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Introduction

Forest degradation often implies a severe change of environment for wildlife. Restoration for wildlife rehabilitation may take very long time if target animals are canopy dwelling species associated with large trees. On the other hand, most species are able to adjust to a modified environment provided some basic requirements are met *viz.* food, shelter and mobility. Although there are some habitats that tend to attract a wide variety of wildlife, species have different requirements and there are interspecific competition, so what is good for one may be bad for another. There tend to be two different strategies for habitat restoration[1]: one is targeting general revitalization of an ecosystem that will attract a rich biodiversity, the other targeted to one or few specific and usually endangered animal species. Example of a general habitat restoration is aeration of small lakes or ponds and restoring the bank vegetation because aerobic conditions of water can support a lot more species than anaerobic. Another example is turning a mono-species natural or man-made vegetation into a more species diverse ecosystem. Example of the single species target is creating habitat for gibbons by planting their favourite fruit trees. Whether focusing on general habitat restoration or single species, change of habitats implies consequences for a number of species since any species has a range of associated species. Sometimes introduced large animals are used to maintain a specific prioritized condition that will benefit the desired target species.

Habitat restoration may imply both physical changes (e.g. water flow, drainage, creating soil slopes / hills and modifying light conditions by thinning or enrichment planting), and biological changes (e.g. planting or removing specific plant species that will create the desired conditions. Forest habitats may take several years to establish. Forests are also dynamic, so conditions will change over time. Hence, animal species may appear and disappear as a natural response to changes. Many animals can survive in a wide variety of habitats while others are quite critical. Where specific species are addressed, their biology and environmental requirements must be known.

Changes in environment necessarily mean changes in conditions for those animals already living there. While for example aeration of ponds may appear a universal solution to restore a lake, it will inevitably deteriorate the conditions for anaerobic organisms.

Objectives for habitat restoration

Habitat restoration aims at improving the environment for one or more specific species, or for a wide range of species. It is a restoration activity where key emphasis is on conservation of animals, and the aim is not necessarily a reversion to a previous stage of environment. Habitat restoration is often an integrated part of a broader physical or biological restoration effort. Habitat restoration may also be used as a stepping stone for self- restoration; creating better habitats for wildlife may initiate animal seed dispersal which in turn will lead to an even more diverse ecosystem.

Basic requirements for wildlife

For wildlife to survive in a given habitat, they must have access to food and water throughout the year, they must be able to escape excessive predation, parasites and diseases, and they must have conditions

[1] A broader concept, ecosystem restoration is often used for the strategy of improving the whole ecosystem

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suitable for breeding. If any of these elements fails, species will eventually go extinct.

Food supply may change throughout the year, and juveniles sometimes have different requirements than adults. Some animals rely on few species; others need or can cope with a shift between a wide range of species. Obligate frugivores often rely on critical resources outside of main fruiting seasons. Some tree species like *Ficus* and species of Myristicaceae tend to provide fruits during the lean season.

Shelter should provide a reasonable cover to protect from predation (preys) – (cover may also provide reasonable cover for predators). Some parasites tend to be abundant under particular environments; these can expose animal to high stress if they cannot escape.

Breeding behaviour in animals are often complex. General stress (shortage of food, shelter, etc.) often results in animals ceasing to breed. Specific stress factors such as disturbance during mating season, specific environments during courtship, lack of nesting sites can reduce or completely prevent breeding behaviour and consequent population rejuvenation. Interpreted inversely, lack of breeding success is often the first indication of animal stress and will inevitably lead to extinction.

Almost all animal have some territorial behaviour which limit how many of the same species that can survive in a given area. However, the richer the food sources, the smaller are generally the territories. Suitable sites for shelter are not necessarily the same as suitable sites for food. Mobility is thus essential. Canopy living mammals (monkeys, gibbons, lories) are usually vulnerable on the ground. Suitable habitats for such animals are canopies where they can move from tree to tree. Animals, even group living ones, need occasional contact with other populations to avoid inbreeding, cf. remarks on corridors.

