
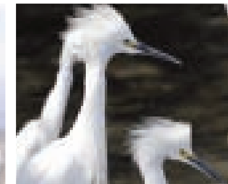



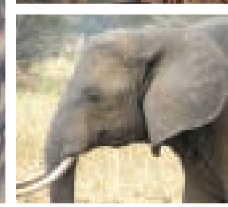

Assessing and Creating Linkages

Within and beyond protected areas

A Quick Guide

FOR PROTECTED AREA PRACTITIONERS

ELEMENTS OF A PROTECTED AREA SYSTEM MASTER PLAN

BACKGROUND

- introduction to the master plan
- linkages to national and regional plans
- process for developing and approving the plan
- mechanisms for reporting

VISION

- overall vision of the protected area network
- desired future conditions
- short and long-term goals and objectives
- range of benefits of the protected area system

PLANS TO STRENGTHEN

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- connectivity and corridors
- ecological processes
- restoration
- monitoring progress

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- management effectiveness
- protected area capacity
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- monitoring progress

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- sectoral laws and policies
- protected area governance
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- monitoring progress

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- a description of key strategies and priorities
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- threat assessment
- management effectiveness assessment
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- benefits assessment
- governance assessment
- sustainable finance assessment
- policy environment assessment

Introduction

Individual, isolated protected areas are not usually enough to protect biodiversity; species need to exchange genetic material for the population to stay healthy over time and many species also migrate or use widely dispersed habitats. Studies show that small isolated populations can be at risk of disappearing: for example local butterfly extinctions in Finland have been linked to inbreeding (Saccheri et al., 1998). Species populations sometimes disappear even if their immediate surroundings are suitable; for instance a small, well-managed protected area may lose species over time unless it is connected to similar habitat (Bennett, 1999). Furthermore, the theory of "island biogeography" helps explain why patch size and connectivity is important (McArthur and Wilson, 1967), with a general principle that the larger the "island" (which could be an isolated protected area), the more species are likely to occur. In consequence many ecologists believe that one large reserve is worth more than a number of small reserves, although there are also those who reject this hypothesis. The point where a habitat becomes "disconnected" will vary between species, its lifecycle needs, mobility and surrounding context (e.g., proximity and types of neighboring habitats). The degree of genetic isolation involved can also vary. Sometime a single break, like a road, can in effect stop two populations on either side from mixing (functional isolation) in some species. Although conservation planners often talk about "landscapes", habitat isolation and the need for connectivity are equally important in many freshwater and marine systems.

HABITAT FRAGMENTATION AND THE IMPORTANCE OF BUILDING LINKS

Unfortunately, many countries and regions no longer have the option of setting aside protected areas large enough to function as complete ecosystems, because habitat loss and degradation have progressed too far, or human population pressure and/or political opposition combine to limit the creation of new protected areas. It is rare for a protected area to be large enough to address all possible ecological interactions, particularly when migratory species are present. Conservation scientists and protected area planners are increasingly looking at ways of linking protected areas and other compatible land uses to allow them to function as if they were larger areas.

LINKAGES TO THE CBD'S *PROGRAMME OF WORK ON PROTECTED AREAS*

The Convention on Biological Diversity (CBD) recognizes the importance of linkages, both through its emphasis on using an ecosystem approach, and in actions outlined in the Programme of Work on Protected Areas (PoWPA). For example, Target 1.2 of PoWPA states that "By 2015, all protected areas and protected area systems are integrated into the wider land- and seascape, and relevant sectors, by applying the ecosystem approach and taking into account ecological connectivity and the concept, where appropriate, of ecological networks". Specific actions include establishing and managing ecological networks, ecological corridors and/or buffer zones (1.2.3); developing tools of ecological connectivity (1.2.4); and rehabilitating and restoring habitats as a contribution to building ecological networks (1.2.5). Target 1.3, relating to transboundary protected areas is also rooted in principles of landscape and seascape connectivity.

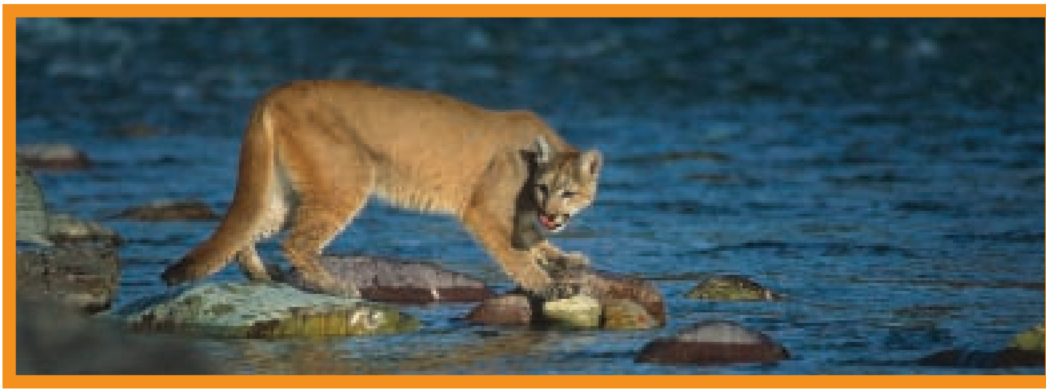
The creation of landscape linkages is one of the most important developments in conservation biology. This guide, aimed at protected area planners and agency officials, summarizes key principles in landscape linkages, and illustrates these principles with six brief case studies.


BEACH & DUNES
beyond this sign are
CLOSED
to protect nesting piping plovers.

Contents

principles of

landscape and seascape integration



Recognition of the importance of connectivity has led to a large and growing literature about linkages; this section extracts some of the information most relevant to protected areas.

