

Biogeography: Historical Development and Recent Scenario

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Abstract: Geography is the study of relations between society and the natural environment and constitutes the disciplines of geography, space, place and time that are very crucial concepts. The objective of this paper is to explore the historical development and recent scenario of Biogeography as a sub field of Physical Geography, which is one of the two major subfields of Geography that deals with the study of processes and patterns in the natural environment in the atmosphere, hydrosphere, biosphere, and geosphere. These spatial organization and changes that take place both in short and long time perspectives. Species interaction with space over time and the influences of geographical factors in species functions is the core of biogeography. Research method: as an analytical model, this paper is divided in to five sections according to the historical time frame to obtain set objective. Secondary data were employed to explore historical events and the contributions of the experts to the field of five eras. Since 2000 the highly use of models, theories, conservation strategies as well as computers, GIS and remote sensing techniques in biogeography has grown considerably.

Introduction and background to the field

Geography provides the broad basis for diverse kinds of exploration in to natural and social sciences. The subject of geography is the fundamental interpretation of the earth's 'spatial diversity'. According to (Hartshone, 2005) it is neither a natural nor social

science, but a study of intimately mixed phenomena. There are a number of sub-fields in Geography¹. The main fields of study in Physical Geography focus around the core fields of Biogeography, Geomorphology, Climatology, Hydrology, Soil Geography etc. While the main fields of study in Human Geography focus on the core fields of Economic Geography, Development Geography, Settlement Geography, Population Geography, Political Geography etc. (Strahler and Strahler, 2005).

Biogeography, the sub field of Physical Geography is the study of the geographical distribution of plants, animals and micro organisms over the surface of the Earth in both space and time (Tivy, 1979; Robinson, 1972; Huggett, 1998). Strahler and Strahler (2005, p.270) states that, "we can think of Biogeography as encompassing two major themes. Ecological biogeography is concerned on how the distribution patterns of organisms are affected by the environment. Historical biogeography focuses on how spatial distribution patterns of organisms arise over time and space". It focuses on the spatial organization, which is important to understand species interaction with space and the influences of geographical factors in species function. It is a dynamic and growing field that seeks to understand the role of historical factors (spatial and temporal) in determining biodiversity and to expand significantly analytical capacities of measuring how biodiversity will respond to drastically altering world through natural and anthropogenic factors.

¹ Strahler, A. and Strahler, A., 2005: *Introducing Physical Geography*, 3rd edition, John Wiley & Sons Inc. USA. Chapter 01, p. 06..

Early stage of the field

The appearance of thoughts concerning to the subject 'Biogeography' has a long history. Aristotle (384 BC – 322 BC) first classified living species into plant and animal Kingdoms. He called 'animals with blood' and 'animals without blood'. Animals with blood (vertebrates) were divided into live-bearing (humans and mammals), and egg-bearing (birds and fish). Invertebrates ('animals without blood') are insects, crustacea (divided into non-shelled – cephalopods – and shelled) and testacea (molluscs)² According to (Szafer, 1975; Starr and Taggart, 2004) in between 371 and 287 BC, Theophrastus classified plants as trees, shrubs and herbs and is considered the founder of 'Plant Geography' and father of botany³. Further, he expressed the interrelationships between biotic and abiotic environments⁴.

Development of the field in 18th and 19th Centuries

Swedish scientists Carl Von Linnaeus (1707-1778) made remarkable contributions to biology as well as biogeography⁵. In 1735, he introduced the currently used methods of plant classification. Linnaeus introduced 'binomial classification system' for plants and animals in 1753 and is considered the 'father of plant taxonomy' (Starr and Taggart, 2004; Raven, et al., 2008). Comte de Buffon work on natural history of animals in 1761 contributed the biogeographic notion. He explored the distribution patterns, adaptation and migration of wildlife. According to Huggett (1998) this has been considered an early contribution to biogeography. According to Myers and Giller (1988) the origin of biogeography is attributed to Buffon, who perceived the biogeographic diversity of the earth⁶.

