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INDIGENOUS RESOURCE TABOOS: A PRACTICAL APPROACH TOWARDS THE CONSERVATION OF COMMERCIALIZED SPECIES

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Introduction

Beginning in the 1960s, dire reports regarding the state of the environment received substantial academic and media attention (Johnston 1997). Much of the concern centered on the explosive growth of the human population and the resultant environmental pollution and resource consumption associated with that growth. Loss of biodiversity was also cause for alarm and, today, ecosystem degradation and species extinctions is one of the top 12 paradigms of concern for the twenty-first century (Christopherson 2001).

Although habitat loss is widely blamed for dwindling populations of plants and animals, commercial traffic in wildlife and plant resources can also burden sensitive species (Wolch and Emel 1998). For example, the poaching of rhinoceroses for their valuable horns has been a major factor in their decline from an estimated one million animals a century ago, to fewer than 10,000 today (Brower 2000). Similarly, Africa and India once supported 10 million elephants but, due largely to the ivory trade, only 600,000 remain (Barbier et al. 1990). In the United States, Bent (1926) wrote that the long, flowing white feathers of egrets used as decorative plumes in the early twentieth century commanded $32 per ounce, or twice their weight in gold. Consequently, tens of thousands of egrets were systematically destroyed at numerous rookeries.

Laws designed to assuage the assault on commercially valuable species often have little impact. Indeed, the financial reward for successfully poaching an extremely rare species often outweighs the risk and consequences of being arrested. As a result of imbalances between reward and penalty, unlawful traffic in ivory, rhino horns, tiger bones, bear gall and other biological resources persists and constitutes the third most lucrative form of international crime after drug smuggling and weapons sales (Brower 2000).

Commercial trade in plant and animal products has a long history of deleterious biological and geographical consequences. In his magisterial analysis of human-induced environmental change, published as *Man and Nature*, George Perkins Marsh (1864:84) described the ecological calamity that often befalls species commercialization:

> So long as the fur of the beaver was extensively employed as a material For fine hats, it bore a very high price, and the chase of this quadruped was so keen that naturalists feared its speedy extinction. When a Parisian manufacturer invented the silk hat which soon came into almost universal use, the demand for beavers' fur fell off, and this animal–whose habits, as we have seen, are an important agency in the formation of bogs and other modifications of forest nature–immediately began to increase, reappeared in haunts which he had long abandoned, and can no longer be regarded as rare enough to be in immediate danger of extirpation. Thus the convenience or the caprice of Parisian fashion...may sensibly affect the physical geography of a distant continent.

Marsh's insights concerning anthropogenic environmental change had a profound impact on the intellectual development of geographer Carl Sauer. Like Marsh, Sauer lamented the efficient manner in which humans exploit earth's resources and wreak environmental havoc. Sauer intuitively understood cultural transformations of landscapes, and it was readily apparent to him that human civilization had been achieved at the expense of massive biological impoverishment (Livingstone 1992). In addressing the cause of accelerated twentieth century environmental degradation, Sauer concluded that modernization and the juggernaut of technology, industry, population growth, and new attitudes and values were to blame (Leighly 1987).

For Sauer, geography was the study of cultural history. At Berkeley, he focused on the transformation of natural environments into human landscapes by examining the economies and technologies of indigenous peoples. "Every human population, at all times, has needed to evaluate the economic potential of its inhabited area," wrote Sauer, "to organize its life about its natural environment in terms of the skills available to it and the values which it accepted" (Sauer 1956:49). Sauer's cultural history approach to environmental management is one of environmental ethics and aesthetics, permeated by a profound sense of nostalgia for earlier lifeways. As Leighly (1987:410) noted, Sauer

> ...had an avowed and durable preference for the simpler economies, to which the term 'ecology' as used by ethnologists may be appropriate. He liked the Indians he found in Mexico and other parts of Latin America—cultivating traditional crops in traditional ways—as he liked the old agricultural regions of the U.S. in which the land is cared for so as to provide support for the descendants of the present cultivators. He liked such societies because he thought they show promise of permanence.

The seeming harmony between society and nature that Sauer witnessed was almost certainly attained at past environmental cost. Moreover, as systems theory has demonstrated, long-term sustainability may be illusory (Brookfield 1980). Nevertheless, Sauer believed society has a moral responsibility to pass on to future generations a healthy environment, and he regularly stressed this conviction while reflecting on the gulf that exists between how industrialized and pre-industrialized cultures view their stewardship of earth's resources:

> As we study how men have used the resources available to them, we do distinguish between good and bad husbandry, between economical or conservative and wasteful or destructive use. We do not like soil erosion, forest devastation, stream pollution. We do not like them because they bring ugliness as well as poverty. We may cast up accounts of loss of productivity but we determine for good or evil the life of those who will come after us....The moralist lives apart from the quotations of the market place, and his thoughts are of other values (Sauer Papers 1949, cited in Leighly 1987).

Sauer (1956:68) became a dominant and guiding intellectual figure in a quest among geographers to locate and study examples of what he called "...wise and durable native systems of living with the land." In the 1950s, when technologically advanced nations viewed swidden agriculture as primitive and unproductive, Sauer (1956:68) countered, citing the folly of agricultural aid programs that

> ...pay little attention to native ways and products. Instead of going out to learn what their experiences and preferences are, we go forth to introduce our ways and consider backward what is not according to our pattern.

Sauer's prescient observations and insights helped spawn an intellectual renaissance among geographers and anthropologists in re-examining and revitalizing indigenous environmental knowledge.

Scholarly Interest in Indigenous Knowledge

Following Sauer's call for the study of traditional economies, geographers looked to indigenous knowledge in their search for models of sustainable development. In Oceania, the region of emphasis for this study, geographers Harold Brookfield, William Clarke, Randolph Thaman and Eric Waddell conducted pioneering studies of sustainable agricultural systems among the indigenes of New Guinea (Brookfield 1962; Clarke 1971; Clarke 1977; Clarke and Thaman 1993), and Randolph Thaman (1993) examined indigenous knowledge as a source of sustainable agriculture in Fiji. Elsewhere, the value of indigenous knowledge to contemporary society continues to resonate among social scientists. In his 1992 report to the United Nations Conference on Environment and Development, Secretary-General, Maurice Strong (1991:39) enthusiastically promoted indigenous environmental knowledge as an institution that offers valuable lessons for sustainability:

> The vast experience of indigenous people, as custodians of some of the earth's most precious and vulnerable ecosystems was frequently referred to in the working group meetings. Indigenous people's organizations and delegations at the plenary session stressed the capacity of local communities to identify their own measures to stem environmental degradation and requested that the UNCED secretariat consider the relevance of traditional knowledge and practices on the UNCED agenda.

Strong's words exemplify the increasingly valuable role that indigenous knowledge has for sustainable development.

The value of indigenous knowledge is also manifest in a growing number of books, professional journals and popular literature. In the 23 September 1991 issue of *Time* magazine, a cover story by Eugene Linden (1991:46), entitled "Lost Tribes, Lost Knowledge" explored the invaluable worth and regrettable loss of indigenous knowledge:

> Over the ages, indigenous peoples...have devised ways to farm deserts without irrigation and produce abundance from the rain forest without destroying...the ecosystem; they have learned how to navigate vast distances in the Pacific...; they have explored the medicinal properties of plants; and they have acquired an understanding of the basic ecology of flora and fauna. If this knowledge had to be duplicated from scratch, it would beggar the scientific resources of the West.

Linden (1991:46) compared the modern loss of indigenous knowledge to the destruction of the great library in Alexandria, noting that from the ashes of the flame ravaged remains, scholars had to "grope" in order to find and reconstruct that which was lost. In a similar vein, Geographer William Clarke (1993:253) recognized the destruction of tribal societies and the irretrievability of much traditional knowledge. "The cups of most indigenous peoples are broken," he said. "In atonement, Western science can at least try to sponge up some indigenous knowledge even if it cannot save indigenous lives."

Research Objectives and Hypotheses

The goal of this study has been, as Clarke (1993:253) admonished, to "sponge up" spilt indigenous knowledge, to devise an economic model based on indigenous conservation institutions, to test the model's effectiveness as a tool for the conservation of wild-harvested biological resources, and to explore the hypothesis that the commercialization and increased consumption of flying foxes in Guam led to the high incidence of neurological disease among the island's native Chamorro population. This dissertation examines the above objectives through three hypotheses:

1) The over-harvesting of flying foxes in Guam was the result of their cultural salience and not because of their caloric value as a food item.

2) If an indigenous culture, attempting to live in a sustainable manner with its environment, uses a biological resource highly vulnerable to over-exploitation, the use of the resource will either be restricted to elites or tabooed during periods of scarcity.

3) There is a strong positive correlation between the decline of Amyotrophic Lateral Sclerosis- Parkinsonism Dementia Complex (ALS-PDC) in Guam and the near extinction of Guam's flying fox populations.

Model Development

Economic models can be effective tools in visually depicting anticipated human responses to certain kinds of environmental stimuli. For example, a number of models have been devised to test whether indigenous hunters, like other predators, function as optimal foragers. According to optimal foraging strategy, a predator will switch prey preferences from a rare species to more common species when the energy return for a successful hunt fails to compensate for energy expended during search and pursuit efforts (MacArthur and Pianka 1966; Winterhalder 1977; Springer et al. 2003). Investigations of Cree Indian hunting patterns in northern Ontario suggest that at least some indigenous human populations do indeed function as optimal foragers (Winterhalder 1977). Changes in prey preferences, as exhibited by human subsistence hunters, are analogous to changes in consumer purchasing habits in a marketplace. If the price of a particular product, such as red grapes, increases substantially, rational buyers will alter their buying preferences and choose a less expensive substitute product such as a different variety of grapes. Among many indigenous cultures, rare game species are not purposefully sought out due to a high risk of harvesting failure and the associated consequences of hunger, reduced energy and possibly starvation. If a particular species can be efficiently harvested, even when it becomes locally diminished, indigenes (provided they are living in a sustainable manner with their environment), often taboo that species until its numbers recover to more stable levels.

Tribal taboos that regulate the harvesting of vulnerable species occur in several forms. Colding and Folke (2001) identified six such prohibitions. These include "segment taboos," which forbid individuals of a certain age, sex or social class from harvesting a resource; "temporal taboos," which ban the use of a subsistence resource during certain days, weeks or seasons; "method taboos," which restrict overly efficient harvesting techniques that may deplete the stock of a resource; "life-history taboos," that forbid the harvesting of a species during vulnerable periods of its life history such as spawning or nesting; "specific-species taboos," which protect a species at all times, except perhaps from elites; and "habitat taboos," which forbid human exploitation of species within particular reefs or forests which serve as biological reserves or sanctuaries.

The declaration and observance of resource taboos described above has been valuable in ensuring sustainable use of biological resources by indigenous peoples. Furthermore, virtually every modern management technique used by state fish and wildlife agencies in the West has been practiced for centuries in Oceania (Johannes 1978). One important difference between state and indigenous management techniques, however, is that state agencies emphasize the *quantity* of a resource that can be collected while tribal conservation strategies are more likely to dictate *when* and *where* a resource is collected. During the investigation of pertinent literature for this study, no examples were found where indigenous conservation strategies include the modern concept of numerical limits on fish and other animal species harvested.

Many indigenous societies historically managed environmental resources conservatively and by informally exercising the "precautionary principle." Conventional resource managers, on the other hand, often employ scientific concepts such as maximum sustainable yield (MSY), a strategy based on the faulty notion that ecosystems always gravitate toward equilibrium and stability. While ecosystems do possess some equilibrating tendencies, Veitayaki (1993:220) warns that MSY is highly subject to human error. Indeed, MSY can be difficult to determine, may be exceeded through illegal harvesting activity, and is subject to temporal change.

The usefulness of MSY in fisheries management has been seriously questioned because it is now known that certain fish communities exhibit chaotic population fluctuations due to unpredictable ecological events (Acheson et al. 1998). Conventional resource management strategies (such as MSY) therefore, sometimes lead to a gradual loss of ecosystem resilience (Berkes et al. 2000). Conversely, indigenous conservation institutions tend to preserve ecosystem resilience. Berkes et al. (2000) identify five ways in which indigenous conservation methods foster continued ecosystem integrity: First, indigenous management is carried out using rules that are locally crafted and socially enforced by the users themselves; second, resource use tends to be flexible, using area rotations, species switching, and other practices; third, the users have acquired a reservoir of ecological knowledge that helps them respond to environmental feedbacks, such as changes in the catch per unit of effort that help monitor the status of the resource; fourth, a diversity of resources are used (as opposed to placing all of one's eggs in one basket); and fifth, traditional ecological knowledge is uses qualitative management wherein feedbacks of resource and ecosystem change indicate the direction in which management should move (more exploitation versus less exploitation) rather than toward a quantitative yield target such as MSY.

The fact that indigenous peoples often exercised restraint in their exploitation of biological resources does not mean that indigenous conservation practices are superior to modern conservation techniques. Nor should one assume that indigenous societies always lived in harmony with their environment. There are ample examples of wasteful exploitation and species extinctions wrought by indigenous peoples. Fish poisoning, for example, was used in many areas of Oceania (Gatty 1953). This method of "fishing" killed both fry and eating-sized fish with equal efficiency. In Hawaii, islanders traditionally imposed closed seasons on tuna harvesting, yet fishing efforts were sometimes so successful that many of the fish rotted (Kamakau 1976). In Tonga, Wilkinson (1977) described a traditional method of fishing where men surround a coral head with a net and then systematically break apart the coral to drive the fish into the net—a practice that not only obliterates coral but destroys fish habitat. In Satawal, McCoy (1974) observed islanders harvesting turtles free of restrictions, despite stringent taboos that govern turtle harvesting in other Pacific Islands. To summarize, examples of wasteful harvesting coexisted with prudent use of biological resources among indigenous peoples of the Pacific (and elsewhere). Nevertheless, the presence of the former does not diminish the significance of the latter (Johannes 1978).

The model created for this study is based upon the concepts of optimal foraging strategy and the indigenous conservation institution of taboo. The purpose of the model is to provide resource managers an instrument to evaluate the vulnerability or resilience of particular species to commercial traffic. To a limited extent, the model is also useful in identifying species that are susceptible to the effects of other exploitative actions (such as deforestation) that can impinge on the sustainability of a wild-harvested species. Details of the model are described in Chapter Two.

Tests of the Model

In Chapter Two, I apply what I hereafter refer to as the "rarity-value model" to the over-exploitation of Pacific Island flying foxes on the island of Guam—an island where the native Chamorro population has been subjected to over 400 years of colonial influence and cultural change. The destruction of flying foxes in Guam and numerous other Pacific islands in order to satisfy the Chamorro dietary demand for the animals can best be understood from a perspective that integrates biological, cultural, technological and political elements. Such is the geographical approach to elucidating environmental degradation (Harvey 1996). Indeed, flying foxes were over-harvested in Guam due to several reasons including their cultural salience, monetization and militarization of the local economy, commercialization of flying foxes, loss of indigenous conservation traditions and the introduction of efficient hunting technologies.

As local flying foxes were nearing extinction in Guam, the island's flying fox market was internationalized. Bats from other islands became available to the Chamorros because of new technologies including air transportation and refrigeration. In the 1980s, during the height of the flying fox trade, legal attempts to quell international traffic in the animals were confounded by the resourcefulness of marketers who diverted shipments of harvested animals through Palau—a U.S. Trust Territory at the time. Flying foxes of Palauan origin were treated as products of domestic trade and were not subject to the stringent prohibitions that regulated international traffic in flying foxes (Lobban and Schefter 1997).

In Chapter Three, I examine the natural history, cultural salience, commercial exploitation and destruction of one of the world's most astonishing birds, the huia (*Heteralocha acutirostris*). The huia is a species of particular value for analysis under the rarity-value model because of its designation as a permanently tabooed bird by New Zealand's indigenous Maoris. The plight of the huia stemmed from its limited historical distribution, the replacement of indigenous traditions and beliefs by a colonial cosmology, and a poorly organized conservation program that replaced time-tested native strategies of sustainable fowling.

Cultural Consequences of Species Commercialization: the Value of Geography's Integrated Approach

The Pacific Islands, with their productive fisheries, forests and household gardens historically supported high human population densities (Thaman 1993). Indeed, at the time of European contact, numerous islands supported population densities of over 250/km^2 (Kirch 1984). Despite their productivity, the future sustainable use of Oceania's ecosystems largely depends on a receding reservoir of indigenous knowledge. Failure to implement that knowledge often leads to environmental degradation, economic collapse and compromised human health (Langdon 1989; Thaman 1993). Geographers and anthropologists suggest that long-term successful management of natural resources could be greatly improved by incorporating traditional approaches to environmental evaluation and exploitation.

During the 1980s in Newfoundland, an economically poor class of inshore fishermen claimed the cod fishery was in trouble when they began catching a large percentage of small, juvenile cod (McGuire 1997). Scientists dismissed the reports of individual inshore fishermen who expressed alarm over the decline in adult fish. Claiming that they had an institutional commitment to hard science, government scientists argued that the observations of local fishermen using traditional methods of capture were incompatible with carefully documented capture rate data among fishermen who possessed large boats and fish-finding technology. It was later learned that when cod populations decline drastically, the remaining fish congregate into large schools. New technologies made locating and capturing these concentrated fish an efficient process. As a result, the last cod became easier—not more difficult—to find and catch. Failure to heed the warnings of local fishermen resulted in the collapse of the cod fishery and 40,000 fishers and fish plant workers lost their jobs (McGuire 1997).

An article from Chapter Four of this study was previously published with Sandra Banack and Paul Cox (Monson et al. 2003). My primary contribution to the article was the description of flying fox consumption by the Chamorro people of Guam. Banack was the principle contributor of information on flying fox ecology, while Cox described the chemistry of cycad neurotoxins. All three authors contributed to the introduction and discussion of that article.

Because the ecology and population decline of Guam flying fox species was germane to the published article, I have included that information in Chapter Four even though similar details are discussed in Chapter Two. Moreover, a review of flying fox natural history and exploitation in Guam is useful in introducing the primary theme of Chapter Four, namely, the human health impacts of flying fox commercialization in Guam. During the twentieth century, a notable increase in the incidence of neurological disease occurred among Guam's native Chamorro population. Indeed, one tenth of all adult Chamorro deaths are attributed to degenerative diseases of the brain. Medical scientists have been searching for the cause of neurological disorders in Guam for a half-century, and geography is critical to unlocking the mystery. As neurologist Oliver Sacks (1997:105-106) observed:

> Epidemiologists are fascinated by geographic pathology, so to speak—the special vicissitudes of constitution or culture or environment which predispose a population to a specific disease. Leonard Kurland, a young epidemiologist at the National Institute of Health in Washington, realized at once when he read these initial reports that Guam was that rare phenomenon, an epidemiologist's dream: a geographic isolate.
>
> 'These isolates,' Kurland was later to write, 'are sought constantly, because...the study of disease in such an isolate may demonstrate genetic or ecological associations that otherwise might not be appreciated.' The study of geographic isolates—islands of disease—plays a crucial role in medicine, often leading to the identification of a specific agent of disease, or genetic mutation or environmental factor that is linked to the disease. Just as Darwin and Wallace found islands to be unique laboratories, hot-houses of nature which might show evolutionary processes in an intensified and dramatic form, so isolates of disease excite the epidemiological mind with the promise of understandings to be obtained in no other way. Kurland felt that Guam was such a place.

Researchers had originally suspected that the Chamorro custom of baking foods using flour prepared from the seeds of native cycad trees (*Cycas micronesica*) to be the cause of the Guam disease. Indeed, cycad seeds are known to harbor potent neurotoxins. However, the Chamorro people know of this danger and soak the seeds for prolonged periods in order to leach-out the toxins. Alternative theories for the cause of neurological disease in Guam were proposed, but none could account for the spike in the incidence of the disease in the 1950s and the subsequent disappearance of neurological disorders in individuals born after 1960 (Sacks 1997).

I suggest that a geographical perspective or multi-disciplinary approach is often necessary to tease out what Sacks called the "special vicissitudes of constitution or culture or environment which predispose a population to a specific disease." In Chapter Four, I provide evidence supporting a recent hypothesis that neurodegenerative disease in Guam was not due to the cultural tradition of using toxic cycad seeds in baking, but rather the custom of consuming flying foxes that eat cycad seeds and accumulate neurotoxins in their organs. Medical researchers have long known that the Chamorro people use cycads seeds to make flour; biologists have long known that Guam's flying foxes eat cycad seeds; but the prolonged failure to identify an additional and crucial link in the intimate connection between culture and nature in Guam appears to be responsible for thousands of premature deaths. If so, I hope this study will stimulate additional interest in Geography's unique integrative approach. Such a perspective was certainly advocated by Carl Sauer.

In Chapter Five, I evaluate the usefulness of several modern management strategies intended to ensure sustainable populations of monetized species. Chapter Six of this dissertation contains a summary of my research results and a discussion of future implications.

Chapter Two

Prestige, Taboo and Sustainability: Predicting Wildlife Population Trajectories in Indigenous Commerce

Introduction

Habitat loss is widely cited as the major cause for dwindling numbers of plants and animals, but commercial harvesting can also negatively impact species' population dynamics (Wolch and Emil 1998). Whereas commercial traffic in plant and animal products has severely eroded the population stability of some wild-harvested species, others, such as berry-producing shrubs in Nordic countries, have sustained little if any negative impacts (Kardell 1986; Salo 1995).

Under what conditions, and for what type of wild-gathered populations, is extirpation likely? Conversely, under what conditions, and for what type of wild-gathered populations is sustainable harvesting possible? Given the rapidity in which wild-gathered species can be introduced into commerce, with explosions of commercial traffic in certain herbal remedies in Europe, bush meat in Africa, or geoduck clams (*Panope generosa*) in North America, it would be useful to have a model that could predict wildlife population trajectories subsequent to commercialization. Such a model could help conservation efforts be proactive in guiding efforts to protect wild-gathered populations and ensure sustainable harvests for gatherers. It may also identify in advance species whose biology, life history, distribution, abundance and cultural saliency predict extirpation and extinction rather than sustainability as a consequence of commercial traffic. Management of wild-gathered species could then become less of an exercise in biodiversity triage and allow sustainable commercial harvest of resilient species while prohibiting traffic in vulnerable ones.

Although species monetization and commercial trade in wildlife resources is often regarded as a relatively modern phenomenon, ample precedents for barter, trade, and simple commerce in wild-gathered species have long existed among indigenous peoples (Kirch 1997). Consequently, I suggest that some solid insights might be gained from indigenous strategies for management of wild-gathered species. Negative population trajectories, such as those that have led to species extinctions (as in New Zealand's moas) have likely led some indigenous societies to develop strategies to anticipate negative consequences of exploitation of wild-gathered species and avoid, or ameliorate, such consequences if they occur. Although such indigenous strategies are often embedded in the taboo systems, religious strictures, legends, myths, religions and other "informal institutions" of indigenous peoples (Colding and Folke 2000), it is possible to simulate such strategies, and test them against observations of indigenous plant and wildlife management techniques. In this chapter, I offer a detailed case of vulnerability to perturbation in the case of traffic in flying foxes in Guam. The concepts of the models described below were developed with the assistance of Paul Cox and Lyndon Wester (personal communications).

Rarity-value Curves and Wild-gathered Species: A Model

As stated in Chapter One, the following model is based upon the concepts of optimal foraging strategy and indigenous resource taboos. Additionally, graphical depictions of mathematical inequalities as described by Levins (1968) were also important to the model's development.