Types of Linkages

"Connectivity" implies that species can move through an area but does not necessarily always require complete continuity of natural habitat. Many species can "jump" some distance over inhospitable territory. We therefore distinguish between structural connectivity (the degree to which the spatial configuration of a network of protected areas and corridors physically link through proximity) and functional connectivity (the degree to which species can utilize widely dispersed patches because of their extended range of mobility). There are four main kinds of linkages:

- **BIOLOGICAL CORRIDORS:** are continuous patches of habitat linking two or more ecosystems. At its simplest, hedges can link woodland. Rivers can be corridors for aquatic creatures and, if edged by native vegetation, for terrestrial species as well. Corridors do not have to be totally natural – for example, modified forests, trees in cropland, pasture and even suburban gardens can be useful, depending on the species-specific patterns of habitat use. As corridors become less natural they are likely to support progressively fewer species.
- **STEPPING STONES:** not all links need to be physically joined. Migratory birds, insects and other animals can pass long distances through inhospitable territory but need suitable habitat to rest and feed. Conservation strategies such as the Western Hemisphere Shorebird Reserve Network (see case study) address this. On a smaller scale, individual trees or ponds can facilitate movement; for example isolated perch trees can greatly extend suitable habitat for some species of birds.
- **BUFFER ZONES:** a buffer zone is not a protected area but a place adjacent to a protected area where management restrictions are in place. It can help a protected area to function as if it were considerably

larger by increasing the size of habitat (even if marginal), and by facilitating movement to and from other large patches. Buffer zones may allow a range of consumptive land uses, including restricted hunting, crop management and/or human settlement. They may also be areas where management practices should take account of wild species. UNESCO Man and the Biosphere reserves are based around core reserves and buffer zones of sustainable management (Hadley, 2002). At present, many buffer zones exist in name only and it is not uncommon to see development right up to the edge of a protected area, even where a buffer zone is theoretically in place, preventing all possibilities of connectivity.
- **MANAGING THE ENTIRE LANDSCAPE FOR CONNECTIVITY:** finally, greater connectivity may be achieved by managing an entire habitat with the aim of facilitating inter-connections, for example with a mixture of protected areas and sustainably managed areas (e.g. Noss, 1995).

We can also and conversely identify "hyper-connectivity" (Crooks and Suarez, 2006), which is a more subtle and less planned form of connectivity, whereby species move around the world along human-created "corridors" either deliberately or accidentally as in ship ballast, on aeroplanes or as seeds attached to the shoes of travellers. This type of connectivity is usually negative from a conservation perspective and is increasingly common.

Moving through habitat linkages

Animals use links in several ways and for various reasons. Plants also use links, and corridors can be effective in plant dispersal (Damschem et al., 2006), but plant populations will generally move more slowly and less is known about management needs – the "fastest" corridors for plant dispersal are probably associated with water, including flooding. Animal species vary in use of links – some do so readily while for other species, corridors do not seem to be effective. Isolated species are usually less likely to make use of linkages than commoner, widely distributed species. Six types of animal movement through landscape linkages occur (adapted from Taylor et al., 2006):

- **REGULAR MOVEMENTS:** for instance between roosting, feeding, and breeding grounds. Many birds use trees or hedgerows as safe passage to avoid predation (Haas, 1995). Larger mammals such as the cougar will use riparian areas, degraded canyons or pasture to connect to wild areas (Beier, 1993).
- **SEASONAL OR MIGRATION MOVEMENTS**: migratory species need stop-over points for resting and feeding. Sometimes these are virtually irreplaceable for slow-adapting species and breaking traditional routes can be disastrous. Seasonal migration is also important; in Sabah, Borneo, the River Kinabatangan maintains annual movement up- and down-stream by jungle elephants (see case study).
- **LIFE-CYCLE LINKS**: connectivity management can also help species that move on a regular basis during their life-cycle. Examples include fish ladders used by salmon to reach their breeding rivers in many countries, or shoreline areas kept from disturbance to allow sea turtles to lay eggs.
- **DISPERSAL:** longer term dispersal is important when young disperse, or in response to population changes. Various secondary vegetation types, such as roadside verges, hedges and plantations, can serve as dispersal routes. Koalas use vegetation patches to disperse through suburban areas in parts of Australia (McAlpine et al., 2006).
- **RE-COLONIZATION:** reconnecting previously isolated habitats can help species to re-establish themselves where they have been extirpated. Creating linkages by opening up riversides to flooding in the Netherlands, for example, resulted in the reappearance of long-vanished species due to seeds being carried downstream.
- **RESPONSE TO PRESSURE:** finally, populations of certain species may need to move because of population expansion, which may be needed regularly to colonize areas where breeding is more difficult, or when environmental conditions shift, as under climate change. Range expansion can include that of invasive species, and this is one criticism of linkages. Links may also provide alternative refuges from large-scale disturbance such as fire.

Scales of Linkages

One important aspect of designing a connected landscape mosaic is the need to consider linkages at every scale. Some butterfly species, for example, will not cross even a few hundred meters of unsuitable habitat, requiring micro-management at field level. At the other extreme, migratory birds need linked habitats across continents, and a weak point at any stage can cause problems. Large-scale shooting of migratory passerine birds on the island of Malta is an example of a damaged link that undermines conservation efforts throughout the migration route.

WITHIN-SITE LINKAGES focus on relatively small-scale connectivity issues aimed at maintaining populations of narrow-range species within sites. Within a protected area this would probably involve restoration of previously degraded habitat. On lands used for farmlands or forestry within buffer zones, efforts might focus on maintaining mosaics of natural or semi-natural vegetation. This can, for example, make the difference between a tree plantation being almost wholly devoid of wild species, and one that plays a positive role in landscape-scale conservation.

BETWEEN-SITE LINKAGES aim more broadly at maintaining genetic interchange between sites and also at facilitating wider dispersal and migration. The concepts of linked networks of protected areas and transboundary protected areas attempt to address these issues at a national or regional scale. The migration of zebra and wildebeest between Serengeti and Masai Mara National Parks in Tanzania and Kenya is an example of the latter (Sinclair, 1979), as is the "Futi corridor" between South Africa and Mozambique, designed to reunite two populations of elephants currently divided by their shared international boundary.

GLOBAL LINKAGES address the species that need the widest possible territories, including particularly those that practice long-distance migration. These are mainly birds and sea creatures, although a few insects also travel long distances: the winter migration of the monarch butterfly may starts in Canada and end in Mexico. Species with specialized habitat needs require suitable habitats at regular intervals along their route (e.g., water birds choose routes linked by lakes and marshes).

