ORIG

Mon, Dec 17, 1990

Dear Henry,

Here is our proposal for the Guana Island Conservation Project. We apologize for its length but felt it necessary to include some referenced background information to explain some of the rationale for this project. Also included are both of our C.V.'s. We would like to conduct the proposed work in six months, from February 1 to the end of July. The goals of the project are to further the preservation of Guana's natural state, to conduct ecological research relevant to conservation of Guana's habitats, and to create an educational facility that will increase awareness and interest in Guana's ecology and the research conducted there. It is our hope that this comprehensive program integrating conservation, research, and education, will inspire a future approach to research on the island focusing on ecosystem ecology rather than (like the existing system) particular organisms.

You have financed biological research on Guana Island for almost ten years. This support has provided rare opportunities for the scientists involved in long-term studies on Guana. Because ecological processes occur over a large time scale, the most useful ecological studies are those in which measurements and observations can be made over a number of years. There are very few situations in which a researcher is able to set up a long-term study with the ease and accomodation that Guana Island has offered. Much more is now known about the Guana Island biota than any other island in the BVI. Furthermore, some of the scientist who have returned yearly are beginning to accumulate a wealth of data that will (hopefully) soon be analyzed and contribute to science. Margaret, for example, has been collecting termites on Guana for many years. She has taken these animals back to the Smithsonian and genetically compared them to termite populations on other islands. She feels that she is very near proving that the termite populations are different from any other termite population, that is, they are genetically unique. George Proctor has contributed greatly to Guana. He has made a very useful list of plants species, in which he notes rare or endangered species and their locations on Guana. There is no need to emphasize Liao's contribution to Guana, but I will point out that many of the trails he cut specifically lead to rare or impressive trees. His current proposal will greatly enhance the island's ecological integrity for both plants and animals. The scientific studies you have supported on Guana have made and/or will make contributions beyond these few examples. In addition, the activity of scientists on Guana has educated and inspired more than a few members of the younger generation, including the field assistants brought there by Skip (some of whom are now in graduate school-e.g., Caitlin) and members of the family. There is great potential for the science program you initiated and continue to support to be applied to educating the BVI community, particularly in association with the incipient educational programs on Tortola. In short, the Guana science program has been productive scientifically and educationally, and it holds much potential to be even more productive in the future. While we believe the scientific benefits of the work you have supported are obvious, the direct returns to the island have been less conspicuous. We wish to, in part, remedy this situation. The projects we propose to do are intended to better Guana Island ecologically (through sheep eradication, monitoring of understory regrowth and coral reef recovery, and studies of rare plant propagation) and to add to the science program in general research documentation (marine censuses) and education (natural history display and library).

Sincerely,

Lianna

Fred

GUANA ISLAND CONSERVATION PROJECT

by
Lianna Jarecki
and
Fred Kraus

December 17, 1990

It is no longer news that the world's natural environments and resources are increasingly beleaguered and its life-support systems increasingly compromised. For thirty years documentation of such threats has grown exponentially, with an attendant increase in the numbers and kinds of environmental problems identified. While most attention has focused on those hazards that directly affect human populations (e.g., hazardous wastes, radiation, industrial pollution), the last decade has seen increasing recognition of the fact that the planet's very life-support systems are under severe stress. The latter problems tend to be global in scope and include severely modified climatic patterns, desertification, ozone depletion, systemic pollution of air and water resources, and loss of biodiversity. The last named evokes the least concern from the average human, is the least understood and poorest studied of the currently recognized global environmental problems, yet is potentially the most disastrous problem facing humankind, with the severest ramifications, both short- and long-term. Instances of ecosystem and community crashes are increasingly common and are affecting a wide diversity of organisms. The sum effect of these crashes and impending crashes is an anticipated reduction in biodiversity unequalled since the mega-extinction events that characterized the ends of the Cretaceous and Permian periods, 63 and 230 million years ago, respectively (Myers, 1983, 1986; Oldfield, 1984).