Economic data of traffic in endangered species, particularly non-commercialized traffic by indigenous people, are patchy. Consequently, production of a continuous function in a strict economic sense is difficult. To provide a simple test to determine from patchy data whether commercialization of a particular species might lead to its extinction, I chose to develop a graphical model which could be tested for convexity (conservation) or concavity (extinction) of the rarity-value curves described in Chapter One. The concept of using graphical models to test for convexity or concavity was originally developed by Levins (1968) in his exploration of the fitness of species placed in different environments. Levins' ideas were later modified by Charnov and Bull (1977) to determine whether sexually monomorphic or diomorphic strategies would prevail in a specific environment. This general approach allows one to quickly test, without knowing all points of a line, whether or not a function dips above or below an isocline. In the model which follows, I have chosen as the isocline the function $N/k + V/V_{max} = 1$.

In wild-gathered species where increasing rarity is negatively correlated with value, market forces will slow harvesting well in advance of extirpation. However, where rarity and value are positively correlated, the shape of the rarity-value curve can be used to predict harvest sustainability. If N is the population size, k is the population size at carrying capacity, V is the market price attributed to a single individual at any point in time, and V_{max} is the maximum value, one can plot N/k versus V/V_{max} with both axes ranging between zero and 1. Note again the following equation:

$$N/k + V/V_{max} = 1$$

The results can be taken to represent a species population where increasing rarity results in a simple linear increase in value (Figure 1). However, species whose rarity-value curves lie above this line possess convex trajectories. Convex rarity-value curves satisfy the following inequality:

$$N/k + V/V_{max} > 1$$

In the case of convex curves, increased effort in obtaining rare individuals produces diminishing rates of return. To the degree that indigenous peoples behave as optimal foragers, they will, if possible, switch from uncommon species to common species once rarity passes a certain threshold. Species with convex rarity-value curves, then, will not be extirpated. In other words, as rarity increases, there will be strong incentive to switch to an alternative resource since increasing effort in hunting or gathering yields increasingly modest gains to the forager (Winterhalder 1981). Examples of species that might exhibit convex rarity-value curves include fruit-producing species with nutritional value or medicinal plants used for minor ailments.

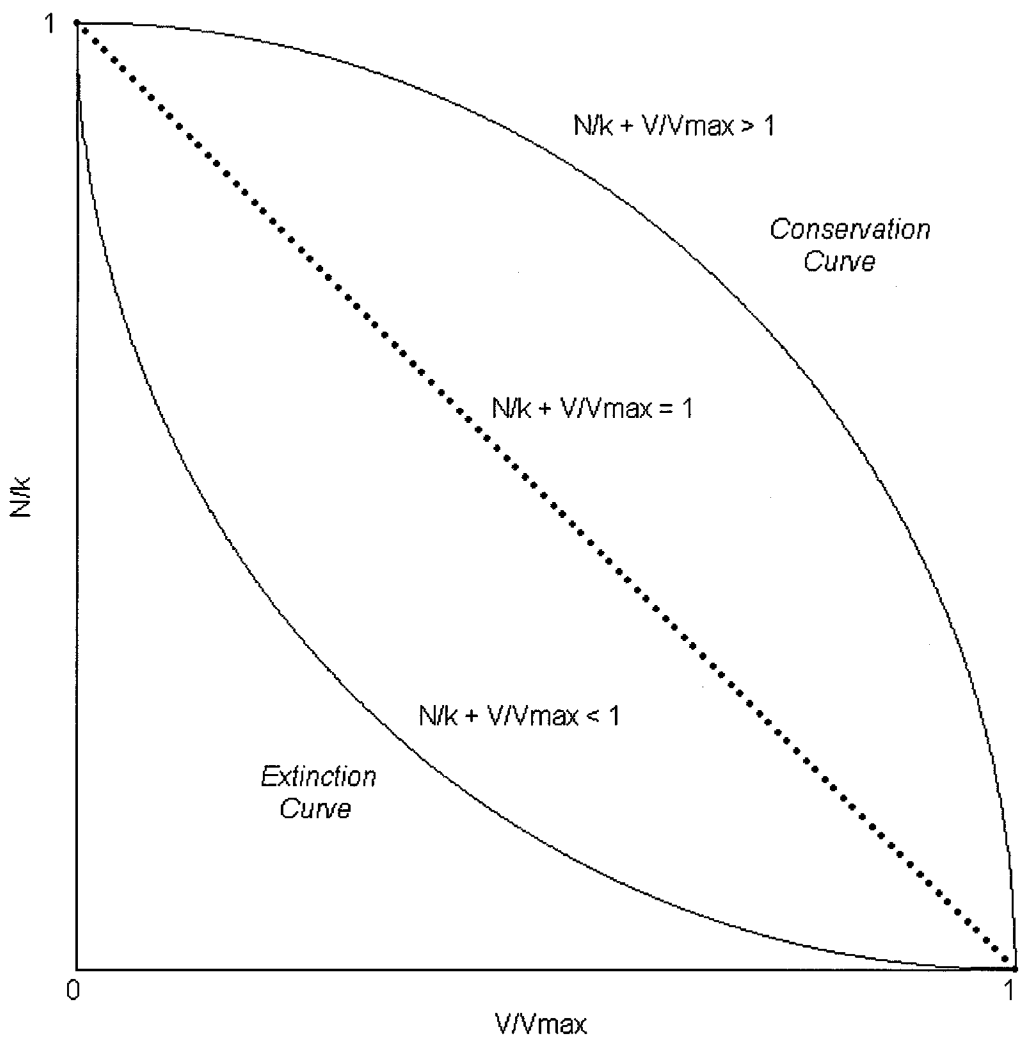

Figure 1. Relationship between rarity and value for wild-gathered and commercialized species. Species with convex curves are likely to endure commercial harvesting while species with concave curves are prone to extinction. In the above figure, N is the population size, k represents carrying capacity, V is the market price attributed to a single individual at any point in time, and V max is the maximum value likely to be attained.

Generally speaking, species with convex curves are those for which alternative resources are available. Once such species reach a threshold of rarity, the added effort in obtaining them no longer justifies the return.

Another set of species includes those whose rarity-value curve is concave and lies below the isocline:

$$N/k + V/V_{max} < 1$$

In these species, value continues to rise as they become rare, possibly yielding high incremental returns per unit even as their numbers plummet. Reasons for persistent harvesting may include an absence of alternative resources or cultural beliefs that existing substitute resources (in the case of aphrodisiacs, for example) are of inferior efficacy. In such species, extirpation or extinction is a likely outcome of commercialization. Tigers used for medicinal purposes and certain rare ladyslipper orchids (*Phragmipedium kovachii*) are examples of species that appear to possess concave rarity-value curves. Trophy animals sporting large antlers or huge tusks are another example of species likely to have concave trajectories. A wealthy hunter, for example, will sometimes pay an enormous sum to harvest such an animal because its display value (particularly if in a museum) imparts prestige to the hunter.

Under this model, convexity, or, concavity of the rarity-value curve becomes diagnostic for species survival under commercial traffic. Although for ease of illustration I have shown these functions as single, simple curves with only a single inflection point, these same arguments hold for rarity-value sets that cannot be portrayed as simple curves; indeed for many species, particularly where markets are small or species particularly rare, there may be multiple values at any point of rarity. In the following discussions I therefore use the term "concave" to refer to species whose rarity-value sets are composed of points primarily below line 1) and "convex" for species whose value-rarity sets lie above this line.

If the rarity-value curve of a wild-gathered species is convex, management techniques and natural market forces are likely to protect it from extirpation. However, this depends upon the threshold of viable population size expressed as a function of carrying capacity. For species with large home ranges, extremely low reproductive capacity, complex life histories or group-foraging strategies, the minimum viable population size when normalized by carrying capacity may in fact be rather high. Examples of such species may possibly include pandas (*Ailuropoda melanoleuca*) and baboons (*Papio ursinus*) or plants that are highly pollinator-limited, or in which pollen aerodynamics are deeply influenced by population structure such as in certain endangered conifers or sea grasses. However, in those species where the minimum viable population is not extremely high, normal regulatory techniques and management could be predicted to protect the species reasonably well from extinction.

However, with species that have a concave rarity-value curve, commercial traffic is likely to lead remorselessly to extirpation, precisely since the value is largely driven by rarity, particularly in the stages immediately preceding extinction. An example of such a species is the *kara tau argali* (*Ovis ammon nigrimontana*), an extremely rare Asian sheep. Recently, a hunter contributed $20 million dollars to a museum that he hoped would legitimize the import of his recently killed trophy (*USA Today*, 3 February 2000).

If cultural or environmental factors do not alter a rarity-value curve from convex to concave, one can assert that such species are likely to persist if commercialized. However, if monetization and the advent of modernity can change that same trajectory from convex to concave, such species are not resilient and are in danger of extinction.

One potential challenge of applying the rarity-value model to modern resource management is that of determining carrying capacity. Historical population figures for a species in a given area, if available, can be helpful, but carrying capacity is subject to both temporal change and spatial variation. Natural disturbances such as drought, for example, can reduce an area's carrying capacity. Additionally, key resources such as food, water and shelter are not uniformly distributed in most environments. Therefore, carrying capacity for one locality can vary significantly from that of an adjacent area. Assessing the distribution of key resources for a species, then, can greatly improve the accuracy of carrying capacity estimates (Zimmerer 1994).

In cases where estimates of carrying capacity are subject to an unacceptable margin of error, the following minimum viable population model provides an adaptable alternative.

Minimum Viable Population Model

In this model (see Figure 2), population is plotted on the x axis from high population to low population, with a point representing the minimum viable

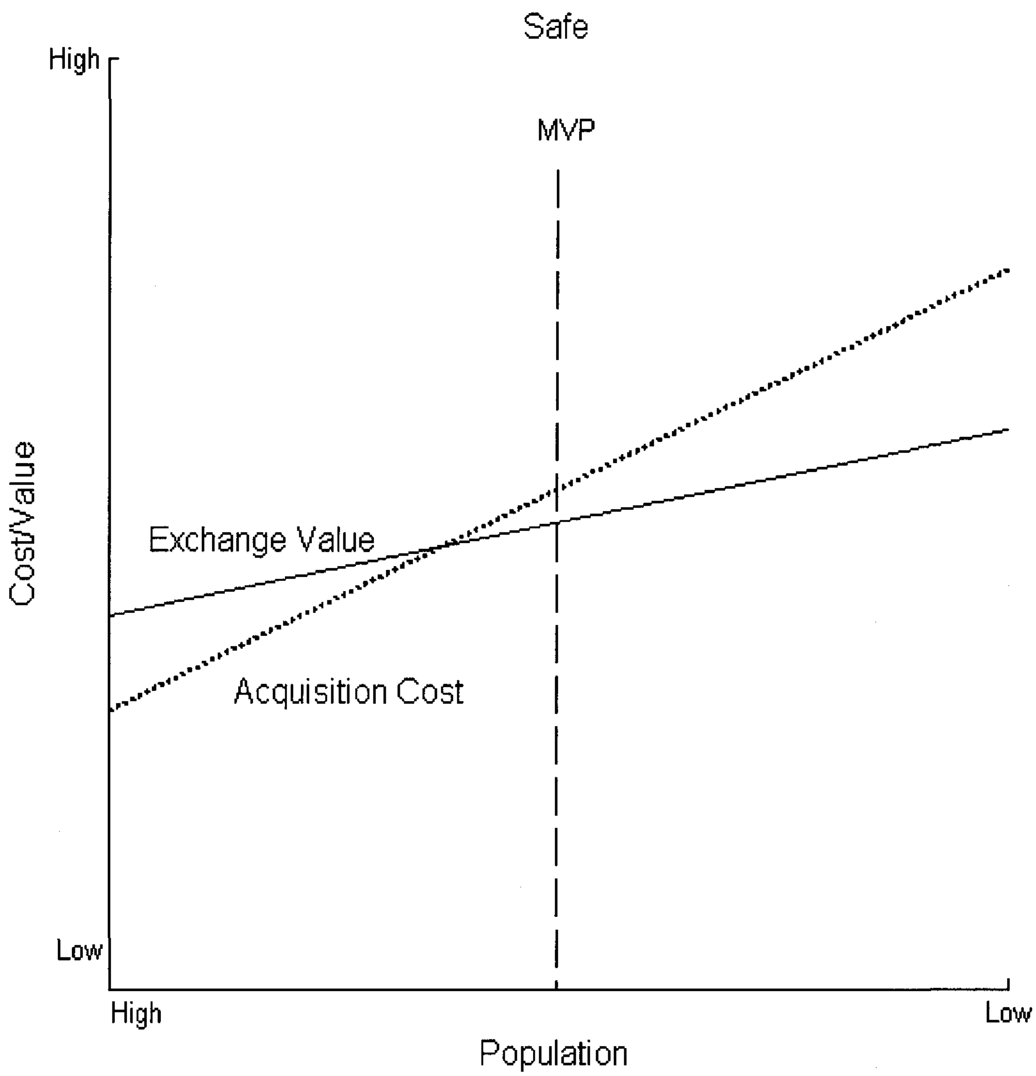

Figure 2. Minimum Viable Population Model (Safe). Populations are reasonably secure when acquisition cost and exchange value lines intersect before the minimum viable population threshold.

population (MVP) for the species under evaluation. The acquisition cost (AC) in a barter system or market is plotted on the y axis from low cost to high cost. One can assume that as a commodity becomes rare its exchange value (EV) will increase and the value will be bid up (Lyndon Wester, personal communication). Several factors will influence the trajectory of this line. Commodities for which no alternative resources exist and resources that have cultural saliency will have steep curves rising to high values. The EV could also be raised by an increase of a society's wealth, or if the potential market for the resource expands.

The other factor that determines the hunting or collecting pressure is the time, energy or monetary cost needed to acquire the resource. This acquisition cost (AC) will presumably increase as a species diminishes, but AC will also be affected by factors such as improved technology. The distance between the lines represents profit, which determines hunting or gathering pressure. In cases where AC exceeds EV before the MVP point is reached, hunting or gathering pressure should diminish and exploitation of the resource may be considered sustainable. Sustainability, of course, assumes that the resource will not be regularly encountered and harvested opportunistically during hunting or gathering forays. If such harvesting does occur, species for which the EV and AC trajectories intersect near the MVP will still be in danger (Lyndon Wester, personal communication). It should also be noted that stochastic disturbances such as fire could drive a species' numbers below the MVP. Therefore, any species whose AC and EV curves intersect near the MVP value should be considered vulnerable. Additionally, if the AC and EV curves intersect at a point beyond the MVP value, the species is highly susceptible to over-harvesting and extinction is likely (Figure 3).

In monitoring the EV for a species over time, several factors may potentially flatten or elevate the trajectory of the curve. The extinction or legal protection of a more desirable resource could increase the EV angle of what was formerly a less desirable, secondary resource. Conversely, the advent of captive propagation or commercial cultivation would likely reduce EV. Factors likely to reduce demand for species of commercial value are discussed in Chapter Five.

A final note regarding the use of the MVP model is in order. For many conservationists, the concept of MVP is ethically problematic. Indeed, conservationists argue that it is their responsibility to promote abundant populations of species, not the minimum number necessary for sustainability (Soulé 1996). Different segments of society, of course, will have varying opinions regarding an acceptable definition of MVP. The number of individuals in a population necessary for ensuring a 70% probability of persistence for 100 years, for example, is lower than the number required for ensuring a 99% probability of persistence for 1,000 years. Moreover, MVP can vary widely from one species to another. For New Zealand's huia, 500 individuals may have been sufficient; while the MVP for North America's extinct passenger pigeon (*Ectopistes migratorius*) may have exceeded 50,000. In determining MVP, then, one must consider a species' biological characteristics as well as the preservation values of the society determining a species' future.

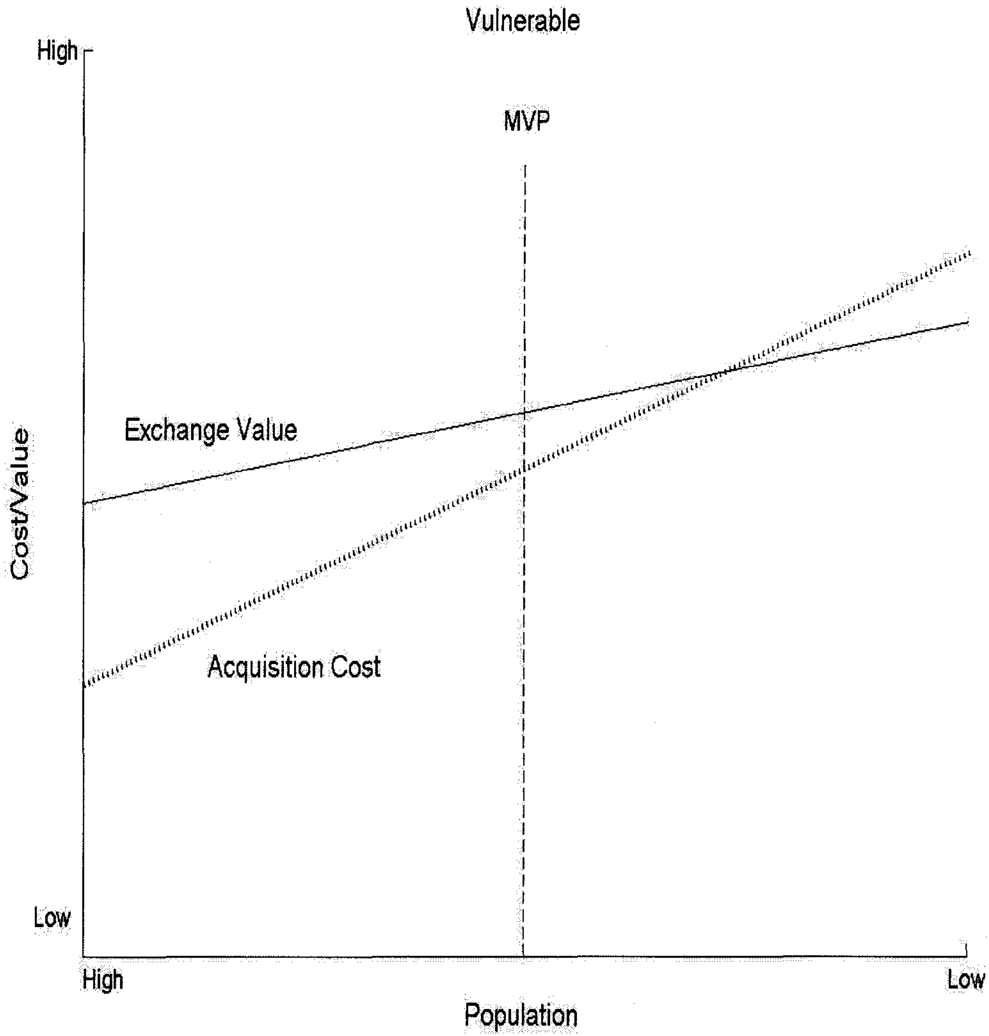

Figure 3. Minimum Viable Population Model (Vulnerable). Populations are not sustainable when the acquisition cost and exchange value lines intersect beyond the minimum viable population threshold.

Conservation Function of Taboo in Traditional Societies

The harvest of an extremely rare species, such as the kara tau argali, described previously, would be unlikely to occur in an indigenous society where social customs and taboos against unsustainable killing are stringently enforced. The nineteenth-century fur trapper, Osborne Russell, for example, described the strict rules that governed bison harvesting among the North American Crow Indians:

> No person is allowed to hunt Buffalo in the vicinity where the village is stationed without first obtaining leave of the council—for the first offense the offender's hunting apparatus is broken and destroyed, for the second his horses are killed, his property destroyed and he beaten with rods, the third is punished by death...(Haines 1965).

Social restrictions governing the harvesting of culturally significant species as described by Russell are found in virtually all indigenous societies. The term "taboo" is derived from the Tongan word, "*tapu*" and is often used to describe certain prohibitions against activities potentially harmful to natural resources, species, and ecosystems. Taboos governing the exploitation of natural resources are still common in many traditional cultures because indigenous communities often rely on limited land from which most of their resources derive (Colding and Folke 2000, Gadgil et al. 1993). This is particularly true for societies inhabiting small, remote Pacific Islands. Indeed, although Pacific islanders trade with distant markets across what Brookfield (1980) calls the open highway of the sea, opportunities for transforming local raw materials into lucrative exports are often scant (Gadgil et al. 1993). Consequently, indigenous societies frequently take a proactive role in the long-term sustainability of local resources (Gadgil 1987).

In Oceania, village chiefs often impose taboos in order to restrict access to certain food items (both plant and animal) when those resources are in short supply in either time or place (Colding and Folke 2000). When the resource is no longer in danger of over-exploitation, the taboo is usually rescinded. Taboos are commonly imposed upon marine resources in Polynesian societies when opportunities for over-exploitation arise (e.g., spawning periods) (Gadgil et al. 1993; Titcomb 1952). Such taboos have proven highly effective in resource management, and while such strictures are quite recent in the developed world, they have been practiced for centuries by traditional societies (Johannes 1978). I suggest that species subject to intermittent taboos are likely to have convex rarity-value curves. In this case, taboo can be interpreted as a resource management technique with extraordinarily strict penalties for abuse.

Some species are perennially under taboo, regardless of abundance. Harvesting of these species may still occur, but take is typically restricted to high chiefs and priests. Continually tabooed species may represent species with concave rarity-value curves for which commercial traffic will likely terminate in extinction.

It is important to note that while some species-specific taboos were designed to protect vulnerable resources by limiting their use to elites or prohibiting their use entirely, other species were tabooed strictly for religious reasons or because they were believed to be poisonous. Among some villages in the Solomon Islands, for example, dolphins are taboo because of traditional religious beliefs that shamans can transform themselves into dolphins. In other villages of the same island chain, dolphins are relentlessly harvested strictly for the cultural value of their teeth

(Dawbin 1966). Regardless of the reasons for tabooing certain species, cultural rules that reduce or prohibit harvesting pressure probably helped preserve biodiversity.

Species-specific Taboos in Oceania

Identifying all species of plants and animals tabooed either temporarily or permanently in Oceania is a difficult task, especially since knowledge of some species taboos may have been lost. Furthermore, a common indigenous resource conservation strategy was to taboo particular habitat patches such as certain forests, reefs and drainages. Habitat taboos had the effect of preserving biodiversity without having to taboo specific species that may have otherwise been vulnerable to over-harvesting. A list of several species permanently tabooed in areas of Oceania is provided below (Table 1):

Species	Island(s)	Information Source
Sea turtles	Tuvalu, Tongareva, Tobi, Sonsorol, Uvea, Lau Group	Zann 1985; Buck 1932; Johannes 1978; Burrows 1937; Thompson 1940
Flying foxes	Tikopia	Kirch and Yen 1982
Huia	New Zealand	Phillipps 1963
Lizards	New Zealand	Phillipps 1963
Sharks	Hawaii, Fiji	Taylor 1993
Dolphins	Solomon Islands	Skehan 2003
Birds of Paradise	New Guinea	Colding and Folke 1997
Whales	Fiji	Roth 1953

Table 1. Species-specific Taboos in Oceania.

Evident from Table 1 is the fact that sea turtles were often taboo in Pacific Island cultures. Often, the taboo on sea turtles applied only to commoners. Elites, on the other hand, often indulged themselves by eating this delicacy. Although sea turtles were consumed by individuals of various social classes on some islands, strict taboos still governed turtle harvesting. Turtle harvesting on beaches, for example, was often prohibited in Samoa, Kiribati and Enewetak (Luna 2003). Interestingly, many sea turtle populations today are endangered. One possible interpretation of this phenomenon is that Pacific Islanders had learned through trial and error that turtles were easily over-exploited.

The taboo nature of sharks in the Hawaiian Islands is an example of a permanent taboo that was probably intended primarily for religious reasons. Nevertheless, sharks, because of their relatively low reproductive potential, are readily over-harvested—particularly with the aid of modern fishing techniques. Recently, the commercial value of shark fins has led to over-exploitation of sharks in Oceania (*Honolulu Star-Bulletin*, 22 June 2000). Mangel et al. (1996) point out that long-lived, slow-reproducing species, such as whales, sharks and primates, may be especially vulnerable to over-harvesting.