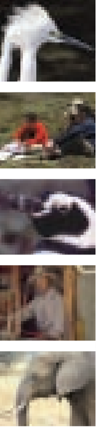
Types of habitat suitable for links

Virtually any kind of habitat can be used as a link, including sometimes semi-natural or even quite unnatural places. Suitability of different types of habitat for links is species dependent; some species have highly specialized ecological needs while others can use virtually any corridor. Invasive cane toads in Australia move down roads and tracks for example. But the large majority of links fall into one of a relatively few categories. Table 1 presents a typology that describes some of the most important linkage habitats, as an aid to planning for links in and between protected areas.

HABITAT TYPES, FEATURES AND PROCESSES	EXAMPLES OF HABITAT	EXAMPLES OF USE
Natural habitats	Forest fragments, prairie, sea grass beds, wetland areas, salt marshes, coral reefs and sea mounts	• Forests protected to maintain water quality also buffering protected areas – e.g. around Brisbane, Australia • Coral reefs put voluntarily off-limits for collection to link coastal marine protected areas
Semi-natural habitats	Managed forests, tree plantations, organic or other low input farming systems, pasture and extensive grazing areas, reservoirs	• Managed forests providing a buffer zone against the bushmeat trade around protected areas as in Gabon • Biodiversity management plans being implemented on organic farms in Italy • Reservoirs forming migration stop-over points or over-wintering places for waterfowl as in SW England
Habitat fragments	Individual trees, small groves, ponds in otherwise altered landscapes	• Perch trees for birds of prey and other species – commonly livestock shade trees in Greece • Breeding places for amphibians in cultural landscapes – such as garden ponds in Europe
Hedgerows and green lines	Hedges, strips of native vegetation beside fields, unsprayed verges on roads	• Refuge and breeding places for invertebrates in farmland, thus also providing food for larger animals • Roadside habitat for plant species that have been extirpated from managed fields
Water edges	Often left relatively undisturbed even in managed landscapes, including riparian areas besides rivers and streams, lake shores and coastline	• Breeding grounds for marine turtles • Migration pathways for otters • Breeding places for water birds
Temporary flooding and drying	Flooding can provide temporary passage for fish and seed dispersal; conversely temporary drying can allows colonization of areas that are otherwise cut off by water. Planned manipulation of water levels or reinstatement of natural flooding patterns can provide temporary but important links.	• Temporary flooding in the Ganges plain in Bangladesh allows fish dispersal routes to spawning grounds • Flooding reinstated in places on the Rhine and its tributaries increases seed dispersal
Artificial habitats	Artificial corridors, perches or nest sites to increase dispersal	• Fish ladders for salmon in Scotland • Artificial nest sites for ospreys in Archipelago National Park in Finland • Underpasses for antelopes

Table 1: Main habitat types suitable for connectivity conservation

Protected area managers can sometimes introduce special management interventions to temporarily increase the suitability of link habitat for wildlife, such as hunting or fishing bans, restrictions on the collection of non-timber forest products or coral, or controlling time of management interventions, such as leaving grass cutting in haymaking fields until flowering and bird nesting is complete. These management considerations can create a type of temporary landscape linkage.



Arguments for and against promoting connectivity

The advantages of linkages have already been outlined – that they prevent genetic isolation, maintain the spectrum of habitats necessary for mobile species and simulate larger natural areas. It is also worth noting that in addition to these direct benefits, some elements of connectivity are also important in maintaining ecosystem services, including soil generation, provision of water, mitigation of floods and drought, waste detoxification, pollination and seed dispersal.

But corridors have their critics as well, who say that some disadvantages can outweigh the benefits (for a review see Bennett, 1999). Problems stem from the same attributes that provide the advantages. By increasing accessibility, linkages also open up new areas to invasive species such as exotic pests and weeds, new diseases and even genetic variations of native species that could disrupt local adaptations, paradoxically reducing net genetic diversity. Links can also open up new areas for human disturbance such as poaching, logging, accidental or deliberate fires, and settlement (Bennett, 1999). Critics argue that invasive species will be able to take advantage of corridors more quickly than many native species precisely because they are invasive and therefore that in some circumstances it is safer to leave some populations isolated. They also point out that knowledge of movements along the various link habitat types remains very incomplete and to some extent still theoretical.

Linkages and landscape or waterscape mosaics are still newer instruments than we sometimes realizes and if badly planned or implemented they can fail to work or can backfire. They are also, in reality, usually a way of trying to patch together a workable conservation strategy from less than perfect components. The general consensus seems to be that ecological linkages are on balance helpful, if conditions are right and they are carefully planned. But it is important to note the potential costs as well and to factor these into planning; in some cases a linkage may cause more environmental harm than benefit.

Connectivity and climate change

If the scale of climate change effects is as large as current predictions suggest, they will, among many other things, create a radical change in thinking about protected area design. We can unfortunately predict that much will be lost, but at the same time the new pressures may create additional scope for protection. The role that natural ecosystems can play in both buffering against climate change and mitigating some of the associated disasters is now being increasingly recognized (Stolton and Dudley, in press). We discuss one response to climate change in the case study on the Somerset Levels.

From the perspective of maintaining biodiversity, rapid environmental change brings with it another role for linkages, fitting approximately into the categories of dispersal and range expansion, as species need to move quickly to keep up with changing environmental conditions. From a planning perspective it is important to collect as much information as is available now about potential changes and their effects and to develop appropriate strategies. Links could, for example, allow species to make altitudinal shifts if weather becomes warmer; to retreat backwards from a shoreline if the sea level is rising; and to move longer distances in the case of major shifts in habitat location. Perhaps most important of all, in conditions where decisions will need to be made quickly, it will be important to ensure as far as possible that linkages are not broken, that habitat fragmentation does not increase as a result of, for example, flood defenses, fire breaks and new developments above a rising tidal reach.

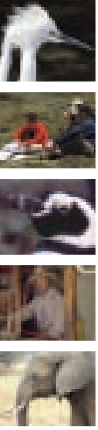
Creating linkages to allow for climate change adaptation

Climate change will likely result in habitat modification in ecosystems around the world, and coastal areas are among the most vulnerable ecosystems. Protected area managers can improve an ecosystem's ability to adapt to climate change by predicting future shifts in ecosystem types, and actively managing and restoring ecosystems in anticipation of these changes.

