Enchanting Islands : Insular Biology Revisited

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Date of Submission: 8th February, 2015 Date of Acceptance: 16th February, 2015

Abstract

Islands represent small, isolated "microcosms" with discrete boundaries, they vary greatly in size, age, isolation, shoreline structure, topography and geology. Due to their isolation from more widespread continental species, islands are ideal places for unique species to evolve. Island biogeography is the study of the distribution and dynamics of species of island environments. In species diversity, Island Biogeography not only highlights allopatric speciation (new gene pools arising out of natural selection in isolated gene pools) but also considers sympatric speciation (different species arising from one ancestral species). Thus islands house unique species – relics of the old – the survivors and the products of evolution – the new species. The Island Biogeography Theory – aptly termed the 'First Law of Conservation Biology' applied to habitat fragments spurred the development of the fields of conservation biology and landscape ecology.

Keywords : Island Biogeography, Insular Biology, Equilibrium Theory of Island Biogeography, allopatric speciation, sympatric speciation

"……….. in the sea of life enisled,
With echoing straits between us thrown,
Dotting the shoreless watery wild,
We mortal millions live alone.
The islands feel the enclasping flow,
And then their endless bounds they know ………"

"Matthew Arnold - "To Marguerite"

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1. Introduction

Islands have always fascinated biologists. Representing small, isolated "microcosms" with discrete boundaries, they vary greatly in size, age, isolation, shoreline structure, topography and geology. These "isolated ecosystems" may be formed either by the disappearance of a connecting land bridge from the mainland or by land rising from the sea. A land mass could be cut off from the mainland if the sea rises in between or if the joining-land is eroded. For both these instances, the island formed will have the flora and fauna already in place. But for islands rising out of the sea (as a result of volcanic activity), this is not the case. Such land masses await the "colonizers" and later succession- species to cross many hundreds of miles of ocean.

Due to their isolation from more widespread continental species, islands are ideal places for unique species to evolve. The patterns of species distribution can usually be explained through a combination of historical factors such as speciation, extinction, continental drift, glaciations and river capture, in combination with the area and isolation of land masses and available energy supplies[1].

2. Objective

While **biogeography** is the science which deals with geographic patterns of species distribution and the processes that result in such patterns, **island biogeography** is the study of the distribution and dynamics of species of island environments[2]. Not surprisingly, they are widely studied by ecologists, conservationists and evolutionary biologists alike and is the main reason for reviewing this topic.

3. Island Biogeography and Insular Biology

The **Equilibrium Theory of Island Biogeography** is the brain child of Robert McArthur and E.O. Wilson in 1967[3]. The theory holds that the number of species found on an island, designated the **equilibrium number**, is determined by two crucial factors – the effect of distance from the mainland and the effect of island size. These, in turn, would affect the rates of **extinction** and **immigration** on the islands.

The basis of this theory supposes that there is a large source area of species and surrounding the source area is a series of islands of different sizes and distances from the source area. Species disperse from the source area to the islands. In the theory's simplest form, species from the source area disperse to an island at a rate known as the **immigration rate**, depending on the distance of the island from the source area. At first, almost every organism arriving on the island will be a new species, so the rate of immigration for the island will be high. As the number of species on the island increases, many of the organisms arriving on the island will be of species already present. So the rate of immigration will decrease and eventually fall almost to zero as the number of species rises.

Species which have colonized the island will simultaneously run the risk of **extinction**. The **extinction rate** rises as the number of species on the island rises. Initially when the number of species on the island is small, the immigration rate exceeds the extinction rate and the number of species is on the rise. As the number rises, the immigration rate is on the decline but the extinction rate shows an upward trend. Eventually a point is reached where the rate of immigration equals the rate of extinction. At this point, the number of species attains an equilibrium. Addition of new species balances the loss of species by extinction. This equilibrium/balance gives the theory its name. The theory predicts that the number of species will be lower on isolated or smaller islands than on closer or larger ones.

One famous 'test' of the MacArthur-Wilson theory was provided by Nature herself in 1883 by a catastrophic volcanic explosion that devastated the island of Krakatoa, located between the islands of Sumatra and Java. Though the flora and fauna of this and adjoining islands were nearly exterminated, yet within 25 years thirteen species of birds had successfully re-colonized.

Between the explosion and 1934, thirty-four species actually became established, but five also went extinct. During the period from 1934 to 1985, a further fourteen species had become established but parallely eight had gone extinct. As per the predictions of the theory, the rate of immigration reduced as more and more species colonized the island. With approaching equilibrium, the number in the cast remained roughly the same, while the "actors" gradually changed.

4. Island biota and Evolutionary Implications

Island biota has certainly been inspirational for evolutionists like Charles Darwin and Alfred Russell Wallace. A striking problem in the validity of the Equilibrium Theory is that it does not include the addition of species *in situ* by evolution. This is very important especially on islands far from the source of new species. Evolution can increase the number of species on the island without the requirement of immigration. This may make it more difficult for "new arrivals" to colonize successfully as the available niches have already been filled by species which have evolved to be a "perfect fit" in each niche [4].