Aside from the aesthetic and moral dimensions of the problem, the loss of biodiversity has considerable direct repercussions for humans in a number of ways (Myers, 1983; Oldfield, 1984). First is loss of genetic diversity among wild relatives of crop plants and among potential crop plants not yet in widespread agricultural use. Modern monocultural agriculture succeeds only to the extent that the genetic diversity of the crops can stay one step ahead of their rapidly evolving pathogens and pests. Maintenance of crop genetic diversity is heavily dependent upon introduction of variant genetic material from an assortment of wild relatives of crop plants (National Research Council, 1978; Prescott-Allen and Prescott-Allen, 1982; Oldfield, 1984; Iltes, 1988). New crops could be derived from the same source (Plotkin, 1988). Loss of such genetic diversity will severely compromise the stability of future agriculture. Second is loss of plants and animals bearing useful medicinal compounds. Many major classes of medicine derive initially from plant secondary compounds, even if derivative compounds have proven amenable to subsequent synthesis. A large proportion of current medicines are extracted directly from wild plants (Farnsworth and Morris, 1976; see especially examples in Farnsworth, 1988), most of them found in tropical rainforests (Oldfield, 1984; Caufield, 1985; Hecht and Cockburn, 1989). The impossibility of predicting which plants will contain useful substances means that loss of significant amounts of plant biodiversity will inevitably result in the loss of innumerable useful species. As well, useful medicinal substances have been derived from animals (Oldfield, 1984;

Farnsworth, 1988), and animals routinely serve as model organisms in research to derive treatments and cures for a variety of illnesses. Not all of these involve lab rats (e.g., armadillos are the only other animal species known to contract leprosy; numerous rare primate species are the only effective models for studying a variety of human ailments). Third, is loss of plants having industrial uses. Primary among these products are fibers used in making such items as clothing, rope, fish nets, and baskets; oils used for lubricants, cooking, and plasticizers; and natural, biodegradable pesticides (Plotkin, 1988). Fourth, loss of biodiversity will result in the gross simplification of many of the planet's ecosystems, making them increasingly subject to catastrophic perturbation, with attendant ramifications on the humans dependent on those ecosystems for food production, oxygen production, and water purification. While such services are currently viewed as free goods in the prevailing economic paradigm, this does not lessen their actual value to society, as a brief consideration of the tremendous costs of human attempts to duplicate these services indicates (Prescott-Allen and Prescott-Allen, 1982; Oldfield, 1984). Given human dependancy on these natural ecosystems for food, air, water, and medicines, the notion that humans will survive a significant biodiversity crash unscathed is ludicrous; whether they can survive it at all is unknown. Hence, it is increasingly clear to biologists, if not to the public at large, that the survival and/or well being of that species they hold most dear is imminently threatened in a manner intimately connected to the ongoing exponential extinction rate among the remaining diversity of the world's species.

Part of the lack of concern for biodiversity depletion stems from the characteristic short-sighted anthropocentrism of the human species especially under the currently prevailing economic paradigm, but also important is that biological systems, from molecular to ecological, tend to be characterized by non-linear dynamics. This particular form of dynamic is frequently the outcome of the multiplicity of interactions, especially from higher hierarchical levels, that typify biological systems (Salthe, 1985) and makes it very difficult to predict the future effects of perturbation or manipulation upon biological systems extrapolating only from the prior behavior of those systems. The most obvious manifestation of this phenomenon is that biological systems will behave predictably (approximately linearly) until a particular threshold has been passed, after which point behavior becomes chaotic or unpredictable. This behavior pattern characterizes such diverse phenomena as heart attacks, algal blooms, and population crashes. Such behavior is especially characteristic of ecological systems (Jones and Walters, 1976; May, 1977) because the vast number of interactions involved and the high degree of connectedness of the constituent members makes phenomena having linear dynamics relatively rare (Allen and Starr, 1982). This makes the effects of major humanmediated ecosystem disturbance difficult to control and frequently catastrophic. This is well-illustrated by, for example, the innumerable of instances in which fish stocks "managed" under the (linear) paradigm of "maximum sustainable yield" have crashed and disappeared (Gulland, 1983), as well as by the increasing frequency of population crashes and extinctions of previously widespread and abundant species.