One example of this is in the Albemarle Peninsula of North Carolina, where The Nature Conservancy is developing strategies for mangroves to adapt to rising sea levels. This region, which is the second largest and healthiest estuary in the eastern United States, includes a rich mosaic of dunes, wetlands, coastal forests and rivers, and has extraordinary biological productivity. However, as much as half of the area, which includes a mosaic of protected areas managed by multiple governmental and non-governmental agencies, is at risk from rising sea levels.

Concerned about the impact of climate change on this ecological system and the system's ability to adapt over time without clear landscape and seascape linkages, a working group of land managers and researchers formed to plan and create such linkages between terrestrial, freshwater and marine systems. One strategy the group used was to create drainage ditches that act as canals, transporting salt water onto peat lands, gradually converting these lands over time into a coastal environment. Another strategy is planting cypress forests, which may take decades to establish, on areas further inland that are likely to be flooded over the next few decades from rising sea levels. The group is also restoring submerged aquatic vegetation beds, establishing reefs on provide new habitat for native oysters, and planting brackish marsh grasses on shore lands that are likely to be submerged.

Protected area managers may often assume that creating landscape and seascape linkages simply means creating corridors between two or more large protected areas. However, climate change may require new thinking about what it means to create landscape linkages. The aim of the adaptation group in Albemarle Peninsula, for example, was to create linkages that promote resiliency and enable functional and structural connectivity not only across space, but also across time.



steps to

assessing landscape linkages

A number of models exist to identify individual connectivity needs (e.g. nearest neighbor, buffer, "incidence function model" – see Crooks and Sanjayan, 2006) but there is no simple method to help choose the "right" approach to developing effective connectivity for a variety of species within and between protected areas or across larger landscapes and seascapes. It is possible, however, to identify a logical set of questions which, if all of them are answered thoroughly, should provide a good base to start from. The following section gives some background, identifies key issues to be addressed and looks at a "landscape species approach" as one possible model for planning linkages.

Tools and approaches to identifying linkages

Over the last 10 to 15 years there has been a dramatic scaling up in terms of conservation planning, with the emphasis shifting from relatively small and discrete sites to much larger areas, referred to variously as ecoregions, bioregions and landscapes. Although these terms are not directly analogous, they all reflect the same philosophy of identifying large patches of land and water that share underlying biogeographical features. Because such regions cannot all be set aside into protected areas, a mixed mosaic approach has become a standard in conservation planning. Concepts of linkages and networks are fundamental to these broad-scale approaches (Sanderson et al., 2003), but as we have seen they also have a role to play in smaller areas, including within and between individual protected areas.

It is clearly impossible to consider connectivity issues for every species within an area. Planners have two practical alternatives:

- Selecting certain species or habitats to act as indicators, with the hope that a carefully chosen set of indicator species will represent the connectivity needs of most other species within the system; and
- Selecting the species with the widest ranges, and hoping that ensuring connectivity for them will ensure connectivity for other species.

Neither approach is perfect. The choice of indicator species is often difficult in conditions where there are serious gaps in our understanding of community ecology. Looking for connectivity of the overall landscape or seascape makes sense from many aspects but does not necessarily represent everything – for example it does not always address the needs of migratory species, and some wide-ranging species (such as elephants or many large predators) have relatively unsophisticated habitat needs and will be able to cross larger areas of poor quality habitat than many smaller creatures. In practice, a combination of both approaches is probably most useful – protected areas or ecoregional plans may well already have specific target species and including the widest ranging species amongst these probably makes sense in most cases.

QUESTIONS TO ADDRESS WHEN PLANNING FOR CONNECTIVITY

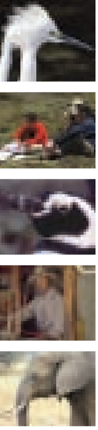
- What is the key purpose of the planned linkage (e.g. daily movement; life-cycle; seasonal movements or migration; dispersal; range expansion or response to changing environmental conditions)?
- What are the requirements for the species involved (e.g. corridors or stepping stones; natural or semi-natural habitat; permanent or seasonal links; artificial links)?
- Is the species known to use link habitats? If not, are there characteristics that make it more or less likely to use such habitats (e.g. wide-ranging or restricted, bold or shy of humans, generalized or specialized habitat requirements)?
- At what scale does the link need to be created or protected (e.g., very local, within a protected area or other site, between sites, or spanning countries or continents)?
- Will connectivity really increase long-term survival chances for the target species?
- Is a link the most cost effective way of achieving conservation?

Once a potential linkage strategy has been identified, four further questions are required:

- What are the potential disadvantages of the link (e.g. use by invasive species, poachers or fire, increase in problem animals and crop raiding)?
- What are the potential limitations on the link (e.g. edge effects on a narrow corridor, threats to the link habitat, lack of certainty about whether the habitat is suitable for the species)?
- What are the practical limitations on particular links (e.g. attitudes of local communities; tenure issues; potential clashes with other uses; space limitations, climate change issues)?
- How will success or failure be measured (what monitoring and evaluation system will be used)?

IMPLEMENTING LINKAGES IN CROWDED LANDSCAPES AND SEASCAPES It is usually only necessary to worry about linkages if there are already pressures on an area. In other words, planning for or restoring connectivity is usually a response to a problem. Complex theoretical models of what would be ideal therefore have only limited usefulness, and social, political and economic factors will often play an equal role in deciding when and if developing linkages is either practical or cost effective.

By its nature, most “link habitat” is owned by someone else and is most likely managed for objectives other than conservation. Maintaining it, and to an even greater extent improving it, for conservation is therefore usually a matter of negotiation and trade-offs. Many models for achieving this exist, ranging from various long or short-term voluntary agreements, through compensation packages to legislative controls. If the link habitat exists, interventions may be aimed at repairing some gap – for example building an artificial corridor under a road or replanting patches of woodland – or in persuading the current landowners to change management to improve conditions for wild species.