Switching Rarity-value Curves from Convex to Concave: The Case for Guam Flying Foxes

Southernmost of the Marianas Islands, Guam (13° N, 144° E) has an area of 540-km2 and is situated in the west Pacific approximately equidistant between Papua New Guinea and Japan. The ancestors of Guam's indigenous population, the

Chamorros, emigrated from Southeast Asia at least 3,500 years BP (Bonhomme and Craib 1987; Athens and Ward 1995). Guam's early inhabitants subsisted mainly on agricultural crops and marine resources but augmented their diet with a number other food items including flying foxes (Thompson 1945).

There were formerly two pteropid species in Guam. One species, the Guam flying fox (*Pteropus tokudae*), is a recently extinct endemic (Wiles 1987a). Guam's extant pteropid, the Marianas flying fox (*Pteropus mariannus mariannus*), is distributed throughout most of the 700 km-long Marianas archipelago (Wiles et al.1989; Lemke 1992).

Flying foxes are relatively long-lived but have low reproductive potential. After attaining sexual maturity in one or two years, females give birth to one young annually (Rainey and Pierson 1992). Many flying fox species, including *P. mariannus*, are highly social and congregate during daylight hours at communal roosts. Preferred roosts are large emergent trees that are dead or sparsely foliated. Flying foxes exhibit considerable fidelity to traditional roost sites where many thousands may congregate.

Flying foxes are generalist frugivores and nectavores. On isolated oceanic islands, local floras are highly dependant on flying foxes for pollination and seed dispersal (Cox et al. 1991; Elmqvist et al. 1992; Banack 1998). Since the diversity of pollinating organisms is low on remote islands, ecologists recognize island flying foxes as keystone species (Cox et al. 1991; Lemke 1992).

Throughout most of their range in western Oceania, flying foxes are occasionally consumed by indigenous peoples (Chambers 1991; Cox 1983;

Wodzicki and Felten 1975). In Guam, however, the eating of flying foxes, known locally as *fanihi*, assumed extraordinary significance (Wiles 1987a).

Three unique features of the consumption of flying foxes in Guam demonstrate their culinary importance. First, many Chamorros identify the eating of fanihi as an important part of their cultural identity (Sheeline 1991). Second, Chamorros often consume the entire body of the animal including brain, liver, entrails, wing membranes and fur (Garcia 1984; Wiles and Payne 1986; Wiles et al. 1989; Lujan 1992). Elsewhere in Oceania, only flying fox breast meat is eaten. Finally, in response to their high cultural value, flying foxes became commercialized in Guam.

When flying fox prices escalated, Chamorro hosts continued to serve fanihi flesh to dinner guests even though portions were necessarily meager. The intent in serving small quantities of fanihi was not to satiate the appetites of guests but had taken on a symbolic function. Lujan (1992) asserts that the offering of small portions represents an “incongruity” on the part of the Chamorro host, since it is bad form to run out of food at a social event. In Chamorro culture, however, this breech of etiquette is ignored when rare foods such as flying fox are served. Indeed, the serving of such foods, even in small quantities, actually elevates the prestige of the host (Lujan 1992).

In spite of what is clearly a hyper-significance of flying foxes in Chamorro culture, pteropid populations in Guam were robust in the early twentieth century and may have approached the island’s estimated carrying capacity of 60,000 animals (see Chapter Four). Indeed, fanihi were so abundant during this period that farmers shot them as swine fodder when breadfruit and other plant resources were scarce (Lujan 1992).

An examination of Guam's colonial history helps elucidate the cultural and economic factors that led to the over-harvesting of flying foxes on the island. Spain claimed Guam as an overseas colony in 1565. During Spanish rule, the Chamorro population remained engaged in a subsistence economy with barter as the primary means of exchange. Following the Spanish-American War in 1898, Spain relinquished Guam to the United States. When the Americans assumed political control of Guam, they promoted a cash-based economy and began building up the island's infrastructure. This required the labor of the Chamorro people. High wages approximately 20 times the pay available during Spanish rule were offered to lure farmers from their land (Thompson 1969). Later, the monetization of Guam's economy became integrated with the U.S. military presence on the island. In 1939, naval salaries, set according to a fixed scale in Washington, were more than double the local market price for labor (Thompson 1969).

In the new financial climate of disposable incomes, the Chamorro people began acquiring numerous items, including firearms. With the aid of shotguns, hunters could readily kill several dozen flying foxes during brief raids on communal roosts (Wiles 1987a; Graham 1992). Prior to the use of firearms, the main flying fox harvesting implements were scoop nets. Called *laguan fanihi* by the Chamorros, the nets were made of rope or thorn-bearing twigs. The net was attached to a pole approximately four meters in length (Fritz 1986). Harvesting success with hand-held nets was probably limited and opportunistic except during periods where flying foxes were particularly abundant.

With the introduction of firearms, flying fox populations became highly vulnerable to over-exploitation. In the early 1900s, Fritz (1986:26) noted that flying foxes occurred "...in great numbers on all islands" of the southern Marianas. "During the day," he said, "the bat is shot from the trees. In the evening, especially in the light of the moon, it is caught in flight with the laguan fanihi. Due mainly to the use of guns, Guam's flying fox populations were sharply reduced by 1931 (Wiles 1987a). During fieldwork in the late 1930s, Thompson (1969) encountered flying foxes for sale in Guam markets and reported that demand always exceeded supply. Concurrent with this period of flying fox declines, guns became sufficiently widespread to be targeted for taxation (Thompson 1969). In 1945 flying foxes were greatly diminished in number and were noted by Baker (1948) as being hunted "continually and persistently." By 1958, only 3,000 flying foxes remained in Guam (Woodside 1958). Flying fox declines continued during the 1960s. In 1967, the last confirmed sighting of the endemic Guam flying fox occurred (Perez 1973), and in 1971, less than 1,000 Marinas flying foxes survived on the island (Wiles 1987a). Flying foxes were finally extended full legal protection in 1973 (Wheeler 1979), but by 1978, poaching had reduced the population to less than 50 (Wheeler and Aguon 1978). Today, Guam's flying foxes persist only as a sink population, dependent on the periodic recruitment of animals from the island of Rota, 60 km distant.

In Guam, then, flying foxes were abundant in the early 1900s when indigenous economies and simple harvesting technologies limited patterns of exploitation. Prior to their commercialization, I suggest Guam's flying foxes had convex rarity-value curves. In the rarity-value model, traditional societies will normally cease harvesting species when the caloric return of the food harvested fails to surpass that expended to obtain it. If rarity fails to shift human attention away from the species either because it has some special value for which no alternative exists or the species can be easily harvested even when rare, societal limitations, in the form of taboos, will intercede in order to preserve its sustainability. Such cultural responses, however, failed to materialize in Guam when flying fox populations became critically endangered. When the advent of market economies and firearms supplanted traditional patterns of subsistence harvesting, the population rarity-value curve for flying foxes "flipped" from convex to concave and flying fox populations plummeted. Moreover, as was stated in the description of the MVP model regarding opportunistic harvesting, highly endangered species can be exterminated by hunting parties searching out more populous quarry. Thus, the endemic Guam flying fox went extinct not because it was specifically targeted, but because it was still encountered and killed by people hunting the much more abundant Mariannus flying foxes.

In 1958, when an estimated 3,000 flying foxes remained in Guam, the price for a fanihi was $3.00 (Woodside 1958). In 1983, after the extinction of *P. tokudae* and the near extirpation of *P. mariannus*, local flying foxes fetched up to $30 per animal (Wiles and Payne 1986). Given Guam's average rate of inflation, $3.00 in 1958 had the approximate buying power of $8.33 in 1983. Substituting this greater value still satisfies the equation for a concave population rarity-value curve as follows (Figure 4):

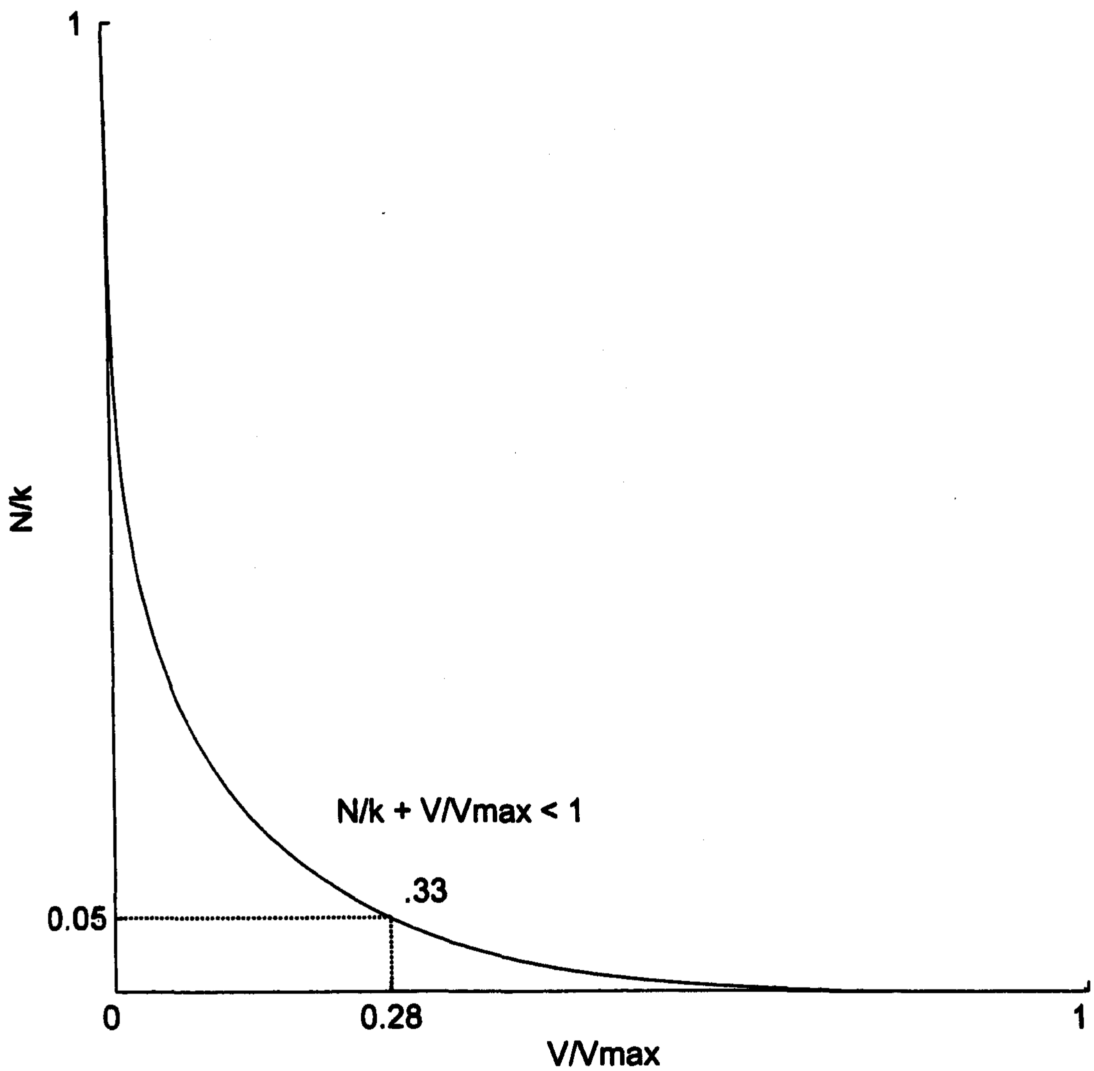

Figure 4. Rarity-value Curve for Guam Flying Foxes.

$$N/k + V/V_{max} \leq 1$$

or

$$3{,}000/60{,}000 + 8.33/30.00 = .33$$

$$.33 \leq 1$$

Although I computed the market values for flying foxes harvested only in Guam (local fanhihi always commanded higher prices than imported animals), I believe the internationalization of the flying fox trade, which supplied the Chamorro market with 10,000-30,000 flying foxes annually during the 1970s and 1980s (Wiles 1992), severely stemmed the rate of price escalation for local *P. mariannus*. Indeed, when Sheeline (1991) asked Chamorro interviewees, "What price would be too expensive to buy one flying fox?" several respondents replied, "No price is too expensive." While such a response is almost certainly an overstatement, powerful sentiments are frequently expressed regarding the hunting of species with concave rarity-value curves and foreshadow their eventual extinction.

Given the high saliency of fanihi in Chamorro culture, it is clear why commercial trade and firearms brought about the demise of Guam's flying foxes. Less obvious, however, is why cultural mores were never invoked in order to interrupt the unsustainable harvest rates of the 1900s. Flying foxes are inherently vulnerable to excessive exploitation due to low reproductive rates, high fidelity to colonial roosting sites in exposed trees, and, when inhabiting islands, restricted geography. Except in twentieth century Guam, these features of flying fox natural history resulted in various taboos among indigenous societies. In southern India, for example, flying foxes at daytime roosts are exempt from hunting in order to reduce over-exploitation (Berkes et al. 1995). In Tikopia, a Polynesian island of only 4.6 km^2, flying foxes are revered for embodying the spirits of the Tikopians' deceased ancestors and are tabooed accordingly (Kirch and Yen 1982). On the Micronesian island of Yap, Falanruw (1988) recorded that the consumption of flying foxes was traditionally limited to a social class inhabiting the interior of the island and who were granted only limited access to marine resources. The practice of prohibiting some segments of society from access to selected resources is common in Oceania and serves as a useful conservation tool by reducing the exploitative pressure on one particular species or group of species (Pernetta and Hill 1984).

A possible explanation regarding why no fanihi taboo emerged in Guam is that the island's flying foxes may not have needed taboo protection in the past when harvesting was restricted to traditional methods. Also, Chamorro culture may have been too severely disrupted during its colonial history to retain and enforce traditional conservation mechanisms and institutions.

In the late 1600s, the Spanish waged war on the Chamorro people after the latter began a violent protest against Jesuit missionaries who attempted to eradicate the Chamorros' deep-rooted cultural traditions (Thompson 1945; Safford 1902). By 1710 the total Chamorro population in the Marianas Islands had been reduced from 80,000 to 3,678 (Thompson 1945). The survivors, mostly women and children, were forcefully relocated to villages containing newly constructed churches (Fritz 1986; Kirch 2000). During the next two centuries, the remaining Chamorros intermarried with Spaniards and Filipinos whose foreign traditions were assimilated into Guam's indigenous culture. "After over 400 years of contact with the outside world," lamented Laura Thompson (1945), "the ancient Chamorro culture has been altered almost beyond recognition…."

There is only fragmentary information regarding Chamorro culture prior to the Spanish conquest, but resource taboos did exist, and a few apparently persisted through the 1700s. Freycinet (Thompson 1945), for example, commented that the violation of rigidly enforced fishing boundaries in Guam was a capital offense. Earlier resource taboos may have also prevented excessive harvesting of fanihi in Guam's pre-history. The need for flying fox taboos, for example, may have emerged when typhoons destroyed many bats as well as most of their food resources. Furthermore, although it is commonly held that primitive hunting technologies in Guam were not very effective, Falanruw (1988) states that traditional flying fox harvesting methods in Yap were productive and resulted in the capture of hundreds of pteropids in a short time. Given the elevated significance of flying foxes in Guam, it is unlikely that early Chamorro technologies for harvesting pteropids were inferior to those utilized in Yap. The Yapese harvests of flying foxes, however, were seasonal, highly organized and imbued with considerable ritual (Falanruw 1988). These facets of flying fox hunting were never observed in Guam. However, the decimation of the Chamorro population and culture, coupled with a greatly reduced need for conservation ethics in a nearly depopulated island under colonial rule, possibly resulted in the loss of many resource taboos.

Gadgil et al. (1993) suggest that as indigenous societies are incorporated into world trade economies, the intimate connections between sustainable use of local resources and human survival, disappear, thereby undermining the need to enforce and retain social self-regulatory mechanisms such as resource taboos.

If traditional Chamorro culture had endured into the twentieth century, the use of shotguns at flying fox roosts might have been abolished by a method taboo. Method taboos, as described in Chapter One, were commonly employed in Oceania to prevent fisheries over-exploitation through the use highly efficient harvesting techniques such as monofilament gill nets and the use of lanterns for the netting of flying fish (Zann 1985). Method taboos are not restricted to modern harvesting technologies. On Satawal Atoll, for example, fishing using bêche-de-mer toxins—toxins that are injurious to corals and that can have long-term deleterious impacts on fish populations—is taboo (Colding and Folke 2001).

In the 1980s, Yap, which is governed largely by traditional chiefly councils, implemented a taboo on modern harvesting methods in order to stop the over-hunting of flying foxes by market hunters who were shipping the animals to Guam. The government not only passed a law that prohibited the killing of flying foxes, but it simultaneously passed a second law or "method taboo" that forbade the legal possession of firearms on the island (Falanruw 1988). The latter law was instituted expressly for the protection of Yap's flying foxes. As a result of these prohibitions, nearly all hunting of flying foxes in Yap ceased, and populations recovered to stable levels.

Characteristic of species with convex population rarity-value curves, flying fox populations have been prudently managed as a sustainable resource through the use of cultural prohibitions in many indigenous societies. In Guam, however, knowledge of many former resource restrictions was lost. Furthermore, once flying foxes became commercialized, attempts to protect them by contemporary western means were resisted and countered by poaching and the internationalization of the flying fox trade. International traffic in flying foxes stimulated Guam's demand for fanihi and led to massive declines in pteropid populations in numerous Pacific island states including Yap, American Samoa, Western Samoa and Palau.

Conclusion

Reminiscent of the former beaver trade, international traffic in flying foxes not only devastated populations of the target species but also altered forest structure. Islands including Guam and Saipan in the Marianna Archipelago and Ofu and Olesega in American Samoa all experienced varying degrees of pollination and seed dispersal failure when their flying fox populations collapsed (Cox et al. 1991; Craig 1993; Balick and Cox 1996).

I have suggested that wild-gathered species, which are either exempt from indigenous taboos or are protected only intermittently by traditional prohibitions, possess convex rarity-value curves under the rarity-value model. These same species are unlikely to be harvested below their MVP in the minimum viable population model. In other words, the expense (either energetically or financially) of acquiring these species is not worth the return benefit once a particular threshold of rarity is reached. These species, then, will normally be "safe" from over-exploitation. If commercialized, the more prolific of these species could endure considerable harvesting within local markets without incurring permanent population losses.

Others would experience declines until legal harvest restrictions or rising costs force markets to shift toward substitute resources.

Based on the findings of this chapter, wildlife and forestry managers should be wary about permitting the commercialization of species whose rarity-value curves are prone toward concavity. This same warning applies to species whose populations can be economically harvested below (or even near) their MVP. This includes species (or their parts) likely to impart prestige to the owner and rare biological resources that possess medicinal value for which there are no alternative pharmacopeias. Failure to prevent traffic in these species is likely to open a Pandora's Box of long-term environmental and law enforcement problems.

Chapter Three

Cultural Constraints and Corrosive Colonization: Western Commerce in Aotearoa/New Zealand and the Extinction of the Huia (*Heteralocha acutirostris*)

Introduction

The founders of New Zealand's indigenous Maori population emigrated from central Eastern Polynesia approximately 1000 years BP, eventually settling from North Island's North Cape southward to Stewart Island; a distance of 1,600 km (Sutton 1994). Dispersion of villages across a diverse ecological palette, agricultural intensification with generation of significant food surpluses, and social stratification common among other Polynesian cultures led to conditions appropriate for the development of trade in objects of cultural and religious rather than survival value (Kirch 1984). Much time and effort were expended by Maoris to secure desirable resources including greenstone, obsidian, shells and feathers which traveled through trade routes far beyond their places of origin (Shortland 1856; Grey 1994). In 1892 a small wooden box containing 70 huia tail feathers was discovered under a rock ledge in the south central region of New Zealand's South Island. Huia feathers were valued possessions of Maori chiefs who wore them as symbols of rank and prestige (Figure 5; Best 1942; Phillipps 1963; Riley 2001). The feathers, believed to have been cached some 70 years previously, constituted a remarkable find since huia distribution was confined to a limited area of North Island. The feathers were likely traded to South Island Maoris for valuable greenstone articles (Phillipps 1963).

Figure 5. Te Kawa and His Nephew. Water color painting by G. F. Angas. Te Kawa (sitting) was the principal chief of the Ngati Whatua tribe. The hair of his nephew, Tamahiki, is decorated with the tail feathers of the huia. The Ngati Whatua inhabited the Orakai Bay region near present-day Auckland—well north of the huia's historical range.

The saga of the huia, the cultural desire for its feathers, and the protection of the species from over-exploitation, is similar to many other scarce resources among indigenous peoples. However, the transference of Maori cultural views of the importance of huia feathers as symbols of aristocracy to a European monarch, and the resultant monetization of the huia feather trade among the fashion houses of London as well as European colonists in New Zealand is unusual. Moreover, this unique cultural exchange had disastrous consequences for the birds themselves—and serves as a lesson in the destructive affects of colonial erosion of indigenous conservation strategies.

Huia Natural History

The huia was one of three species of wattle birds, members of the endemic New Zealand family, Callaeidae. Although critically endangered by the early 1900s, small isolated populations and individual pairs of huias apparently endured as late as the 1930s. Small populations of the other two wattle bird species, the kokako (*Callaeas cinerea*) and the saddleback (*Philesturnus carunculatus*), are still found in New Zealand's forests. Saddlebacks, however, persist only on several small predator-free islands.

Wattle birds are believed to have descended from a crow-like ancestor that colonized New Zealand long ago, but their precise ancestry remains controversial. Some systematists assign wattle birds to the starling family (Sturnidae). Others group them with birds of paradise (Paradiseidae), bower birds (Ptilonorhynchidae), butcher birds (Cractidae) or magpie larks (Grallinidae) (Fuller 2001).

Wattle birds are identified by fleshy lobes at the base of their bills. Huia wattles were orange and measured 2 cm in diameter. The body length of the huia was 45-48 cm. The huia's plumage was nearly black but possessed a striking blue-green iridescence. Its tail was distinguished by a white terminal band. The bill was cream colored.

Huias had the most restricted distribution of New Zealand's wattle birds. Their nineteenth century range was confined to several mountain ranges and adjacent lowland forests in the southern half of North Island, but this represents a reduced range following the Polynesian colonization of New Zealand. The huia fossil record indicates the species was formerly widespread from Wellington to North Cape (Flannery 1995; Trevor Worthy personal communication). Huia fossil remains are fewer than those of its congener, the kokako, suggesting huias had a more restricted ecological distribution.

Huias were famed for their unique bill characteristics (Figure 6). Male huia bills were stout, straight and approximately 6 cm in length. Female bills were delicately curved and pliant and measured over 10 cm (Phillipps 1963). This remarkable sexual dimorphism led Gould (1837), the first ornithologist to describe the huia, to classify male and females as different species. The divergent bill types possessed by male and female huias facilitated a partition in foraging strategies. Huias consumed a variety of insects, worms and berries, but their summer diet consisted largely of the huhu beetle larvae (*Prionoplus reticularis*). Potts (1885:475) monitored a breeding pair of huias and made this observation regarding their foraging techniques and habitat:

Figure 6. Pair of Huias. Male (lower front). Painting by J. G. Keulemans from W. Buller's History of the Birds of New Zealand (1887-1888).

> Their activity was remarkable, especially the speed with which they traversed the wood, hopping or rather bounding with a slight opening motion of the wing, flying only very short distances. Owing to the moist character of the locality, the huge trees were clothed in mosses and ferns, and fragments of this parasitic vegetation were constantly dropping down from the branches where the huias were so zealously working for their young.