Alexander von Humboldt's (1769-1859) quantitative work on botanical geography laid the foundation for the field of biogeography. According to Huggett (1998) and Lomolino & Heaney (2004), Humboldt further explained the climatic influences on vegetation zones. He also explored the biogeographical phases of biota and contributed a lot to develop the field biogeography. He has been considered the Father of 'modern plant geography'. Another most crucial contribution was made by Augustine P. de Candolle in 1820. He coined the term 'taxonomy' and contributed to the development of plant taxonomy through his book on 'Geographical Botany' (Huggett, 1998).

From 1855 to 1866 a number of books were published on climatic impact on the distribution pattern of vegetation. Alphonse de Candolle (1855) wrote a book on 'Plant Geography' and in 1864, George Perkins Marsh's (1801-1882) wrote a book 'Man and Nature or Physical Geography as Modified by Human Action' (Robinson 1972). In 1866, A. Grisebach wrote a book on 'Vegetation of the Earth'. These books have emphasized very much the influences of geographical factors on species distribution patterns and function. Thus, these publications have played a donated significant role in developing biogeography as a distinctive branch of geography. In 1858, P.L. Sclater made a tremendous contribution to biogeography. He introduced 'Biogeographic Regions' of the Earth (Huggett, 1998). Then, J.D. Hooker (1866) studied the development and interrelations of floras of the globe. According to and, (2010) this study focused on the biogeography of flora. His involvement in biogeography should be admired. The most important figure and in the 19th century and prominent ecologist Earnst Haeckle's immense contribution to 'Biogeography', 'Biology' and 'Ecology' must be admired. According to (Raven, et al., 2008) in

² Wikipedia., 2013. [online] Available at: <<http://en.wikipedia.org/wiki/Aristotle>>[Accessed 15.03.2013].

³ Tim Rhodus., 2002. [online] Available at: <<http://www.hcs.ohio-state.edu/hort/history/009.html>>[Accessed 15.03.2013].

⁴ Taylor (1984) 'Biogeography: recent advances and Future directions', Barnes and Noble Books, USA.pp.5

⁵ Natural History Museum., 2013. [online] Available at: <<http://www.nhm.ac.uk/nature-online/science-of-natural-history/taxonomy-systematics/index.html>>[Accessed 15.03.2013].

⁶ Myers and Giller (1988) 'Analytical biogeography: An integrated approach to the study of animal and plant distributions', Chapman and Hall (London and New York).

1866 he introduced the Kingdom of Protista, with Plantae, and Animalia. The greatest contribution of Earnst Haeckle was that in 1869 he pioneered the term 'ecology' and biogeography deviated with ecological thoughts⁷. Five years later, according to (Huggett, 1998) in 1871 J.A. Allen introduced eight 'Ecogeographic Realms' of the earth based on mean annual asotherms, and thus pioneered 'Allen's Rule' of biogeography or 'proportional rule'⁸.

The next event made a noteworthy contribution to biogeography. A biologically rich geographical area has been declared as a national park to conserve biological diversity in the US. In 1872, US President Grant signed an Act on National Parks, and thus the Yellow Stone area was declared the first National park in the world⁹.

Again in 1876, the most prominent biogeographer, Alfred Russel Wallace contributed much to delineate biogeographical region. He conceptualized 'Zoogeographical Realms' based on Darwinian Theory in his book; 'The Geographical Distribution of Animals'. He is considered the 'father of zoogeography' (Huggett, 1998). Since, the realms called as Wallace's realms. The realms are; Palaearctic, Ethiopian, Oriental, Australian, Nearctic, and Neotropical Starr and Taggart (2004, p.894). In this stage, Alexander Supan's (1879) 'timberline' view¹⁰ has contributed very much to strengthen the development of the field of biogeography.

In 1887, Stephen Alfred Forbes used the term 'ecosystem' in his essay on 'the Lake as Microcosm' but at this stage the term ecosystem had not yet been conceptualized. S.A. Forbes is a founder of aquatic ecosystem science and a dominant figure in the growth of American ecology. The life zone concept was

developed by Clinton Hart Merriam in 1889 as a means of describing areas with similar plant and animal communities¹¹. In 1894, C.H. Merriam proposed the 'Life Zone' model. This was comparative model of vegetation cover, climatic factors and geographical zones and a pure biogeographical model which made significant contribution to biogeography at this stage.