The Landscape Species approach

Given that wildlife, ecological processes and human activities often spill across the boundaries of protected areas, conservation that is focused solely within the limits of protected areas is often faced with difficult challenges. The management of protected areas cannot occur in isolation from the surrounding human-dominated landscapes. The Wildlife Conservation Society has adopted the "Landscape Species Approach" as a planning tool for conservation, including the identification of landscape linkages. Landscape species use large, diverse areas and have significant impact on the structure and function of natural ecosystems. Their habitat requirements in time and space make them particularly vulnerable to the land-use and resource harvesting practices of people. The Landscape Species Approach defines the conservation landscape based on the ecological needs of wildlife and the geographic location and severity of human-wildlife conflicts. By meeting the habitat needs of, and reducing threats to, a suite of landscape species the approach aims to better maintain the biodiversity and ecological integrity of the wild landscapes within which they reside.

The key steps in implementing the Landscape Species Approach are identified below (taken from LLP, 2001)

1. **Select the conservation site**, based on the results of global and regional conservation priorities (e.g., species ranges, ecoregions, hotspots, and/or critical sites).
2. **Select a suite of Landscape Species** for the site which, as individuals and/or populations:
   a. Require a large area to meet ecological needs
   b. Rely on a heterogeneous array of habitats
   c. Are threatened by human resource-use practices
   d. Play important roles in ecosystem structure and function
   e. Are culturally and/or economically significant, and
   f. In combination with other selected species, constitute a complementary conservation umbrella. [See Coppolillo et al. 2004 for more on selection criteria for suites of landscape species.]
3. **Define the biological landscape:**
   a. Map the spatial patterning of resource-use by each landscape species population over time
   b. Describe a landscape that contains sufficient resources for the persistence of a healthy, functioning population of each landscape species
4. **Define the human landscape:**
   a. Map the pattern and intensity of human land and resource use practices that occur within, or affect, the area defined by the biological landscape
5. **Examine the intersection of the human and biological landscapes,** and identify the key conflicts that adversely affect landscape species and other wildlife they represent
6. **Focus conservation actions** on avoiding or mitigating key conflicts
7. **Monitor the effectiveness** of conservation actions and changes in threats to wildlife and wildlands conservation

NEEDS TO IMPLEMENT THE LANDSCAPE SPECIES APPROACH:

- Scientific information on the biological requirements and ecological roles of the landscape species
- Maps that characterize the distribution and abundance of landscape species, habitats and resources within and beyond the site
- Maps that characterize the spatial pattern and, where possible, the intensity of human land use practices that affect landscape species
- An understanding of the causes and consequences of human-wildlife conflicts
- Adequate personnel and financial resources to implement activities to reduce threats including human-wildlife conflicts
- Cost-effective tools to monitor progress on achieving conservation objectives and reducing threats to landscape species.

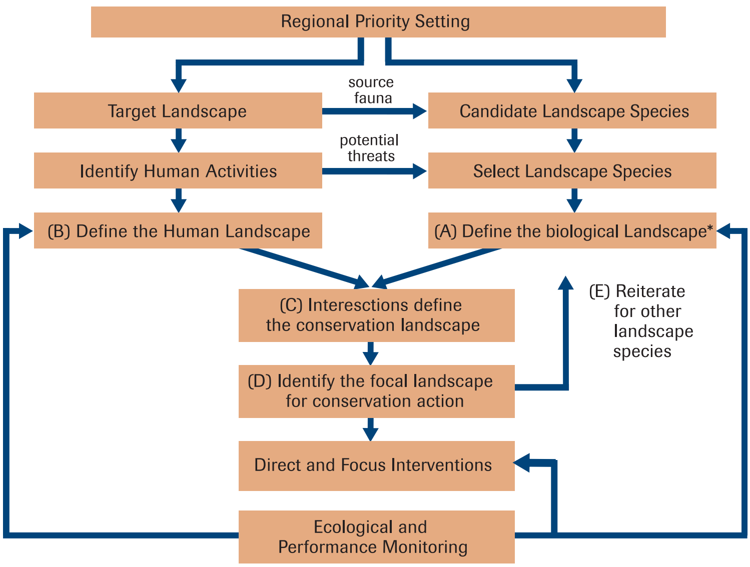


Figure 1: is a conceptual diagram illustrating the Landscape Species Approach (paragraph in LLP 2001)

The flow chart summarizes the steps in implementing a landscape species approach for the conservation of one species. Planners can designate a candidate set of species or a target area based on global or regional priority-setting exercises. Potential landscape species and human activity in the area are simultaneously examined. Based on the requirements of the landscape species, planners can then define a biological landscape. The biological landscape is intersected with the human landscape to define the conservation landscape. A subset of those landscape elements can be selected that most effectively meet the requirements of the landscape species. Human activities within the focal landscape that conflict with the landscape species requirements are considered threats and are the focus of conservation interventions. Ecological and performance monitoring allow for the adaptive management of this process as new information becomes available (Sanderson et al., 2002).

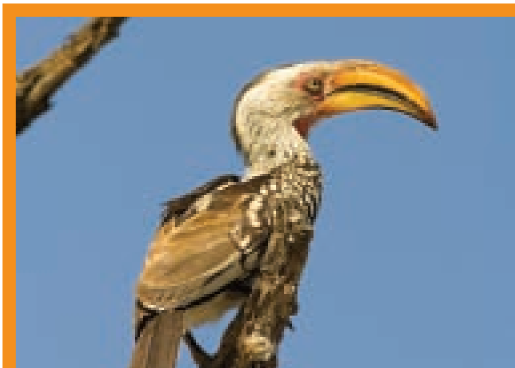
PROTECTED AREA NETWORKS AROUND THE WORLD:

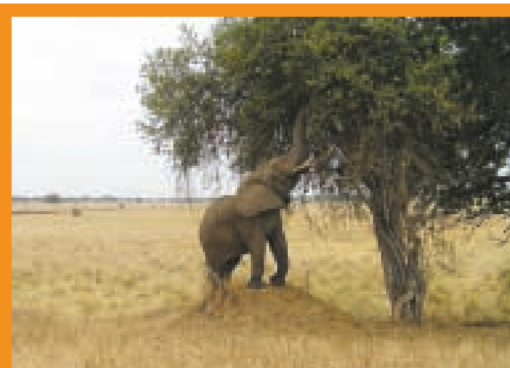
The concept of linked approaches to protected areas and wider conservation strategies is taking off all over the world. A recent analysis (Ervin et al., 2008) identified the following, by no means complete, list:

