TERRESTRIAL NATURE RESERVES ON ISLANDS

By CRAIG L. SHAFER *

With 3 figures

A proposal for an international convention to conserve islands was made by an advisory committee to the U.S. government before the Stockholm Convention (BAKER et al. 1972). Today the best way to conserve islands still warrants much more discussion. The work of MACARTHUR and WILSON (1963, 1967) instigated many papers attempting to apply insights derived from island studies to the design of continental terrestrial nature reserves. The ensuing debate, starting in the mid-1970s, paid less attention to providing guidance for nature reserve systems *on* islands. This perceived result may be because small islands provide few spatial options. Alternatively, it may reflect that "human influence" concerns have long dominated thinking about island conservation. The following review attempts to integrate these two approaches: past experience with anthropogenic impacts on islands and theoretical island conservation biology. Island conservation is often intertwined with the fascinating topic of marine and coastal conservation (e.g. IUCN 1976, KELLEHER and KENCHINGTON 1992, MCNEILL 1994, GUBBAY 1994) but the marine realm will receive brief treatment here.

HUMANS IMPACTS TO ISLANDS

When Captain Cook arrived in the Hawaiian Islands in 1778, the original lowland vegetation had already been greatly changed after 1,000 years of Hawaiian occupation (CUDDIHY and STONE 1990). OLSON and JAMES (1982) identified 44 extinct but unknown species of birds from fossils (about half of the original endemic 84). Dating revealed they had been lost before Europeans arrived in 1778, presumably by the hand of native Polynesians. This pattern of large pre-European bird extinctions on islands is found elsewhere (OLSON 1989). There could have been 2,000. Pacific Island bird species extinctions over the last 1000-4,000 years (PIMM et al. 1995; STEADMAN 1995).

CURRY-LINDAHL (1972) described extinctions on islands around the world. Can

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people live in harmony with island biota? The Hawaiian experience is not supportive of this idea. After Captain Cook arrived, cattle, goats, sheep, pigs and rats were brought in and the extinction rate greatly accelerated (ROYTE 1995). However, in New Guinea man has been present longer than in Australia and New Zealand, yet it has been least affected by humans (CURRY-LINDAHL 1972). In Australia and New Zealand, like in Hawaii, the largest extinctions occurred after Europeans arrived though evidence of impacts by native pre-European people on Pacific island biota is growing (KIRCH and HUNT 1997).

Extinction rates are higher on islands than continents presumably because of small populations and restricted genetic diversity. After settlement, these inherent island population characteristics must face two foremost human impacts: 1) high numbers of exotic species (i.e., non-native introduced species) and 2) habitat destruction (VITOUSEK 1987). This is consistent with specific island disturbances most commonly recorded in the 1969 survey of Pacific islands carried out by the Conservation of Terrestrial Communities (CT) section of the International Biological Program (IBP): coconut planting-197 instances; cattle, sheep, horses, pigs, cats, dogs, poultry-105 instances; goats, rabbits, mice, rats-88 instances; mining-39 instances, military bases-35 instances; tourism-26 instances; and airports-20 instances (in ELLIOTT 1973). Introduced discase is another problem (VAN RIPER et al. 1986).

Habitat Destruction

Habitat elimination is one major impact to island conservation. It leaves a landscape patchwork that can be detrimental to the viability of a species. Reserve design considerations can either encourage "planning ahead" so fragmentation is less detrimental, and/or try to mitigate for fragmentation that has already occurred.

Development projects seem to be the primary negative force. Dredging, explosives, tourism facilities, water salinity-circulation-diversion projects, dumping pollutants, jetties or harbors, and mining all pose specific risks to islands and their associated marine habitats--coral reefs, mangroves, beaches, estuaries and lagoons, and seagrass beds (SNEDAKER and GETTER 1985).

Any island conservation projects and strategies should be evaluated, especially in the context of the broader coastal system, before development projects are approved (SNEDAKER and GETTER 1985). McEACHERN and TOWLE (1974) argue environmental impact analysis and monitoring should proceed and continue during various island development or agricultural projects. If it does not, last minute efforts to block harmful development projects often result (GOSNELL 1976) and are frequently not fully successful.

Exotic Species

The earliest natural history studies involved observations on islands (DARWIN 1859,

WALLACE 1869, 1880). DARWIN (1859) also mentioned the problem of human introduction of non-native species on a few islands--they occurred "on every other oceanic island which can be named." HOLDGATE (1967) claims a first prerequisite to island conservation is to prevent the importation of exotic species. In Hawaii, they are viewed as the number one national park problem STONE and LOOPE 1996, (Figure 1) and one that extends to many other island groups, e.g., the Galapagos (LOOPE et al. 1988).

