SELECTED CONSERVATION TOPICS WITH A CONCENTRATION ON SRI LANKA

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Module # 2

Island Ecosystems

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What Are Islands?

In very simple terms, islands are areas of land that are completely surrounded by water and smaller in size than Australia (the world's smallest continent at 7.6 million sq. kms. By contrast Greenland, the world's biggest island, is 2.2 million sq. kms.) There are two main types of true islands – oceanic and continental.

Oceanic islands are built up from the ocean floor through volcanic processes and are part of the underlying basalt structure of the earth and not in any way attached to continents. The Galapagos Islands and the Hawaiian chain are examples of classic oceanic islands.

Continental islands, on the other hand, are effectively part of the geological structure of neighbouring continents and were at one time attached to those continents either via land bridges or as continental mountaintops prior to a rise in sea level. Java, Tasmania, Japan and Sri Lanka are examples of the former type of continental island while Norway and Scotland typify the latter.

The very different formation histories of these two types of islands ensure that their ecological structures are also quite different. Continental islands, having at one time been attached to larger, continental landmasses, tend to have floral and faunal populations similar in function and arrangement to those larger landmasses. Of course the degree of difference or similarity will be a function of the length of time that the island has been separated. Oceanic islands evolve from beneath the ocean surface, usually in a violent eruption of fire and ash, so their plant and animal life necessarily start from scratch.

Therefore when a continental island is first formed by the disappearance of a land bridge, it already has a developed ecosystem. The total number of species on the new island may approximate that on the mainland. However due to the decrease in habitable area resulting from the separation, some species – particularly those requiring large areas – will not be able to survive in their new environment. As a result species numbers on continental islands will generally decline after the separation. Oceanic islands, however, are starting from bare rock and absolutely no inhabitants and therefore rely on the immigration of species in order to make them biologically vibrant.

The Colonization of Islands

The arrival of plant and animal species from a source – be it the mainland or another, pre-existing island – to a newly created island depends on a number of factors. These include the size of the new island, its distance from the source and the climatic features of the area. The colonization of new islands is essentially a random process so the chance of a species arriving on a small island or one very far from the source will be much less than the chance of it landing on a larger island or one close to the mainland. This means that for very remote or very small islands, the gap between the arrival of species can be enormous. The Hawaiian islands, for example, are a relatively small chain of volcanic islands situated in the middle of the Pacific Ocean, approximately 3500kms west of the continental United States, a similar distance north of the South Pacific islands and even further away from Alaska to the north and Japan to the west (fig. 1).

Due to the very low probability of a dispersing species coming to rest on these islands the estimated gaps between arrivals are truly staggering: One plant species every 30 000 years, one land snail every 200 000 years and one bird species every 350 000 years. These estimates are based on the average age of the islands being 5 million years; however, it is believed that some of the smaller islands in the chain are as much as 20 million years old, which would make the arrival gaps even greater (Gorman 1979).

Of course, obtaining accurate information concerning island colonization is not easy. The recent birth of several oceanic islands however, has allowed scientists a rare insight into this intriguing phenomenon.

Box 1

The birth and development of two latitudinally different oceanic islands

An example of how climatic conditions can affect the colonization rate of new islands can be clearly seen in the comparison between two of the youngest islands on earth: Surtsey and Krakatoa.

The island of Surtsey, appropriately named after the Icelandic fire giant Surtur, was born dramatically on November 14, 1963 in an eruption of the North Atlantic ocean 40 kms SW of Iceland. While the rumblings did not stop for three and a half years, the colonization process got under way in relatively short order. Six months after the initial blast the first bacteria, fungi and even a species of fly were recorded on the barren, rocky isle. Within 2 years the first vascular plant, the sea-rocket (*Cakile edentula*), had established the beginnings of a colony. In 1967 the first moss colony was reported, and within three years 158 arthropods, one fifth of Iceland's total, were documented although not all of them became established on the island. In 1973, 10 years after the island was brought to life, there were 13 vascular plants and 66 different species of moss clinging to life on Surtsey. While the proximity of the new island to a source (Iceland) ensured that colonization would begin relatively rapidly, the harsh climatic conditions and very short growing season mean that this process will not be complete for many years to come.

