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The bioregionalisation revival

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Abstract

The aim of this paper is to review some of the economic drivers of large scale bioregionalisation, using examples from deep sea hydrothermal vent communities, the Antarctic and sub-Antarctic, and Australia. These economic drivers are mainly recent conservation efforts, while early 20th century bioregionalisation was driven by 19th century taxonomy and exploration to assess available biological resources for economic exploitation. Modern regionalisation, particularly of the Antarctic and deep sea hydrothermal vent communities, are driven by conservation studies to protect areas from economic exploitation, rather than biogeographical questions concerning endemism and natural classification.

Key words: Antarctica, Australia, bioregionalisation, conservation, deep sea biogeography, hydrothermal vent communities, resource exploitation

Introduction

Bioregionalisation, the classification of the Earth into natural biotic units (e.g., vegetation, biotic areas, endemic areas), has been an ongoing practice that may be traced back to 18th century geography and taxonomy (Nelson 1978). As a form of area classification, bioregionalisation has become a mainstay of plant and animal geography (later called biogeography), which has flourished between intermittent periods of inactivity. Early flourishes are traditionally seen as driven by early natural resource exploration for the purpose of utilisation and exploitation. More recently, however, biological surveys are also used to assess what remains to be conserved. With another revival before us, namely the regionalisation of the sea floor, I hope to reveal what is driving bioregionalisation today, how it differs from earlier attempts and, whether these regionalisations will stand the test of time.

Speaking at the 500th meeting of the Cambridge Natural Science Club on March 12, 1894, Alfred Russel Wallace finished off his presentation on a poignant topic, reminding us that bioregionalisation is like any other classification system, a tool that serves a purpose:

> “There is thus, in my opinion, no question of who is *right* and who is *wrong* in the naming and grouping of these [zoological] regions, or of determining what are the *true* primary regions. All proposed regions are, from some points of view, natural, but the whole question of their grouping and nomenclature is one of convenience and of utility in relation to the object aimed at” (Wallace 1894: 613, original emphasis).

Australian bioregionalisation is a prime example of large-scale classification occurring in the 19th century which underwent a revival in the 20th century, driven by different purposes as our conceptualisation of the use of bioregionalisation changed. The early exploration of colonial Australia, for instance, uncovered sufficient information for the British Crown to fund Baron Ferdinand von Mueller as botanist to the North Australian Exploring Expedition. Based on his and other’s observations, von Mueller presented the first classification of Australia’s natural biological regions (von Mueller 1857), a practice that marked the beginnings of Australian biogeography. Indeed, a large part of early Australian regionalisation was commissioned by the colonial government and British Crown, and were driven primarily by the need to catalogue the resources available for exploitation, for instance to “find plants that might be useful for the newly developing imperial plantation

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economy" (Verran 2009: 176). These included the North Australian Exploring Expedition (1855–1856), the Horn Expedition to Central Australia (1896) and several smaller state-wide expeditions commissioned by Colonial governments, the British Crown, and Joseph Banks (see Ebach 2012). These expeditions resulted in the first Australian botanical and zoogeographical regions, which were used by biogeographers for the 19th and 20th centuries. Since the original flurry of Australian large-scale regionalisations, the frequency of new continental scale regions decreased until 1995, when another governmental driven initiative resulted in a revival in continental scale regionalisations.

The Australian Government funded *Interim Biogeographical Atlas for Australia* (IBRA, Environment Australia 2000) and the *Integrated Marine and Coastal Regionalisation for Australia* (Commonwealth of Australia 2006) were two continental scale regionalisation projects which heralded this revival. Unlike the original projects, their aim, "identify appropriate regionalisations to assess and plan for the protection of biological diversity" (Environment Australia, 2000: 4), is driven by the need to identify areas of conservation. The regionalisation itself is based on data such as vegetation, topography, climate and soils, which together provide areas of overlap through the development of state and federal databases. While IBRA and IMCRA have not used existing regionalisations (other than vegetative maps), they have utilised data from areas such as agriculture, forestry, mining and water resources. Conservation, however, was not their only aim. IMCRA was created to assess "the scale and extent to which different human activities affect either biodiversity and/or ecological processes and the extent to which these human activities or impacts can be managed [...] As such, biogeographical regions or bioregions provide the boundaries and framework for biodiversity or conservation management and the integrated, multiple-use management of other specific human activities or uses, such as fisheries, mining and tourism" (IMCRA Technical Group 1998: 3). Hence, while both the 19th century projects and both IBRA and IMCRA are government funded initiatives aiming to determine natural biological areas, their motivating purpose was quite different: originally primarily exploitation, later emphasis on conservation while allowing ongoing resource use. But is this true for other parts of the world?

Globally there has been regionalisation proposed as far back as Forbes (1856) for marine regions, Candolle (1820) and Sclater (1858) for terrestrial areas (Parenti and Ebach 2009). More recent bioregionalisations provided by Udvardy (1975), Olson *et al.* (2001) and Spalding *et al.* (2007) are driven by concerns about conservation:

> "Biological conservation has then two theoretically founded aims, viz. the preservation of members of the biota (individuals, populations, species, etc.) and the preservation of functional ecological systems. Cataloguing both of these is a biogeographical task, thus we now focus on biogeography" (Udvardy 1975: 5, original emphasis).