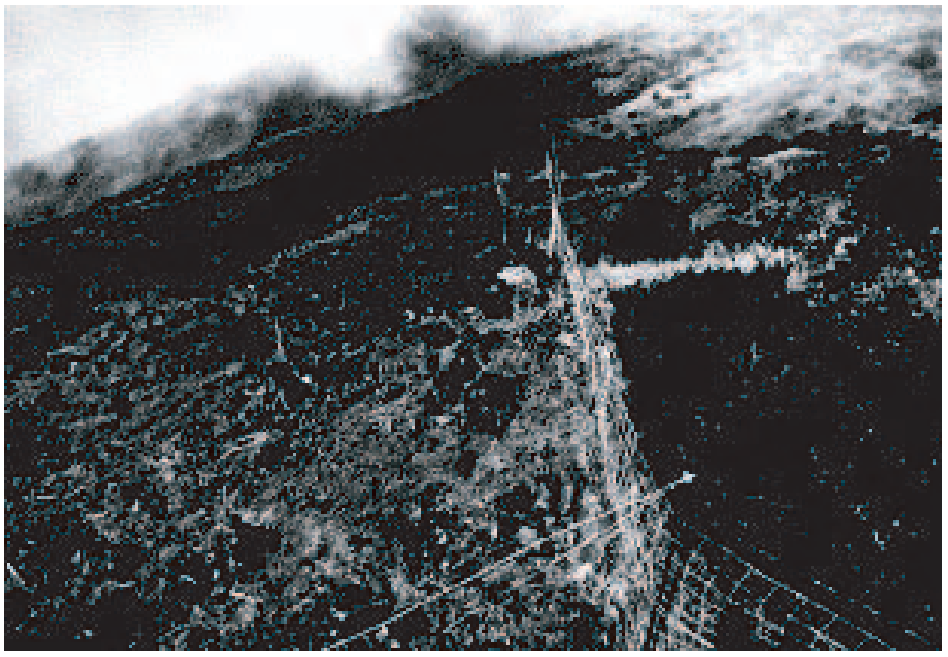

Fig. 1 - Illustrated are some very simple reserve design options for islands: 1) a whole-island protected reserve 2) reserve segregation 3) buffer zones around reserves, possibly coupled with economic incentives 4) buffer zones combined with corridors 5) buffer zones with both corridors and replicates, and 6) metapopulations theory requiring more than one small island or more than one population on the same island.

Two thirds of the extinct plants and animals in the United States are from Hawaii (VITOUSEK et al. 1987). However, amidst this gloom (OTA 1993, pp. 223-266) are a few park management success stories, such as removing some exotic species in Hawaiian national parks. About 70,000 goats were removed from Hawaii Volcanoes National Park, Island of Hawaii, between 1920 and 1970 with no lasting success. Continued removal and fence maintenance now has the goats under control. An external fence 112.6 km encloses about 1/3 of its rainforest. At Halealaka National Park, Island of Maui, goat control did not succeed until the construction of a 57 km fence in 1986 over mountainous terrain (LOOPE et al. 1988). "The effort required to remove the last 10 animals may equal that required to kill the first thousand; getting the last is absolutely essential" (KEPLER and

SCOTT 1985). The exotic plant control activity in Hawaiian parks is much younger, and it is too early to gauge its effectiveness (TUNISON 1991). In Channel Islands National Park, California, goats were removed from Santa Catalina Island, pigs from Santa Rosa Island, and rabbits from Santa Barbara Island (RICHARDS pers. comm.). The problem extends to non-Federal U.S. reserve systems (RANDALL 1993). There are exotic species removal success stories elsewhere. For example, VEITCH and BELL (1990) report that at least one of twelve species of mammals (e.g., cats, rats, possums) have been removed from 60 New Zealand islands and TOWNS and BALLANTINE (1993) note over 120 successful island pest eradication campaigns.

Can park design thwart invasion by exotic species? Probably not significantly. However, land adjacent to reserve boundaries with few native species (e.g., agricultural crops) might be preferable to a field undergoing secondary succession rich with invasive species (JANZEN 1983, HANSKI 1992). The down side of this recommendation is that cropland may not be as effective in encouraging animal movement across the reserve boundary. Reserve design takes on more significance in other contexts.

RESERVE LOCATION

New Guinea

Irian Jaya is the western part of the Island of New Guinea, owned by Indonesia. The nation of Papua New Guinea encompasses eastern New Guinea and the western Solomon Islands. DIAMOND (1986) mapped the terrestrial reserves established or approved by 1983 in Irian Jaya. Two reserves exceed 8,047 km^2 and 8 exceed 1,609 km^2.

Diamond indicates that presumed **centers of endemism** were one basis for establishing these New Guinea reserves. Such centers are usually species-rich for some taxa compared to other areas on an island. SCOTT et al. (1987) pioneered in trying to encourage new reserves being located at species-rich sites (e.g., forest birds on the Island of Hawaii) and identifying protected area vegetation gaps in a more methodical manner. Patchiness on islands is a real phenomena. GENTRY (1986, cited in HUSTON 1994) reported that of 22 species of the plant family Bigoniaceae on the Island of Hispanola, 19 are found on single small areas or outcrops. Centers of endemism/patchiness are useful considerations for locating reserves and do not flow from the Theory of Island Biogeography.

Diamond's second basis for New Guinea reserve selection was **capturing habitat diversity**--altitudinal and horizontal sequences of biotic communities. Habitat diversity is often, but not always, a function of area. Seeking habitat diversity per se does not flow from the Theory of Island Biogeography either, but from the work of WILLIAMS (1943).

A Lesson from Idaho

MCKENDRY and MACHLIS (1991) describe an "extended gap analysis" technique, applied to the state of Idaho, which includes socioeconomic factors such as human population growth and current land use, or specifics like pollution or mining. They rightly argue this technique could be useful in studying or predicting the effects of land use practices on biological diversity, not addressed in conventional gap analysis. Its formal or intuitive application could be useful for islands as well as continents.

Reserve Segregation with Entry Restrictions

One common sense approach to island conservation is locating villages or towns away from protected areas. BROOKFIELD's (1981) primary recommendation for future management of the Fiji Islands was to concentrate human populations and development in certain areas. It is not surprising that some of the best biotic communities in Puerto Rico and on some other islands in the Caribbean are on military reservations where entry is restricted (HOWARD 1977). Some impacts to islands are confined to lower elevations, with different undisturbed habitat types higher on the island (e.g. JUSTE B 1994). This is not because people could not get there but because the lower elevations were easier to settle.