In the latter part of the 19th century, according to (Huggett, 1998) two Americans Roscoe Pound and Frederic Edward Clements (1898) introduced 'Plant Succession' and in the same year, A.F.W. Schimper based on field study on 'geographical distribution of the plants in relation to physical environmental factors' introduced the term 'Tropical Rainforest' (Whitemore, 1990).

Developments of the field in the 20th Century

Along with the developments of the field of biogeography in the 20th century, remarkable contributions were made by number of prominent experts. In 1911, British Ecologist Sir Arthur George Tansley wrote on 'Vegetation Types in British' which was directed international plant geography symposium in 1911 and, 2010).

Space, Place and Time are core factors in geography, in this sense, Alfred Wegener's continental drift theory in 1915, influenced to study the species distribution pattern in different continents over time (Taylor, 1984). These studies have contributed much to the development of the field biogeography in 20th century. The next development in field was American plant ecologist, Frederic Edward Clements's (1916) two concepts on 'Plant Succession' and 'Climax Vegetation' (Robinson, 1972; Huggett, 1998).

⁷ Raven, P., et al., 2008: *Biology*, 8th edition, M.C. Grow – Hill, New York.

⁸ Huggett, R.J., 1998: *Fundamentals of Biogeography*, Routledge, New York, p.17.

⁹ National Park Service., 2013. [online] Available at: <<http://www.nps.gov/yell/index.htm>>[Accessed 04.03.2013].

¹⁰ Koppen (1939) used the same line as the boundary between his tundra climates in his classification.

¹¹ Merriam., 1944. [online] Available at: <<http://www.nasonline.org/publications/biographical-memoirs/memoir-pdfs/merriam-clinton.pdf>>[Accessed 09.11.2012].

August Thienemann of Germany promoted the concept of 'Tropic Levels' in ecosystem in 1920. Thus, hard ecological ideas enhanced biogeography (Taylor, 1984). In 1925, Alfred Lotka initiated the use of quantitative methods in biology. In addition Lotka elaborated that living and non-living environment of the earth as an ecosphere (Huggett, 1998).

British ecologist Charles Sutherland Elton's books had a tremendous impact on biogeography. Elton wrote 'Animal Ecology' in 1927 and 'Animal Ecology and Evolution' in 1930 that examined the geographical distribution of animals from an ecological view-point (Taylor, 1984). In addition to that he expressed food webs and conceptualized the 'Ecological Niches' and 'Ecological Pyramids' ('Elton's Pyramids' / 'Eltonian Pyramids') (Huggett, 1998). The next development in biogeography was Vladimir Ivanovich Vernadsky's¹² contribution. Vernadsky coined the term 'biosphere', which are still the terms used very much in fields such as biogeography, ecology and biology (Myers and Giller, 1988; Huggett, 1998).

Again in 1935, English ecologist A.G. Tansley introduced¹³ the word 'Eco-system'. In 1938 Herbert Copeland¹⁴ encouraged Prokaryotes as a separate kingdom instead of Kingdom Monera, which included all types of bacteria. The two publications published in 1936 and 1947 was by Marion Newbegin's (1936) 'Plant and Animal Geography' and Ronald Good's (1947) 'Geography of flowering plants' (Lomolino and Heaney, 2004). These were considered as most successive developments in the field of biogeography by the end of the first half of the 20th century.

According to Taylor (1984) in 1939, the German geographer 'Carl Troll' (1899 - 1975) coined the term 'Landscape Ecology' and in 1968 he defined it as the

study of the main complex causal relationships between the life communities and their environment in a given section of a landscape or geographical area¹⁵.

