, Asia and Africa) and the New World (North and South America) had no mammalian species in common. Buffon's work was monumental: 44 large volumes published over a period of 50 years.

The early explorers, the natural history excursions of the 19th century and scientific expeditions of the 20th century, have moulded the study of the geographical distribution of life on land and in the sea. Amongst the notable biogeographers (Fig. 1.1), one stands out as having made a notable contribution and that was the Prussian naturalist and explorer of South America, Alexander, Baron von Humboldt (1769–1859). He was interested in the manner by which plants contributed to the landscape and is sometimes referred to as the father of plant geography.

Early studies (Table 1.1) of plant and animal distributions played a key role in the development of the theory of evolution; for example the observations made by both Charles Darwin (1809–1882) during his passage on the ship *HMS Beagle* (1831–1836) and Alfred Russel Wallace (1823–1913) during his expedition to the Malay archipelago, returning to England in 1862 with a

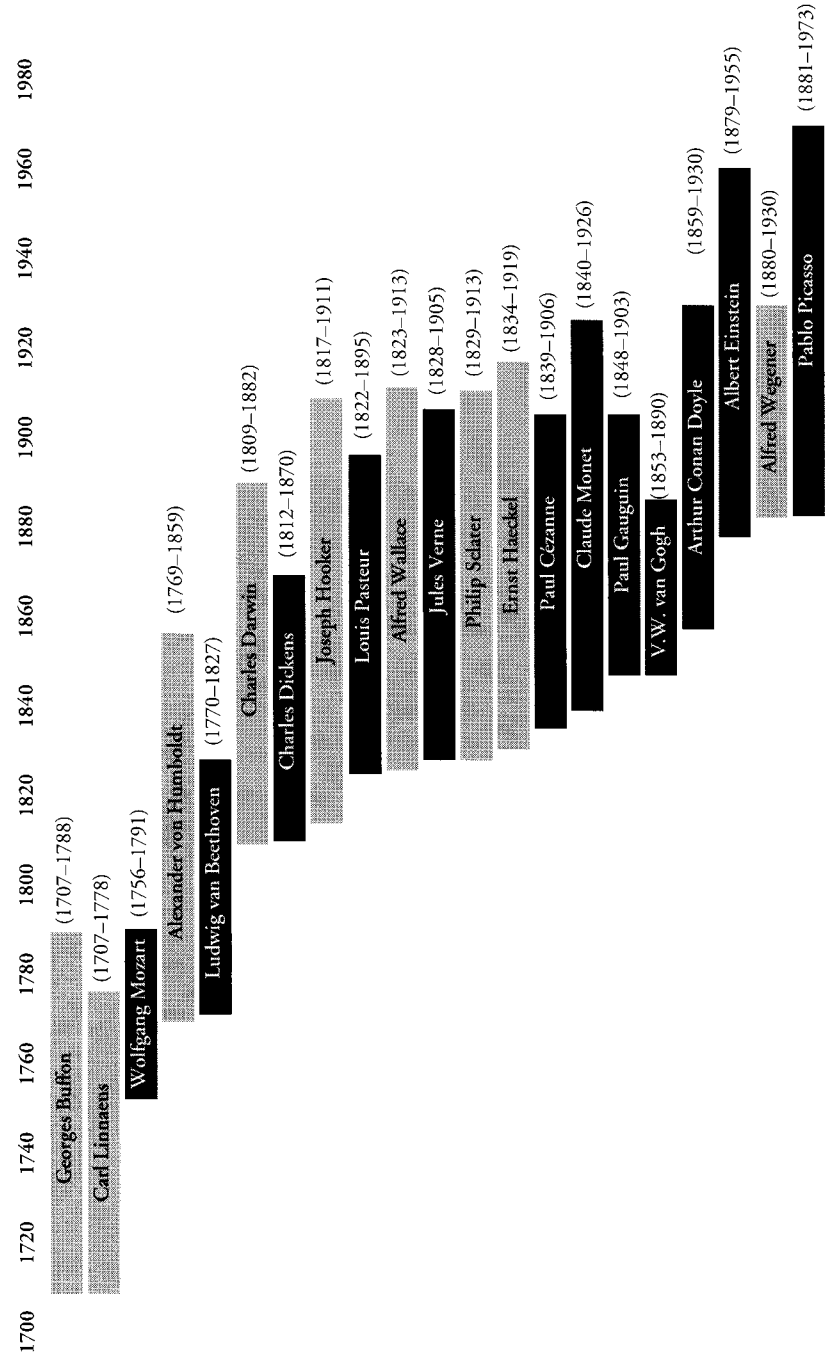

Fig. 1.1. Some notable biogeographers from the 18th and 19th centuries. Names of other famous people are also shown to help to put this chronology into perspective.

Table 1.2. *Texts on biogeography mentioned by Hans Gadow*

The 18th and 19th centuries were rich in biogeographical studies of animals. (References taken from Hans Gadow, 1913, *The Wanderings of Animals*, London, Cambridge University Press).

1707–1788. *Historie Naturelle*, by G. Buffon. 44 volumes published over 50 years during the life of Buffon. (Contains the first general ideas about geographical distribution.)

1777. *Specimen Zoologiae Geographicae Quadrupedum*, by E. A. W. Zimmerman. (The first special treatise on the subject and, according to Gadow, deals in a statistical way with mammals.)

1778. *Philosophia Entomologica*, by J. C. Fabricius. (The first to divide the world into eight regions.)

1803. *Biologie*, by G. R. Treviranus. (This included a chapter on the distribution of the whole animal kingdom.)

1810. *Anatomie und Naturgeschichte der Voegel*, by F. Tiedemann. (Deals with the influence of environment, distribution and migration of birds.)

Text by Latrielle (Date not mentioned). (Proposed that temperature is the main factor in the distribution of animals.)

1822. Text (unknown) by Desmoulins. (Suggested analogous centres of creation – meaning that similar groups of creatures may have arisen independently in different parts of the world.)

1835. Text (not stated) by W. Swainson. (The first book dealing with the geography and classification of the whole animal kingdom.)

1830–1833. *Principles of Geology*, by Charles Lyell. London. Looks at the history of the distribution of animals over time.)

1852. *Physikalischer Atlas: Thiergeographie*, by H. Berghaus. Gotha. (Has the earliest maps dealing with animal distributions.)

1853. Text (not stated) by L. K. Schmarda. (The distribution of the whole animal kingdom. He discusses the possible physical causes and modes of dispersal from original centres of creation and divides the land into 25 'realms'.)

1857. 'On the geographical distribution of the members of the Class Aves'. *Journal of the Proceedings of the Linnean Society, Zoology*, **11**, 130–145, by P. L. Sclater. (He suggests six 'regions' which have been the basis for a classification of biogeographical regions until this day.)

1859. *The Origin of Species*, by Charles Darwin. (A benchmark in biogeographical studies; especially mapping and characterising regions.)

1866. *Geographical Distribution of Mammals*, by A. Murray. (101 coloured distribution maps.)