This retarded colonization process is underlined when Surtsey is compared to the equatorial island of Krakatoa. A violent volcanic eruption between the source islands of Java and Sumatra created the tiny island of Krakatoa in the year 1883. Located in the species rich lower latitudes and just 25kms from Java, this island exhibited a much more rapid rate of colonization than its northern counterpart. Three years after its fiery inception the island was covered in a layer of blue-green algae and was home to 11 species of ferns and 15 vascular plants while at ten years old the entire island was drenched in thick vegetation. Fifty years on there were 271 identified plants, 36 bird species, 5 types of lizard, a crocodile species, a python species, 3 species of bat and one type of rat. It is interesting to note that the bird species had been stable for 21 years while the plant diversity was growing every year, an indication of their relative mobility and dispersal ability (Gorman, M. L., 1979).

How do species colonize islands?

The crossing

Saltwater provides an imposing and effective barrier for species of all kinds. For freshwater organisms the salt is potentially deadly, for land animals the water itself is a major obstacle while for plants it is often the combination of the two that refuses them easy passage. Therefore it seems rational that avifauna are the best suited for the colonization of islands, especially those close to a mainland. However, while birds and bats are often quick to make the crossing from source area to island habitat, they are not necessarily the first to establish themselves. While seabirds can inhabit rocky, barren islands, feeding on fish and scratching nest sites out of the sand or pebble, other species require some form of plant species to precede them. As if to comply plants have developed extremely varied methods of dispersal, which often allow them to be the pioneer species. Mosses and ferns specialize in utilizing the power of the wind to disperse their minute spores and as they send these tiny seed equivalents out by the million, they often succeed in landing upon virgin coastlines. Many plants that inhabit coastal areas on the mainland produce seeds that can float for long periods of time, even in saline waters. Occasionally these drifting seeds will be taken by the current and deposited on the shores of new islands where the colonization process begins. Other plants are even more cunning and take advantage of the dispersal ability of birds by producing seeds that are sticky or replete with tiny barbs or hooks, enabling them to hitch rides on feathers, while others manufacture seeds that can still germinate after passing through the digestive tract of a bird. Finally, it is possible for the seeds of some colonizing plants to arrive at their island destinations embedded in mud on the foot of a bird.

Of course oceanic islands are not inhabited only by plants and birds. With an expanse of open water between the mainland and the distant island it seems the only avenue available to terrestrial animals is to swim. While many are capable of doing so, particularly when the island is not far from the mainland, there are very few non-aquatic creatures with the ability to cross even relatively short stretches of water. The semi-aquatic monitor lizard is one exception and has been known to swim hundreds of kilometers between islands. The majority of land animals and freshwater mollusks, crustaceans etc. that make the journey to new oceanic islands do so riding on vegetation mats that enter the ocean from coastal areas after storms or heavy winds. The result of this is a very non-random selection of terrestrial organisms inhabiting oceanic islands as almost all would, of necessity, have originated in coastal areas of the mainland. Perhaps it is not so surprising, then, that many island ecosystems lack a wide range of land animals.

Aquatic, freshwater fish are also capable of traveling relatively small distances in ocean water. This rare phenomenon has been observed between the mainland and close, offshore islands in the northern latitudes where periods of sudden snowmelt cause the volume of freshwater entering the ocean to be particularly high. When the ocean water is sufficiently diluted by the input of freshwater from rivers and streams, it becomes possible for certain hardy freshwater fish to cross small ocean expanses.

Upon arrival…

It is not enough to make the journey from mainland or source island to a new island, for once a species has arrived it needs to become established. For this reason most colonizing species have high reproductive rates, allowing them to quickly secure a beachhead. If this is not done rapidly the probability that a random event will destroy the population before it can get started, increases. A second attribute that increases the likelihood of success for a colonial species is the ability to integrate with existing species and even adapt in various ways to fit into the new environment.