This characteristic non-linear behavior of ecological systems means that population declines and extinctions will usually not be evident to the untrained observer (and often to the "experts" as well, c.f. fish stocks above) until such phenomena have become irreversible (Pimm, 1986). Only then will evidence of a population crash be obvious -- at a time when little can be done to alter the outcome. The consequence for natural ecosystems will be that catastrophe will come rapidly and unexpectedly and that potential mitigation at this point will become prohibitively expensive and increasingly unlikely to restore the *status quo ante* (see, e.g., discussion by Kushlan, 1990). Thus, for example, the average observer seeing green trees in a forest will conclude the forest is healthy, not stopping to consider whether there is evidence that the species comprising that forest are reproducing themselves: whether the pollinators of the flowers still exist, whether those animals responsible for dispersing seeds still exist, whether the conditions needed for seed germination obtain, whether the mycorhizae required for successful growth are present in the soil, whether a diversity of age classes occurs for each species, whether the mature trees show signs of pathogenic or physiological stress that reduces their survivability and fecundity, or whether those adult trees present are all post-reproductive and senescent (Janzen, 1988). Similar questions pertain to all species inhabiting an ecosystem and contributing to the ecological interactions that guarantee its continued existence.

The component extinctions contributing to the total mega-extinction event derive from a variety of causes. Notable among them have been over-hunting and over-harvesting, inadvertent introduction of pathogens and predators, and poisoning with biocides (see, e.g., Oldfield, 1984). However, far and away the most important factor has been outright elimination of the habitat required by particular species for their existence (e.g., see the IUCN Red Data Books or any issue of the USFWS's Endangered Species Technical Bulletin). This is the cause of the high extinction rates in tropical rain forests, but operates with equal facility elsewhere as well. Thus, the United States, while lacking the immense diversity found in the tropical regions, still has the decline of the vast majority of its endangered and threatened species due to the direct destruction of the habitats upon which those species depend (ibid.). The problem is worldwide in scope, although the consequences will be most severe in the tropics, given the immense biodiversity of those regions (Myers, 1983; 1986). Precisely because the primary reason for loss of biodiversity is habitat destruction, the disappearance of species proceeds with little notice by the average person. Few obvious warning signs attend this destruction until the critical population-level thresholds have been passed and entire species begin to disappear precipitously. The high degree of endemism among the world's wildlife (e.g., see Gentry, 1986; Erwin, 1988) is not apparent to the general public, and thus the disappearance of the majority of a particular type of habitat may occasion little alarm, as long as some is thought to exist in a "protected" location. Of course, such a parcel may be of insufficient size to guarantee the continued existence of all but a small fraction of the species characteristic of that particular type of habitat (Terborgh and Winter, 1980; Wilcox, 1980; Wilcove et al., 1986). This is a very common problem in the United States and its importance elsewhere expands with the shrinkage of natural habitats. Thus we are faced with another instance of a threshold phenomenon: habitat continues to disappear gradually until a point is reached where many of the species dependent on that habitat can no longer survive, and they start to disappear (Franklin, 1980; Soule, 1980; Gilpin and Soule, 1986; Wilcove et al., 1986). Because of the high level of interconnectedness among those species, the extinction of one tends to pull others along with it (especially in tropical habitats), and this continues in an expanding circle of extinctions (Gilbert, 1980). Ecosystem stability may again be reached, but at a new point with a highly impoverished fauna. The initially gradual nature of this decline (until the threshold is attained) frequently induces complacency and leads to surprise when the unanticipated population and ecosystem crashes occur. Thusly does global biodiversity diminish, its passing noted by few.