In 1947, L.R. Holdridge¹⁶ introduced vegetation zones of the world. He used 'Bio Temperature Index' – BTI based on evaporation, precipitation, humidity, altitude and latitude'. Holdridge's remarkable contributions to biogeography must be admired. An incredible development of the 1950s was American biologist Eugene Pleasants Odum (1913 – 2002) introduced the 'energy flow approach' to ecology and ecological biogeography in 1953 through his book on the 'Fundamentals of Ecology' (Huggett, 1998; Cox and , 2010). In 1959, another important contribution was made by ecologist Robert .H. Whittaker. He proposed Fungi as spate kingdom of the kingdoms of species Starr and Taggart (2004, pp.405-409). Since Rachel Carson's 'Silent Spring', in the 1960s ideas on environmental concerns had enriched the field biogeography and contributed a lot to 'Environmental Geography'. According to (Saxena, 2004), in 1960s environmental movements were highly stressed and focused on human activities against the environment.

The years 1967, 1969 and 1970 were significant for biogeography, as three considerable views emerged during these years. An enthusiastic work made by ecologist Robert .H. Mac Arthur and an American biologist, researcher (sociobiology, biodiversity), theorist, naturalist and author. Edward Osborne "E. O." Wilson together, attempted to apply the theory of species equilibrium to the contained environment of small islands. In 1967, they wrote a book on 'the Theory of Island Biogeography' (Huggett, 1998; Lomolino and Heaney, 2004). Since then, many studies have been made on this theory, particularly on its simplicity, applicability and practicability to the design

¹² Russian mineralogist.

¹³ S.A. Forbes (1887) used the term 'ecosystem'

¹⁴ US Scientist.

¹⁵ Taylor (1984) 'Biogeography: recent advances and Future directions', Barnes and Noble Books, USA, p.8.

¹⁶ GeoNetwork., n.d.. [online] Available at:<<http://www.fao.org/geonetwork/srv/en/metadata.show?id=1006>>[Accessed 11.03.2013].

and study of national parks, man and biosphere reserves, biological corridors etc.

Two years later, in 1969, James Lovelock introduced 'Gaia Hypothesis'. It was a very important contribution as it helped perceive the Earth's biotic and abiotic systems as a whole. Then in 1970, Richard Levins introduced 'the "Theory of Metapopulation"¹⁷ (a population of populations) which consists of a group of spatially divided groups of population of similar species which interact at various levels, as a result of habitat fragmentation. All these views provided an incredible development to biogeography. Again another most crucial contribution was made by Robert .H. Mac Arthur in 1972. He wrote a book on 'Geographical Ecology' which made remarkable contribution to enrich the field biogeography¹⁸.

In early 1971, UNESCO proposed the Man and the Biosphere¹⁹ (MAB) Programme. It is an Intergovernmental Scientific Programme focused on interdisciplinary research schema and capacity building that aim the ecological, social and economic scopes of biodiversity loss and conservation. In the same year, the international convention on wetland²⁰ (Ramsar convention) was held in Iran. This convention directed to maintain, conserve and sustainable use of wetlands. And also it emphasized its role, ecological importance, functions and their scientific, economic, cultural, and recreational value. The declaration of these geographical areas conserves biodiversity and enriches the field biogeography.

The term and idea of 'Deep Ecology' were introduced by the Norwegian philosopher Arne Naess in 1973²¹. This was directly rooted in the 'Gaia

Hypothesis'. Next, the Journal of Biogeography was introduced in 1974. It covers aspects of spatial, ecological, and historical biogeography. In 1975, Miklos D.F. Udavardy introduced 'eight biogeographic realms'²² on a classification of biogeographical provinces of the world. Again E.O. Wilson in 1978 published an outstanding book on 'Human Nature' which methodically examined the scientific arguments surrounding the role of biology in the evolution of human culture (Jeffries, 1997).

According to (Wilson, 1992) the term 'Biodiversity' had been conceptualized in 1980²³. Walter Rosen of the National Academy of Science, USA, coined the word 'biodiversity' from the two words "biological-diversity". Two important biogeography text books appeared in this era; The two documents which were published in 1980s, were directed to originate the concept of biodiversity, one by the Council of Environmental Equality (1980) and the other by Norse & McManus (1980). He used this terminology 'biodiversity' to describe a concept that incorporated both ecological and genetic diversity²⁴.