The apparent rate of evolution on islands is sometimes amazingly rapid. For instance, there are nearly 50 species completely adapted to cave life on the Hawaiian Islands. Each of the five main islands of the archipelago has its own endemic (exclusively native to the biota of a particular place) species. In fact, 70.8% of the ferns and 94.4% of the angiosperms of this region are endemics, which could either be products of evolution or survivors of original mainland species.

Colonizers arriving on an island group adapt to suit conditions of that particular island that they are to occupy. Such changes result in a group of closely related species on the archipelago. This speciation process is a form of **adaptive radiation**. Darwin noted the striking effects of adaptive radiation in the finches of Galapagos Islands. The variation from island to island in a closely related group of finches which appeared to have a common ancestor drew his attention to the possibility of a selection process resulting in the production of new species. The variation in Galapagos Islands certainly triggered Darwin's thoughts on the "origin of species."

The other major evolutionary feature of islands is the way in which some species take on very unusual forms or structures which are not typical of the group found on the mainland. The lack of predators seems to have resulted in the evolution of ground-foraging flightless birds. A predator being absent flight has become unnecessary and the lack of ground-dwelling mammals has resulted in nil competition with ample food supply for these birds. Such is the instance in New Zealand where the kiwi and the flightless parrot kakapo occupy the niches of the foraging mammals[5].

But islands contain not only new species but very old relic species as well. A good example is St. Helena, a volcanic island in the South Atlantic Ocean almost 2000 km. away from the mainland of Africa. The island contains several endemic genera more closely related to genera in Australia, South America, India and Madagascar than to genera in Africa. This island is closer to Africa than to any other land mass. Such a strange distribution suggests that the endemic genera are relics of an earlier period when their ancestors were spread worldwide. The earlier genera survived in Australia, South America, India, Madagascar and St. Helena but went extinct in Africa. The endemic woody members of the daisy family, the Asteraceae in St. Helena are probably descendents of an ancient woody species.

In species diversity, Island Biogeography not only highlights **allopatric speciation** (new gene pools arising out of natural selection in isolated gene pools) but also considers **sympatric speciation** (different species arising from one ancestral species). Thus islands house unique species – relics of the old – the survivors and the products of evolution – the new species.

5. Correlation with Conservation Biology

Though the lessons of island biogeography are age old, they have tremendous implications for the future. The Island Biogeography Theory – aptly termed the '**First Law of Conservation Biology**' applied to habitat fragments spurred the development of the fields of **conservation biology** and **landscape ecology.**

Continental species are experiencing an unprecedented level of habitat fragmentation as a result of anthropogenic activities. Suitable habitat is becoming fragmented into small patches located in a "sea" of disturbed land. These small patches function very much like isolated islands in a real sea. Mountains surrounded by low-lying land are also comparable with real islands cut off from one another by water, so mountains are isolated by "seas" of low-lying land. Species located in these habitat fragments become more vulnerable to extinction because of the same factors (small geographic range, low population numbers besides natural causes such as disease, fire and normal population fluctuations) that doom their island cousins. The theory can be a great help in understanding the effects of habitat fragmentation, including forecasting floral and faunal changes caused by fragmenting previously continuous habitat[6].

The utilization of island biogeography theory in determining the most effective reserve design has recently been an important issue in conservation. Yet, islands themselves have also been an issue in conservation biology, mainly due to detrimental human impacts in island environments.[6] There are numerous heated debates as to what type of impact the earliest human colonizers had on island ecosystems. Some ecologists and biogeographers argue that most of the earliest island colonizers were respectful of the island ecosystem, and that negative impacts occurred only after secondary arrivals of colonizers conflicted with the interests of the initial inhabitants. Others argue that earliest inhabitants of some islands devastated the environment because of their ignorance and negligence concerning island ecosystems. One rather undisputed fact is that as human communities on islands reached the carrying capacity, humans often modified island landscapes to support the rapidly growing population. A classic example is the terracing of steep terrain on islands in order to maximize agricultural productivity[7]. Through history and into the modern age, negative anthropogenic impacts have continued and increased. Humans can easily damage pristine island environments in four ways: overexploitation and predation by humans, habitat loss, fragmentation, and degradation, as well as introduction of exotic species and diseases (biological invasions).

6. Looking to the Future

By identifying potential mechanisms underlying the loss of species diversity, Island Biogeography Theory may help suggest ways of designing nature reserves to maximize their ability to maintain diversity. The recommendation that "a single, large reserve protects more biodiversity than several smaller reserves of equal size" has led to the debate known as SLOSS (single large or several small) described by writer David Quammen as 'ecology's own genteel version of trench warfare[8].

While certain conservation planners maintain that one large reserve can hold more species than several smaller reserves, and that larger reserves should be the norm in reserve design, other ecologists emphasize that **habitat diversity** is as or even more important than size in determining the number of species protected.

While research in this field forges ahead with classic biogeography expanding with the development of molecular systematics to create an all new discipline of **phylogeography**, the work of Nature also continues relentlessly on these islands. Certain facts even now remain unaccountable by ecological theory, as the work of Nature like her ways is never completely understood or explained.

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