Historically, tropical islands have been among the most degraded natural areas in the world, suffering inordinately high extinction rates of their native species (e.g. see Greenway, 1958). Their special sensitivity has resulted from the isolation of their floras and faunas -- the very factor that resulted in those distinctive floras and faunas in the first place. Frequently evolving in the absence of predators and pathogens, island biotas are especially sensitive to the introduction of such species with the advent of human activity. Mongooses, rats, and cats have eliminated endemic birds and reptiles from scores of islands worldwide, a recent inadvertant snake introduction has caused the extinction of a half dozen or so endemic forest birds in Guam, and the introduction of avian malaria has decimated an entire family of dozens of bird species endemic to the Hawaiian islands. Such examples could be multiplied *ad nauseum* . Similar problems apply to plants (Carlquist, 1965) and are not restricted to strictly island situations (Johnson and Barbour, 1990). One of the important and unique attributes of Guana Island is that the impact of introduced species has been of considerably less extent than on numerous other tropical islands, especially within the Caribbean region. This largely owes to the fact that mongooses have never been established on the island, but is also a reflection of its lack of feral goats and dogs. Only a relatively few species of introduced plants have escaped cultivation on Guana, though one of these (Australian Pine, *Casuarina equisetifolia*) is a serious threat to native lowland plant communities. As a consequence, Guana Island is in the unique position of retaining a relatively undisturbed, and therefore very diverse, sample of the native flora and fauna of its particular biogeographic province. This is reflected in the fact that Guana serves as a final refuge for populations of several plants and animals that are extremely rare or extinct elsewhere. The relatively undisturbed nature of Guana's ecosystems makes it an extremely important asset in preserving and enhancing the biodiversity of this particular region of the Caribbean. The combination of having this relatively undisturbed ecosystem along with the considerable scientific research on the island's biota that has already been supported, provides Guana with the unique position of serving as a model for natural resource and species conservation in the Caribbean.

The comprehensive conservation program that we wish to conduct will enhance this model role by allowing the re-establishment of a more lush and moist forest with richer soil, a healthier and more productive coral reef, and a higher overall species diversity. Though Guana serves as a unique reserve for many species, its forest is in a state of decline. Little recruitment of new generations of the assorted tree and shrub species that comprise the forests on the island is evident. Most seedlings available for such recruitment are apparently consumed as forage by the introduced sheep that roam the island. The herbaceous plants that would normally form the ground cover in the forests and keep the soil intact are also largely absent for the same reason. Should this pattern continue for much longer, the trees that currently produce seeds and comprise the majority of the forest will begin to senesce, and eventually the forest will die, as the lack of recruitment of new trees begins to make itself felt. Lack of successful reproduction by island forests for periods of 15-25 years due to sheep grazing of tree seedlings has been documented in California (Hobbs, 1980). A similar phenomenon appears to be occurring now on Guana. Its extent is suggested by the rarity of several of the forest trees, and is clearly apparent by the lack of undergrowth in the forests -- a situation that is unnatural in forests of almost any climate. Not only does this lack of undergrowth indicate an absence of recruitment of new generations of plants, it also increases the erosion of the island's topsoil -- a resource that is clearly of limited extent in the first place. This erosion can lead to a non-linear dynamic, with lack of topsoil making it increasingly difficult for seeds to find the proper conditions in which to germinate, and the resulting thinning of the forest leading to yet more exposure of the soil to the elements, resulting in yet more erosion and creating an accelerating feedback system of increasing habitat degredation until such point as only desert-adapted species can survive in the bare ground that remains. Such erosional changes can also result in changed climatic conditions leading to less rainfall (Howell and Towle, 1976). This will reinforce the desertification of the landscape. Again, it should be clear that while the early warning signs of such a problem are apparent in a few minutes to those willing to observe the relevant indicators, the drastic symptoms of forest decline will not be apparent to some people until the current generation of forest trees begins to disappear -- a process that may take many years yet. It should also be clear that once this process has reached such a drastic state it will be irreversible to all extents and purposes. The importance of an active program of reforestation in reducing runoff throughout the BVI has already been noted (Howell and Towle, 1976).