- Australian Alps to Atherton (A2A conservation corridor) initiative
- Greater Mekong biodiversity conservation corridor in Vietnam
- Ecological green corridors in Hungary
- Meso America Regional Network
- Alpine Protected Area network
- Pan European Ecological Network
- Central Africa Network of Protected Areas
- Marine Protected Areas Network for the Western Indian Ocean Countries
- Transnational River Basin Districts on the Eastern Side of the Baltic Sea Network
- ZIMOZA (Zimbabwe, Mozambique and Zambia) Trans-boundary initiative
- KAZA (Namibia, Botswana, Zimbabwe, and Zambia) Trans-boundary initiative
- Trans-frontier marine conservation between Tanzania and Mozambique
- Danube Delta and Prut river initiative between Romania, Ukraine and Moldova
- Eastern Carpathian migratory corridor (Polish-Slovak-Ukrainian Biosphere Reserve)
- Transboundary protected areas between Eritrea, Djibouti and Somalia
- The East Asian Australasian Flyway

A representative selection of these are described briefly in the following case studies

case studies





Case study: Nam Kading National Protected Area – using the Landscape Species approach in Lao PDR

Many attempts at linking landscapes start from a single protected area. The Bolikhamxay Province in Lao PDR contains the highest quality dry evergreen forest left in Indochina, with the largest block centered on the 1570 km2 Nam Kading National Protected Area. Many important species occur and some, like the large hornbill, cannot survive without large areas of this forest (Duckworth et al., 1999). In the eastern province, bordering Vietnam, areas of wet evergreen forest in and around the Nam Chat-Nam Pan Provincial Protected Area contain ice age refugia, including several newly described species such as Saola (*Pseudoryx nghetinhensis*) and Annamite Striped Rabbit (*Nesolagus timminsi*). Conserving this globally important biodiversity with the Landscape Species Approach is a key goal of the Wildlife Conservation Society's programme in Lao PDR.

Using a WCS Species Selection Software (Strindberg at al., 2006), the project brought together government, community and NGO stakeholders to select seven landscape species for the province: Asian elephant (*Elephas maximus*), tiger (*Panther tigris*), southern serow (*Naemorhedus sumatraensis*), Eurasian wild pig (*Sus scrofa*), white-cheeked crested gibbon (*Nomascus leucogenys*), great hornbill (*Buceros bicornis*) and Asian redtail catfish (*Hemibagrus wyckoides*) (Strindberg, 2006).

Government staff worked with WCS ecologists to create a Conservation Landscape for each species; i.e. maps identifying areas that are a management priority for the species. The team identified and mapped the best habitat for each landscape species (*biological landscapes*), and then mapped the location and relative importance of human-caused threats (*threats landscapes*) (Rasphone et al 2006, Johnson et al., 2006).

The completed maps helped to build conceptual models and define population targets for six of the landscape species:

- A 10 percent increase in white-cheeked crested gibbon population
- A 35 percent increase in great hornbill population
- A 20 percent increase in tiger population
- A 50 percent increase in southern serow population
- A 100 percent increase in Eurasian wild pig population
- No decline in Asian elephant population

The team identified management interventions (e.g., reduction of hunting, wildlife trade and habitat loss) needed to reach the targets, and worked with a WCS biostatistician to design a monitoring program to measure population change for landscape species during the project. Limited resources, a rugged terrain and the elusive nature of many of the landscape species made this a challenge. However, a monitoring program using camera trapping and line transects is now allowing WCS to measure the effectiveness of interventions in the Nam Kading NPA (Strindberg at al., 2007), and to adapt actions accordingly.
Case study by Arlyne Johnson, Wildlife Conservation Society

Case study: The Futi Corridor – Linking elephants in South Africa and Mozambique

Species that need a lot of space can often be the target around which link projects develop. Wide-ranging species such as elephants frequently cross political boundaries in their movements over a landscape. Many international boundaries that are physically marked with fences or similar markers often present an impenetrable barrier to species that can limit a population's access to needed resources or prevent migration and movement through a landscape. In such situations, designation of corridors for animal movement through the removal of obstacles has proven to be an effective solution.

A fence constructed along the border between Mozambique and South Africa divided a population of elephants – the only indigenous population remaining on the coastal plain of Southern Mozambique and Kwa-Zulu Natal province in South Africa. These elephants traveled along the "Futi Corridor" (a seasonal river and marshland) that links Tembe Elephant Park in South Africa to Maputo Elephant Reserve in Mozambique.

Following the end of political unrest in June 2000, the governments of Mozambique, Swaziland, and South Africa signed the *Lubombo Transfrontier Trilateral Protocol,* an agreement whose goal is to remove borders to support conservation. Using satellite radio tracking to track elephant movements along a section of the Mozambique and South African border, scientists confirmed that elephant populations still traveled traditional routes they had used prior to the installation of the fence. Based on the elephant population's movement patterns, and their impact on the landscape and interaction with humans, a series of recommendations were proposed to facilitate movement across the boundary while minimizing disruptions to the landscape and to human populations. The recommendations included removing the border fences entirely, formally designating the "corridor" as a protected area in Mozambique, and creating specific boundary parameters for the corridor. The Ndumo-Tembe-Futi Transboundary Frontier Conservation Areas was established to protect the migration corridor. This area will conserve 79,500 hectares of elephant habitat, and link the Maputo Special Reserve (78,500 hectares) in Mozambique with the Tembe Elephant Park (30,500 hectares) in South Africa (Van Arde and Fairall, 2002).