New Zealand's celebrated nineteenth century ornithologist and statesman, Sir Walter Lowry Buller, managed to acquire a live pair of huias. Placing his captives in an aviary, Buller provided them a rotted log infested with huhu. "They at once attacked it," he said,

> carefully probing the softer parts with their bills, and then vigorously assailing them, scooping out the decayed wood till the larva or pupa was visible.... The very different development of the mandibles in the two sexes enabled them to perform separate offices. The male always attacked the more decayed portions to the wood, chiseling out his prey after the manner of some woodpeckers, while the female probed with her long pliant bill the other cells, where the hardness of the surrounding parts resisted the chisel of her mate. Sometimes I observed the male remove the decayed portion without being able to reach the grub, when the female would at once come to his aid, and accomplish with her long slender bill what he had failed to do.... I noticed, however, that the female always appropriated to her own use the morsels thus obtained (Buller 1882:31).

Disregarding Buller's remark to the contrary, nineteenth century science writer, John Lubbock took literary license with Buller's description of huia foraging habits by asserting that females, after withdrawing larvae from bored-out passages, shared them with their mates. Buller was quick to correct this poetic error: "It seems a pity to destroy the pretty sentiment of the case as put by Sir John Lubbock," he said, "but science is inexorable, and the truth must be upheld" (Galbreath 1989:84). While females withheld food items from their mates, male to female food transfers were described by several observers.

> He hops along with a fine spider and very politely offers it to his better half, who seems to always appreciate his fine attention. And so they keep close together...the female, with her slender bill, often getting a fine, fat insect, which, however, she does not give to her mate" (Caldwell 1911 as cited in Riley 2001:103-104).

The advantage to the huia of possessing strikingly different bill types may explain why huias were almost always found foraging in pairs, keeping strictly to the shade of the forest. Observers noted that paired individuals always remained within audible distance of one another (Phillipps 1963). Buller (1882:31) noted a strong attachment between his own huias:

> It was most interesting to watch these graceful birds, hopping from branch to branch, occasionally spreading the tail into a broad fan, displaying themselves in a variety of natural attitudes, and then meeting to caress each other with their ivory bills, uttering at the same time a low affectionate twitter.

Buller intended to export his huias to London's Zoological Society for display, but before the birds could be transferred the male was inadvertently killed, whereupon the female, "manifesting the utmost distress, pined for her mate and died ten days afterwards" (Buller 1882:31). Buller anthropomorphized the death of his remaining huia, but his belief is supported by Maori portrayals of surviving huias when pair bonds were severed:

> I was always told by my old people that a pair of huia lived on most affectionate terms. The female dug the ground for the worms, but it was the male bird that picked the worms up to feed her, as she was unable to do it on account of the formation of her bill. If the male died first, the female died soon after of grief (Makereti, n.d. as cited in Riley 2001:104).

Regardless of whether female huias succumbed to despair upon the death of their mates, the fact that such a phenomenon existed in Maori perception may partially explain the profound admiration Maoris had for the birds.

The Huia in Maori Lore and Trade

Cultural Uses

Sacred and highly revered by the Maoris, the huia was admired for its stunning beauty, unique foraging habits and pair fidelity. Maori regard for the huia was manifest in myriad ways. Female huia heads with their gracefully curved and tapered bills were worn as pendants around the neck or dangled conspicuously from the ears of high-ranking individuals (Oliver 1930). A headdress or plume of 12 huia tail feathers, still joined at the base by the bird's own skin, was known as a *marereko* and was worn by chiefs at various ceremonies and when going into battle (Riley 2001).

Fuller (2001) observed that huias acquired a curious association with death. Indeed, Maori chiefs were especially inclined to don the huia's white-tipped tail feathers during funeral rites or *tangis*. A tangi scene painting by George Angas in the 1840s depicts a deceased Maori chief in repose with a halo of huia feathers about his head, signifying the fallen leader's eminence (Figure 7; Petersen and Mead 1972). In all instances, the wearing of huia feathers conveyed distinction and was traditionally restricted to elites (Best 1942; Phillipps 1963; Riley 2001).

So valuable were huia tail feathers that Maori chiefs housed them in ornately carved wooden boxes called *waka huia* (Figure 8). *Waka* is the Maori word for hollowed out canoe, and waka huias were indeed fashioned in the manner of Maori watercraft (Buck 1952). An elaborately carved waka huia was presented to Captain James Cook during his first voyage to New Zealand, an illustration of which appears in Hawkesworth's (1773) account of the Endeavor voyage. Like the feathers they contained, waka huias were highly taboo or tapu. Balick and Cox (1996) suggested that a person could defile a waka huia by speaking disrespectfully of it or even looking upon it. In Maori cosmology, such individuals became subject to severe supernatural consequences unless properly purified.

Huia Folklore

A cultural intrigue with the huia is manifest in Maori legends and folklore. Maoris asserted the huia was obtained by their ancestor, Tawhaki (demigod of thunder, lightening and health) from the heavens to provide feathers for his wife Maikukumakaka (Riley 2001). On earth, the huia became the leader of the "multitudes of Hakuturi," sacred birds of the forest appointed to persuade Rata to follow forest protocol by seeking permission from Tane (god of the forest) before

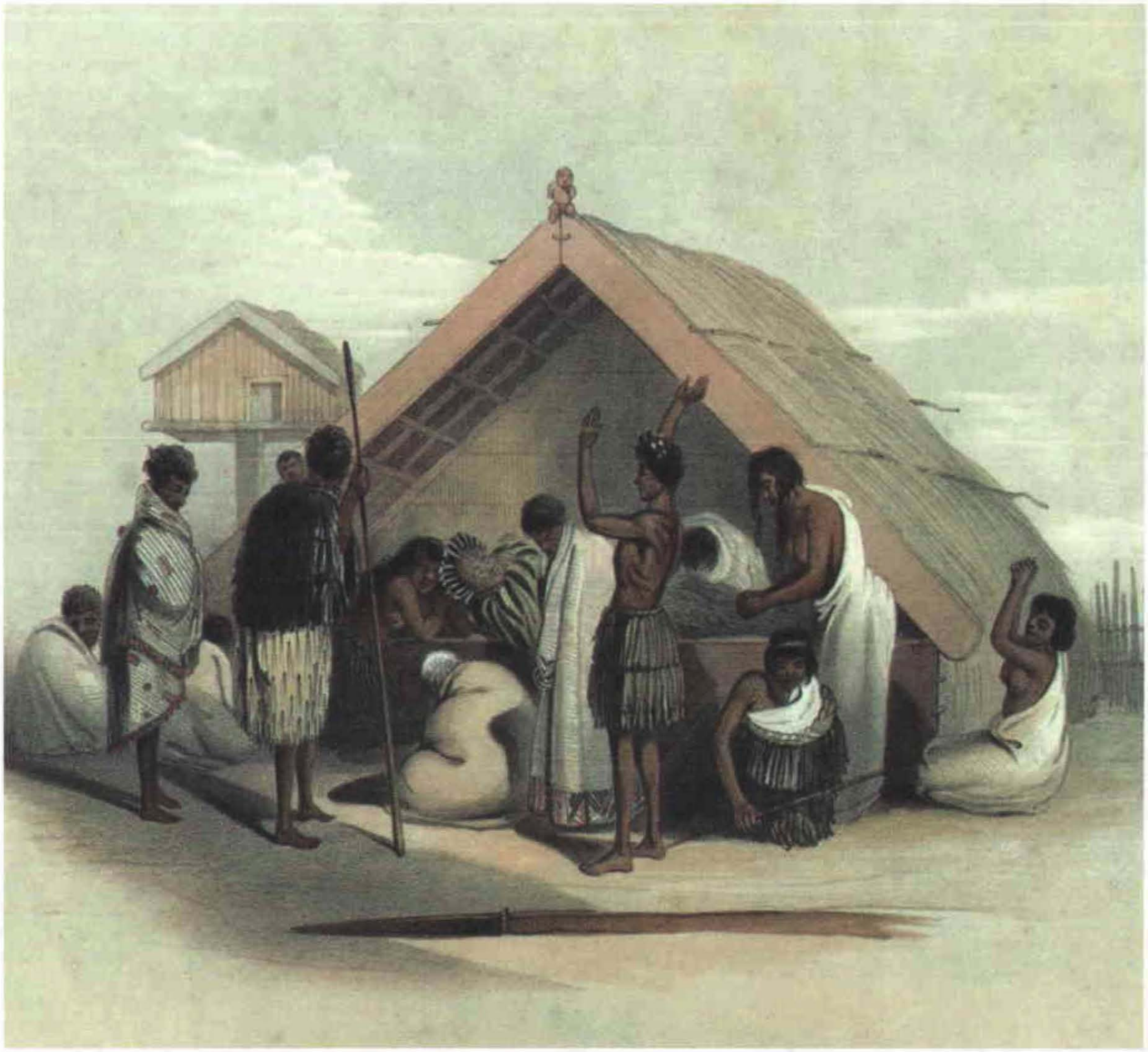

Figure 7. Lamentation Over a Deceased Chief. Water color painting by G. F. Angas. The corpse is laid out beneath the verandah of the dwelling, wrapped in the finest mats. A halo of huia tail feathers about the head of the fallen leader signifies his eminence. Another high-ranking individual in the foreground wears huia feathers while uttering incantations over the deceased chief.

Figure 8. Waka Huia. Such boxes were designed to house the sacred tail feathers of the huia. The carved spirals depict the unfolding fiddle head of a tree fern, a Maori symbol of life and rebirth after death.

felling a tree from which to hollow out a canoe (Riley 2001).

A mythical explanation for the female huia's curved bill was described by Phillipps (1963) who learned of the following folktale from a Maori informant. Shortly after the Maori migrations to New Zealand, a high-ranking chief was surprised to encounter an unfamiliar bird in one of his snares. The chief was enamored of the bird which turned out to be a female huia. He plucked two feathers from the bird's tail and placed them in his hair as a decoration. Before releasing the huia, the chief bestowed upon it a magic spell and mana with the command that the huia was to appear before him whenever he asked. On one occasion, the huia dutifully appeared before the chief during the nesting season. The chief was displeased because the huia's tail feathers were in poor condition. The chief angrily inquired of the bird why its feathers were disheveled. The huia told him that it was through sitting on its nest. The chief replied: "I will provide you with a means whereby you may keep your feathers in good order when next I call on you." He took hold of the huia and bent its beak until it assumed an elegant curving shape. He then instructed the bird to use its bill to lift its tail clear of its nest each time it prepared to settle onto its eggs.

Huias were sometimes kept as pets and trained to converse (Rout 1926; Best 1942; Riley 2001). "Let the ears listen to the whispering of the pet of Tautu," urges a Maori song about a pet huia that once wandered the Tararua range. Tautu's huia was known throughout the district for its defamatory language and was consequently celebrated in song (Riley 2001). Rout (1926) stated that trained huias were indeed given considerable liberty, but they regularly returned to their cages where they were periodically stripped of their valuable tail feathers.

Huia Snaring

The huia possessed little natural fear of people and was even curious of human activity. On trapping expeditions, Maori fowlers tapped trees with sticks to arouse the huia's inquisitive nature (Riley 2001). Hunters, who often made no effort to conceal themselves, then mimicked the huia's call and lured the birds to within one or two meters where they were readily captured with snares. Such snares were made of a flax fiber attached to the tips of poles called *tari* (Best 1942). Sometimes a huhu grub was tied to the snare as an additional enticement, but Best (1942:223), who managed to capture a huia by hand without any artifice, reiterated that "the taking of the huia was by no means a difficult performance, for it had either a bold, simple, or trustful nature."

Huia Feather Trade

Due to New Zealand's temperate climate, Polynesians colonizing Aotearoa failed to establish most of their traditional tropical food crops such as coconut (*Cocos nucifera*) and breadfruit (*Artocarpus altilis*). Consequently, fowling became highly important and even assumed dietary primacy in some regions. Nearly all literature accounts of the huia describe the tapu nature of its flesh, but huia meat was almost certainly consumed for an indeterminate period in Maori pre-history. Moreover, as Polynesians began burning lowland forests, huia habitat diminished. Due perhaps to its dwindling range, the huia was tabooed, and its feathers became the prerogative of chiefs. Eventually, an indigenous trade in huia tail feathers materialized.

The huia's limited distribution enhanced its value among the Maori (Best 1942). Yate (1970) stated that huia feathers were sometimes sent by Maoris in the Wellington area to tribes in the Bay of Islands 500 km north. Similarly, Best (1942) noted that feather plumes were passed from tribe to tribe by means of barter throughout North Island and South Island. South Island Maori tribes exchanged greenstone for huia feathers, while tribes far to the north of the huia's range traded shark teeth for huia plumes (Orbell 1985).

Commercial trade in a species of high cultural saliency and of such a limited range and population as the huia is likely to terminate in extinction. Indeed, unless the extent of trade is highly restricted and a management strategy exists to insure that no unauthorized commerce occurs, extinction is imminent. Such strategies for the conservation of wild-gathered species exist in nearly all traditional indigenous cultures (Colding and Folke 2000).

In Polynesia, unwritten rules or taboos historically prohibited activities deemed deleterious to society. Numerous taboos were designed to protect wild-gathered resources from over-exploitation. Such prohibitions included the temporary closing of octopus gathering areas; forbidding the harvest of certain fish species during spawning season; size limits on fish harvested; restrictions on taking seabirds and their eggs; bans on entering turtle nesting areas; and permanent prohibitions against the taking of fruit doves and flying foxes in sacred forests (Johannes 1978, Brooke and Tschapka 2002). In New Zealand, taboos that forbade (either temporarily or permanently) the harvesting of wild-gathered species in order to ensure their perpetuation were called *rahui*. Some researchers dismiss the legitimacy of rahui, citing the Maori plunder of moas and other flightless birds as evidence that a conservation ethic was absent among native New Zealanders (Anderson 1997). Others contend that such extinction events are precisely what led Polynesian societies to develop resource conservation strategies like rahui (Orbell 1985; Belich 1996). Still others, including Elsdon Best, are reluctant to implicate the Maori as the primary factor in the demise of the moas. In a personal communication to Myers (1923:70), Best wrote: "though the stragglers of the moa family may have been killed off by the Maori, it is incredible that the extinction of the Moas as a whole can be laid at their door." Best's faith in Maori conservation strategies may appear naive in light of modern revelations concerning the extinction of the moas, but his views are supported by geographer Patrick Nunn, who attributes the extinction of the moas to catastrophic changes to forest structure due to large scale climatic changes in the Pacific approximately 1300 B.P. (Nunn 1993). Like Best, Nunn concedes that the Maoris played an ancillary role in the demise of the dinornithiformes, but it is presumptuous, he maintains, to place the entire blame on humans.

Rahui in Maori Forest Lore

Ecological conditions in Maori tribal areas were continually evaluated by individuals assigned as *kiatiaki. Kiatiaki* were stewards of all living things on behalf of past, present and future generations (Gillespie 1998). For the Maori, the fruits of the land and sea were intended for human use, but when a particular forest or marine resource became vulnerable to over-exploitation, its use was strictly prohibited (Best 1942; Best 1982; Riley 2001). Forest birds, for example, were protected by a rahui during the breeding season. "In olden times," wrote Raymond Firth (1929:138),

> birds were strictly preserved. When they were nesting, or when the young were newly fledged and unable to fly, no person was allowed to take them unless under circumstances of extreme need. A tapu was set upon the forest, and no one would dare break it....

The conservation value of rahui is also described in Meyers' (1923:69-70) account of Maori fowling ethics: "Birds formed a very considerable portion of the food of the ancient Maori;" he noted,

> but his exploitation of these, as of all other forest products, was carried on under the most scientific and rigid supervision of the tohunga, or priestly expert. The most numerous and complicated rules were punctiliously observed as religious rites to prevent in any way the disturbance of the bird population, leading possibly to its exodus into the hands of another tribe; while on any signs of fright, diminution, or poor condition the tohunga might place under tapu either the whole of a certain area or all or certain of the bird species in that area.... All these restrictions were enforced purely by spiritual authority, acting on a living faith in immediate punishment.

Usually the protection of wild-gathered resources for a particular locality was manifest by a physical marker such as a stake either festooned with fern fronds or capped with a lock of human hair (Best 1942; Best 1982). In many instances, a chiefly declaration of the rahui was also issued. "Such a pronouncement as this," noted Best (1942:163), "would very soon be known far and wide."

Penance for an inadvertent breech of rahui might be for the offender to offer a gift to the individual who had imposed the restriction, but intentional infractions could provoke warfare, particularly if conducted on burial or other sacred grounds (Riley 2001). Best (1942:165) described the potential consequences for such a desecration:

> ...when Mahia was slain at Te Papuni, the lands thereat were made tapu at once, he being a prominent man of the district. Some of the people of the district violated the condition of tapu by procuring and consuming certain food-supplies of the land.... This enraged the widow of Mahia, who raised a party of her relatives at Maungapohatu, and descended upon Te Papuni like a wolf on the fold; when the raiders marched homeward they left the offenders past all need of future food-supplies.

Even more ominous in the Maori mind than the threat of physical punishment for a breach of rahui was the fear of retribution by the dread powers of witchcraft (Best 1982). When a high-chief or priest (*tohunga*) declared a rahui on a particular resource, it was strictly observed by the populace due to their "...living faith in immediate punishment" (Meyers 1923:71). Domett (1883:150) also recognized the spiritual powers wielded by the tohunga: "Departed spirits were their dumb police, and ghosts enforced their lightest laws."

Riley (2001) noted that for the Maori, huia tail feathers were of celestial origin and were highly tapu. In some areas, only tohunga fowlers were permitted to capture huias. In a personal communication to Meyers (1923:70) Elsdon Best, based on several decades of ethnological work among the Maori, stated unequivocally that under the ancient regime of rahui, the Maori would never have exterminated a single species. Humans and birds, he argued, "had reached a state of equilibrium." Indeed, although the huia was tapu, as a result of its close association with Maori elites, tapu also served an important conservation strategy against indigenous hunters who might otherwise have sought wealth and elevated social status by trading its feathers for other valuable items. By the 1840s, the cultural saliency of tapu and its power to conserve nature was steadily being undermined by the introduction to Aotearoa of a foreign cosmology.

Huia Commercialization and the Demise of Tapu

Nineteenth century Europeans were ardent collectors of exotic wildlife mounts and study skins. Consequently, when word arrived from New Zealand of a bird possessing sexually dimorphic bills, orange wattles, and white-tipped tail feathers prized by Polynesian chiefs and shamans, the huia was instantly demanded. Although many specimens were harvested for display in colonial drawing rooms, dealers found foreign markets for mounted specimens and study skins among museums, universities and private collectors. During the latter half of the nineteenth century, several thousand specimens were shipped to Europe and the United States (Phillipps 1963).

To increase their success at harvesting huias, hunters hired Maori guides who, ironically, were willing accomplices in the assault on the huia. Dealers who trafficked in huia skins lured Maoris into harvesting the birds for miniscule cash rewards. In the 1880s, Buller (1888) recorded that a team of eleven Maoris, scouring the forests between Manawatu Gorge and Akitio, harvested 646 huia skins in a single month's time. Such a devastating raid may not have occurred without the widespread demise of the Maori taboo system. As Meyers (1923:70) noted: "Needless to say, tapu is now a thing of the past, and the present-day Maori shoots pigeons and kakas in great numbers with no more compunction than his *pakeha* brethren."

Krech (1999) investigated a similar phenomenon among eighteenth century Native Americans that apparently ignored traditional hunting taboos in order to engage in the European trade in deer and beaver pelts. He largely dismisses the conventional wisdom that American Indians were corrupted by Europeans into forsaking traditional conservation strategies. Instead, he opts for a view where Indians merely "created choices for themselves, defined new roles, [and] ...found paths in the new order in myriad and sometimes contradictory ways...." (Krech 1999:152). Unlike the violation of Native American hunting taboos described by Krech, however, historical Maori infractions of rahui could be lethal. Consequently, there was great incentive to adhere to traditional harvesting protocol unless the former system of physical punishment and faith in supernatural retaliation was no longer operational. It is unlikely that financial reward alone would have offered sufficient motive to desecrate traditional taboos in Aotearoa.

Early Christian missionary work in New Zealand coupled with the rapid and widespread immigration of colonists to the country in the mid-1800s introduced new customs and world views wholly alien to the Maori mind. Indigenous beliefs and practices rapidly disintegrated (Cowan 1910). "Indeed, there was a disconsolate feeling among the older Maori at that time," notes Murdoch Riley (2001:37),

> ...that both their race and the native birds of the country were declining radically in numbers for the reason that belief in the old gods, spirits and the laws of tapu had been forsaken.

Speaking of this loss of traditional Maori beliefs, a Maori informant of Elsdon Best somberly stated:

> We have no *mana* now.... Our clothing and our bodies are now washed with warm water, and there is no more tapu. We have abandoned our own gods and their laws (Riley 2001:38).

Having abandoned their strictest laws of taboo, huia feathers were no longer the sole possession of elites. Soon, Maoris with any claim to rank desired at least one huia feather (Phillipps 1963). Despite the rapidly waning power of tapu, the demise of the huia was not lost upon the minds of Maori leaders. In the 1880s, several influential chiefs in Manawatu and Wairarapa tabooed the Tararua Range in an attempt to reassert the huia's former protection as a sacred species (Phillipps 1963), but such proclamations had lost their religious potency.

The erosion of cultural taboos coupled with the introduction of a new and powerful economic system may have been perceived by some Maoris, particularly those of lower social classes, as an opportunity to improve their status among both their peers and the colonists. Given that the preservation of native biological resources could not have appeared important in the new socioeconomic order, selling things of former value (such as huias) for things of modern worth (such as cash) was probably a rational, adaptive response to changing patterns of power.

As indigenous conservation strategies rapidly deteriorated under Western religious and political influences, New Zealand's colonial government gradually began implementing Western style conservation practices. In 1890, an event occurred that placed the huia's plight squarely on New Zealand's colonial consciousness. Lady Onslow, wife of New Zealand's governor-general, the Earl of Onslow, gave birth to a son in Wellington. It was the first time a governor's wife had borne a child in New Zealand. Newspapers drew attention to the fact that the child's birth coincided with New Zealand's 50th jubilee year since the signing of the Treaty of Waitangi and expressed the hope that a Maori name might be bestowed upon the child (Galbreath 1989). Governor Onslow, who was sympathetic to the plight of the Maori people, was enamored of the idea and sought advice from respected leaders regarding a name. Walter Buller, a close friend to the governor, suggested "Huia." The name was enthusiastically embraced and a week later, the child was baptized Victor Alexander Herbert Huia Onslow. As Galbreath (1989:179) noted: "The first three names were hardly noticed; in New Zealand he would always be Huia Onslow, and so he was known all his life." Newspapers reported that the culminating event of the ritual occurred when an elegant huia feather was affixed to the child's headband, a symbolic act that established the child as a chief in Aotearoa.

Several days following the infant's baptism, the Onslow and Buller families traveled to Otaki for a pre-arranged ceremony with the Ngati Huia, an important and aristocratic sub-tribe of the Ngati Raukawa (Phillipps 1963). Governor Onslow had evidently received prior permission to give his son the clan's name, and he now desired the child to be formally presented before the Ngati Huia elders for adoption into the tribe (Galbreath 1989). Upon arriving at Otaki, the governor's party was welcomed to the Ngati Huia marae. Buller, who spoke fluent Maori, translated for the group as the tribe's orator commenced speaking:

> Other governors have said kind things and done kind things, but it has been reserved for you, O Governor, to pay this great compliment to the Maori people—that of giving to your son a Maori name.... It has long been said, let the Pakeha and the Maori be one people.... We invoke the spirits of our ancestors to witness this day that in your son Huia the friendship of the two races becomes cemented.