An excellent historical example of this type of behaviour comes from a mongoose species in the late 1800s. Brought to the West Indies from India in 1870 to reduce the damage done to sugar cane fields by rats (another successful colonizing species), nine mongooses were let loose in the fields. So successful were these individuals that by 1900 mongoose populations stemming from the initial group were established throughout the West Indies, northern South America, Hawaii and the Pacific islands. (Gorman, 1979). While humans aided their dispersal - they were brought by boat and moved between the Caribbean, Hawaii and the South Pacific in a similar manner - their ability to thrive in new and unknown environments was breathtaking. Of course it helped that rats had already established themselves in numbers to provide food. Interestingly, it is a lack of suitable prey numbers on islands that is responsible for many such islands lacking species high on the trophic (food) ladder. Those species, like top carnivores, that typically have large ranges, require sizeable prey bases and reproduce slowly are the least likely to effectively colonize islands. Species requiring specialized habitat also find themselves left out of many island ecosystems.

Super Tramps

Some species, most notably certain sea birds, specialize in colonizing new islands. They have developed extremely effective dispersal abilities that allow them to be the first occupants of small islands upon which they rapidly reproduce in order to establish themselves. Their goal however does not seem to be to carve out a long-term niche but rather to muster enough individuals to allow them to disperse again and colonize yet other uninhabited islands. These "super tramps" specialize in colonizing islands too small to maintain stable, long term populations and are almost invariably excluded from the islands eventually by more successful competitors that arrive later.

Theories pertaining to species numbers on islands

The general rule pertaining to islands is that they will contain fewer species than will a comparable area of mainland. This is because organisms are more easily able to move in and out of non-island areas. For the same reason it is often the case that the density of a given species will be higher in an island environment.
The number of species extant on any given island is a function of the size of the island and the distance it is from the source. In terms of island size, Darlington's rule of thumb states that an island one-tenth the size of another island will have half the number of species. That is to say that there is a linear relationship between island size and species number. Why this relationship exists is a contentious one involving two schools of thought:

1. Species numbers are a function of habitat diversity so a larger island will be more diverse than a smaller one, hence the increase in species numbers.

2. The number of species on an island is dependent on the size alone and has no relationship with the habitat diversity.

To confuse matters somewhat, both of these theories have resonance in the real world, making it difficult to apply one of them to all situations. Ignoring the reasons behind the concept what is true is that larger islands have more species than smaller ones and islands close to a source have more species than remote islands. This simple relationship has been formalized in what is known as the Island Equilibrium Theory.

Box 2

Island Equilibrium Theory

Introduced in 1967 by MacArthur and Wilson, the island equilibrium theory provides a model that aims to explain how the carrying capacity of an island is reached. It states that the number of species present on an island is a dynamic equilibrium between the continuing immigration of new species and extinction of old ones and that once equilibrium is reached the species numbers will stay constant while the composition of those species may change. The rates of immigration and extinction that create the species numbers at equilibrium are affected by three familiar factors: Time, island size and distance from source.

Early in the development of a new island the immigration rate will be high and the extinction rate low. This is because the chance of an arriving species being new to the island is great while the relatively low initial species numbers means that the chance of a species becoming extinct is reduced. Later in the evolution of the island, these rates will switch with the immigration rate being low and the extinction rate high as the island gets filled up with species. This leads to increased competition, which is manifested in reduced population sizes and correspondingly increased chances of a random event causing extinction.

The size of the island further affects the extinction rate, as a small island will become "full" much more quickly than a larger island. The distance of the island from a source affects the immigration rate with it being higher closer to a source and lower as the island becomes more remote. The satisfying aspect of this theory is that it is simple in application and can be tested in the real world, where it has been borne out.

The graphical depiction of this theory makes it easier to understand:

Graph 1- Equilibrium Theory

Competition on Islands

It is in the best interest of any species to avoid direct and continuing competition. Islands and island archipelagos have provided natural laboratories for scientists to study how this competition is important to the geographical or ecological separation of species. On mainland, tropical environments with rich biodiversity, it is often the case that individual species will be restricted to narrow ecological niches as a result of intense competition from other species. To determine how important the competition is with regards to habitat selection it would be necessary to remove competitor species and then observe whether the remaining species expand their niches. In the real world environment this is not very plausible, however many islands have evolved in just this manner, with a lower degree of competitive selection acting upon them. Observations indicate that indeed competition is instrumental in the division of an ecosystem by existing species. There are several "shifts" that species make from their typical mainland ecological niches when there is an absence of competition on islands. These are:

1. Abundance shifts – often species living on islands exist in higher densities than they do on the mainland.
2. Altitudinal shifts – species restricted to a particular altitudinal zone on the mainland often "spread out" and occupy all zones or different zones on islands.
3. Habitat shifts – species restricted to a particular habitat on the mainland similarly "spread out" and occupy different or a higher number of habitat types.
4. Vertical strata shifts – this occurs particularly in forest environments where species that occupy one particular level of a habitat on the mainland, come to occupy various levels on islands.