The Barbados in the West Indies had 851.3 people/km^2 in the 1960s, much denser than the Atlantic Islands (GOUROU 1963). In 1994, the Barbados had 2,520 people/km^2. The number of bird extinctions in the West Indies correlates with humar population density (GREENWAY 1967). As island human populations increase, it not unreasonable to expect problems to worsen. This argues for land use controls such as zoning adopted for Hawaii (MYERS 1976).

RESERVE DESIGN

The Human Dimension

From Continents to Islands: Buffer Zones

Islands are unique, and there is danger in trying to view them as microcosms of continents or extrapolating from continental situations (TOWLE 1985). Nevertheless, are there other ecological lessons on continents relevant to biological diversity conservation on islands? Yes, and buffer zones are a good example (Figure 2). The need for buffer zones does not flow from the Theory of Island Biogeography either.

Biosphere reserves are often associated with the buffer zone concept. Efforts to

apply the biosphere reserve model to coastal and marine areas began in the United States in 1981 (RAY and MCCORMICK-RAY 1987, RAY and GREGG 1991). An example of an island U.S. national park biosphere reserve is Virgin Islands National Park on the Island of St. John, while another is the privately-owned complex of barrier islands called the Virginia Coast Reserve, Virginia. Neither biosphere reserve has the real buffer zones of the "model", but a great amount of work has been instigated in cooperative research and training to assist in better managing their natural resources (see Department of State 1995).

Fig. 2 - Timanfaya National Park, Island of Lanzarote, Canary Islands, is surrounded by a zone called a *natural park*, where agriculture and buildings of a prescribed architecture are permitted. Volcanoes in the national park are visible in the background (Photograph CRAIG SHAFER, February 1996).

Ecotourism

One way to better facilitate community participation in helpful reserve or island biotic management is by providing economic incentives to local people (MCNEELY 1988). Long-established human economic patterns or consumptive traditions can be extremely harmful when pressure to harvest increases. For example, Equatorial Guinea cannot sustain current heavy hunting there (FA et al. 1995). A reserve often cannot be walled-off from the effects of human settlements on the island so a key to reserve management success can

hinge on community participation. After educational efforts by conservation organizations, much of the local community on the Island of St. Lucia in the Caribbean embraced the need to protect the island's biota (WALTERS and RENARD 1992, STONE 1991).

Tourism and islands go hand-in-hand (CONLIN and BAUM 1995). The existence of a national park on an island can bring in revenue. For example, Virgin Islands National Park on the Island of St. John was estimated to have brought in $21.3 million in 1980 to the economy of St. John and St. Thomas. Virgin Islands National Park covers about 2/3 of the Island of St. John. The protected areas on Kangaroo Island, South Australia, especially the large Flinders Chase National Park, were estimated to bring in about A$1,700,000 each year from 1980-1983. The sixteen parks on Kangaroo Island range from 10-74,000 ha and cover about one-quarter of the island's 435,000 ha (references in DIXON and SHERMAN 1990).

The development of large tourist resorts on islands often provide lodging for some tourists who arrive just to relax, but who also may have come to see the undeveloped part of the island. Most of the islands in the Caribbean suffered this development backlash.

A study of twenty-three Caribbean islands revealed they passed through three stages of tourist development described as emerging low-impact, rapidly growing, and high-density mass-market destinations (DE ALBUQUERQUE and MCELROY 1992). However, there is another type of ecotourist who does not require luxury resorts on the island itself but who may seek or accept physical discomfort to see nature on a less-disturbed island. Ecotourism of this type is receiving more attention (e.g. BOO 1990, WHELAN 1991), and islands provide key opportunities (DASMANN et al. 1973). The methods usually entail providing jobs for local people as guides or subsidies. Such benefits for many can be more appealing than profits for a few people based on resource extraction. A remote protected area on New Guinea has been successful in using ecotourism to encourage the support of local people (PEARL 1994).

Saba Marine Park, located in the marine zone surrounding the nearby 12.5 km^2 Caribbean Island of Saba, was created in 1987. With Saba's approximately 2,000 permanent residents, it appears to be on its way to becoming economically self-sufficient just from revenue generated largely from scuba and snorkeling trips (SHERMAN and DIXON 1991). The Bonaire Marine Park, Dutch Antilles, established in 1981, is another good example of biodiversity conservation and economic development being compatible (POST 1994). A gross revenue of $23.2 million based on dive tourism was generated in 1991, but only $150,000 per year was needed to run the park (DIXON et al. 1993). This involved about 200,000 dives with degradation being limited enough to consider increasing the number of dives per year. Diving is not alway benign (HARRIOTT et al. 1997). The Islands of Bonaire and Aruba had a large amount of their tropical forest set aside which can also facilitate the generation of more tourist dollars.

A familiar ecotourism example is the Galápagos Islands, Equador. Controls are in place, e.g. qualified guides must accompany visitors, but the park is not without problems. An increasing number of tourists are disturbing animals and plants near the trails and owners

of private yachts, or pilots of small tourist boats, sometimes ignore existing rules (DE GROOT 1983). A smaller-scale successful example (where entry is more limited but also using approved quides) occurs for tiny islands offshore from the Island St. Lucia in the Caribbean (STONE 1991).