Turning and pointing toward the distant mountains, the orator resumed his speech:

> There yonder is the snow-clad Ruahine range, the home of our favorite bird! We ask you, O Governor, to restrain the Pakehas from shooting it, that when your boy grows up he may see the beautiful bird whose name he bears (Phillipps 1963:64; Galbreath 1989:180).

At the conclusion of the speech, Onslow replied by reciting a quote he'd seen engraved on one of his son's christening gifts: *E hoa ma, puritia mai taku huia*— friends, hold onto my huia! The phrase derived from an old Maori song and was most fitting as it was based on the figurative meaning of "huia," a word connoting something valuable. For the Maori, "the huia was like the pearl of great price," and Governor Onslow applied considerable effort to ensure that the publicity surrounding his son's Maori name was linked to the huia's conservation (Galbreath 1989:180).

Buller wrote an account of the tribal ceremony in Otaki for the *New Zealand Times*. The story also appeared in British newspapers where it was enthusiastically received by readers "…as a tale of Empire: the fair child of a noble English house taking his place at the head of a dusky tribe, amid curious native customs" (Galbreath 1989:180). British newspapers pointed out that if strict measures were not swiftly taken to ensure the huia's protection, it would suffer the same fate as the moa.

Governmental protection for the huia did come, and the huia's inclusion on the Wild Birds Protection Act in 1892 was the direct result of an eloquent letter written by Governor Onslow to Prime Minister, John Balance. Thereafter, on all hunting proclamations, a statement appeared that expressly prohibited any molestation of the huia. Reflecting on the former efficacy of Maori conservation strategies, Meyers (1923) pointed out that "the protection laws of our own time will bear not the faintest comparison with the game laws of the old-time Maori." Indeed, the law had little effect. In 1896, two dealers in the commercial traffic of New Zealand birds, Henry Travers and A. J. Jacobs, were convicted of killing seven huias. Each man was required to pay a £5 fine—hardly a deterrent since a single huia skin was worth more than that (Galbreath 1989).

Commercial harvesting was the major factor in the huia's extinction (Meyers 1923), but deforestation also played a significant role. Buller (1905:157), for example, lived to see an extensive podocarp/hardwood forest near Wellington (where he had formerly collected numerous huias) converted to a district completely covered in "green pastures and smiling farms." The destruction of the bush, wrote Buller (1905:157), angered Maori leaders who were greatly distressed over the huia's plight: "You have prohibited the killing of the huia under a heavy penalty," they told the colonial government, “and yet you allow the forests, whence it gets its subsistence, to be destroyed!”

In the early 1890s, the New Zealand government sponsored the first of a number of expeditions into North Island’s southern ranges for the purpose of securing several huia pairs for liberation on offshore islands where they would be free from human persecution and habitat loss. Specifically, Little Barrier Island north of Auckland and Resolution Island in Fiordland were identified as potential sanctuaries. Governor Onslow was the principle champion of this acclimatization project, but ornithologists such as Buller were pessimistic that huia relocation efforts would succeed (despite publicly supporting the governor’s plan). Little Barrier Island, for example, was considered too warm and dry for the huia. Moreover, it was infested with feral cats (Galbreath 1989; Riley 2001). Despite these concerns, a reward of £4 per pair of live huias was promised to several individuals experienced in trapping the birds (Phillipps 1963).

Concurrent with efforts to prevent the huia’s extinction, an event occurred that ultimately sealed the huia’s fate. During his 1901 tour of New Zealand, the Duke of Cornwall and York, the future king, visited Rotorua where the local Maoris presented a grand welcoming ceremony (Phillipps 1963). During the affair a native guide ceremoniously removed the single huia feather from her hair and placed it in the hatband of the Duke as a gesture of respect and in acknowledgement of his royal status. Pictures of the simple act ran in London newspapers, and a British mania for the Maori symbol of rank and prestige commenced. The price for single huia tail feather began at £.25, but soon increased four-fold to £1.00 (Phillipps 1963). Some years later, the price topped out at £5.00 for a feather in good condition. A huia with a full compliment of 12 tail feathers was a highly valuable commodity. North of Wellington, hunters took to the mountains hoping to bag even a single bird. Other individuals pilfered feathers from mounted huias and museum study skins hoping to cash in. From his examination of huia specimens in New Zealand's Dominion Museum, Phillipps (1963) found that only six of 53 birds possessed all 12 tail feathers. Some museum skins possessed no tail feathers at all.

In the same year that the Duke visited Rotorua, Henry Travers offered to provide live huias for release on Little Barrier Island at £20 a pair (Galbreath 1989). This was five times the amount the New Zealand Government was willing to pay collectors for a pair of huias, and the offer was ignored. With the huia worth more dead than alive there was little incentive to turn in live birds for a meager reward. Unfortunately, law enforcement officials did little to discourage the thriving feather trade.

The last huia sighting documented by a trained ornithologist occurred in 1907. However, virtually all literature on the species suggests isolated pairs probably persisted for a considerable time afterward. Purported huia observations after 1907 were generally made by non-scientific observers. A summary of these sightings, many of seemingly indisputable veracity, is detailed by Phillipps (1963).

Discussion

The Huia and the Rarity-Value Model

The Polynesian taboo system of species management, as exemplified by the former protection of the huia in New Zealand, provides a predictive model for wildlife managers attempting to determine organisms likely to become endangered by species commercialization. Species vulnerable to over-harvesting are apt to possess high cultural value (at least historically) among indigenous peoples (otherwise they might already be extinct). Conversely, resilient species can be predicted to have comparatively low cultural value. Several characteristics of each category are listed in Table 2.

As outlined in Chapter Two, a concave trajectory occurs for species when the rarity-value equation yields a number less than 1. Rarity drives demand for these species either because there are no suitable alternative resources or because possession or use of the species imparts prestige to the consumer. These species are likely to possess low reproductive rates, have small geographic ranges, occur in naturally low densities or have high cultural salience. Species with concave curves were either permanently tabooed by indigenous cultures or their use confined to a certain small segment of society—usually elites.

The Case of the Huia

In traditional Maori culture, the huia exemplified the characteristics listed under species of "high value" in Table 1. Although precise population and carrying capacity figures for the huia at any point in time are unknown, the history of the species' rapidly appreciating value as well as its ultimate extinction permit the construction of a concave rarity-value curve. In 1901, the price of a huia tail feather was £.25. A wild-harvested bird with all 12 tail feathers would therefore be worth

Indices of Value

High Value	Low Value
•Rare	•Ubiquitous
•Hard to obtain	•Easy to obtain
•Restricted to elites	•Everyone has them
•Conveys prestige	•Does not convey prestige
•Respect terminology	•Common terminology
•Associated with clan of distinction	•No particular clan association

Table 2. Indices of Value for Culturally Salient Species. Species esteemed as having high value are vulnerable to over-exploitation and are often permanently tabooed as a conservation strategy.

£3.00. Feather value peaked in 1916 at £5.00, or £60.00 for a fully-feathered huia. In this instance, the V/V_{max} portion of the rarity-value formula becomes:

$$3/60 = .05$$

Any value for N/k that is less than .95 will produce a point that establishes a concave population rarity-value curve for the huia. In other words, regardless of whether the carrying capacity for the huia remained as high as 1,000, or had been reduced to 100, unless that remaining habitat was at least 95% saturated with huias, the species had a concave curve. Hypothetically, even if continuing deforestation had reduced huia carrying capacity to a mere 300 birds by 1901, and a remaining population of 200 huias is allowed, one is left with the following N/k value for the rarity-value formula:

$$200/300 = .67$$

The complete rarity-value equation, then, yields the following sum:

$$200/300 + 3/60 = .72$$

Despite the probability of this value being artificially high, it is still establishes the huia as possessing a concave rarity-value curve (Figure 9).

Rarity-value trajectories can be constructed for any commercialized species

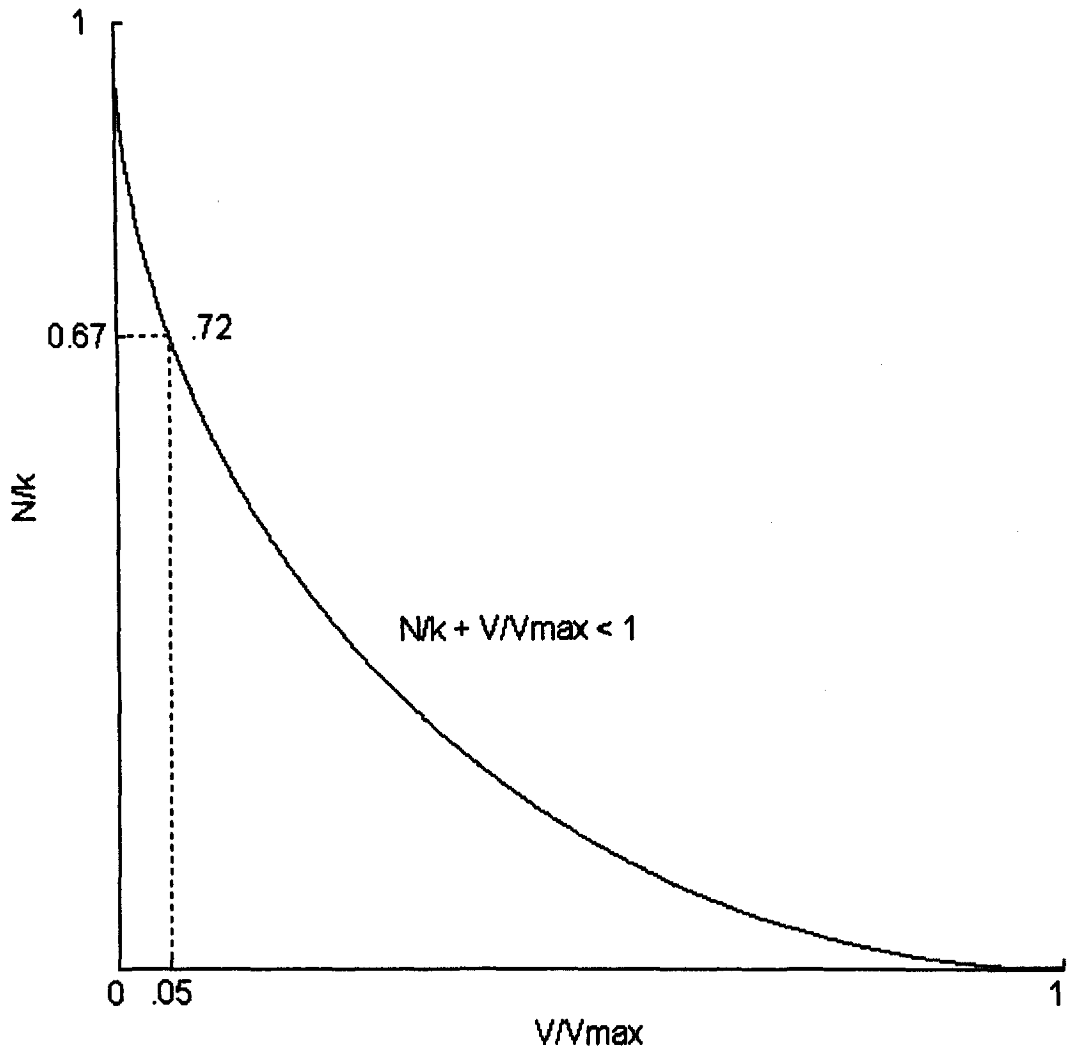

Figure 9. Hypothetical Rarity-value Curve for the Huia.

provided that figures for carrying capacity, population and maximum values are known or can be ascertained with reasonable accuracy. A concave curve, for example can be constructed for African elephants based on data derived from international trafficking in ivory (Barbier et al. 1990). Detailed harvesting records were also recorded by the Hudson's Bay Company during the eighteenth century beaver pelt trade in eastern Canada (Carlos and Lewis 1995). Likewise, the government of Guam recorded population and price histories associated with that island's recent trade in Pacific Island flying foxes (Wiles and Payne 1986). The usefulness of the taboo-based conservation model is that it permits managers to predict wildlife population trajectories subsequent to species commercialization. The model can therefore help conservation efforts be proactive and proscriptive in guiding efforts to protect wild-gathered populations while ensuring sustainable harvests for indigenous gatherers. In the absence of population and price data for newly commercialized species, the characteristics of species of "high value" in Table 2 should be consulted. Resource managers should then apply the minimum viable population model described in Chapter Two and track the emerging trajectories of exchange value and acquisition cost slopes.

Resource managers should be extremely wary of any action that might lead to the commercialization of a culturally salient or high value species. High value species were permanently tabooed by indigenous societies who possessed profound knowledge of each organism's vulnerability to over-exploitation. Even species that were only temporarily tabooed probably should not be commercialized unless harvesting techniques are restricted to traditional methods (see Chapter

Five). Indeed, rarity-value curves can dip from convex to concave by the adoption of modern harvesting technologies such as firearms and sonar fish-finding equipment (McGuire 1997). Similarly, modern harvesting methods have the effect of flattening the slope of the acquisition cost line in the minimum viable population model. This flattening leads to economical harvesting of a species even as its population decreases below MVP.

Conclusion

Elements of indigenous conservation strategies are increasingly incorporated into modern resource management models because patterns of aboriginal resource use often achieved long-term sustainability (Gillespie 1998). Such practices, however, were not characteristic of original colonizers settling virgin lands as the record of extinctions coinciding with Polynesian dispersal events attests (Steadman 1997). The loss of wild-gathered food resources through over-exploitation and the possible resultant diminution in human carrying capacity may have been the reason many cultures developed conservation strategies. Redclift (1987) suggests that Indigenous societies, including the Maori, adopted sustainable practices because such measures helped ensure long-term survival. The rahui system of wild-gathered resource conservation in New Zealand effectively served Maori society by curtailing the persistent and unsustainable harvesting practices that caused (or at least contributed to) the extermination of the archipelago's famed moas. Indeed, if conservation had never been adopted by the Maoris, their favorite bird of the bush, the huia, may have disappeared long before curious Europeans desired mounted specimens and emulated their future king by wearing the bird's prestigious feathers.

A modern analogue to the indigenous taboo system of wildlife management is the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), a global treaty that protects plant and animal species (and their parts) from unregulated international trade. Species threatened with extinction are classified as Appendix I by CITES. Trade in Appendix I species is permitted only in exceptional circumstances. Species listed as Appendix II by CITES are those which are not threatened with extinction, but which may become threatened if trade is not carefully managed. Appendix III species are usually common organisms, the trade in which is highly unlikely to diminish species populations. CITES imposes few trade barriers on Appendix III species.

At some point in Maori pre-history, the huia's former widespread range on North Island, New Zealand was diminished by at least 50%. Perhaps in response to its reduced distribution, the Maoris tabooed the huia and protected it in much the same manner that CITES prohibits trade in Appendix I species. Unfortunately, the corrosive effect of European colonization on Maori conservation traditions led to widespread and unregulated harvesting of huias. The species soon received less protection than an Appendix III CITES species. Western legal laws intended to preserve the huia were implemented too late and without sufficient penalty for infractions.

Walter Buller, privileged to witness and study New Zealand's stunning avifauna in the mid-1800s, resigned himself to the inevitability of its destruction. In his later years, he immigrated to England, and although he intended to return to New

Zealand, he fell seriously ill. Feeble, and unable to carry on in his former robust manner, Buller dictated the final pages of the *Supplement* to his monumental work, *A History of the Birds of New Zealand*. "The old order changeth," he reflected. Buller was regretting that the native fauna, flora and people of New Zealand were being supplanted by European invaders. He recalled the words of an elderly Maori friend, Ihaka, who likewise lamented the demise of Aotearoa's native birds and the invasion of exotic species:

> "Now they are all gone—as completely as the moa! Soon also will my race vanish from the land, and the white man, with his sheep and his cattle and his birds, will occupy the country" (Buller 1905:11).

In the end, the Maori people, and even some of New Zealand's indigenous avifauna, proved more resilient than Ihaka predicted. The huia, however, was doomed. Reflecting back to his antipodal roots in New Zealand and his adventurous life among the archipelago's unique biota, Buller wrote a characteristically colorful and poignant memorial to the huia:

> I do not know of any more picturesque sight in the New Zealand woods—now, alas! the opportunities are becoming few and far between—than that of a small party of these handsome birds, playfully disporting themselves among the branches, in the intervals between their customary feeding times. Take for our purpose a dense piece of native vegetation…and furnish it, in imagination, with two pairs…they are hoping actively from branch to branch, and at short intervals balance themselves and spread to their full extent their broad white-tipped tails, as if in sheer delight; then the sexes meet for a moment to caress each other with their beautiful ivory bills, while they utter a low, whimpering love-note; they bound off in company, flying and leaping in succession, to some favorite feeding-place, far away in the silent

depths of the forest.

Buller had long foretold the huia's inevitable demise. The traditional cultural constraints that successfully preserved it for hundreds of years had been broken down and replaced by reckless exploitation. Indeed, as Ross Galbreath (1989:11) noted, the huia "passed into a myth, a symbol of the nobility of an old New Zealand living on only in the mind."

Chapter Four

Conservation Implications of Chamorro Consumption of Flying Foxes as a Possible Cause of Amyotrophic Lateral Sclerosis—Parkinsonism Dementia Complex in Guam

Introduction

Guam, the largest and southernmost island in the Mariana archipelago, has two primary geological compositions. The northern half of the island consists mainly of an elevated limestone plateau fringed by steep slopes and marine cliffs. Numerous caves, sinkholes and other karstic landforms occur in the carbonate bedrock. Due to the porous nature of the limestone, virtually all drainage is subterranean (Fosberg 1960). In striking contrast to the topography of northern Guam, the southern half of the island is characterized by deeply weathered volcanic mountains eroded into rolling hills. Numerous perennial streams drain the mountainous interior of Guam. Mt. Lamlam, at 406 m, is the highest point on the island.

Guam has a tropical moist climate that on the northern plateau supports dense forests of *Artocarpus mariannensis*, *Ficus prolixa*, *Pandanus tectorius*, *Pisonia grandis and Cycas circinalis* (Fosberg 1960). Although much of southern Guam has been deforested, remnant patches of volcanic ravine forest contain *Hibiscus tiliaceus*, *Ficus prolixa*, *Pandanus tectorius, Cocos nucifera*, *Freycinetia* *reineckei* and *Cycas circinalis* (Fosberg 1960). Deforested regions are maintained by fire and livestock grazing and resemble an open savanna ecosystem (Stone 1970).

The international neurological community has long been interested in the Chamorro people of Guam (Sacks 1997) because of the high incidence of a complex neurological disease with similarities to Amytrophic Lateral Sclerosis, or Lou Gehrig's disease (ALS), Parkinson's disease, and Alzheimer's disease at perhaps the highest rate known in the world. Known by the Chamorro people as *lytico-bodig*, the incidence of ALS or an ALS-like disease was found by American researchers visiting Guam after World War II to occur at a rate more than one hundred times the incidence of ALS in the continental United States (Zimmerman 1945). Measured in human terms, the toll wreaked by the disease was massive; in the village of Umatac alone, one third to one fourth of all adult deaths from 1944 to 1953 were due to ALS-PDC (Mulder et al. 1954). The disease is characterized by wasting and muscular weakness, as well as spasticity, flaccid paralysis and atrophy culminating in death. Initially, the disease was believed to be indistinguishable from ALS, but in the mid-1950s, Mulder et al. (1954) noted other manifestations of lytico-bodig disease in the Chamorros including Parkinsonianism and associated dementia. Neuropathological features of lytico-bodig include spinal cord pathology that is identical to ALS. More ominously, even Chamorro individuals lacking overt symptoms of lytico-bodig showed neocortical pathology consistent with developing ALS (Anderson et al. 1979). In addition, neurofibrillary tangles in the brains of individuals with lytico-bodig have the same biochemistry, immunohistology, and structure of those found in Alzheimer's disease patients.

The linkage of these three disparate neuropathological diseases as manifestations of the same neurological disease in Guam, now known as ALS-PDC, was suggested by Daniel Perl to be the "Rosetta Stone" of neurodegenerative diseases (Stone 1993). For this reason a variety of workers tried to suggest possible causes of ALS-PDC in Guam. Kurland and Mulder (1954) initially thought that there could be a genetic basis because the disease seemed to occur more frequently in certain villages and families. Certain symptoms of lytico-bodig were similar to those of post-encephalitic Parkinsonism, but no evidence of heritability or an infectious agent could be found (White et al. 1976). The consumption of cycad seeds, known as "*fadang*" by the Chamorros, who knew of their toxicity, were suggested by Kurland in the 1950s as the possible cause of ALS-PDC in the Chamorro population (Kurland 1964). The use of tortillas made from cycad flour, claimed by Safford (1905) to have been used by the Chamorros since pre-contact time, continued after World War II as noted by Margaret Whiting (1963) in her ethnobotanical survey of Guam.

When a neurotoxic amino acid, beta-methylamino L-alanine (BMAA), was isolated from the cycads as well as the neurotoxic aglycone of cycasin, methylazoxymethanol (MAM), interest in the cycads as a possible cause of ALS-PDC increased. However, experimental feedings of cycad seeds and cycad flour to animals did not generate any equivalent neurological disease (Dastur 1964). Moreover, when a similar disease was discovered in the Kii peninsula of Japan (Yase 1979) and in Irian Jaya (Gajdusek and Salazar 1982), the cycad hypothesis was largely abandoned. Other environmental factors, including excesses of aluminum (Yase 1987), heavy metals (Garruto et al. 1984) and deficiencies in other minerals in the drinking water and diet were proposed as possible causes of ALS-PDC. Other unusual infectious agents, such as prions, were also proposed (Sacks 1993). Recently, Cox and Sacks (2002) suggested that Chamorro consumption of flying foxes in Guam may have resulted in sufficient cumulative doses of cycad neurotoxins to account for the high incidence of ALS-PDC (a reasonable hypothesis since flying foxes forage on cycad seeds). In this chapter I explore the cultural and conservation implications of that hypothesis.

Cycads and Flying Foxes

Cycads are arborescent gymnosperms which produce fleshy seeds that superficially look like fruits. The scientific taxonomy of the genus *Cycas* in Guam has varied through time: *Cycas rumphii* and *C. circinalis* are closely related species sometimes treated as distinct species and sometimes grouped as a single variable species (Stone 1970; Norstog and Nicholls 1997). In *Flora of Guam, C. circinalis* is recognized as the only indigenous species and one that is common throughout the island (Stone 1970). Norstog and Nicholls (1997) consider this species to be restricted to the Indian subcontinent, thus excluding it from Guam altogether. Given the ethnobotanical and ethnographic focus of current investigations by myself and two colleagues (Paul Cox and Sandra Banack) I will consider the indigenous cycads or fadang of Guam as a single ethnotaxon.

Fadang is eaten for its starch content and flavor. The Chamoros, who are keenly aware of cycad toxicity, process the seeds with a series of water baths to remove the toxins. The seeds are then prepared into flour and cooked into thin cakes or tortillas (Thieret 1957; Stone 1970). Formerly, the green sarcotesta was chewed to relieve thirst (Whiting 1963).

Flying foxes are members of the suborder Megachiroptera and the family Pteropodidae. Species include the largest living bats, with wingspans up to 1.7 meters. Although the term flying fox is occasionally applied to other genera (Hall and Richards 2000), most uses of this colloquial term refer to species of the genus *Pteropus*, which has 60 recognized species (Nowak 1999). The distribution of *Pteropus* ranges from Mafia and Pemba islands, only 25 and 40 km respectively off the African coast, through Madagascar, India, southeast Asia, New Guinea, Australia, and many islands of the western Pacific Ocean. The map in Figure 10 shows both cycad and flying fox distribution for Oceania. Many flying fox species are restricted to island habitats (Rainey and Pierson 1992). As stated in Chapter Two, flying foxes feed exclusively on plant products (predominantly fruits, nectar, floral bracts, and pollen) and depend on sight and olfaction to find food (Mickleburgh et al. 1992; Banack 1998; Hall and Richards 2000).