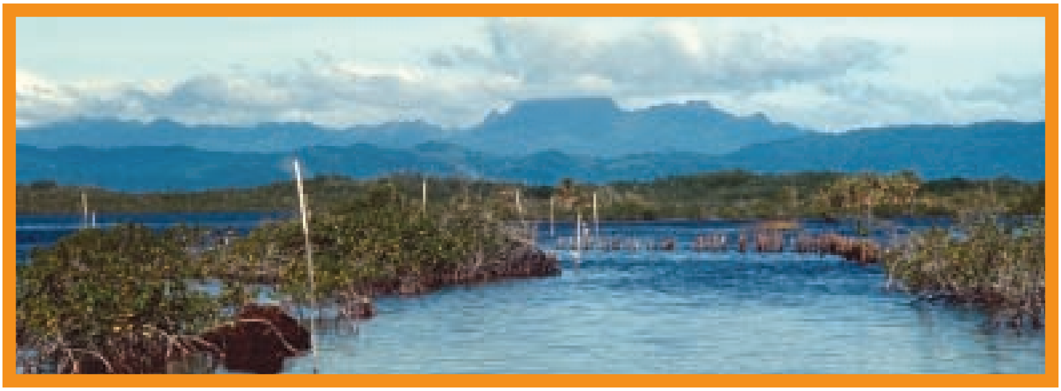
Case study: Kinabatangan River – restoring linkages along an area of critical freshwater habitat in Sabah, Malaysia

Biological corridors and issues of connectivity are as important in aquatic environments as on land; in some cases rivers can also act as a focus for maintaining more general connectivity. In the Malaysian state of Sabah, on the island of Borneo, extensive oil palm establishment has fragmented remaining natural forest, threatening species such as the orangutan, the Borneo subspecies of the Asian elephant and hornbills. The Kinabatangan River acts as a partial corridor between remaining mountain forests and coastal mangroves. However, the line of riparian forest at its edge has been broken in places by illegal planting of oil palms right down to the river banks, and deforestation in the lowland mountains is causing increased flooding and impacting water quality. The river is experiencing infestation with exotic water hyacinth in places, and, more seriously, the weed is also clogging some associated lakes, changing their character and making some of them unsuitable for native otter. A road cuts across the river just before the upland forests, which has isolated a population of around a hundred elephants in the lower part of the river, where they cause tensions by crop raiding and are occasionally shot at by oil palm workers (Dudley et al., 2008).

Various state agencies and NGO conservation projects are trying to maintain and where necessary restore the freshwater and associated forest corridor through:

- Protecting remnant forest and mangrove areas in both government-owned and private protected areas, to maintain wildlife but also to contribute to sources of pure drinking water and to flood mitigation (Azmi, undated)
- Undertaking strategic replanting of trees to re-connect forest fragments along the course of the river
- Helping local communities to build up ecotourism and provide an outlet for local fish products
- Working with some community conserved areas, including a forest preserved as habitat for a colony of swiftlets that are a source of valuable "birds nest soup" found in a local cave system
- Liaising with oil palm companies in an attempt to reclaim areas in the floodplain that are poor habitat for oil palm and could be restored
- Working with timber companies to introduce reduced impact logging in the upland forests and to prevent conversion to oil palm
- Attempting to reduce pollution and invasive plants in the river system to maintain healthy aquatic life including commercial fish harvest

The various projects aim to develop the Kinabatangan into a permanent freshwater and forest corridor linking the largest remaining blocks of upland forest and coastal forest in the region.



Case study: Mesoamerican Biological corridor – linking reserves in eight countries

Although the concept of transboundary conservation started with two countries, multi-country initiatives are becoming increasingly common. The Mesoamerican Biological Corridor (MABC) aims to create a continuous corridor of habitat capable of sustaining biodiversity in the five southern states of Mexico and seven Central American states: Guatemala, Belize, Honduras, El Salvador, Nicaragua, Costa Rica and Panama. The region has extremely high levels of biodiversity – for example Panama contains more bird species than the United States and Canada combined. The MABC is joining together protected areas with various buffer zones and corridors, trying to use the corridor concept to help add value to products produced in the linking areas.

The corridor was initiated in 1997 and since then the Central American Commission for Environment and Development has worked with national and international partners to help make it a reality (Miller et al., 2001). Originally perceived as literally a corridor linking a range of protected areas, the MABC is now more of a concept of a landscape approach for Central America, involving all the protected areas in the region and intervening land. Currently there are around 600 protected areas, covering a fifth of the region. But most contain human populations, including many of the original indigenous peoples, and the survival and success of conservation efforts will depend on maintaining a strong focus on the needs of people along with that of biodiversity. The extent to which many of these areas will remain as traditional protected areas or merge more into some kind of sustainable development areas remains uncertain and protected areas also remain under political pressure in some countries.

Given the human pressures and lack of money in the area, integration of conservation with economic objectives is a keystone of the concept. This integration takes the form of three main types of market opportunity: tapping environmental services such as aquifer recharge or soil stabilization; exploring green businesses including particularly ecotourism; and establishing niche markets for shade-grown coffee, organic products and other products of the corridor. The frequency of devastation linked to extreme weather events such as Hurricane Mitch over the past few decades means that the role of natural ecosystems in disaster relief is particular important in this context. The MABC is hugely ambitious in scope and concept although it is still uncertain the extent to which political realities in the region allow it to be completed in the manner originally envisaged.

Case study: Western Hemisphere Shorebird Reserve Network – a pole-to-pole link

The Western Hemisphere Shorebird Reserve Network (WHSRN) is perhaps the longest set of ecological stepping stones in the world, reaching from Tierra del Fuego at the southern tip of Argentina right along the coasts of South and North America to Alaska. The aim of the WHSRN is to conserve shorebird species and their habitats through a network of key sites in the Americas. Its formation is a recognition that conservation of migratory species such as shorebirds only makes sense if addressed on a landscape scale (Haig et al., 1998).

WHSRN was first proposed in 1982 and established in the mid-1980s, when scientists recorded an alarming decline in shorebird populations (Morrison et al., 1995). Among the world's great migrant species, flying hundreds or thousands of miles each year, many of the 88 western hemisphere shorebird species were suffering because of serious habitat loss or degradation on the course of their annual journeys.

Sites are nominated and accepted on the basis of their importance to shorebirds and the commitment of owners to shorebird conservation (Myers et al., 1987). Starting with Delaware Bay in the United States in May 1986, to date 69 sites have been accepted in ten countries (Argentina, Brazil, Canada, Ecuador, Mexico, Panama, Paraguay, Peru, Suriname and the United States) covering 8.5 million hectares, with the latest being Ensenada de Pabellones (Mexico) and Asunción Bay (Paraguay) in January 2008. Many but not all of the sites are also official protected areas. Some WHSRN sites have chosen to set up "sister-site" relations based on shared species or habitat types. One of the oldest is the "Linking Communities" project that joins Marismas Nacionales in west Mexico with the Great Salt Lake of Utah, USA and the Chaplin-Old Wives Lake Complex in Saskatchewan, Alberta.