Fortunately, the cause of the forest's decline is quite apparent, and lies, as we have said, with the presence of the introduced sheep on the island. Ungulates, such as sheep, introduced onto islands whose biotas have evolved in their absence, tend to degrade the islands' environment in two ways. First, they consume to virtual extinction many of the island's unique plants. Plants in continental areas, exposed to grazing pressures for long evolutionary periods, tend to evolve natural chemical or structural defenses (such as tannins, alkaloids, or thorns) that limit their consumption by grazers. Plants endemic to islands and lacking exposure to grazing pressure usually lack such defenses (Thorne, 1969; Vitousek, 1988). Thus, island endemics usually prove to be the most succulent forage for introduced grazers and, correspondingly, suffer the severest population declines from grazing (Van Vuren and Coblentz, 1987). Such overgrazing may continue to the point of extinction of the island endemics (e.g., Carlquist, 1965). Second, ungulates trample those plants they do not eat and greatly hasten the process of erosion by the action of their hooves on the resulting exposed ground. It is estimated that up to one half of all damage inflicted by sheep to islands is the direct result of trampling of non-targeted plant species (Van Vuren and Coblentz, 1987). Taken together, the effect of introduced ungulates on islands is uniformly one of severe environmental degradation (Vitousek, 1988). Removal of ungulates can lead to rapid recovery of native vegetation (e.g. see Van Vuren and Coblentz, 1987).

Accelerated erosion due to lack of understory vegetation and constant trampling not only results in loss of fertile topsoil, but can have drastic effects on the near-shore marine environment. Erosion on land leads to sedimentation in the water, which under natural circumstances is quite low on oceanic islands. Tropical marine organisms are adapted to the characteristic high water clarity, low nutrient levels, and low dissolved oxygen concentrations of tropical seas (Johannes and Betzer, 1975). Corals, because of their dependence on sunlight for growth and their susceptibility to fouling by suspended particles, are especially sensitive to changes in normal water characteristics. High suspended sediment levels in the water affect corals in a number of ways: they scatter sunlight, upon which coral growth depends; they directly foul coral polyps; they scavenge the already limited dissolved oxygen from the water; and they create an unstable soft bottom unsuitable for coral larval settlement (which can prevent recovery of a perished reef) (Johannes, 1975). Coral reefs, which are often thousands of years old, can be completely destroyed by even a short-term increase in sedimentation, such as that caused by nearby dredging (Kimmerer, 1989). Coral reefs are the most extensive, productive and diverse ecosystems found in shallow tropical waters, and the lives of all reef-associated organisms depend upon the growth of the corals that create the reef (Johannes 1975). Once the corals die, the diversity, productivity, and beauty of this ecosystem are soon lost.

The accelerated erosion caused by sheep has had drastic effects on Guana's reefs. Areas of White Bay and Muskmelon Bay reefs that are near the shore are for the most part completely dead. Only farther out (ca. 500-1000 feet beyond the shore) does one see large living corals with the associated diversity and astonishing beauty of marine life. In both bays, reefs extend nearly to the shoreline, but a majority of the near-shore reef exists only as dead coral heads covered with sand and silt. The only common reef building invertebrate found near-shore in either bay is fire coral, and this is especially common (and dangerous) in Muskmelon Bay. The success of fire coral (actually a painfully stinging hydrozoan, not a coral) can be attributed to its growth form. It has a fluted growth habit that leaves it with very little horizontal surface area exposed to settling sediment particles. Most corals, especially the large brain corals, have a more expanded, horizontal growth habit, resulting in a much greater horizontal surface area exposed to fouling sediment particles. At about1000 feet or more from shore in both White Bay and Muskmelon Bay, one sees a dramatic increase in abundance of large brain corals and elkhorn corals , with a concurrent dramatic increase in overall abundance and diversity of marine life. In addition, fire coral is rare or nonexistent in most reef areas far from shore.