In order to preserve biodiversity, conservationists have turned to biogeography, making a scholarly topic highly applied. The issue here is not how biogeographical areas are chosen, but why we bioregionalise. Where as 19th century bioregionalisations were about discovering natural or endemic regions in order to determine the extent of biological resources, they are now "used to estimate the urgency of action based on the opportunities for conserving distinct units around the world" (Olson & Dinerstein 1998: 509).

The change in why we bioregionalise from exploitation to conservation, can be seen in present day continental scale bioregionalisation. I will use a recent example that focuses on two of the largest and relatively unexplored regions on our planet: Antarctica and the ocean floor. Like Australia, these areas host phenomenal amounts of resources, from the coal and ore deposits in Antarctica to the manganese deposits on abyssal plains, the gold and base metals extruded from mid oceanic vents, the potential near shore oil and gas deposits, and fishing. In addition, these underpopulated areas are also at risk of human impact in the form of tourism and field science (Ramirez-Llodra *et al.* 2011). The broad range of readily exploitable resources available with a potentially high environmental impact of extraction, has driven conservation science to designate 15 regions that "identify biologically distinct areas in need of representation in a protected area network" within the ice-free regions of Antarctica (Terauds *et al.* 2012: 726). This recent Antarctic regionalisation heralds a revival in bioregionalisation, with the emphasis on conservation, while also harking back to earlier drivers, namely exploration and resource exploitation.

The early exploration of Antarctica was driven by the need to improve maritime navigation systems, which were crucial to trade and utilisation of marine resources:

> "In the beginning of the year 1839, the British Government having determined on fitting out an Expedition, for the purpose of investigating the phenomena of Terrestrial Magnetism in various remote countries, and for prosecuting Maritime Geographical Discovery in the high southern latitudes, H.M ships Erebus and Terror [...] sailed from Chatham on the 29th September 1839..." (Hooker 1844: v).

In turn, this lead to many scientific partnerships during the 19th century and a push toward Antarctic exploration (Cawood 1977). The latter resulted in the first Antarctic biogeographical regionalisations, from the Swedish Antarctic Expedition (1901–1903), the British Antarctic "Terra Nova" Expedition (1910) and the Australasian Antarctic Expedition (1911–1914). Results of each had divided up Antarctic and the sub-Antarctic islands into taxon based provinces (e.g., Skottsberg, 1905 for plants; Waite 1916 and Regan 1914 for fishes) and laid the foundation for future Antarctic biogeographical research (e.g., van Oye & van Mieghem 1965).

However, present day Antarctic bioregionalisation has a different driver. Terauds *et al.* (2012) have earned their place in Antarctic biogeography by creating the 15 Antarctic Conservation Biogeographic Regions (ACBR), a bioregionalisation that encompasses all taxa. Conservation to protect natural areas, rather than exploitation, has driven this recent Antarctic regionalisation:

> "Despite a long history of biogeographic research in the Antarctic, spatially explicit conservation planning frameworks for the region are largely lacking [...] One exception is an Environmental Domains of Antarctica (EDA) analysis based on abiotic variables [...] However, the EDA contains no biological information. Our aim here is therefore to develop further the EDA with additional data on the distribution of biodiversity to provide a systematic environmental-geographical framework comprised of a first tier, spatially explicit set of Antarctic Conservation Biogeographic Regions" (Terauds *et al.* 2012: 727).

> "In conclusion, our work provides a novel first-tier set of sites that should form the basis of a '*systematic environmental-geographical framework*' for conservation management of the terrestrial Antarctic" (Terauds *et al.* 2012: 736 original emphasis).

Unlike Australian and Antarctic regionalisation, which have their origins in the 19th century, deep sea bioregionalisation is a more recent pursuit, has in part been driven by economic and military aims. The development of the French-American Mid-Ocean Undersea Study (Project FAMOUS) was initiated in order "to provide data on the details of the spreading process of the Mid-Atlantic Ridge" (Heirtzler & Van Andel 1977: 481). Run through the Woods Hole Oceanographic Institute (WHOI) and funded by the US government with ships supplied by the United States Navy, Project FAMOUS consisted of four components: taking geological and geophysical measurements, training a new generation of divers, diving onto the ridge, and holding French-American planning committee meetings (Heirtzler & Van Andel 1977). The United States Navy coordinated the logistics and chose the company to build a new deep sea submersible Alvin:

> "Alvin's first decade of operations [1965–1975] had focused more on engineering and operational matters than on science. Only a few scientists, almost all from Woods Hole, had ever used it [...] In the oceanographic community at large, most people considered Alvin a Woods Hole toy " (Toye 2000: 66 original emphasis).