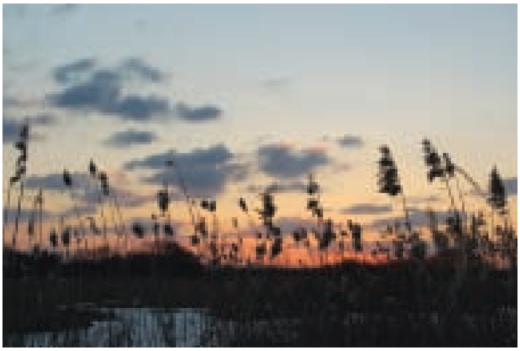
The Network is governed by a Hemispheric Council, backed up by regional and national councils currently active in Canada, the United States and Argentina. The Manomet Centre for Conservation Science, a not-for-profit in the United States, is the home of the WHSRN Executive Office. The network is as yet not wholly secure and many sites face problems from habitat loss, disturbance of the birds, development and pollution. An assessment tool has recently been launched to collect more data about sites and to plan strategies to respond to threats. The WHSRN is the site-based conservation component of Manomet's Shorebird Recovery Project along with initiatives to improve the science of shorebird conservation.

Case study: Somerset Levels – restoring connectivity in marshland and buffering against climate change in a cultural landscape

Connectivity conservation is not simply a technique for linking remaining areas of natural habitat; in severely altered landscapes and seascapes it can also be used in conjunction with restoration. The county of Somerset in southwest England has extensive low lying areas that are naturally flooded every winter; Somerset literally means "summer settlement" because in the winter people moved to higher ground with their livestock. Centuries of drainage have destroyed much of the wetlands and extensive peat cutting for the horticultural trade ripped up most remaining heath, while other natural habitats have also been reduced and fragmented. The county was the site of bitter confrontations between conservationists and land-owners in the 1970s and 1980s, and many of the remnants of natural and semi-natural areas were lost during this period. Nonetheless, despite much of the region having undergone radical changes, Somerset still retains 25 percent of the UK's coastal and floodplain grazing marsh, over 75,000 hectares, much of which is important bird habitat (English Nature, 1997).

Examples of natural habitats have been retained in a series of state and NGO protected areas and through enacting conservation controls on 25 Sites of Special Scientific Interest (a legal designation) and through Environmentally Sensitive Area designation (ADAS, 1995). As peat supplies were exhausted, some former peat-cuttings were bought by government or NGOs and restored for wildlife, digging a series of inter-connected lakes and encouraging native vegetation. As a result, populations of some important bird species are increasing and the once-threatened otter has spread. But the fragility of the individual sites is recognized and there have been losses of some species from protected areas. Current conservation efforts focus on linking remaining native habitats through restoration and bringing back natural flooding patterns, which also connect sites on a temporary basis, allowing dispersal of aquatic creatures.

These efforts are being given further impetus by the likely impacts of climate change. In the next twenty years, the frequency and scale of flood events are likely to increase, and sea-level rise will accelerate this process (Heathwaite, 1993). National and local governments are recognizing that it will be too costly to protect the whole county and are aiming to focus on centers of population, allowing seasonal flooding to return to some low-lying and marginal farmland. Changes in the next century could bring back habitat types that have been declining or absent for thousands of years. A combination of pragmatic attempts to address likely climate change with focused restoration could create habitat links throughout the county and, because of the presence of migratory water birds, have important regional impacts as well.



conclusions

Lessons learned and need for further work

Connectivity is a key component in many protected area programs, but it is also one of the most challenging of conservation strategies. We still know frustratingly little about how many of the tools used to promote linkages work in practice, or for how many species they are likely to be effective. If we get things wrong the results can easily be worse than when we started.

A recent analysis (Morrison and Reynolds, 2006) identified three potential pitfalls: the real costs of implementing links, the opportunity costs of spending time and money on links rather than other strategies, and the risks of failure in what are often experimental systems. If connectivity is to play a larger and more effective role in the future, we need – with some urgency – to find out more about some of the key questions identified in the preceding text.

- **Effectiveness of link mechanisms:** we need to know far more about movement through connecting habitats. Most of the research that has taken place is still mainly descriptive rather than experimental (Beier and Noss, 1998) and in many cases our predictions of movement remain theoretical. The fact that something occurs in a corridor is not necessarily evidence that it is using the corridor to move along (Rosenberg et al., 1979), yet the two issues are often confused.

- **Selection of target species for planning linkages:** Although we are beginning to better understand how to create functional linkages for individual species (e.g., Bennett, 2003), and computer algorithms exist than can help planners identify the most efficient spatial configuration of core habitat for multiple species, little is known about how to be most efficient in creating a linked network that has the highest degree of connectivity for the greatest number of species.

- **Additional benefits of links:** most research has focused on the ecological role of connectivity, yet many of the people who will have to implement and manage links are not primarily concerned with biodiversity conservation. Wider understanding of, for example, environmental services, recreational potential and other values would help develop a suite of arguments to make the case for connectivity.

- **Negotiation approaches:** connectivity is often mainly about the art of the possible, linking together fragments of habitats in crowded areas (otherwise we probably do not need links in the first place). Currently too much of the emphasis of research is on the minutiae of design, and too little on the practicalities of how to build social and political support for implementation.

- **Linkages in water:** distribution in oceans and to some extent in freshwaters is as patchy as on land, but far less is known about developing connectivity in these situations. As marine communities come under increasing stress from over-fishing, pollution and climate change the potential restoration of connectivity needs to be a priority (e.g. see Dawson et al., 2006)

- **Politics:** many links cross local, regional and national borders, adding extra complications. While knowledge about transboundary conservation is growing fast (see Sandwith et al., 2001) the political challenges in addressing conservation issues in several countries simultaneously can be very complex. Collecting existing experience and drawing lessons (e.g., are informal relationships better or worse than formal relationships in transboundary protection?) would provide valuable background for practitioners.

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