In 1984, James A. Taylor wrote a book on 'Biogeography: Recent Advances and Future Directions' (Huggett, 1998). Taylor made a great contribution to biogeography by this book. In 1987, Our Common Future and the Brundtland Report published by the WCED influenced biogeography which expanded to address the conservation of biodiversity including genetic diversity at local, national and global levels. At this stage the thought on sustaining biodiversity was highly emphasized in biogeography.

¹⁷ Amrita., 2013. [online] Available at: <<http://amrita.vlab.co.in/?sub=3&brch=65&sim=772&cnt=1>>[Accessed 08.03.2013].

¹⁸ Mac Arthur., n.d. [online] Available at: <<http://uts.cc.utexas.edu/~varanus/MacArthur.html>>[Accessed 09.03.2013].

¹⁹ UNESCO., 1995-2012. [online] Available at: <<http://www.unesco.org/new/en/natural-sciences/environment/ecological-sciences/man-and-biosphere-programme/>>[Accessed 09.03.2013].

²⁰ Ramsar., n.d. [online] Available at: <http://www.ramsar.org/cda/en/ramsar-about/main/ramsar/1-36_4000_0_>[Accessed 23.03.2013].

²¹ wikipedia., 2013. [online] Available at: <http://en.wikipedia.org/wiki/Deep_ecology>[Accessed 23.03.2013].

²² Udavardy.,1975. [online] Available at: <<http://cmsdata.iucn.org/downloads/udvardy.pdf>>[Accessed 23.03.2013].

²³Wilson.,1992.[online]Availableat:<[http://books.google.lk/books?id=ZS9ehqHqTYC&printsec=frontcover&dq=inauthor:"Edward+O.+Wilson"](http://books.google.lk/books?id=ZS9ehqHqTYC&printsec=frontcover&dq=inauthor:)>[Accessed

²⁴ Andrew J. Hamilton* Species diversity or biodiversity? Journal of Environmental Management 75 (2005) 89–92, Australia., n.d. [online] Available at: <http://flash.lakeheadu.ca/~rrempel/ecology/Biodiversity_Papers/PDF0230-Hamilton.pdf, pp 90.>[Accessed 07.02.2013].26.03.2013].

The most significant figure in the second half of the 20th century was biogeographer and ecologist E.O. Wilson. Besides his contribution to develop the theory of island biogeography with R. H. Mac Arthur, he wrote a book in 1992 and used the term²⁵ 'biodiversity' in his publication. His great contribution to 'Biogeography', 'Biology' as well as 'Ecology' should be admired. The concept of 'Biodiversity Hotspots' was introduced by Norman Myers²⁶ in 1988. He introduced a biogeographic region in his articles on "The Environmentalist" (1988). A biodiversity hotspot is a biogeographic region with the most significant, biologically richest and most endangered (human pressure) global pool of biodiversity. In the 1980s, the conservation of biodiversity and related issues became very prominent at global, national and local levels (Jeffries, 1997).

In 1990, Carl Woese divided the kingdom Monera organisms into two kingdoms; Archaeobacteria and Eubacteria (Starr and Taggart, 2004; Raven, et al., 2008). In 1991, Hanski and Gilpin further explained certain additional characteristics on the theory of Metapopulation²⁷. 'Biodiversity' and related issues were discussed as one of the main themes at the United Nations Rio Conference which was held in 1992. As a result of the 1992 Rio Conference conservation of biodiversity was included in the international agenda and it has been understood and that the conservation of biodiversity must deal with geographical perspective at global, national and local levels.

According to (Jeffries, 1997) in 1992, Wilson wrote a book entitled 'The Diversity of Life'. Again two years later in 1994, he wrote another book known as 'Naturalist'. Wilson is known for his scientific career, his role as 'the father of sociobiology'. As a theorist and a sociobiologist, his contributions to biogeography

in its different stages must be appreciated. In the last decade of the 20th century, Michael Jeffries's views on 'biodiversity' in his book on 'biodiversity and conservation' in 1997 should be highlighted. Since 1997, Jeffries's thought on the conservation of biodiversity in a sustainable manner after agenda 21, highly influenced biogeography.