Islands for Science

Some islands may be too fragile for ecotourism. Chapman (1969) mentioned the need for a series of uninhabited and undisturbed islands-'islands for science'- set aside in the South Pacific strictly for scientific purposes. The idea emerged in 1966 (Björkland 1974) and a *draft* international convention existed in 1971. Others (e.g. DASMANN et al. 1973) supported the idea. This need is easy for scientists to understand, though harder perhaps for the general public to embrace. We need these baselines to measure what conditions were like before human onslaught (JENKINS and BEDFORD 1973). Without such yardsticks, we do not know how far we have come, or where we are going. The best examples in the United States are probably the seven small islands in the Hawaiian Islands National Wildlife Refuge, established in 1909, and some of the more than 200 islands in the Aleutian Islands National Wildlife Refuge, Alaska, established in 1913.

Biogeography and Population Theory

Some History

The beginning of "conservation biology" is sometimes attributed to MACARTHUR and WILSON (1963, 1967) who proposed general models to explain island species abundance and distribution. The MACARTHUR and WILSON (1963, 1967) models are often looked at today with skepticism (e.g. WILLIAMSON 1989a). ROSENWEIG (1995) provides a more supportive analysis.

These models were applied to designing continental nature reserve systems (e.g. DIAMOND 1975, WILSON and WILLIS 1975, DIAMOND and MAY 1976), resulting in much controversy (see SHAFER 1990). The reserve guidelines proposed by DIAMOND (1975) have been debated for two decades. Some revisions have been proposed (SHAFER 1994). Are any of the original reserve guidelines (e.g. DIAMOND 1975) still useful for islands? Yes, and they relate to size, connectivity and number.

Reserve Size

That certain species are absent below a certain minimum area is a real phenomenon, often illustrated as "incidence functions" derived from island observations (DIAMOND 1978).

Therefore, the recommendation that bigger is better for certain island species seems difficult to argue against (e.g. DIAMOND 1975). Incidence functions are related to the Theory of Island Biogeography. Small reserves have value (SHAFFER 1995; TURNER and CORLETT 1996). Ten mini-reserves on the Island of Mauritus may include 80% of its 300 endemic plants (McNEELY et al. 1990).

Reserve Corridors

Corridors are important (SAUNDERS and HOBBS 1991) in association with small reserves on an island. SCOTT et al. (1988) recommended a corridor for the non-contiguous protected areas on the Island of Hawaii. On the large Island of New Zealand, the 1,505 protected areas totaling 4,480,707 ha in 13 different management categories (DINGWALL 1984) provide an opportunity to incorporate corridors, another DIAMOND (1975) recommendation.

SLOSS versus Replication

After 20 years, the SLOSS controversy (i.e. will a **S**ingle **L**arge reserve preserve more species **O**r **S**everal **S**mall reserves whose combined area equals the single large one) still remains a topic of publication, perhaps because of the hope for a generic answer. Some of these papers have been couched in terms of island conservation. For example, BECKON (1993) found no evidence to suggest the maximum fragmentation strategy (i.e. maximizing the number of islands) would preserve more land bird species in the Fiji Islands than the minimum fragmentation strategy (i.e. maximizing the size of island components).

Ignoring SLOSS, reserve replication is important for a variety of reasons (SHAFER 1995). This can be expressed as three similar reserves on one island or as three distinct but fairly similar individual islands. The danger of chance events is as real on islands as continents. MACARTHUR and WILSON (1967) mentioned small populations on low islands are in constant danger of extinction from storms. "Catastrophe, such as volcanic eruption, has longer-lasting effects in an island situation, for there is little opportunity for a species to vacate the area and return subsequently, neither is reinvasion easy should extinction take place" (COX et al. 1973). However, some catastrophes do not turn out to be catastrophes for island biota, e.g., a recent major hurricane on Puerto Rico reduced the number of the rare Puerto Rican parrots but within a few years they rebounded to their former population level (Lugo pers. comm.). Therefore, although the SLOSS controversy is viewed as a red herring by many, the need for more than one reserve is very real.

Natural and Anthropogenic Extinctions

ATKINSON (1989) claimed that 90% of post-1600 extinctions of birds, reptiles,

amphibians and almost half the extinctions of mammals, occurred on islands. Most island extinctions Atkinson documents are human induced. MACARTHUR and WILSON (1967) were focused primarily on "natural extinctions", involving natural colonizations (we must ignore exotic species introductions). Although island size could exacerbate human impacts, we are stretching the context of MACARTHUR and WILSON's theory if we claim the findings of Atkinson are a reflection of its predictions. The same is true for plant extinctions on islands documented by LUCAS (1979). It is very hard, perhaps impossible, to attribute extinctions today due solely to natural events (WILLIAMSON 1989b) because human influences are ever-present (BROWN 1986). Nevertheless, RICHMAN et al. (1988) argues there was a post-Pleistocene "background" reptile extinction rate on South Australian and Baja California land-bridge islands that was independent of human impacts. These much slower "relaxation rates" over 10,000 years would be in accordance with thinking precipitated by MACARTHUR and WILSON. This slow natural relaxation provides an extinction "background" for the much faster and more obvious human (i.e. anthropogenic) island impacts we see today all around us. The combination of long-term natural change and short-term human impacts result in today's island landscapes (GOODMAN and PATTERSON 1997).

Autecology: An Alternative Focus

The Theory of Island Biogeography included stochastic models pertinent to all species. However, the importance of information on the natural history of a species was overlooked, a great oversight. "Waterfowl or seabirds, adapted to small patchily distributed habitats, might thrive in a series of small reserves; systems of comparable size would be inadequate for montane forest birds" .... Essential data include range, densities within that range, and critical ecological needs such as nest-site preferences, food, migration patterns, etc." (KEPLER and SCOTT 1985).