5. Diet shifts – this is a very rarely observed shift. It is when a species will actually change or expand its diet from that exhibited on the mainland.

Adaptive Radiation

On some very remote islands a process called "speciation" occurs. This is when populations that have derived from a single ancestral species become reproductively isolated and develop ecological requirements so different that sympatric existence becomes possible. Normally this process demands that the populations in question be geographically separated from one another by some physical barrier such as open water or mountains, which reduces the gene flow between them. For these topographical barriers to be effective species must lose their original dispersal ability which brought them to the island in the first place. While this seems unlikely it does happen with birds becoming flightless, insects losing their wings and the seeds of some plant species losing their "parachutes". When speciation occurs to such an extent as to produce a series of closely related species with different ecological requirements it is called adaptive radiation.
For island niches to be filled by this process and not by immigration, two conditions must be present:

1. The island must be sufficiently large and contain enough topographical relief for effective reproductive isolation. Obviously the size of the island required for speciation to occur differs from taxon to taxon.
2. The island must be sufficiently remote as to make dispersal to it difficult. As different groups have different dispersal abilities it is possible for speciation to occur in one group and not another on the same island.

When a species evolves in this manner it becomes peculiar to one particular island or archipelago and is found nowhere else in the world. This is known as endemism and the species is referred to as endemic. The Hawaiian Islands are a famous place for studying adaptive radiation for they fulfill both criteria that allow this process to occur. In fact so remote are they that after a minimum of 5 million years they still do not have any freshwater fish, amphibians, reptiles or land mammals. The floral makeup of the Hawaiian Islands meanwhile is upwards of 90% endemic.

Threats to Island Species

Endemic species, with their unique features, exist in relatively limited numbers and inhabit a very limited geographical range. This makes them prone to extinction from random events, disease, competition from introduced species or more frequently, human activities such as hunting and habitat destruction. Because of this, island habitats hold a special conservation implication.
An example of the inherent fragility of island species comes from the history of avian extinctions. Of all the world's avifauna, only 10% exists on islands. However, of the known 94 species of birds that have become extinct in the past four centuries an incredible 88 were island endemics.

Continental Habitat "Islands"

While real islands are surrounded by water, there are numerous habitats on continental environments that exhibit typical island characteristics in that they are effectively surrounded by inhospitable vegetation or habitat. Desert oases, sphagnum bogs and high altitude forest patches are examples of this. Like real islands these continental habitat "islands" contain specialized species and depend on a similar pattern of immigration and extinction. However the isolation between real islands tend to be more absolute than those between habitat "islands".
With an ever increasing human population and a matching rate of expansion into previously undisturbed natural areas the need to protect remaining ecosystems has become more acute. Protected areas in the form of national parks or nature preserves are therefore essentially becoming "islands" of nature surrounded by seas of human endeavour. As a result, theories relating to island ecosystems are gaining more significance with regards to the planning and maintenance of protected areas.

Relaxing to Equilibrium

Unlike real islands that start with nothing and then gradually fill up with arriving species, continental habitat islands tend to go through a different pattern. As a protected area is effectively chiseled out of an existing swath of natural habitat it is already populated with an established selection of species. Depending upon the effectiveness of the area's protection and the degree of habitat destruction outside the boundaries, there may be an initial influx of species seeking the relative safety that the protected area offers. However as the new preserve is smaller in extent than the original undivided environment, its carrying capacity will be smaller. Therefore at the beginning there will usually be an inappropriate floral and faunal species density making the protected area supersaturated. With so many species in a restricted area the subsequent pattern displayed by the park or preserve is to decline in species numbers due to low immigration and high extinction rates. This is euphemistically called "relaxing to equilibrium". The rate at which an area will undergo this process primarily depends upon the size of the area, with small areas losing their "excess" within 10 000 years. Although not exactly a "small" island Java, in the Indonesian archipelago, has lost many of its larger mammal species that were present during the ice-age when it was still connected to Sumatra via a land bridge. Sri Lanka's relatively large size ensures that the rate of "relaxation" is slow.