Elimination of sheep on Guana will allow understory regrowth and succesful reproduction of forest trees and will greatly decrease the presently high sediment influx into Guana's bays. This will prevent further death of corals in these bays, but recovery of already dead reefs will probably not occur quickly. One study in Castle Bay, Bermuda, showed that 35 years after nearby dredging, the reefs had not fully recovered from the increased sediment load produced by the dredging operation (Dodge and Vaisnys, 1977) Recovery of Guana's near-shore reefs will depend upon the ability of coral larvae to settle on the dead reef areas. Judging from the amount of sand and silt overlying the dead reef, natural recovery will most likely take many years. It may be possible, however, to enhance recovery by transplanting live corals from healthy reefs to near-shore areas, or by providing substrate suitable for coral larval settlement. Such possibilities can be investigated through experimentation and observations of existing reef dynamics.

1) The first part of our conservation proposal for Guana Island involves eradication of the introduced sheep by means of an intensive hunting project. This strategy has been shown to be successful and cost-effective for islands up to 100 times the size of Guana (Van Vuren and Coblentz, 1987; Coblentz et al., 1990). Hunting will employ two strategies. To begin with, we will intensively cover the island, shooting sheep as they are encountered. This may be expected to remove a significant number of the sheep (Coblentz et al., 1990). Once sheep begin to be encountered with less frequency, we will release several radio-collared "Judas sheep" (Taylor and Katahira, 1988). Sheep are naturally gregarious animals, and newly released females will search out and join resident groups of sheep on the island. Because these released females will be radio-collared, we can track them to their places of hiding and shoot the resident sheep they have joined with. Once the resident band has been dispatched, the radio-collared female will be free to find another resident group, and the process repeated. By the release of up to six such radio-collared sheep, we should be able to exterminate the resident population of sheep within the period of 3-6 months (Coblentz, pers. comm.). Females are used instead of males, because males will often live singly; females will more reliably join resident groups. Non-resident females must be used for release (instead of capturing and releasing resident females) because resident animals will have established home ranges and will return to only those areas. Thus, their effectiveness in tracking down new groups is limited. We intend to buy up to six female sheep from Tortola, radio-collar them on Guana, and release them separately on different parts of Guana. The most logical course would be to release one on Anegada Hill, two on the northwest part of the island, and three on the southern part of the island. By tracking one (or two) of the released sheep each day, removing the resident sheep associated with that sheep in one or two days, next focusing on another sheep, and proceeding in sequence, one may exterminate the resident groups joined by the six radio-collared sheep in turn. By the time the first sheep is the focus of attention for the second time, she will have had approximately a week in which to find and join another group of resident sheep, and the process may be repeated. By following this circuit in an iterative manner, we expect to be able to exterminate all the resident sheep on Guana in the alloted time of this project. We estimate the costs of sheep eradication on Guana to be approximately $4400. This is broken down as follows: Two Remington .223 centerfire rifles with 4x scopes, $2000; 1000 rounds of ammunition, $200; 6 radio-collars, $1100; 16-channel receiver, $650; head set, $150; antenna, $100; six sheep from Tortola, $200. We should note that the purchase of .223 rifle is necessary, because the small-caliber rifles currently on Guana

lack sufficient power to reliably kill sheep. Such rifles (.22) are usually used in killing rodents and rabbits.

Additionally, Dr. Bruce Coblentz has offered to assist us in our efforts from March 19 to April 6. Dr. Coblentz is a recognized expert in sheep eradication [among other projects having successfully removed 36,551 sheep from Santa Cruz Is., California -- an island 100 times the size of Guana (Van Vuren and Coblentz, 1989)]. We strongly recommend accepting his offer of assistance, which we believe is likely to greatly enhance the success of the sheep-removal project, a project we have noted is absolutely critical to the successful recovery of the ecological health of Guana. The costs of bringing Dr. Coblentz to Guana would be his airfare from Corvallis, Oregon, and room and board for two and one-half weeks.