Metapopulations

One design concern relates to the concept of "metapopulations" (see GILPIN and HANSKI 1991). The study of dynamics of dispersal between islands (e.g. GILPIN 1980) helped in formulating the idea of metapopulations on continental habitat patches (e.g. GILPIN 1987). This concept also applies to a group of islands that are within frequent dispersal range of a species on one or more nearby islands. How many habitat patches and how many islands do we need to sustain metapopulations? Future research on a species will have to provide such insight. For continental situations, HANSKI et al. (1996) provided a guess for the long-term persistence of the Glanville fritillary butterfly: minimum viable metapopulation (MVM) is about 10 extant populations and number of suitable patches

should exceed 20.

Large distances between islands would preclude "metapopulations" except for some highly volant species. As DARWIN (1859) illustrated with the finches on different islands in the Galápagos, isolation of individual islands causes divergence within a species. This would preclude thinking in terms of metapopulations for this type of sub-species divergence situation. We need to retain these divergent races if we can. Figure 3 summarizes some of the previous discussion.

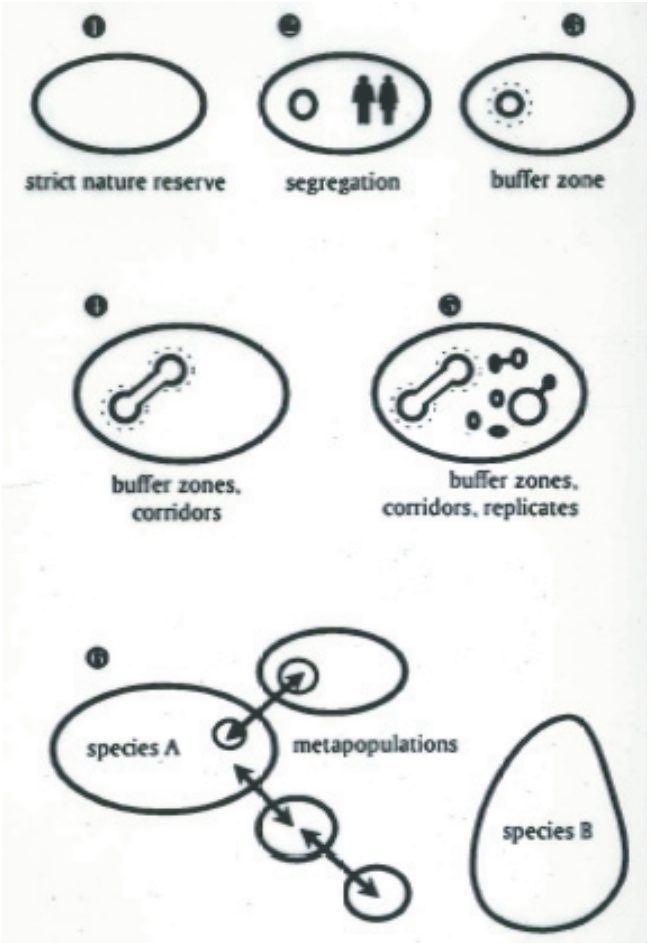

Fig. 3 - Simple designs of islands reserves: 1) a whole-island protected reserve; 2) reserve segregation; 3) buffer zones around reserves, possibly coupled with economic incentives 4) buffer zones combined with corridors 5) buffer zones with both corridors and replicates, and 6 metapopulation theory requiring more than one small island (or more than one population on the same island).

Population Viability

The persistence of a minimum viable population (MVP) has been defined as hinging on genetic, demographic, and environmental stochasticities, and natural disasters (SHAFFER

1981). Early on very rough generalizations emerged about how large a population needs to be to persist for a certain amount of time. For example, it was proposed that a mean of 2,000 vertebrates (give or take one order of magnitude) was needed for a 95% expectation of population persistence for 200 years (SOULÈ 1987). LANDE (1995) argues for an "effective" population size of 5,000 "to maintain normal levels of potentially adaptive genetic variance in quantitative characters under a balance between mutation and random genetic drift." A population viability analysis, a projection of a species' chances of persistence based on populations parameters and other influences (BOYCE 1992), is far better than relying on generalizations.

Genetics is presumed the least important component of MVP and catastrophe the most important (SHAFFER 1987). Additionally, the "deterministic" human dimension (e.g., human population density, development and pollution, or exotic species and climate change) could overshadow any so-called "stochastic" events in traditional PVA. Most ultimate causes of animal extinction today are probably anthropogenic, while the proximate cause (i.e., reason the last individuals die) could be genetic, demographic, due to catastrophe or direct human action like collecting or hunting (SIMBERLOFF 1986).

Small populations are highly vulnerable on islands or continents. Based on present guesses, can reserves on islands have minimum viable populations of all native species? This is unlikely for all species. However, management or planning actions like increasing reserve size, adding buffer zones, adding corridors/habitat connectivity/other reserve proximity, or translocating individuals of the same subspecies to bolster a population's size are all positive actions to reduce the probability of extinction. If it is not possible to preserve viable populations of some mammals, birds or reptiles, many smaller members of the island ecosystem still deserve our concern, e.g., insects (HOWARTH and RAMSAY 1991).