There are certain characteristics that make a species prone to extinction. These are:

1. Low population densities
2. Very large range requirements
3. Being high up the trophic ladder
4. Living only in rare habitats

Reserve Design

There are some basic tenets that relate to reserve design that have come directly from the study of island habitats. Of these the most consistently apparent is summed up in the mantra Bigger is Better. Simply put, the more habitat area that is enclosed within the protected ecosystem the higher the number of species that can be supported within the area. Where two areas are to be protected a connector between them is of value, as it allows for the dispersal of species from one area to the other. The conventional way of thinking always had it that it was better to make one large preserve than three separate ones of equal size however this has become more and more site specific as the existence of three (or more) protected areas has its own benefits. These include the fact that multiple parks or preserves are less susceptible to natural disasters such as disease or fire than a single park, they allow for the parallel existence of competitors and are essential for the protection of rare or scattered (or both) habitats.

The Sri Lankan Example

Sri Lanka is a proto-typical continental island that was at one time connected to the Indian mainland through a land bridge at Adam's bridge. This ancient isthmus allowed for the passage of flora and fauna between the two landmasses ensuring that their respective species compositions are very similar. When the earth's climate warmed and the glaciers melted, sea levels rose around the world drowning out many land bridges such as this and beginning a period of separation between the mainland and the island now known as Sri Lanka. The length of time that these two environments have been separated is reflected in the subtle changes in species morphology between Indian populations and those in Sri Lanka.

Focusing upon the mammals, there are a number of species residing in Sri Lanka that bear a compelling resemblance to, but remain largely distinct from, their Indian counterparts. Within the primate family both the endemic toque macaque monkey and the larger endemic purple-faced langur have very similar distant relatives living across the Palk Strait. The toque macaque (*Macaca sinica*) his like India's bonnet macaque (*Macaca radiata*). However morphological differences are obviouse in head hair and ear pigmentation, which amongst other factors classifies them as different species. When looking at the Purple faced langur (*Semnopithecus vetulus*) of Sri Lanka a casual observer may well mistake it for its northern cousin from the Indian Ghats, the Nilgiri Langur (*Semnopithecus johnii*). It takes a trained eye to see the minor morphological differences that separate the two. These are ideal examples of how speciation and then endemicity occur in the event of long-term separation.

Sri Lanka's leopards are also different, in certain ways, from those of the Indian sub-continent. They were all grouped together under the scientific name *Panthera pardus fusca* until relatively recently when a study by Mithipala et al (1995) suggested that the Sri Lankan race is in fact genetically different from the Indian and deserves its own sub-species delineation – *Panthera pardus kotiya*. Whether this genetic difference is accompanied by behavioural and morphological differences is the subject of on going study.

<u>Sinharaja - An island within an island</u>

With 11 250 ha of rolling hills (representing just 5% of its original extent) Sinharaja is Sri Lanka's last remaining patch of virgin rainforest and its only representative of lowland evergreen rainforest. Unique in the entire sub-continent region in that it receives a surplus of water throughout the year, Sinharaja is truly an island within an island. As a classic continental habitat island existing within the larger context of Sri Lanka it encapsulates the wondrous diversity and tender fragility of island ecosystems.

Of the more than 400 species of birds extant in Sri Lanka there are 23 endemics, 95% of which have been found upon the forested slopes of Sinharaja. It is within the rain-drenched Sinharaja environment that upwards of 60% of Sri Lanka's 830 endemic plants can be found (reference). The number of endemic species of amphibians and insects are also quite high although the process of documentation is still in its infancy so meaningful statistics are hard to come by.

With no other habitat within the region, let alone the island, offering alternate areas for the denizens of Sinharaja it is an ecosystem unfairly indebted to the future decisions of the island's people. The wealth of this forest habitat is in grave danger as it cannot afford further fragmentation or denudation and therefore must be carefully and fully protected.

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