Recent scenario of the field

In the recent scenario: the International Biogeography Society²⁸, founded in 2001 and the inaugural meeting was held for biogeographers worldwide in 2003. The society hosts conferences, publishes, supports an online facebook community, delivers news on the blog, and fosters interaction among members. In 2013, 6th International Conference of the International Biogeography Society was held in Miami, Florida (USA). In this scenario, another important contribution was made by Lomolino and Heaney in 2004. They wrote a book entitled 'Frontiers of Biogeography: New Directions in the Geography of Nature' that book focuses on advances in historical biogeography and island biogeography.

Among the event of biogeographic importance of the recent scenario, in 2006, Al Gore's film²⁹ on Climate Change and Global Warming ('An Inconvenient Truth'-2006) highly focused trend of species migration due to Global climatic change. His immense contribution to 'Biogeography' and 'Environmental Geography' should be respected. It gave a new direction to conserve biodiversity at global, national and local level. The next work was by and (2007) on . This book has given much attention to ecological aspects of biogeography. Besides it has given emphasis to species isolation, species extinction, hotspots and biodiversity conservation. It gave a new thought to ecology via biogeography.

²⁵ Time Toast., n.d. [online] Available at: <<http://www.timetoast.com/timelines/62411>>[Accessed 22.03.2013].

²⁶ Conservation International., 2013. [online] Available at: <http://www.conservation.org/where/priority_areas/hotspots/Pages/hotspots_defined.aspx>[Accessed 17.03.2013].

²⁷ Anon., n.d. [online] Available at: <<http://www.esd.ornl.gov/programs/SERDP/EcoModels/metapop.html>>[Accessed 17.03.2013].

²⁸ IBS., 2008. [online] Available at: <<http://www.biogeography.org/index.html>>[Accessed 20.03.2011].

²⁹ New Scientist., 2007. [online] Available at: <<http://www.newscientist.com/blog/environment/2007/10/al-gores-inconvenient-truth.html>>[Accessed 20.03.2013].

The year 2010 was a milestone for biogeography. The United Nations declared 2010 as the International Year of Biodiversity³⁰ (IYB). IYB is a unique opportunity to enhance understanding of the crucial role that biodiversity plays in sustaining life on Earth. It was meant to help raise awareness of the importance of biodiversity through activities and events in many countries. Conservation of biodiversity is vital for current and future human wellbeing. By the end of first decade of the 21st century, a book on was published as the 7th edition. This book series created quite a ripple in the field of biogeography. Again in 2010 the Convention on Biological Diversity was held in Nagoya, Japan and the Nagoya Protocol³¹ was adopted. The Biosafety Protocol seeks to protect biological diversity from the potential risks posed by living modified organisms resulting from modern biotechnology, which was adopted in January 2000. On 22 December 2010, the UN declared the period from 2011 to 2020 as the UN-Decade on Biodiversity. They, hence, followed a recommendation of the CBD signatories during COP10 at Nagoya in October 2010.

The field Biogeography is historically mostly descriptive with theories, models, hypotheses and equations. But after quantitative revolution (1960s), and with rapidly developing technologies including GIS and remote sensing technique, together with the availability of complicated data (including e data) and increasingly sophisticated analytical tools, the field is incorporated with new technology. Specially paleontology, bioinformatics, global change biology, conservation biodiversity, and invasion biology, as well as genetically modified techniques, genetically modified food system, sustainable food systems and ecosystem services. In the recent scenario, the highly use of computers, GIS and remote sensing techniques in biogeography has grown considerably since 2000.

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³⁰ IUCN., 2011. [online] Available at: <<http://www.iucn.org/iyb/>>[Accessed 20.03.2013].

³¹ wikipedia., 2013. [online] Available at: <http://en.wikipedia.org/wiki/Convention_on_Biological_Diversity>[Accessed 23.03.2013].

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