Climate Change

Since nature reserves will be impacted by climate change (PETERS and DARLING 1985), island systems may be particularly vulnerable. The major threat is the inability of species to move to higher latitudes to adjust to rising temperatures, unless oceans moderate changes in air temperature (LOOPE et al. (1988). There are options available to potentially thwart the effects of climate change for continental reserves (SHAFER 1994) but they have less relevance for islands. This prospect of species having difficulty in making latitude adjustments can produce a feeling of despair (PETERS and LOVEJOY 1992). However, the innate dispersal abilities of some biota does not mandate they will all vanish. They could move to remaining nearby islands with higher elevations.

Another aspect of this is rising ocean levels. Rising sea level during the Pleistocene created many "continental islands", e.g., Borneo in the Sunda Shelf. Studies of land-bridge islands facilitated the development of the Theory of Island Biogeography (MACARTHUR and WILSON 1963, 1967). Even oceanic islands far from continents were connected together,

e.g., many in the Solomons Archipelago. REVELLE (1989) projected a rise of 1.16 to 4.64 m by 2,100 AD, depending largely on how much polar ice would melt. A more modest projection of 0.1 to 1 m sea level rise by 2,050 AD was made by SCHNEIDER et al. (1992), assuming a 2-5°C rise in air temperature. Inundation of many of the 1,200 tiny islands in the Republic of the Maldives, Indian Ocean, could occur as their average island height above sea level is 1-2 m. Fringing barrier islands, like along the Atlantic and Gulf Coasts of the United States, could be broken up (SILVER and DEFRIES 1990). On the positive side, additional islands may be created from what are now peninsulas.

Terrestrial Island Reserves and the Marine/Coastal Component

Espousing the need to set aside marine parks is not new (RAY and CIAMPI 1956, RAY 1962) and the literature on coastal zone management is exhaustive (e.g. CLARK (1974, 1977, 1995). There is a growing awareness that a protected marine area benefits the harvestable biotic resources outside it (AGARDY 1994, SHACKELL and WILLISON 1995). A few common sense ideas in relationship to island reserves seem appropriate.

Reserves on larger islands should be extended to include the adjacent marine coastal area, if possible (DORST 1974). This is because some biota use both terrestrial and marine systems, and it is more difficult to protect a species if one habitat is being degraded. Indonesia may have followed such logic, demonstrated by its remarkable number of existing and proposed marine parks along with terrestrial reserves on the larger islands bordering the sea (SOEGIARTO et al. 1984).

RESERVE MANAGEMENT

Active Management or Laissez Faire

In contrast to most continental reserves, a hands-off or "laissez faire" approach might be best for those islands not already heavily impacted by humans. Unfortunately, there appear few, if any, such islands left today. Additionally, we do not always have the option of setting aside an entire island as the protected reserve (e.g. land donated in 1956 for Virgin Islands National Park consisted of 2/3 of the Island of St. John). This argues for an active role in island management.

If preserving the entire island is not feasible, MCEACHERN and TOWLE (1974) say land available on islands may force us, out of necessity, to ignore notions of minimum acceptable size. Similarly, pristine remnants is an ideal often not available to us. "There has been a tendency, where Hawaiian conservation is concerned, not to preserve some areas because they have been damaged" (CARLQUIST 1980). This is not a wise approach unless there are many more better examples still on an island or islands. All natural plant communities

for some islands in the Indian Ocean were gone by 1875 (MELVILLE 1970).

HOUSTON (1971) recognized most U.S. national park management consists of simply compensating for the influences of man. I think management of the world's reserves on islands will also have this same focus. For example, trying to reduce the numbers of exotic species, working to persuade local people to conserve native island biota, and keeping ecotourists from harming what they have come to see.

Development of a formal management plan for island parks is useful (e.g. COOPER and RYAN 1992). SALM and CLARK (1984, pp. 187-191) provide some general guidelines for small island management. They deal with construction and siting of facilities, sewage disposal, groundwater supplies, garbage disposal, human carrying capacity, education and interpretation, monitoring, planning, access, human movement within, souvenir collection, litter, tourism, permits, communal land ownership, and so forth. There are plenty of island reserves in the Unites States. Ninety-five islands, or part of islands, are managed or retained by The Nature Conservancy, a full 20% of its total reserve acreage in 1978 (CULTER and JENKINS 1978).

Islands have served a positive role as "analogues" for "habitat islands" in a "sea" of continental landscape alteration. Small islands in particular often become the "patient", suffering from too little management intervention. This can be said for some of our largest islands too (e.g. Madagascar). The welfare of our islands could be a barometer of what we value.

Managed Inter-Island Movement

Intraspecific Management Swamping

Genetic considerations are very significant for island design and management (SCHONEWALD-COX 1985). A management concern is unintentional or unplanned mixing of intraspecific gene pools. This could dilute the fitness of genomes that have taken millennia to evolve on islands (e.g. CONANT 1988). Any potential inter-island intraspecific transfers to bolster a declining population must first weigh the potential for genetic swamping (i.e., diluting the fitness of each highly-adapted population through outcrossing). Any management action can result in being highly beneficial or highly deleterious. In lieu of a crystal ball, caution and study are warranted any time a species is moved from one island to another for conservation purposes.

Interspecific Manager Rescue: Orphan Species

Ongoing island habitat destruction is resulting in little habitat left for some species. TEMPLE (1981) argues that inter-island transfers of "orphan" species is an alternative to consider. An orphan species is one that is endangered because its habitat is nearly gone. The problem is that it is hard to know beforehand if the orphan species will adjust to a new previously unoccupied habitat/island and how the species already on the island will adjust to

the orphan? New Zealand is wisely eradicating exotic species from some offshore islands before they introduce an orphan species. Some orphans come from the mainland (PRYDE 1997) and others from islands overrun by exotics (TOWNS and BALLANTINE 1993). Foresight and study is preferable to an impulsive management action for sub-species or orphans.