This should not come as a surprise. Since 1965, Alvin was an economic/military driver for deep sea exploration, such as salvage work for the United States Navy as well as establishing deep sea listening posts, radioactive waste dump surveys and drilling (WHOI History of Alvin: http://www.whoi.edu/page.do?pid=10737). Given the Cold War was in full swing one should not wonder that "Alvin was a Navy project and scientific concerns were secondary. Even when researchers had made plans to use the submersible, the need to recover a lost hydrogen bomb trumped intellectual missions" (Dennis 2003: 813). Yet Alvin is also famous for discovering the deep sea hydrothermal vent communities, which lead to current deep sea bioregionalisations

> "The submarine hydrothermal activity on and near the Galapagos Rift has been explored with the aid of the deep submersible Alvin [...] In the course of our explorations, we discovered extraordinary communities of organisms living in the thermal vent areas at the rift axis ..." (Corliss *et al.* 1979: 1073–1074).

Discoveries like these are serendipitous and result in future surveys, some that have recently shown hydrothermal vent communities to be far more diverse geographically, leading to an increase in world-wide biogeographical provinces:

> "These discoveries have suggested the existence of separate biogeographic provinces in the Atlantic and the North West Pacific, the existence of a province including the South West Pacific and Indian Ocean, and a separation of the North East Pacific, North East Pacific Rise, and South East Pacific Rise" (Rogers *et al.* 2012: e1001234).

Deep-sea bioregionalisation was originally driven by economic and military drivers, as well as the potential for resource exploitation; however, as the vast biodiversity of the ocean became apparent, conservation had become a more influential target:

> "However, the deep sea has remained rather remote from public consciousness and the first exploitations and anthropogenic activities did not have any major social impact. The deep sea was (and still is) perceived as a service provider [...] In the last decades, decreases in the amount of land-based and coastal resources combined with rapid technological development has driven increased interest in the exploration and exploitation of deep-sea goods and services, to advance at a faster pace than the acquisition of scientific knowledge of the ecosystems. […] Human encroachment into the deep sea creates a new conservation imperative. Effective stewardship of deep-sea resources will simultaneously require continued exploration, basic scientific research, monitoring and conservation measures. Each of these activities will benefit from application of basic ecological and conservation theory" (Ramirez-Llodra *et al.* 2011: 2–19).

Studies like that of Rogers *et al.* (2012) eventually lead to the classification of our remaining biological resources in the form of worldwide regionalisations. While much of the sea floor remains undiscovered, the rate of exploration will over time see a dramatic increase in biogeographical provinces or bioregionalisation, perhaps the largest yet, with 75% of the Earth left to carve up into natural biotic areas. As the area covered by large-scale regionalisation increases, so too will the biotic investigation within these large areas, resulting in the development of numerous small-scale bioregionalisations.

The development of bioregionalisations is crucial to our understanding. However, will current attempts at bioregionalisation stand the test of time? After all, a conservation biologist and a taxonomist/zoogeographer, for instance, will classify regions differently for different reasons.

It is difficult to assess the longevity of any bioregionalisation, but it is possible to make some predictions based on the pattern of bioregionalisation over time. Large-scale regionalisations are the first step in most biogeographical studies made by geographers and taxonomists. Following this is the inevitable process of revising larger areas into smaller taxon specific provinces or endemic areas creates a plethora of regions aimed specifically at a certain taxon or vegetation type, as seen in Australian biogeography (Ebach *et al.* 2013). Sometimes this effectively re-writes the original large scale regionalisation. While in other cases, many of these large regions are still in use after centuries or use, for example, Indo-Pacific (Perrier 1878), Bassian (Spencer 1896), Sonoran (Merriam 1892), Antillean [Caribbean] (Wallace 1876).

Following this, new bioregionalisation revivals at continental scales, which apply to all taxa described on a small scale, have an integrative and potentially lasting effect. Given that present regionalisations made by conservationists are generated using Geographical Information Systems based on specific point data (e.g., rainfall, vegetation types etc.), they are far more precise and user-friendly than traditional mud maps. These new bioregionalisations are more likely to stand the test of time, and can serve as a framework for continuing regionalisation on both the small and large scale. For example, the smaller IBRA regions are being combined to form larger biotic areas in new regionalisations, which in turn resemble older established regions (e.g., Ladiges *et al.* 2011). While this is not problematic, it does raise the question why older regions are not retained in the first place? In any case, for areas that have not been regionalised, a systematic and rigorous approach is needed, whether the driver is conservation, economics or scientific enquiry.

The ACBR of Teraud *et al.* (2012) and the biogeographical provinces of Rogers *et al.* (2012) might be utilised in similar ways by future biogeographical studies, however each represents a different stage of development. The ACBR represent a maturing bioregionalisation similar to that of IBRA, first launched in 1995, and is more likely to be utilised long term. Deep-sea hydrothermal vent regionalisation, however, is in its infancy, still growing rapidly with each exciting discovery. This is likely to be followed by a multitude of small-scale regionalisations, which will be updated, renamed and rewritten as additional discoveries are made. Interestingly, the drivers for each of these recent examples are the same, namely economic exploitation of fragile barely known areas and the need for a better knowledge of areas for conservation management. Unlike the regionalisation of the 19th century, more recent regionalisation is driven by both factors, regardless of whether the regionalisation is in its infancy, or a more mature revival of an existing classification. Understanding the changes in these drivers is both historically important and relevant to biogeography today.

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