Before attempt is made to undertake habitat restoration it is essential to gather detailed information on species biology, including food, feeding habit, territorial behaviour, reproductive habits and requirements, and possible threats.

Tools for habitat restoration

General habitat restoration (for a broad range of unspecific biodiversity) targets areas with low biodiversity. Specific habitat restoration targets the best possible areas and restores factors that are considered limiting factors for the target species.

Water management: All animals depend on drinking water, but some use water sources for other purposes. Several large animals cool down bodies in water and mud; mud baths are also used to get rid of ticks. Mud ponds may be created by digging trenches or stemming up running water sources. Some animals avoid steep or soft ground when they go for drinking. Stones, trunks or ground fixing trees may improve access to water sources.

Fig. 1. Upper: Gibbon. Habitats for gibbons consist of large size fruit trees. Lower: Malayan tapir. The habitat is dense forest with waterholes with grass and low bushes

Food species: Most leaf eaters feed on a wide variety of species. Frugivory is sometimes more specific, but most frugivores feed on several similar types of fruits, albeit with clear preferences. Challenge on supporting frugivores is often to plant species fruiting outside the main season.

Habitats for shelters and breeding. Due to logging operations there is often shortage of deadwood, e.g. dead standing trees that can provide holes for birds, squirrels, bats and other small animals. Standing deadwood can be created simply by girdling single large standing trees. Nest boxes can occasionally attract burrow nesting animals. Habitat for round burrow animals (rodents, porcupines) may be promoted by creating piles of soils that cannot be filled with water during heavy rain.

Very dense ground vegetation like bamboo thickets is usually avoided by large mammals, except for occasional shelter. Glades with tall grass (elephant grass) provide generally a better niche for large grazers.

Fig 2. Hornbills are dependent on large hollow trees for nesting. Nesting boxes can sometimes compensate for shortage of natural hollow trees

Wildlife corridors

Wildlife corridors are bridges that connect two or more key habitats for wildlife. In the developing worlds' anthropogenic landscapes, individual habitats are often small and occur as 'islands' in large unfriendly habitats. Even relatively large habitats of say 100 hectares may be too small to support large mammals, especially during seasonal changes. Wildlife corridors are essentially migration routes. Migration serves several purposes:

1. Species enrichment where species are not already present. Fragmentation of habitats may lead to situations where suitable habitats are not occupied because animals and plants cannot migrate between areas or species can go locally extinct..
2. Gene exchange. Small populations may suffer from inbreeding. Corridors allowing movement of species can mitigate such inbreeding.
3. Enlarging the potential area for territorial animals. Space is a problem for most large territorial animals in landscapes with fragmented forest. Bringing patches of suitable habitat into a network by corridors enlarges effective territories.
4. Guiding animals from one habitat to another. Unsuitable environments can sometimes form obstacles for animal migration, especially for ground living mammals. For example monoculture plantations or farmlands where they could also be destructive (elephants) or dangerous (tigers).

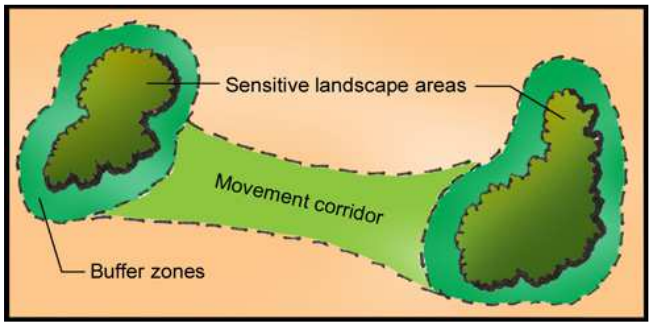

Figure 3 Model of wildlife corridor in a fragmented landscape. The two care areas are surrounded by a less protected buffer zone and a corridor has been created between them allowing 'safe' migration

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