Historically, Guam was home to two flying fox species, *Pteropus tokudae* Tate *and P. mariannus* Desmarest (Tate 1934). The IUCN classifies *P. tokudae* as extinct (Nowak 1999). It has not been observed since 1968 and there is no published information on the diet or ecology of this species (Tate 1934; Perez 1972; Wiles 1987a). *P. mariannus* is considered endangered by the IUCN (Nowak 1999). The population of *P. mariannus* in Guam today may be less than 100 animals. Annual movements of animals between Guam and the island of Rota (60 km north of Guam)

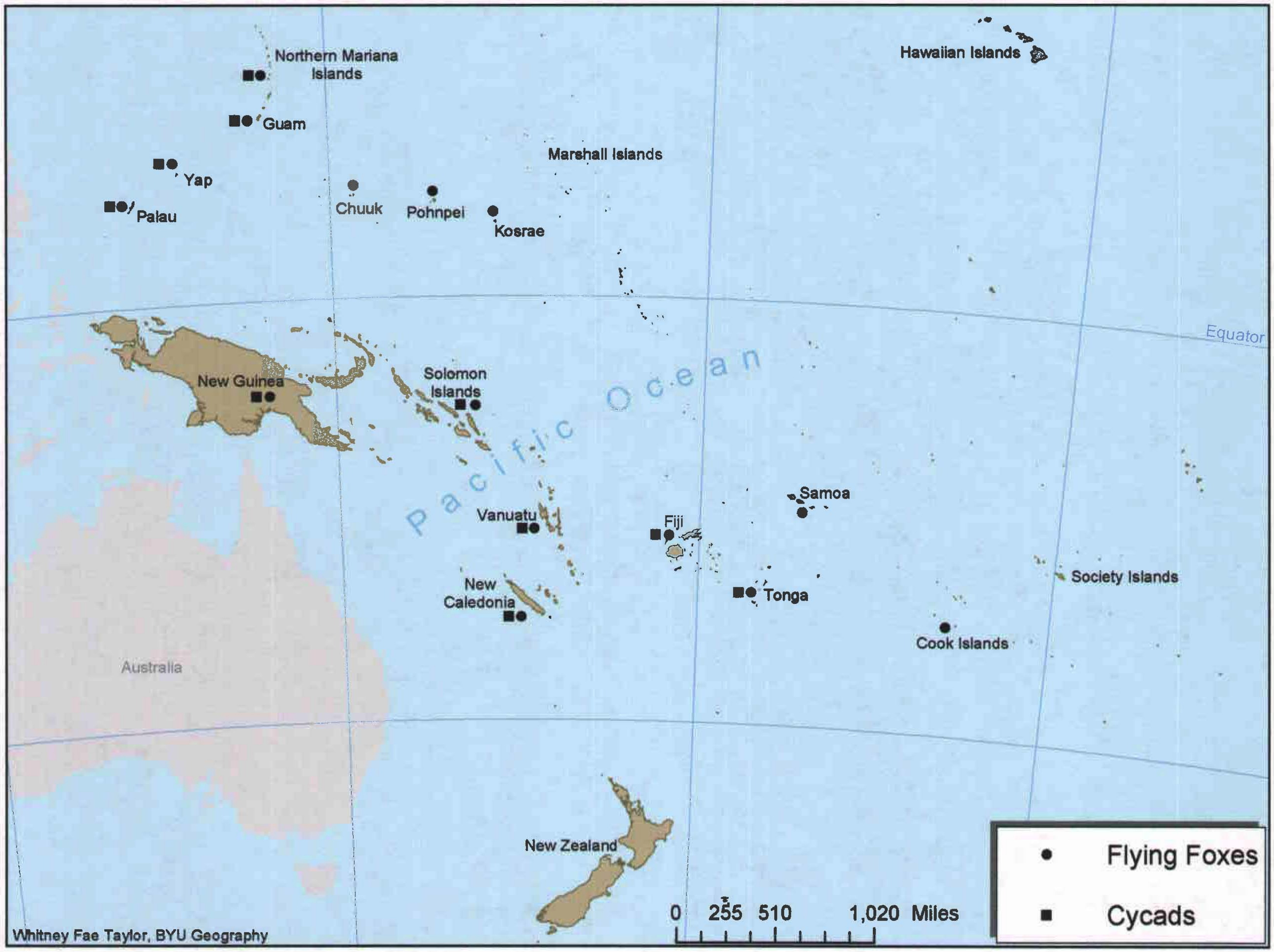

Figure 10. Distribution of the genus *Cycas* and the genus *Pteropus* in Oceania.

results in some seasonal variation in the number of animals in Guam (Wiles et al. 1995).

Most individuals of *P. mariannus* in Guam aggregate in a single colony (Wiles et al. 1995). Small numbers of individuals also roost solitarily or in small groups throughout mature and secondary forests (Wiles et al. 1995). These animals forage nocturnally over a range of about 12 km along the north shore of the island and coastline cliffs (Wiles et al. 1995).

Although flying foxes are generalist frugivores and nectarvores with broad diets, they eat a taxonomically nonrandom subset of plants (Banack 1998). A detailed dietary analysis indicated that flying foxes preferred fruits found in the primary forest to those found in agroforest (Banack 1998). *P. mariannus* is no exception with a diet consisting of 58 species of plants identified from 33 plant families, most of which are from the primary forest (Safford 1905; Wiles and Fujita 1992; E. Taisacan personal communication). There are no studies systematically examining the dietary preference of this species. However, Wiles (1987b) lists five fruits as favored in the diet of *P. mariannus* including the fleshy seeds of cycads. Since flying foxes are known to consume up to two and a half times their body weight in fruit and nectar each night (Dobat 1985), flying fox tissues could be rich in cycad secondary metabolites. Two other limited accounts of the principal fruits eaten by *P. mariannus* list predominantly cultivated fruits (and one forest species) in the diet (Safford 1905; Perez 1973). However, cultivated foods are more likely to appear on dietary lists simply by virtue of the fact that people are more likely to notice the consumption of these fruits because of their proximity to human activity.

Recently, Sandra Banack (personal communication) searched the forests of Guam during a five week period and Rota for one week for evidence of plant use by *P. mariannus*. Plant transects were conducted and fruiting trees sought out in primary forest on the military bases and private land. Evidence of bats eating fruits and leaves can be found in ejecta pellets and discarded fruits with distinctive triangular shaped tooth marks and scratches (Banack 1998). The seed shadow under fruiting trees noted to be eaten by flying foxes was searched for evidence of flying fox foraging. During this time, the flying fox population was very small (100-150 animals) in Guam and less than 2000 individuals on Rota. Banack found cycad seeds with definitive bat tooth and claw marks, thus confirming literature accounts of their preference by flying foxes. No other seeds, fruits, or leaves bearing evidence of flying foxes foraging was found in Guam during her survey. Some of the cycad seeds were far enough away from a parent tree to indicate the bat had dispersed the seed. Although the number of flying foxes on the island of Guam was very low, flying foxes showed a high preference for cycad seeds which clearly represents an important food source for *P. mariannus*.

Consumption of Flying Foxes by the Chamorro

As described in Chapter Two, flying foxes are enjoyed as a food item in numerous Pacific Island societies, but Chamorros are especially renowned for their enthusiastic desire for bat flesh. When legally available, flying foxes topped the list of desirable food items served at Chamorro weddings, village fiestas and religious events (Wiles and Payne 1986). When the animals became rare and difficult to obtain, social consumption was restricted to the most respected family members and guests (Lemke 1992) who were usually male.

During a visit to Guam, I was able to confirm the reported cultural importance of flying fox consumption. I talked to several people in Malojloj and Umatac, two of the more traditional villages on the island. If during a conversation, I determined that an individual had eaten fanihi, I asked additional questions concerning the frequency of consumption, dates of consumption, method of preparation, and the circumstances under which flying foxes were eaten. Chamorro appreciation for this delicacy was evident by the ritualistic manner in which the animals are cooked and consumed. Ordinarily, the only preparation for cooking is to wash the animal's fur. Chamorros told me that they preferred to boil fanihi before eating them in their entirety. Flying foxes reportedly emit a musky odor while being cooked, and people who eat them enjoy the distinctive taste of the animals (Thompson 1969). After cooking, the entire animal is consumed including all internal organs (Garcia 1984; Wiles et al. 1989; Wiles and Payne 1986; Lujan 1992).

I noted gender differences in the way the flying foxes were consumed; men were more likely to consume the entire flying fox than women, who tended to eat only the breast meat. In contrast, flying foxes are consumed less zealously in Samoa, where only the breast meat of the animals is eaten and the remainder is discarded. Many Chamorros were so fond of flying fox flesh that they discriminated between the tastes of different flying fox species; 43% of respondents in a survey conducted by Sheeline (1991) reported that flying foxes from islands other than Guam are less desirable.

Lemke (1992) suggested that one reason the Chamorro people relentlessly hunted flying foxes in Guam, even when extirpation of the animals was imminent, was because consumption of fanihi was one of the few traditions that pre-dated Spanish contact. I learned that the consumption of flying foxes was so central to Chamorro culture, that some Chamorro people were willing to risk fines and potential imprisonment to illegally obtain flying foxes. Although CITES placed nearly all of the Pacific island flying foxes on Appendix I or II of the treaties, illegal importation to Guam persists. Even the few remaining individuals of *Pteropus mariannus* in Guam, protected both by the U.S. Endangered Species Act, and the significant security surrounding the U.S. military base where the remaining *P. mariannus* colony is found, are vulnerable to poaching. A teenager in Umatac informed me he had recently eaten a native flying fox. Considering the extreme rarity and inaccessibility of flying foxes on the island, I was somewhat skeptical of his story. When I asked this individual where he obtained the animal, he reported that he and his friends clandestinely entered the U.S. Air Force Base at the north end of the island and shot the animal. Given that the young man accurately identified the only plausible place on the island where one could obtain a flying fox and the fact that he confessed the illegal deed with his parents present, I was reluctant to dismiss his claim as mere bravado, and consider this anecdote as evidence of the extraordinary significance that flying foxes have in Chamorro culture.

Prior to the introduction of firearms in Guam, several traditional methods existed for capturing flying foxes. Fritz (1986) and Sheeline (1991) reported that large, Polynesian-like dip nets were employed to capture individual flying foxes as the animals fed in trees. Often the hunter would position himself on a platform erected high in a tree where flying foxes were known to feed. Another primitive technique was to affix branches of thorns to the end of a long stick. This device was used to capture a flying fox by entangling its wings on the thorns or by rendering an animal flightless by tearing its wing membranes (Lemke 1992). Still another method demanded the use of long nets suspended between trees to intercept flying foxes as they left their communal roosts to make nightly foraging forays (Lemke 1992). This latter technology was employed when large numbers of flying foxes were desired. Attempt to harvest large numbers of flying foxes required considerable ritual and organization (Falanruw 1988).

Traditional tools for harvesting flying foxes in Guam have long been abandoned. Since Guam's economy has become monetized and firearms have become readily available, guns are the preferred method of taking flying foxes. During Spain's occupation of Guam, civilian access to firearms was strictly prohibited (Lemke 1992). In 1898, following the conclusion of the Spanish-American War, Spain ceded Guam to the United States, and guns eventually became available to a small segment of the population. In 1902 guns apparently did not play a major role in flying fox hunting (Safford 1902-1904). By 1931, however, the use of firearms had severely reduced flying fox numbers on the island (Wiles 1987a). By 1939 guns were sufficiently widespread that taxes were levied on firearm ownership (Thompson 1969). Deleterious impacts of firearms on flying fox populations accelerated after World War II when both cash and weapons were more available to the general public. With the common use of firearms, the formerly negligible impact of subsistence hunting was altered. With shotguns, hunters could easily kill several dozen flying foxes at a roost in a short time (Graham 1992).

I became interested in comparing the size of the flying fox population in Guam to the increasing accessibility of cash and firearms among the Chamorro people. However, it is impossible to obtain a precise baseline figure for Guam's flying fox populations at the beginning of the twentieth century. Nothing is known concerning the historical population status of the now extinct endemic *P. tokudae*, except that it was always considered rare (Perez 1972; Wiles 1987a). However, Guam's extant flying fox species, *P. mariannus*, was abundant. Indeed, Lujan (1992) reported that they were so numerous in the early twentieth century that farmers sometimes fed them to their hogs. This flying fox species is still common on numerous small, remote islands in the Northern Mariana archipelago, and it is possible to examine population characteristics for these northern islands to estimate Guam's flying fox population before the use of firearms.

Wiles et al. (1989) surveyed the islands in the northern Mariana chain and estimated a minimum total population of 7,425 flying foxes for seven islands containing flying fox habitat. However, many of the forested slopes in the northern Marianas have been severely degraded by rooting and browsing activities of feral animals while others have been destroyed by recent volcanic activity (Fosberg 1960, Wiles et al. 1989). Two islands, Anatahan and Guguan, contain a total of 36.5-km^2 and an estimated minimum population of 3,400 flying foxes, or 93 animals per km^2 (Wiles et al. 1989). However, only half of the area of these islands was forested, suggesting that the available habitat supported double this density, or 186 flying foxes per km^2. This figure is consistent with estimates made by Stinson et al. (1992) who predicted that forested areas of nearby Rota could potentially support 195 flying foxes per km^2. In the early 1900s, Guam's forests were reportedly in pristine condition (Lujan 1992), and 40 years ago, Fosberg (1960) remarked that the majority of Guam was still forested. Then, as today, the northern plateau contained most of the forest while the volcanic areas of the south have always been subject to periodic burning. Based on this information, I believe that a conservative estimate for Guam's forest cover in the early 1900s is approximately 60% of the island's 541-km^2. Given these conditions, Guam could have supported a population of over 60,000 flying foxes. Considering the primitive hunting technology of the time and the fact that there were fewer than 10,000 people in Guam in the early 1900s (Wiles 1987a), the impacts of subsistence hunting was minimal.

Although flying fox numbers were robust in the early 1900s, a population decrease quickly ensued (see Chapter Two; Figure 11). Rapidly increasing incomes following WWII and liberal guidelines governing firearms purchases made guns more readily available (Lemke 1992). By 1958 D. H. Woodside estimated that a maximum of 3,000 flying foxes remained in Guam (Wiles 1987a). In 1966 flying foxes were granted limited protection (Lujan 1992), but hunters could still make huge profits, even after paying the requisite fines (Perez 1973). Regular poaching of flying foxes forced Guam's Division of Aquatic and Wildlife Resources to recommend prohibiting all hunting in 1971 when the population fell below 1000 animals (Wiles 1987a). This request, however, was not granted until 1973 (Lujan 1992). Throughout the final period of population collapse, poaching continued. From 1974 to 1977 the

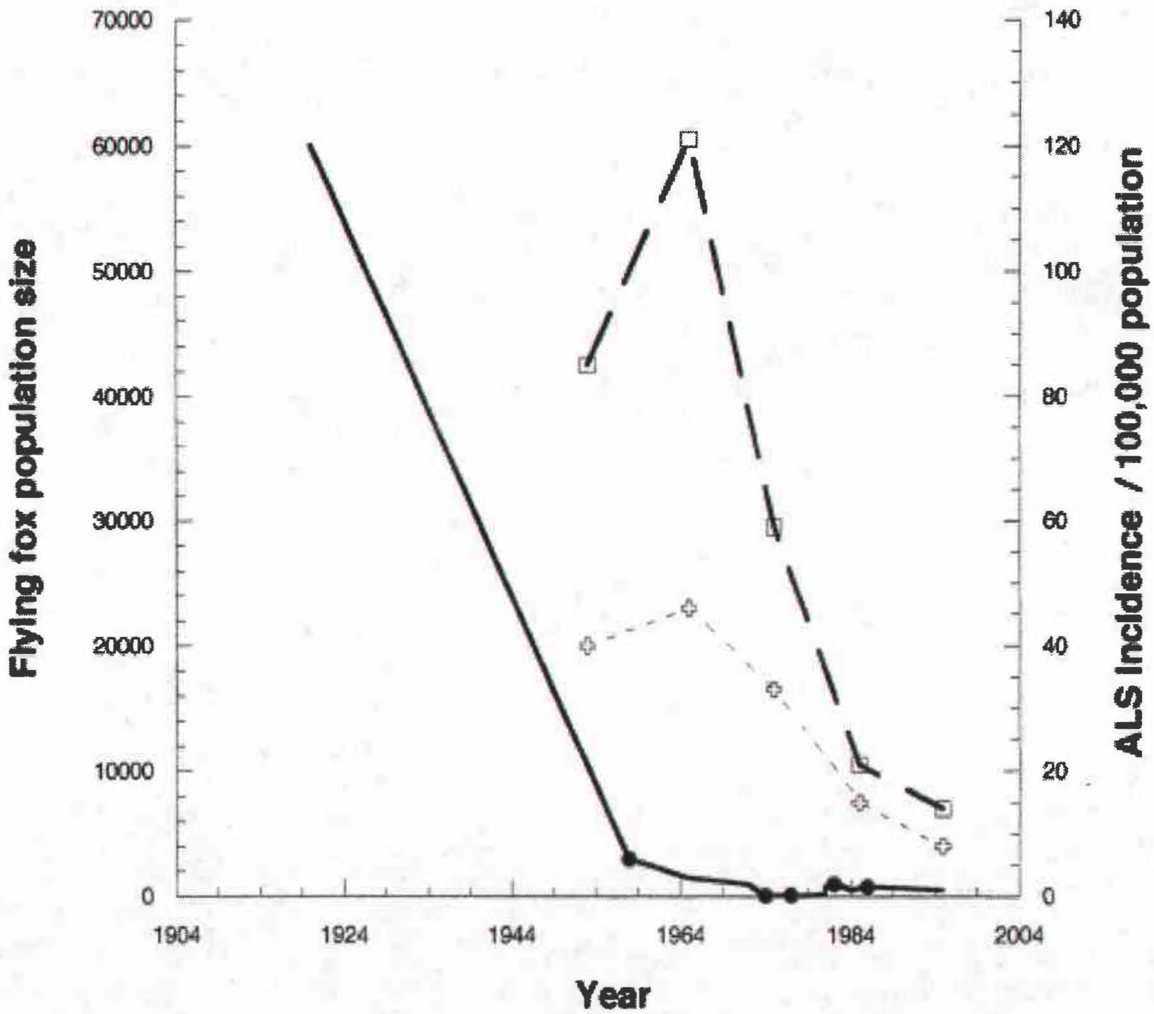

Figure 11. Decline in Flying Fox Populations of Guam Plotted Against the Rise and Fall in Incidence of Amyotrophic Lateral Sclerosis-Parkinsonism Dementia Complex (ALS-PDC) in Chamorro Men and Women. Solid line with closed circles represents the flying fox population size. Dashed lines represents ALS incidence per 100,000 people in men (open squares) and women (open crosses). Data for flying foxes as noted in text; ALS-PDC data from Kurland and Mulder (1954) and Zhang et al. (1996).

flying fox population dropped below 100 (Wiles 1987a). In 1978 the population was reported at an all-time low of less than 50 animals (Wiles 1987a). From 1978 to 1982 the population fluctuated between 50 and 1000 and from 1987 to 1994 ranged from 200 to 750 individuals (Wiles 1987a, Wiles et al. 1995). Today, Guam's flying foxes persist only in very small numbers.

Flying Fox Foraging and Biomagnification of Cycad Neurotoxins

Toxic elements found in cycad seeds in Guam include pakoein, cycasin (0.10% fresh weight), and macrozamin (0.42% fresh weight) (Whiting 1963; Norstog and Nicholls 1997), and the toxic nonprotein amino acid BMAA (β-methylamino L-alnine) (480-720 µg/g fresh weight) (Charlton et al. 1992; Oh et al. 1995; Li et al. 1996). Cycasin and macrozamin have similar chemical structures with a toxic aglycone, MAM (methylazoxymethanol), attached to a sugar (Figure 12; Norstog and Nicholls 1997). While attached to the sugar, the compound is not known to have any deleterious effects but when the molecule is cleaved, the sugar and the highly toxic MAM are released (Norstog and Nicholls 1997). Although this enzyme is widespread in the gut flora and tissues of mammals, *P. mariannus* should specifically be checked for this enzyme. Were individuals of *P. mariannus* to suffer neurological impairment from foraging on cycad seeds, selection pressures would be strong for loss of this enzyme or evolution of an inhibitor (Paul Cox personal communication).

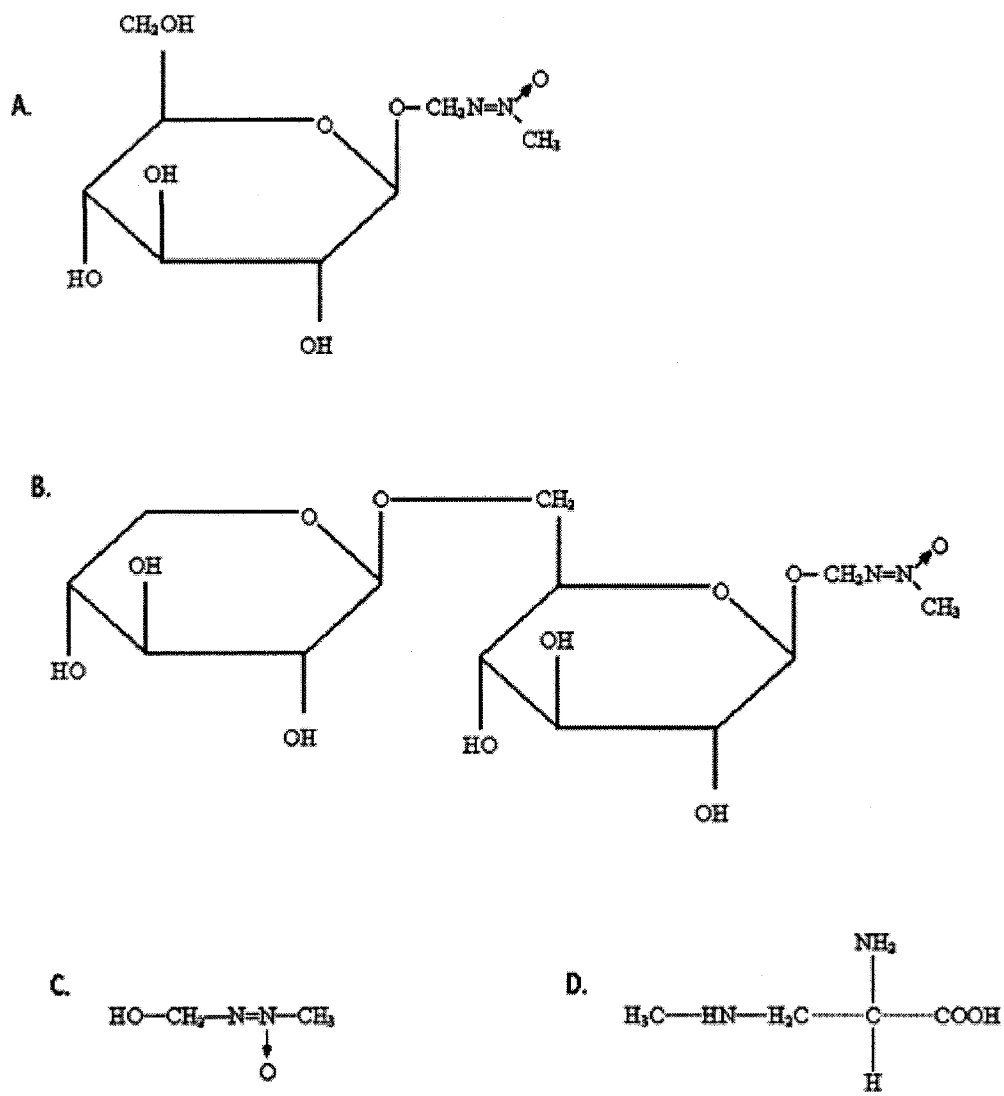

Figure 12. Chemical Structure of Compounds Found in Cycad Seeds: (a) cycasin, (b) macrozamin, (c) MAM (methylazoxymethanol), which is released from cycasin and macrozamin when the molecule is split and the sugar removed, and (d) BMAA (beta-methylamino L-alanine) (after Norstog and Nicholls 1997).