The Marine Zone

The coastal component of an island reserve involves some processes that are very widely regional in scale (e.g. coastal water movement bearing pollutants). Management of island reserves therefore requires regional ecosystem management to an even greater degree than for mainland ones because erecting fences in the sea is not feasible (RAY 1974). SAVINA and WHITE (1986) describe the creation of a marine sanctuary in the Philippines: local fishermen were involved in its establishment and they now assist in ongoing regulation and policing of fishing activity. Australia's Great Barrier Reef is not categorized as a national park, but as a protected area with a multiple use management plan. It consists of approximately 120 core areas connected by continuous buffer and transition zones covering 350,000 km^2 (KELLEHER and KENCHINGTON 1992, GUBBAY 1994). In fact, KELLEHER and KENCHINGTON (1992) recommend the sustainable multiple use concept for marine reserves instead of isolated, highly protected marine parks, to be accompanied by six "human use" principles:

> "establishing area boundaries for specific activities, i.e. zoning;
>
> enforcing closure during parts of the year critical to life histories of species or for longer periods;
>
> setting size limits, maximum permitted catches, harvest limits;
>
> prohibiting or limiting use of unacceptable equipment;
>
> licensing or issue of permits to provide specific controls or to limit the number of participants in a form of use; or
>
> limiting access by setting a carrying capacity which may not be exceeded."

PROTECTING ISLANDS IN THE UNITED STATES

Inventories

In the United States, data bases are being constructed about the locations of the best examples of about 180 different identified Hawaiian biotic community types, and a list of

potential reserves. The State, The Nature Conservancy, and others are involved in doing this. However, only about half of these 180 Hawaiian biotic communities were located in reserves (GAGNE 1988). The island state of Hawaii has more endemic flowering plant species per unit area than any other U.S. location (STONE and STONE 1989). Only Hawaii and California have 600 or more imperiled species (STEIN 1996).

Another inventory effort revealed that of 4,253 miles of barrier islands along the U.S. Atlantic and Gulf coasts, 1,399 km (33%) were developed, 307 km (7%) were committed to development, 1,458 km (34%) were protected, leaving 1,093 km (26%) undeveloped and unprotected (GREGG 1980). This led to legislation in 1981 to eliminate government subsidized flood insurance on remaining barrier islands (RAY and GREGG 1991). This is an example of a major inventory having an influence on deterring some future potentially harmful island development.

A number of island inventories were conducted for the National Park Service to identify potential national natural landmarks: the U.S. Virgin Islands (1975), Puerto Rico (1976), the Hawaiian Islands (1981), and the Pacific Island Trust Territories (1982). These data bases have been shared with more recent inventory activities.

All the above described inventories provide information that would be valuable in designing future reserves, possibly adding corridor connections, and generally allowing us to make good decisions about the future of the remaining natural island landscape. Knowing what you have is a necessary prerequisite to effective reserve design and management.

Land Protection Tools

Marine reserve establishment does not mandate a reserve's future protection. For example, of 104 Caribbean marine protected areas surveyed, 46% are regarded as "paper parks," predominantly in Central America (GROBER-DUNSMORE 1997). This is higher than the 27% calculated by OAS (1987, cited in REID and MILLER). The 46% had no management plan or enforcement ability and, only 3% on of all the reserves surveyed by GROBER-DUNSMORE (1997) prohibited all extractive uses. A federal government study made recommendations on how to better preserve the islands within the jurisdiction of the United States (i.e. 26,325 islands consisting of 11.6 million ha), including proposed draft legislation (HOFE et al. 1970). Besides outright land purchase, other potential methods include zoning by local or state governments, taxation, easements, and environmental permits (DASMANN 1973, HOOSE 1981). A number of United States and Canadian laws provide for establishment of marine reserves with varying degrees of protection, recently reviewed in terms of application in the Gulf of Maine (WATERMAN 1995).

U.S. MARINE PROTECTED AREAS

WALLIS (1971) provided an early review of United States and worldwide attempts

to create underwater parks. Below are a few U.S. examples of island reserves with a marine component. The first two (i.e. Virgin Islands National Park and Channel Islands National Park) have some adjacent submerged lands and waters within the park boundary but the third one (i.e. Hawaii Volcanoes National Park) does not. The last site (i.e. Channel Islands National Marine Sanctuary), an additional designation for Channel Islands National Park and beyond it, confers some additional protective benefits.

Virgins Islands National Park, U.S. Virgin Islands: Although the terrestrial part of the park was authorized in 1956, boundary changes have been authorized through 1978. In 1962, 2,691 ha of submerged lands and waters adjacent to the Island of St. John were added to the park. The 1962 legislation permitted fishing and boat landing, subject to follow-up regulations. Current regulations state fish traps and small nets to capture baitfish can be used by local residents, lobsters and conchs can be taken in limited numbers, and a few areas in the park are off-limits to any type of fishing. The regulations do not permit dredging, excavating or filling, or anchoring that causes damage. The park staff does not allow spearfishing. The Territorial Government adds additional restrictive regulations.