After successful sheep eradication on Guana, we would like to initiate a long-term study of the recovery of Guana's most affected ecosystems: the forest and the coral reef. By measuring ground cover, number of stems, and age of stems in random quadrats, we can quantitatively monitor the regeneration of the forest. We would measure percent cover, species composition, and diversity of corals in random quadrats over the dead reef. This would indicate the rate of natural reef recovery and species recruitment onto Guana's near-shore reefs. Included in this study would be attempts to enhance, e.g. by transplantation, regrowth of both the forest understory and the coral reefs. We would have to take measurements annually for a number of years to fully document successional recovery in both ecosystems, although it is expected that full recovery of the reef will take longer than the forest. Annual measurements and observations can be performed during science month or whatever time of year is convenient, though it would be best to make separate measures during the dry and wet seasons for each year. This would only involve a few days effort each time. Much of the equipment we will need for collecting, identifying , and measuring species for the other projects listed will be necessary for this one.

2) The second exotic we strongly recommend removing is the introduced Australian pine, *Casuarina* , living on White Beach. Currently, there appear to be three of these trees on White Beach. We recommend the removal of them all, the search for any seedlings that may have rooted nearby, and continued annual surveys to locate and remove any further seedlings that may have established themselves. The role of this species in the ecological degradation of beach and lowland habitats throughout the New World tropics cannot be overstated. It has aggressively established itself as a monoculture throughout this region, displacing native vegetation and drastically altering the character of the beaches in some instances (Johnson and Barbour, 1990). Below is a photograph of Loggerhead Key, Dry Tortugas, which is one example of the many tropical islands on which *Casuarina* has entirely taken

over lowland and beach areas. This photograph shows the *Casuarina* monoculture which extends completely around (and, in some places, across) this island. Similar effects may be ovbserved throughout much of the former "everglades" of southern Florida and along the air strips at San Juan Airport in Puerto Rico.

These plants are monoecious (male and female flowers borne on the same tree); thus, a single individual can establish a thriving population in short order. Their population growth is characteristically explosive (and, hence, initially unpredictable), and seems to be especially high after the passing of hurricanes (Klukas, 1969; Johnson and Barbour, 1990). Given these characteristics of the species, and the fact that it has not yet experienced a population explosion on Guana, we recommend that the few trees currently on the island be removed now while such a task can be successfully accomplished with relative ease. Should this species persist on Guana for very much longer (a few years perhaps), it will be likely to spread and form dense, monocultural stands throughout White Beach and the adjacent lowland area of the Flat. Once populations have reached such a size, they will be very difficult to control or eradicate. Eradication of the current population of *Casuarina* may be effected by cutting down the three known trees and applying herbicides on the stumps. The herbicides are needed to kill the root system and prevent resprouting from the trunk stump. Otherwise, cut trees tend to resprout and remain a continuing problem. As well, we will survey the surrounding area for currently overlooked seedlings, to ensure that a new generation of the plants does not gain a hidden foothold.