In the early 1990s, the cycad neurotoxins BMAA and cycasin were reexamined as a possible cause of ALS-PDC in Guam, perhaps as a “slow toxin” (Spencer et al. 1991). Subsequent to the writing of this chapter, biomagnification of BMAA in Guam flying foxes was confirmed (Banack and Cox 2003; Cox et al. 2003).

The Cox-Sacks (2002) hypothesis suggests that the incidence of ALS-PDC disease among the Chamorro people rose and then declined in the twentieth century as a function of rising and then declining consumption of cycad-fed *Pteropus tokudae* and *P. mariannus* in Guam. Through the consumption of cycad-fed flying foxes, the Chamorro people unknowingly ingested large quantities of cycad neurotoxins, which were biomagnified within the flying foxes or otherwise sequestered or metabolized. Cycad neurotoxins were ingested by the flying foxes of Guam during their regular foraging on cycad seeds, which were one of the more important items in the flying fox diet. Indeed, cycad seeds may have occasionally served as the primary item of food for flying foxes in the aftermath of typhoons that afflict Guam with unusual frequency and intensity (Lobban and Schefter 1997). Prior to European contact, the indigenous people themselves relied on cycad seeds as a famine food subsequent to typhoons. “In the times of famine following hurricanes,“ reported Safford in 1905,

> they resorted to the woods for ‘fadang,’ or nuts of *Cycas circinalis,* the poisonous properties of which were removed by soaking and repeatedly changing the water, after which the macerated starchy substance was ground in cavities of convenient stones and baked (Safford 1905:98).

Cycads have been known to respond to environmental perturbation by increasing seed production. For example, after fire, seed production in some cycads has been found to increase seven-fold (Beaton 1992). It is therefore possible that flying fox consumption of cycad seeds and ingestion of cycad neurotoxins dramatically increased after typhoons. At such times, as has been noted after hurricanes in Samoa, flying foxes are even more vulnerable to capture by human beings (Pierson et al. 1996, Daschback 1990) and may even be hunted more eagerly when alternative sources of protein, including fish and livestock, are inaccessible or have been destroyed. As a result, during typhoon-induced famines, cumulative doses of cycad neurotoxins in the Chamorro population may have increased due to 1) increased human reliance on cycads as a famine food with perhaps hasty or inadequate detoxification of the seeds, 2) increased consumption of flying foxes due to their increased vulnerability to capture, and 3) increased neurotoxin concentrations in flying foxes since after typhoons cycads likely assumed a far larger role in their diet. Even in the absence of typhoons, however, biomagnification of cycad neurotoxins in the flying fox population may have been sufficient to generate the high incidence of ALS-PDC in the Chamorro population that consumed them.

Any explanatory hypothesis for the high incidence of ALS-PDC in Guam must also account for the rise and the subsequent decline of ALS-PDC rates in Guam in the twentieth century (Figure 11). Although flying foxes were long prized by the Chamorro people, their capture was limited at the beginning of the twentieth century by traditional techniques and tools. As noted above, the primary method of flying fox capture among the Chamorros involved stealthily netting them while they were feeding in trees, a decidedly difficult endeavor given the flying foxes visual and auditory acuity.

Beginning in the early twentieth century, Guam's importance increased as a trading center and military outpost with the result that a cash economy—including discretionary funds—became more prominent within the Chamorro community (see Chapter Two). At the conclusion of Spain's occupation of Guam in the late nineteenth century, virtually the entire Chamorro population was still engaged in a subsistence economy with barter as the principle means of exchange. A visitor to Guam at the beginning of the nineteenth century called the island "a lump of Oriental lovliness" and described the typical Chamorro as "less than a child, obstinately gentle, full of caprice...apparently wealthy, utterly poor" (Rogers 1995:127). When Spain relinquished Guam to the U.S., Americans introduced a cash-oriented economy and considerable pressure was applied toward merchants to pay Chamorro farmers cash in exchange for copra and other produce (Thompson 1969). Additionally, as in other European colonies, the indigenous population was encouraged to pay taxes in the form of cash. Concurrent with the introduced emphasis on cash, the U.S. began to build up the Guam's infrastructure. Roads, bridges and public buildings were constructed.

As the U.S. built up its large administrative force of naval personnel in Guam, imports increased greatly. The Chamorro people, envious of items obtainable for cash, flocked to Guam's capital, Agana. By 1919, one-third of Guam's adult Chamorro males were working for the government or in other businesses in Agana (Thompson 1969). The shift toward a cash-based economy from a traditional barter system led to the need to import large quantities of food. As a result, large parcels of arable land were left uncultivated. By 1911, four-fifths of Guam's Chamorro people lived wholly or partially on imported food. The monetization of Guam was intimately connected to the U.S. military presence. In 1939, Naval salaries, set according to a fixed scale in Washington, were more than double the local market price for labor.

In the new financial climate of disposable incomes, the Chamorro people began acquiring numerous items, including firearms, previously unavailable during the more oppressive Spanish rule. Commercial trade in flying foxes soon began. By the 1970's, flying foxes could fetch up to $35 each on the local market. While money was a crucial pre-curser to the acquisition of firearms by Chamorros, the primary agent that jeopardized flying fox populations was their cultural salience which in turn drove commercial trade. Sheeline (1991) found that 80% of Chamorro respondents believed flying foxes to be a symbol of Chamorro culture and 49% considered consumption of flying foxes an important part of Chamorro identity. Given these cultural and financial factors it was inevitable that flying foxes would be over-harvested.

Cash could be used to purchase firearms and ammunition as well as flying foxes themselves (Thompson 1969). Thus, increased accessibility of flying foxes and the unwitting consumption of biomagnified cycad neurotoxins increasingly characterized the diet of the Chamorro people. However, there are distinct gender preferences within the Chamorro population for flying foxes; 61% of men report favoring flying fox flesh while only 47% of women stated this preference (Sheeline 1991). My conversations with Chamorros also suggest a male preference for flying foxes. Differential palatability and cultural access to flying foxes may account for the significantly higher incidence of ALS-PDC in men than women: men are three times as likely to develop the disease as women (Anderson et al. 1979). However the other non-Chamorro inhabitants of Guam, who find flying foxes repulsive to eat, did not suffer from an increased incidence of ALS-PDC (Torres et al. 1957; Anderson et al. 1979).

The possible etiological role of flying fox consumption in ALS-PDC is also strengthened by analyses of the disease among expatriate populations of Chamorro people. Chamorros who spent their childhood and adolescence in Guam and later left for other countries exhibit a lower rate of ALS-PDC than Chamorros who remained in Guam, but a higher rate than the resident populations of their new host countries (Garruto et al 1980). Chamorros who left Guam for the United States mainland after they turned 18 years of age had one-third the rate of ALS-PDC compared with Chamorros who did not leave the island. Even so, the incidence of ALS-PDC among these expatriate Chamorros was one-third higher than that among other U.S. mainland residents. These expatriate Chamorros attempted to maintain their dietary traditions and occasionally ate "a few traditional Chamorro foods" sent from Guam (Garruto et al. 1980:614). It is not clear if flying foxes were imported from Guam to the U.S. mainland as part of these "traditional Chamorro foods:" or if the expatriate Chamorros ate flying foxes during return visits to Guam, but such behaviors would be unremarkable given the centrality of flying fox consumption in Chamorro culture. And although Torres et al. (1957:385) did not believe that the "articles of food which were received occasionally by [expatriate] Chamorros" were of “etiological significance,” they were unaware of the possibility of significant bioaccumulations of cycad neurotoxins in flying foxes.

Relationships between the consumption of flying foxes and patterns of ALS-PDC disease may have a historical basis. Safford (1902:715) noted that the Chamorro people “were remarkably free from disease and physical defects, and lived to a great age...more than 120 said to be past the age of 100 years.” The aversion to flying fox consumption by other ethnic groups in the Mariana Islands, who did not develop ALS-PDC at the same rate, was noted by early explorers. In 1819 Arago (1823:276) wrote from Rota, “We find here also monstrous bats, similar to those of Guam, perhaps even larger. The Carolinians would not eat them.” The cultural aversion of Carolinians to flying fox flesh then, may explain the relative absence of ALS-PDC among them. During two decades of extended surveillance of Carolinians in Yap and Guam, no cases of ALS-PDC were found (Yanagihara et al. 1983).

The suggestion that the over-consumption and subsequent extirpation of flying fox populations in Guam were linked to the devastating epidemic of ALS-PDC is consistent with the known epidemiological, cultural, and ecological data in nine different ways. First, epidemiologically, lytico-bodig is a disease primarily of the Chamorro people, but did not characterize non-Chamorro residents in Guam unless they adopted a traditional Chamorro lifestyle (Brody et al. 1978; Garruto et al. 1981; Reed et al. 1987). Second, Chamorro residents in Saipan, Tinian, and other places outside of Guam did not exhibit neurodegenerative disease at rates higher than the surrounding population (Garruto et al. 1980; Yanagihara et al. 1983). The “strikingly lower mortality rates of [neurodegenerative disease among the Chamorros] on Saipan" suggest that environmental factors contribute to ALS-PDC (Yanagihara et al. 1983:79). Third, the only significant statistical correlate of ALS-PDC in Guam is eating a traditional Chamorro diet (Reed et al. 1987). Fourth, although the traditional Chamorro diet did include flour made from detoxified cycad seeds, that flour did not contain sufficient concentrations of neurotoxins to account for ALS-PDC (Duncan et al. 1990; Kisby et al. 1992). Fifth, the Chamorro diet and indeed the Chamorro cultural character were uniquely characterized during the twentieth century by mass consumption of flying foxes (Sheeline 1991; Wiles 1992). Sixth, the proclivity for Chamorro men to eat more flying foxes or to have greater access to flying foxes as a meal is mirrored by gender-specific incidence rates of ALS-PDC, with men consistently having higher rates of the disease (Kurland and Mulder 1954; Anderson et al. 1979 Lavine et al. 1991). Seventh, consumption and commercial traffic in flying foxes contributed to the extinction of one flying fox species in Guam and the near-extinction of the other species (Wiles 1987a). This in turn led to the importation of an estimated 230,000 bats representing at least 10 species from islands where cycads are not native or do not have a prominent role in the vegetation structure (Wiles 1992, Bräutigan and Elmqvist 1990). Eighth, as a result of the change in sources of flying foxes, the inadvertent ingestion of biomagnified cycad neurotoxins began to decrease in the 1960s and reached negligible levels in the 1970s when the entire genus *Pteropus* in Guam teetered on the edge of extirpation. Ninth, the rise and fall of consumption of Guam flying foxes was shadowed by a rise and fall of the incidence of ALS-PDC in Guam (Figure 11; Garruto et al. 1985; Haddock and Santos 1992).

The hypothesis of a possible link between the consumption of flying foxes in Guam and the high incidence of ALS-PDC among the Chamorro people has not gone unchallenged. When Cox and Sacks (2002) published the hypothesis in the journal, *Neurology*, Chen et al. (http://www.neurology.org/cgi/eletters/58/6/956#404) criticized the article on several points. One criticism was that while flying foxes consume the skins of cycad seeds, they do not ingest the extremely hard gametophyte—the portion of the seed that contains BMAA. Cox and Sacks replied that the fleshy sarcotesta of cycad seeds is actually rich in BMAA, as confirmed by HPLC testing (http://www.neurology.org/cgi/eletters/58/6/956#404).

In addition to the ALS-PDC hypothesis investigated in this dissertation, another recent study suggests that neurological disease on Guam may have been caused by bacteria that occasionally release large quantities of toxins in Guam's streams—a common source of drinking water (Miller et al. 2002). This water was formerly untreated, but it is now filtered through activated carbon. Authors of the study suggest that the modern decline in neurological disease among Guam's Chamorro population may be due to modern filtration techniques that destroy cyanobacteria.

Cyanobacteria may indeed have played a role neurological disease in Guam. Cox et al. (2003) recently discovered small amounts of cyanobacterial BMAA in root systems of Guam cycads. Greater quantities of cyanobacteria were found in cycad seeds and, as discussed above, even greater concentrations in Guam flying foxes

(Banack and Cox 2003). While BMAA occurs in increasing concentrations through ascending trophic levels in Guam, there may have been abiotic sources of BMAA in Guam such as in the island's streams. Miller et al. (2002), while attributing neurological disease in Guam to cyanobacteria, make no mention of BMAA.

Conclusion

Based on the evidence cited above, it is very possible that the initial increase and subsequent decline in the consumption of flying foxes in Guam, as well as the rise and fall of ALS-PDC among the Chamorro population, is linked to monetization on the island and the commercial traffic in Guam's indigenous flying foxes. The association of commercial traffic in wildlife species with human health crises occurs elsewhere. In Minamata Bay in Kyushu, Japan, the consumption of wild fish with elevated mercury concentrations led to neurological malfunction, debilitation, birth defects, and death in over 2,265 people (Greimel 2001). Another example of toxin biomagnification imperiling human health can be found in the elevated levels of methyl mercury and PCB's in the inhabitants of the Faeroe Islands where whale meat consumption is an integral component of local culture (Jørgensen et al. 1997).

Unlike cultivated or agricultural species that have a history of trade and hence have been culturally vetted for safety, wildlife species recently introduced into commercial traffic potentially threaten human health for the reasons noted in the Chamorro history of consuming flying foxes. The increased availability of firearms and the introduction of a cash economy to an indigenous people characterize areas as diverse as post-colonial Africa, Papua New Guinea, and vast regions of the

Amazon Basin. Based on the neurological disease crisis among the Chamorro people of Guam, health officials should seriously consider an international moratorium on commercial traffic in bush meat until such wildlife flesh can be proven safe for human consumption.

Chapter Five

Management Strategies for Vulnerable Commercialized Species

Introduction

Many species that historically possessed monetary value are already extinct. New Zealand's huia and the Guam flying fox, for example, proved highly vulnerable to commercial harvesting, but so too did North America's super-abundant passenger pigeon. Other commercialized species, though still extant, may be vulnerable to extinction due to the often pernicious effects of economic forces. As stated in Chapters Two and Three, species known to have been protected by tribal taboos may be highly susceptible to over-exploitation and are likely to require some kind of protection if commercialized. Other species, even if they were not tabooed by indigenous societies, may become subject to modern over-harvesting due to factors such as new fashions and habitat loss.

Individuals from government agencies are the most likely resource managers to implement strategies to help protect vulnerable commercialized species. This conservation effort presents daunting challenges to resources managers because there are often a variety of negative factors simultaneously impacting such species. Expanding human populations, for example, can increase market size. Habitat destruction (also often the result of population pressures), which by itself is a common cause of extinction, not only reduces species numbers but also leaves formerly healthy populations fragmented. Such populations often become completely isolated and, if reduced below a species' MVP (see Chapter Two), are highly susceptible to extirpation. Improved harvesting technologies further burden commercialized species as was seen in the case of flying foxes in Oceania and the cod fishery in North America.

Following are six management strategies that have provided many commercialized species protection from extirpation and extinction. The list is not an all-inclusive menu of possible management techniques, but includes tested strategies that that have been implemented in a wide variety of species management programs:

1) *Commercial Cultivation and Captive Propagation*
2) *Establishment of Hunting Reserves*
3) *Education*
4) *Use of Substitute Resources*
5) *Encouraging Fashion Changes*
6) *Mandatory Use of Traditional Harvesting Methods*

Discussion of Management Strategies

Commercial Cultivation and Captive Propagation

For some species, harvesting pressure on wild populations has been relieved by increasing supply through commercial cultivation and captive propagation. Ginsing (*Panax ginseng*), for example, is commercially cultivated in order to satisfy a large international market for the plant's medicinal properties. In the United States and Great Britain, gyrfalcons (*Falco rusticolus*) and peregrine falcons (*Falco peregrinus*) are routinely bred in captivity to satisfy the demand for these species as falconry birds. In the last 40 years, the eland (*Taurotragus oryx*), the giant pouched rat (*Cricetomys gambianus*), the musk ox (*Ovibos moschatus*), the Asian forest tortoise (*Manouria emys*) and the capybara (*Hydrochaeris hydrochaeris*) have all been added to the list of animals propagated in captivity for human consumption.

While commercial cultivation and captive propagation of wild-harvested species has proven beneficial in protecting certain populations from excessive exploitation, the practice also has potential challenges and drawbacks. One obstacle is that some species take a long time to mature sexually and may have low reproductive potential (e.g., elephants). Such species are difficult if not impossible to propagate in a cost-efficient manner. Other species may fail to reproduce because of extreme wildness, complicated courtship rituals that cannot be performed in confinement and lack of breeding stimuli when removed from their natural environment. A common difficulty encountered in propagating certain plants (at least on a commercial scale) is the necessity of providing the necessary pollinating organism(s). Additionally, many tropical plants are highly vulnerable to pest and disease infestations when planted in dense, monoculture plantations (Clay 1992).

In addition to direct obstacles to commercial cultivation, there are also indirect problems. If a significant increase in Brazil nut supply were to occur through plantation production, prices would fall and indigenous harvesters who make part or all of their living from collecting nuts from the forest would be forced to earn money in far more destructive and unsustainable activities such as logging and ranching (Clay 1992).

Commercial cultivation and captive propagation can also open the door to illegal take of rare species. In the early 1980s, for example, falcon breeders were regularly fetching $2,000 for young peregrines. The high prices enticed several raptor breeders to illegally remove young falcons from wild nests (McKay 1989). These birds were then claimed to have been produced from captive stock.

Similar deceit might also accompany captive propagation of flying foxes in Guam if captive propagation was permitted. Flying foxes produce only one young annually, and any person who raised bats would be forced to charge high prices for animals reared. If demand were to exceed supply, which could easily occur during the early stages of a captive propagation industry, there would be great incentive for bat breeders to obtain animals from nearby islands and sell them as captive-raised individuals. Wildlife law enforcement agencies in Guam and the Commonwealth of the Northern Marianna Islands would have to implement safeguards against such an illegal take. Furthermore, when a wild species is initially permitted to be commercially propagated, relatively large numbers of people attempt to enter the captive breeding business. Wild populations of rare species may become further jeopardized when many hopeful breeders simultaneously attempt to obtain breeding stock.

Another popular captive breeding industry is aquaculture. Aquaculture is successful in conserving many species of fish from extinction, but it too can have undesirable effects. Biologists contend that the release of hatchery raised salmon (used to replenish wild harvested stocks) has deleterious effects on the reproductive capacity and genetic variability of wild populations (Wapels and Teal 1990). The relative ease with which great numbers of salmon can be propagated in hatcheries can also lead to complacency regarding the conservation of wild populations. For decades, governmental policies toward salmon in California, Oregon and Washington focused on hatchery production. At the same time, these states allowed and even promoted major alteration and degradation of local river systems to facilitate development and mining interests. Consequently, salmon habitat in the region has been irreparably damaged, genetic diversity has diminished and numerous wild salmon populations have either declined or been extirpated (Wilderness Society 1993).

Despite the obstacles and negative consequences cited above, captive breeding and commercial cultivation still hold value and promise (provided sound judgment is exercised) for preserving commercialized species vulnerable to over-exploitation. Furthermore, provided that there are people or institutions possessing the necessary expertise to succeed at cultivating or breeding a particular species, commercial propagation should be encouraged before a species becomes imperiled. Indeed, it is important that the door to well-planned commercial propagation be opened before the potential for profit becomes so great that it encourages illegal activities that undermine conservation objectives.

If captive propagation had been more widely practiced during the era of European colonial expansion, it is probable that more species would have survived the ecological onslaught of colonialism. Indeed, it is unfortunate and curious that nineteenth century naturalists and hobbyists in New Zealand were not more diligent in acquiring huias for aviculture. From Buller's account of the huia, the species readily adjusted to captivity, was hardy (one survived the long voyage to England), and demonstrated remarkable adaptability by its willingness to consume common table fare such as rice, potatoes and minced meat. Buller not only described the difficulty that many wild species have adjusting to captivity, but also the complete ease with which the huia accepted confinement:

> The captive Eagle frets in his sulky pride; the Bittern refuses food and dies untamable; the fluttering little Humming-bird beats itself to death against the tiny bars of its prison in its futile efforts to escape: and many species that appear to submit readily...ultimately pine, sicken and die. There are other species, again, which cheerfully adapt themselves to their new life.... Parrots, for example, are easily tamed.... This character of tameability was exemplified to perfection in the Huia.

There is quite possible that, with reasonable care and attention, captive huias would have reproduced in captivity. However, as was described in Chapter Three, conservation was instead directed toward the relocation of huias to offshore islands—a project that was poorly planned and initiated too late in the species' decline.

Establishment of Hunting Reserves

An increasingly popular approach to the conservation of rare game species in South Africa (and other countries) is the creation of large hunting reserves on privately owned land. Typically, an individual (or group of individuals) secures exclusive hunting rights from owners of several large adjacent ranches—usually in more arid regions where conditions are marginal for cattle ranching (Merten 1993). The entrepreneurial individual, who may be one of the ranchers, makes his living by providing living accommodations, meals and guide services for hunters (usually wealthy foreigners willing to play large fees for quality trophies and an "African experience") (Crowe et al. 1997). The fee to shoot common species, such as impala, may be as little as $100. But large, rare game animals such as rhinoceroses and elephants (if they indeed occur on a particular reserve) can cost at least $12,000 and $28,000 respectively (Anderson and Hill 1995). These high fees exclude most hunters from the market and ensure that a particular species is not over-hunted. Landowners receive a portion of the daily guide fees as well as up to two-thirds the trophy fees paid by successful hunters (Anderson and Hill 1995). A significant amount of these monies are re-invested to improve wildlife habitat. Improvements include projects such as removing cattle and fences from the hunting area and the conversion of watering troughs to natural looking watering holes.

Collected fees are also used to reintroduce additional game species that were extirpated from areas of South Africa when much of the region's savannah biome was converted to cattle ranches. A common source of animals purchased for restocking purposes in South Africa is the Rooipoort Estate, a 42,000 hectare property of De Beers Mining Company near Kimberly (Crowe et al. 1997). De Beers struggled for decades to make cattle ranching on the Rooipoort profitable. The company eventually converted most of its farming property to a hunting reserve. By the 1940s, the De Beers farms around Kimberly "...had become game-rich islands in a sea of properties that had retained little or no wildlife" (Crowe et al. 1997:365).

This kind of wildlife management or "enviro-capitalism," based as it is on killing animals for horns and skins, is offensive to anti-hunting groups. However, these modern reserves have restored native species to areas long devoid of game herds. Moreover, the success of these hunting businesses demonstrates that conservation can be more profitable than agriculture.

While hunting reserves may be financially lucrative, the high prices commanded for harvesting rare species can facilitate bribery and corruption (Freese 1997). Moreover, they encourage poaching of rare species for products such as ivory and rhino horns. Fortunately, private hunting reserves usually have the financial means to ensure the protection of their wildlife assets.

Education

A challenging but effective conservation strategy is to change negative exploitation habits of a culture through education. In American Samoa, flying foxes were traditionally harvested on a subsistence basis but were not, at least in historical times, hunted below sustainable numbers by the local people. Unlike Guam, where dinner hosts derived prestige by serving expensive flying fox flesh, Samoans were generally prudent about flying fox exploitation. Nevertheless, the Westernization of American Samoa and its increased dependence on imported foods appears to have led to a degree of apathy towards natural resources.