Channel Islands National Park, California: This site was created as a monument in 1938, but there have been boundary changes and additional islands added (currently five islands) through 1978. The Islands of Anacapa (1938) and Santa Barbara (1949) included waters within one nautical mile (1.85 km) from their shorelines as inside the Monument. When San Miguel and Prince Islands, Santa Rosa, and Santa Cruz were added in 1980, it included "the rocks, islets, submerged lands, and waters within one nautical mile of each island". The result was that about half of the area of the park is underwater. However, the 1980 regulations said "no provision of this title shall be deemed to affect the rights and jurisdiction of the State of California within the park, including, but not limited to, authority over submerged lands and waters within the park boundaries, and the marine resources therein." This is because the marine resources were excluded from National Park Service administration when the Monument was created. The marine resources belong to the state, which they manage. The Secretary of the Interior in 1980 was further directed to enter into agreements with the State of California and the Secretary of Commerce to enforce state and federal laws and regulations. Current park regulations specify some commercial fishing is allowed by permit (with specifics on species, type of fishing, and permissable areas in the Park) in accordance with State laws. It prohibits boat landings without a permit and does not permit any boats near one pelican colony. Park rangers are all deputized wardens and enforce California fish and game laws. The Service has gathered data (see DAVIS 1989) which persuaded the State to provide further protection to certain species, e.g., abalone. Other state regulations include an ecological reserve on part of Anacapa Island prohibiting the removal of all sea life out to a depth of 18.3 m. There are also invertebrate closures at Santa Barbara

and Anacapa Islands designed to protect intertidal species, and a closure at San Miguel Island to protect pinniped colonies.

Hawaii Volcanoes National Park, Island of Hawaii, Hawaiian Islands: This park was authorized in 1916 but boundary additions occurred up to 1976. The 1916 legislation permitted fishing by hook-and-line and June 1930 legislation specifically allowed fishing by native Hawaiians. Current regulations indicate sport fishing is allowed from about half of the 48.3 km park coastline but not commercial fishing. Only native Hawaiians can sport and commercial fish, gather food, and use fishing throw nets (with a State permit) from the other half of the park coastline. The State owns land offshore--1,093 ha of tidewater and submerged lands extending 1.6 km from the park shoreline. Rough ocean waters limit offshore boating, swimming and scuba diving.

Channel Islands National Marine Sanctuary, California: A national marine sanctuary provides federal "recognition" to a marine area by authority of Title III of the Marine Protection Research and Sanctuaries Act of 1972 (P.L. 92-532). The recognition is intended to provide additional protection in whatever manner is agreed upon by the state or federal agencies involved. Channel Islands National Marine Sanctuary extends six nautical miles (11.1 km) from the high-tide shoreline of the islands in Channel Islands National Park (described above). Prohibited activities include oil drilling and discharging materials (with exceptions). Within two nauticial miles (3.7 km) there should be no construction (with exceptions), dredging, anchoring, or commercial bottom trawling. Within one nautical mile (1.85 km) there should be no oil tankers. No airplane flights under 305 m are permitted to protect birds and marine mammals and disturbance to historic shipwrecks is not allowed.

There are many other types of marine or coastal protected natural areas in the United States such as federal national wildlife refuges, state preserves, and tracts owned by cities or universities. Circumstances involving island land ownership, authorities, regulations, and so forth usually varies from site to site. Based on the above, they even vary within different units of the National Park System. Additionally, there are other U.S. federal laws that influence what occurs within marine reserve boundaries, e.g., the Endangered Species Act of 1973 and the Marine Mammals Protection Act of 1972.

CONCLUSION

The location of reserves on islands can be based on centers of endemism, capturing island habitat diversity, or other biological factors. However, location will increasingly be determined by anthropogenic influences (e.g. location of towns or villages, projected human

population growth, and the sympathy of local people for reserve management goals).

Discussion of reserve design for smaller islands has been neglected compared to continents, with some exceptions (e.g. FRANKLIN 1985). Reserve design on islands, or amongst island groups, should also focus heavily on thwarting human impacts. Such impacts can be formidable and immediate, such as development or exotic species invasions (e.g. HOLDGATE and WACE 1961). Hence, the application of sociology and economics to biodiversity conservation is essential (MACHLIS 1992).

Endogenous influences in reserve design, precipitated in part by MACARTHUR and WILSON's (1963, 1967) influence, are not trivial. A few of DIAMOND's (1975) reserve design guidelines, often associated more with continents, are certainly applicable to islands: size, connectedness, and replication. The outright loss of some islands to development, and loss of parts of other islands, increases the importance of such considerations.

Protecting island reserves can involve segregating them from centers of high human population. In lieu of this, buffer zones, land use restrictions, and economic incentives are potentially useful tools outside reserve boundaries (SHAFFER 1998). The potential marine component of an island reserve involves some common sense considerations. It also requires the will and means to regulate human activity within the marine offshore area.

ELTON (1958) said "the reconstitution of their [islands] vegetation and fauna into a balanced network of species will take a great many years. So far, no one has even tried to visualize what the end will be." We probably do not know today. A lot of heroic conservation efforts have made an enormous difference for islands.

The long duration of scientific study on islands, and the voluminous number of publications about them (see WILLIAMSON 1981), does not mean we have all the answers about how to proceed to protect their native biota over the long term. We are still learning from oceanic island experience (e.g. JOHANNES 1978, BRANWELL 1990) and from all types of islands. Hopefully, this will continue based on between-country sharing of island reserve management and planning experiences. This must include any guidance natural and social scientists can provide us. Therefore, we must proceed based on our best available judgement while reminding ourselves of our ignorance. Such humility was advocated by FRANKLIN (1985): "We scientists and resource managers should repeat statements of fallibility to ourselves nightly, lest we begin to believe that our limited understanding of ecosystems is complete, let alone represents 'truth'."

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