In February, 1990, hurricane Ofa struck American Samoa. On the island of Tutuila, at least 40% of the forest was destroyed and most of the remaining forest was badly damaged. In the days and weeks that followed, many of the standing trees shed their leaves and fruit, leaving nothing to eat for the island's two species of flying foxes. Large numbers of bats began foraging on the ground, particularly near plantations and villages (Daschbach 1990). As time passed, the forest continued to languish and bats began to starve. Then, boys began killing hundreds of weakened, ground-foraging bats with sling-shots and guns.

Flying foxes in American Samoa were protected by recently passed laws designed to prevent the harvest and exportation of local animals to Guam. The laws were not well publicized, however, and many people remained unaware of the protected status of the territory's flying foxes. Then, Bat Conservation International (BCI) raised money to create a media campaign designed to raise local awareness of the flying foxes' fate (Daschbach 1990). Full-page newspaper ads printed in English and Samoan appeared twice a week and a popular radio station aired several different educational ads up to 30 times a day. Television commercials were also aired and buttons showing a silhouetted flying fox against the moon with the caption "*Fa'asao o le Pe'a*" (save the flying foxes) were distributed.

Next, the American Samoa Community College Land Grant Program assisted the conservation effort by translating a slide program prepared by BCI into the Samoan language. The program was presented to all of the island's mayors who were asked to assist in the protection of the island's flying foxes.

The media campaign and education program successfully increased public awareness and interest in Tutuila's flying foxes. Some people kept injured or starving bats in their homes, nursed them back to health, and liberated them. Many other individuals began leaving fruit out for flying foxes. Most people on the island knew of at least one person caring for an injured bat and were suddenly provided their first opportunity to view the animals at close range. Several of Tutuila's mayors collected all of the known sling-shots in their villages—ending the harassment of bats by adolescent boys (Daschbach 1990).

Another example of educating the public against excessive exploitation of biological resources, again pertaining to the conservation of flying foxes, is an article generated by the research described in Chapter Four. The paper describes consumption of flying foxes as a possible cause of ALS-PDC in Guam. The disease has long been feared in Guam and now that the public is largely aware of the possible health risks, it is anticipated that the Chamorro people will cease eating flying foxes that are occasionally smuggled into Guam from other islands in the Mariana Chain.

Use of Substitute Resources

Encouraging alternative, more environmentally friendly uses of biological resources (and promoting resource switching) can potentially save large rain forest tracts from deforestation. It may also preserve endangered animals such as tigers, bears and other species of medicinal value.

bear gall. The development of Viagra and UDCA provides promise that advances in modern science, with the aid of education, may be able to curtail and possibly arrest what have become unsustainable and ecologically destructive cultural traditions. Current efforts to quell the trade in animal body parts through law enforcement efforts, while occasionally effective, often fail to ensure adequate protection for endangered species.

Encouraging Fashion Changes

Related to management recommendations 3) and 4) above is the promotion of fashion changes that divert demand away from luxury items such as expensive clothing articles and accessories made from the hair, feathers or skin of rare animals. As Marsh (1864) noted, beaver populations in North America recovered only when the popularization of silk for top hats supplanted the former preference for beaver fur. Similarly, the desire for egret feathers diminished as the popularity of hat-wearing declined.

Freese (1997) reasonably asserts that the demand for luxury animal products should be easier to control through consumer awareness programs than the desire for animal resources that provide basic human needs. O'Connel and Sutton (1990), for example, draw attention to the sharp decline in demand for ivory products in the United States when consumers learned of the impacts that the illegal ivory trade had on elephant populations. The fashion industry, however, is sometimes impervious to the plight of severely exploited species. As recently as 1999, popular American fashion magazines including *Vogue*, *Harper's Bazar* and *Elle* touted the virtues of bear gall. The development of Viagra and UDCA provides promise that advances in modern science, with the aid of education, may be able to curtail and possibly arrest what have become unsustainable and ecologically destructive cultural traditions. Current efforts to quell the trade in animal body parts through law enforcement efforts, while occasionally effective, often fail to ensure adequate protection for endangered species.

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Shahtoosh has long been regarded as an almost sacred textile in India. Each illegally sold shawl fetches $2,000 in India and at least $10,000 in the United States and Europe. Shahtoosh scarves and shawls are esteemed for their warmth, exquisite softness and light, almost vapory appearance. The fine hairs of Tibetan antelope are meticulously separated from the coarse outer coat of each harvested animal and transported to professional weavers in Kashmir’s capital city of Srinagar. From Srinagar, shahtoosh products are shipped to fashion outlets worldwide. A new cashmere weave is said to come close to the quality of shahtoosh, and these fine scarves sell for only $100. The new cashmere weave has not become a popular alternative for shahtoosh, however. Wealthy fashion-conscious consumers still desire shahtoosh for the same reason that women prefer authentic diamonds to cubic zirconium stones.

Chiru, whose herds numbered over one million animals in the early 1900s declined to an estimated 70,000 in 1999. Since then, Tibet has invested over $7 million annually to police its remaining chiru herds. Numerous poachers have been apprehended and imprisoned, and chiru numbers on the Tibetan plateau have subsequently increased to 100,000 animals. The increase is fortunate since the

Tibetan antelope is not considered a candidate for captive rearing due its frigid, high elevation habitat and the migratory nature of female chiru to traditional calving grounds.

The commercial trading industries that exploited beaver, egrets and (to a limited extent) chiru are similar in that the products of these animals were worn as outward expressions of opulence and high-fashion. While fashion crazes can lead to the over-exploitation of targeted species, individual desire for a particular item is often unpredictable and subject to manipulation. However, this is not always true for species (or species' products) whose use is part of a long cultural tradition such as the Chamorro consumption of flying foxes. Deeply rooted customs can still be changed through education, but as the above examples suggest, it is easier to alter recently adopted cultural behaviors such as new clothing fashions.

The obvious reluctance of consumers to respond to the plight of the Tibetan antelope can partially be attributed to ignorance regarding the manner in which shatoosh is harvested. Dealers in shatoosh frequently disseminate falsehoods regarding the manner in which chiru hair is collected, claiming that the animals are harmlessly captured and shorn during the summer. The demand for shatoosh items in India, however, was largely due to the fact that its use is a deeply imbedded tradition in Indian culture. Indeed, most shatoosh artisans are Indians themselves. Nevertheless, law enforcement has made significant inroads into the illegal manufacture in shatoosh products in India. Furthermore, as the widespread decline in the wearing of fur articles in North America attests, people are reluctant to wear animal products when it becomes either socially inappropriate or, as is the case of wearing shatoosh in India, legally hazardous.

Mandatory Use of Traditional Harvesting Methods

One way to dampen the impact of hunting on vulnerable, culturally salient species is to limit harvesting methods to traditional technologies. Brief mention was made of this management strategy in Chapters One and Two. There is ample evidence that excessive harvesting is frequently associated with improved hunting technologies. In Guam, for example, the over-harvesting of flying foxes became a chronic problem when firearms replaced traditional hunting methods. The ease with which flying foxes are killed with shotguns led government authorities in Yap to outlaw the use of firearms (see Chapter Two). Other examples of cultural restrictions against overly efficient harvesting methods are common in Oceania. In Tuvalu, for example, Zann (1985) describes taboos against pearl shell lures fitted with steel hooks.

A potential benefit of enforcing the use of indigenous harvesting methods in places like Guam, New Zealand, Hawaii (and other areas where Western influences have profoundly impacted indigenous cultures) is that such laws may be more readily adopted than Western-style restrictions such as bag limits; short hunting/fishing seasons, and, especially, permanent hunting and fishing closures. Indigenous peoples of each of the above islands/island chains are experiencing varying degrees of a cultural renaissance and are eager to become reacquainted with traditional customs. Learning how to successfully harvest game using indigenous technologies would likely instill cultural pride in successful harvesters.

Conclusion

This chapter has provided examples of proven conservation techniques that may be valuable in preserving commercialized species—particularly those that may have been subject to taboos by indigenous societies. While all of the above conservation strategies can protect vulnerable species from extinction, some species, particularly island endemics, pose unique challenges to conservationists. Many islands in Oceania, for example, now have introduced predators and diseases for which native species have few if any defenses. For these species, captive propagation is probably the most promising conservation tool.

An apparently successful conservation technique similar to captive propagation is the manipulation of marine turtle survival. Johannes (1978) notes that islanders on Tobi and Sonsorol place special enclosures around turtle nesting sites to protect hatchlings from seabirds. When hatched, young turtles are fed until large enough to be safe from most predators. Turtles are then released in the open sea. This technique protects turtles from the often terrific rates of loss to seabirds when hatchling turtles move en masse down the beach toward the sea.

Captive propagation, then, can be a useful conservation tool provided that it is carefully monitored. Conservationists, however, must be diligent to make sure that success in captive propagation not be used to justify unsustainable wild harvesting or habitat destruction of vulnerable commercial species.

The use of hunting reserves in southern African countries is an innovative way to protect highly sought after game species. This conservation strategy has already spread to other continents due to the obvious economic benefits available to hunting outfitters. The value of private hunting reserves over state-run wildlife sanctuaries is that the former is likely to generate sufficient profits to ensure strict protection of wildlife resources. While protection is strong, most private reserves are probably not large enough to support MVPs of rare species such as rhinoceroses. Therefore, it is imperative that at least some relocation of animals between private reserves occurs to prevent undesirable levels of inbreeding. In contrast to private hunting reserves, national wildlife sanctuaries are often so large and law-enforcement monies so limited that it is often impossible to completely prevent poaching activity.

The poaching of some species exists because of their medicinal value. For these species, conservationists need to promote less expensive, ecologically benign alternative resources such as modern synthetic drugs. Education efforts to this effect may take time as cultural beliefs regarding the efficacy of traditional treatments are often deeply entrenched.

Education can also be effective in discouraging fashions that exploit rare species. Such education efforts have reduced demand for ivory and, more recently, shatoosh. Education can also be effective in revitalizing indigenous appreciation of wildlife resources. This phenomenon was seen in the case of the media campaign to protect American Samoa's flying foxes.

Finally, in the wake of the injurious effects of modern harvesting technologies on many species, the return to, and enforcement of, traditional harvesting technologies may offer promise for the sustainable use of wildlife resources by indigenous peoples. Promise for the successful implementation of this conservation strategy is especially strong among cultures where the revival in traditional customs is surging. Such self-imposed restrictions on harvesting technologies (method taboos) are well known from numerous areas of Oceania.

Chapter Six

Conclusion

The loss of biodiversity due to species commercialization has been of interest to geographers since George Perkins Marsh (1864) described the phenomenon in *Man and Nature*. Marsh recognized that species of monetary value are easily over-exploited and that demand for plant and animal products abroad has the capacity to alter the physical geography of landscapes at home.

In the 1950s, Carl Sauer (1956), following in the environmental tradition established earlier by Marsh, recognized the rapid loss of biodiversity in the wake of industrialization. Sauer had little faith that the extractive, destructive nature of modernism could prove durable in the long run. He was more interested in societies that live harmoniously with their natural environment. As a result of his interest in sustainable economies, Sauer encouraged other geographers to examine the lifeways of native peoples.

Numerous geographers answered Sauer's call for the investigation of sustainable economies among non-industrialized societies. Many geographical investigations centered on indigenous agricultural systems—particularly in the New Guinea highlands (Brookfield 1962; Clarke 1971). Here, Clarke (1993:239) found "...agriculture to be energy efficient (with regard to labor) and to possess a resilient permanence, unlike industrial agriculture."

Geographers successfully identified cultures that practiced sustainable agricultural techniques. Moreover, their field research generated a large and valuable literature. Compared to indigenous agricultural systems, however, geographers paid little attention to native hunter-gatherer conservation strategies. For millennia, indigenous peoples have harvested (either for their own use or for trade with other groups) certain species that modern cultures (and Westernized native societies) have endangered or extinguished over short time periods. Therefore, knowledge of native harvesting protocols can provide valuable information for modern resource managers. Furthermore, because some indigenous peoples are still intimately acquainted with their environmental resources, including knowledge of harmful plant and animal toxins (e.g., unprocessed cycad seeds), they possess knowledge that may elucidate causes of local and global human diseases. Due to these features of indigenous knowledge, this study examined the following three hypotheses:

1) The over-harvesting of flying foxes in Guam was the result of their cultural salience and not because of their caloric value as a food item.

2) If an indigenous culture, attempting to live in a sustainable manner with its environment, uses a biological resource highly vulnerable to over-exploitation, the use of the resource will either be restricted to elites or tabooed during periods of scarcity.

3) There is a strong positive correlation between the decline of Amyotrophic Lateral Sclerosis-Parkinsonism Dementia Complex in Guam and the collapse of Guam's flying fox populations.

Hypotheses 1 and 2 were tested using the indigenous-based conservation model developed for this thesis and described in Chapter Two (see Figure 1). The survival prognosis for species under monetized trade is represented by either convex or concave rarity-value curves. A convex curve suggests harvest sustainability, while a concave trajectory indicates over-exploitation and eventual extirpation or extinction. To determine the shape of the rarity-value curve for a species possessing trade value, the following equation was used:

$$N/k + V/V_{max} = \text{Rarity-value}$$

To review this equation, N represents the population of a species at a specified point in time; k represents the carrying capacity for the population; V is the cost or value for a harvested individual of the species at any point in time; and V_{max} is the maximum value likely to be attained. As stated in Chapter Two, if the rarity-value equation for a species yields a number larger than 1, that species will have a convex curve. Successful management of these species is fairly straightforward because there is little incentive to harvest these species when they become scarce. Instead, alternative resources are usually pursued (although some incidental take of those species may occur by harvesters collecting more common species). Conversely, if the rarity-value equation yields a number of 1 or smaller, imperilment is likely.

Management of these species often presents difficult challenges since successful harvesters either receive large cash rewards or enjoy the prestige of obtaining a rare or expensive item of value. Management techniques that often help counter unsustainable harvesting practices include captive propagation/commercial cultivation, education, the promotion of substitute resources and other strategies described in Chapter Five.

The determination of convexity or concavity for a harvested species can also be determined using the MVP model described in Chapter Two. This model is particularly useful for evaluating the sustainability of a species when carrying capacity is difficult to determine. For some species, the line representing acquisition cost intersects the line depicting exchange value prior to reducing a population below MVP. In this scenario, harvesting is likely to be sustainable. However, if a species can be efficiently exploited until its population declines below MVP, extirpation or extinction is likely.

In many cases, modern harvesting technologies have caused rarity-value curves to dip from convex to concave in the rarity-value model. Similarly, they have sometimes had the effect of flattening the slope of acquisition cost trajectories represented in the minimum viable population model. Traditional flying fox harvesting in Guam, for example, was apparently sustainable since both native bat species persisted into modern times. The advent of firearms and monetized economies in the early twentieth century, however, destabilized traditional hunting patterns. With modern hunting technology, bats were much easier to harvest. Some who shot bats began selling them to local vendors. As flying fox populations declined, prices escalated. Despite rising prices, Chamorro people persisted in their cultural desire for bat and paid prices far in excess of market prices for other available meat products. Legal international and domestic trade in flying foxes was shutdown by the early 1990s, but occasional poaching and smuggling exists today despite risks of fines and imprisonment (personal observation).

The rarity-value equation for flying foxes in Guam yielded a sum of .33. Because this number is well below 1, the rarity-value trajectory is deeply concave. If flying foxes in Guam were desired mainly for their caloric value rather than their cultural saliency, the rarity-value number would have been a number larger than 1. In other words, some people in Guam were willing to pay handsomely for the chance to eat flying foxes, while indigenous peoples in other Pacific Island cultures generally do not prefer bat over other meat products.

Hypothesis 2 was confirmed by the results of a case study of New Zealand's now extinct endemic bird, the huia (see Chapter Three). Long revered as a sacred species by Maori chiefs and shamans, the huia succumbed to international demand for its mounted effigies and tail feathers. Such an outcome was perhaps predictable considering the strict protective measures Maoris granted the huia in order to avert excessive take. The potency of tribal taboos governing huia harvesting dissolved with the introduction of Western values in New Zealand. Still, Maori chiefs desperately attempted to protect the huia during the height of its decline by reasserting the taboo nature of the species, but such decrees had lost their religious efficacy.

The rarity-value equation for the huia, based strictly on known market prices, produced a figure that gives the huia's rarity-value trajectory a very high probability of being either linear or concave. For visual purposes, conservative estimates were substituted for unknown population and carrying capacity numbers in order to complete the equation for the huia's rarity-value curve. However, several factors suggest that the early twentieth century trade in huia feathers was not sustainable. The limited distribution of the huia, the taboo nature of its feathers, the use of the bird's name by an aristocratic Maori tribe, and the high prices commanded by its feathers during the twentieth century trade were all predictors that the trade could not be sustained. Indeed, while nineteenth century New Zealand naturalists predicted the huia's eventual demise, the high cultural saliency of the bird and the strict rules governing its trade among Maori elites suggested that the Maoris had long known of the huia's vulnerability to unmanaged harvesting.

Hypothesis 3 was examined through describing the high correlation between declining rates of ALS-PDC among Guam's indigenous population and the diminution of the island's flying fox populations. Three factors were important to identifying flying fox consumption as the most likely cause of neurological disease in Guam: First, the high rate of ALS-PDC was restricted to the Chamorro population. Second, an accurate hypothesis would likely include the prospect of cycad poisoning since cycad seeds possess high quantities of neurotoxins. Third, since the incidence of neurological disease in Guam has diminished to rates typical of other human populations (at least for individuals born after 1960), the causative factor must be something that is no longer operational in Guam's Chamorro population.

The hypothesis that regular consumption of flying foxes led to high rates of neurodegenerative disease in Guam (described in Chapter Four) incorporates all three of the above factors. First, flying fox consumption in Guam is a uniquely Chamorro custom. Non-Chamorro inhabitants of Guam did not experience increased rates of ALS-PDC (Torres et al. 1957; Anderson et al. 1979).

Second, the hypothesis that consumption of local flying foxes in Guam led to ALS-PDC rates up to several hundred times the incidence of the disease encountered in other human populations, still implicates a connection to cycad toxins. Of all the previous theories regarding the cause of ALS-PDC in Guam, cycad poisoning seemed the most promising (Sacks 1997). Chamorro preparation of cycad flour, however, successfully detoxifies the seeds used, and no one previously considered an alternative path through which Chamorros might ingest cycad neurotoxins. Biomagnification of cycad poison through the consumption of flying foxes laden with cycad toxins appears to provide the necessary link.

Finally, any explanation for the high incidence of neurological disorders in Guam must account for the rise and subsequent decline of ALS-PDC on the island. When firearms became available to Guam's native populace in the early twentieth century, harvesting rates and consumption of Guam's flying foxes rose dramatically. Consequently, some local people may have unwittingly ingested large doses of cycad neurotoxins. By the 1950s, however, flying foxes were relatively scarce over most of the island. Flying foxes were eventually imported as a delicacy in large numbers from Samoa and Palau, but most islands that supplied flying foxes to Guam supported few if any cycad trees, so the imported bats would have been largely free of neurotoxins. Accordingly, the incidence of ALS-PDC in Guam has subsided, and virtually all new cases of neurodegenerative disease in Guam occur in individuals born before 1960.

The hypothesized linkage between the formerly high rates of Guam flying fox consumption and the high incidence of ALS-PDC among the Chamorro people described in Chapter Four has been further substantiated in research subsequent to this thesis (Banack and Cox 2003; Cox et al. 2003).

Implications for the Future

Geographical research has a rich tradition of combining indigenous knowledge with modern science and technology in order to foster environmentally sound resource management practices (Clarke 1993; Zimmerer 1994). Indeed, both sources of knowledge can be treated as complimentary. While the quantitative aspect of science can make it a powerful tool for resource managers, the qualitative nature of indigenous knowledge is equally valuable because that knowledge has sustained human societies for thousands of years.

The Westernization of indigenous societies and the resultant decline in the observance of resource taboos has often had deleterious consequences. These consequences provide two warnings for the contemporary world: First, because of modern harvesting technologies and the economic demands of expansionist economies, newly commercialized species can be over-exploited very rapidly. Laws can be passed to reduce or arrest exploitation, but laws take considerable time to formulate and enact (as seen in the case histories of the huia and Guam's flying foxes). Additionally, developing countries often lack sufficient resources to enforce conservation laws. Therefore every effort should be made by resource managers to discourage commercialization of species that indigenous peoples have already identified as vulnerable to over-exploitation.

The second warning concluded by this thesis is that increased rates of bush meat consumption (due to increasing availability of firearms and newly acquired disposable incomes for many indigenous societies) may not only threaten biodiversity, but may also have serious implications for human health. As increased rates in the consumption of flying foxes and the incidence of neurological disease in Guam suggest, harmful environmental toxins can be biomagnified in the food chain. Unlike most domestic livestock animals that live primarily on non-toxic grasses, animals harvested for bush meat from tropical forests may potentially harbor toxins derived from extraordinarily diverse vegetation sources. Infrequent consumption of these animals (as occurs when hunting with primitive weapons), is generally safe (excluding species recognized by indigenous hunters as being toxic), but a diet that regularly includes such fare may be dangerous. It is interesting to note that of 34 species of mammals identified by Colding and Folke (1997) as being permanently tabooed by indigenous societies, 12 are predators and seven more are primates. Given that these animals occupy high trophic levels, the potential for biomagnified toxins is high. This does not necessarily imply that the consumption of these animals is dangerous. However, if medical researchers become interested in using an enzyme from a particular organism for human health experiments, they may want to learn what traditional knowledge or taboos exist concerning that particular species.

While this dissertation describes the conservation value of resource taboos for both traditional and modern societies, future research endeavors that investigate political ecology's role in the demise of sustainable tribal resource practices and associated consequences may prove valuable. Alcorn (1994:14) asserts that state destruction of traditional resource institutions is one of the most significant threats to indigenous peoples' conservation success. Johannes (1978), for example, implicates the rise of commercial fisheries among native peoples in Oceania for the widespread abandonment of traditional sailing canoes. As a result of state programs that encourage Pacific Islanders to practice commercial fishing, Johannes argues persuasively that local resource taboos cannot survive. In the push to continually harvest a surplus for outside markets, fisheries are exhausted and local fishermen are left with large debts incurred from borrowing money to purchase efficient fishing boats.

Another example of political ecology's tendency to undermine local people's traditional harvesting patterns was cited in Chapter One regarding the Atlantic cod fishing industry. Interestingly, instead of leaving the fishery to recover on its own (which may never happen), Canada's government not only encouraged but subsidized the harvest of harp seals (*Phoca groenlandica*) in order to reduce predation of cod by seals. Harp seals, however, consume substantial quantities of ilex squid (*Illex illecbrosus*) which in turn consume young cod. Therefore, this control measure may in fact suppress cod recovery (Mackenzie 1996). The lesson here is that ecological systems are complex and that science alone is sometimes an insufficient source of knowledge for resource management. Experience of local resource users can sometimes modify or enhance scientific knowledge.

Finally, it is important to restate that indigenous societies did not always practice sustainable harvesting. As archaeological investigations in Oceania by Kirch (1984) and Steadman (1997) reveal, colonization of the Pacific was characterized by destructive practices that led to considerable loss of biodiversity. Clarke (1993) summarizes this phenomenon:

> ...the Islanders did what all peoples, especially pioneers, do: in their efforts to make a living, they manipulated, modified, and, at times, degraded the ecosystems in which they lived, producing environmental changes that in turn required ecological adaptations and social adjustments.

Social and natural scientists have deciphered the events of the largely successful transition from destructive exploitation to sustainable use of biological resources by indigenous societies. Given the extent of this recently acquired knowledge and its profound implications for the future, contemporary society should strive to avoid the costly and potentially disastrous consequences of repeating the indigenous experience.

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