3) It should be clear that the success of Dr. Liao's excellent proposal to

assist in the reforestation of several tree species of critical importance to bird populations on Guana is dependent on our success in eradicating the introduced sheep from the island. While we are in the process of eradicating the sheep from Guana, we also intend to begin efforts aimed at propagating from seed a few of the rare tree species that Dr. Liao will work with in greater detail during the tenure of his proposal. This research will provide Dr. Liao's proposal with a head start, for we expect to work out the conditions required for successful germination of the species *Sida eggersi*, *Eugenia underwoodi*, *Myrcianthes fragrans*, *Sabal causiarum*, and *Coccothrinax barbadensis*. *Sida* is one of the rarest trees on Earth, with only one specimen on Jost Van Dyke and 23 on Guana. *Eugenia* is perhaps as rare as *Sida* (Guana may have the only population in existence). *Sabal* and *Coccothrinax* (the two native palms) are also increasingly rare, and all of these trees, with the exception of *Sida*, provide excellent food for pigeons, doves, and other forest birds, which in turn scatter the seeds around the forest and thereby aid in the forest's regeneration. We will begin these efforts at once upon arriving at Guana. We will collect seeds, germinate them in potting soil, raise the individual plants to a stage at which they may be successfully transferred back to the forest and around the club, and then transfer them upon successful completion of the sheep eradication program. It will also be important to test soil quality in Guana's forests. Measuring humidity, pH, and nutrient concentrations in the soil will indicate treatments that may be necessary for succesful transplantation. Such measurements will also provide basic ecological information which can be used to predict the limitations of the soil for forest regeneration. Soil analysis equipment will cost $500.

During the few months that are required to eradicate the sheep, we will be cultivating seedlings of several of the rarest, showiest, and most ecologically important of the native forest tree species, so that upon eradication of the sheep, the forest may have a head start in its regeneration. As well, this will assist the recovery of some of the rarest plant species in the Caribbean and, thereby, reduce the chances of their extinction. Some of the seedlings we grow will be permenantly transplanted to areas near the club. They will grow to be very attractive trees and will enhance the appearance of the club as well as provide easy viewing of Guana's most rare native plants. If time and money allow, we would also like to identify and label some of the native plants already growing near the Club to develop a botanical nature walk with descriptions of native flora that can be viewed along the way. For the plant germination and transplantation project we will require only a few hundred dollars for a couple of large bags of potting soil, some growth hormone, a couple hundred pots, several large seedling trays, and a shovel or two. All of these supplies may be readily purchased in a gardening store in the U.S. and shipped to Guana (if not available on Tortola).

Total cost is $500.

4) The establishment of a marine program on Guana will be necessary for many aspects of our work as well as for the on-going flamingo reintroduction project. With some basic facilities and equipment (including the microscope listed under the museum budget) we can conduct sophisticated ecological research as well as collect and identify organisms for the museum display.

Although many different scientists have been invited to work on Guana, very little has gone into the study of Guana's most diverse and productive ecosystem, the coral reefs. The goal of the marine program is to establish a basis for marine research on Guana. It would require the construction of a continuous-flow sea water table, in which marine animals could be kept alive while under study. Once this facility has been constructed and basic research equipment has been purchased, the following three studies will be conducted:

1) Comparative salt pond ecology (what conditions are necessary to support flamingos?).
2) Effects of increased sedimentation (due to accelerated erosion by sheep) on near-shore coral reefs, and the regrowth of coral after sheep eradication (how productive are Guana reefs?).
3) Marine invertebrate species census (how diverse are Guana's marine ecosystems?).

Marine program budget:

Sea Table: $2000

We would need to hire someone to help build the sea table, especially to lay the foundation. It could be constructed from wood, fiberglass, and pvc pipe, with a concrete foundation, and would be about 12 feet long, 4 feet wide, 4 feet high. It would need a roof for protection from direct sun and rain, but the sides would remain open. Various fittings, such as valves and nalgene tubing, would also be needed. The most appropriate place to put a sea table would be near the generator house and RO system. There is already seawater flowing into the "lobster tank", and use of this source of sea water would minimize construction and pumping costs.

Collecting and experimental equipment $500

e.g. Plankton nets, sediment settling tubes, chemicals, jars, buckets, under-water measuring devices, quadrats, etc.

Water chemistry and sediment analysis equipment:

weighing balance $150

water chemistry kits $2000

(to measure concentrations of dissolved oxygen, nitrogen, phosphate, pH, temperature, and salinity.

Scuba Diving:

Air fills and possibly extra tanks $1000

Note: this includes dives to collect and photograph marine fauna for the museum.

Boat use and transportation:

We would need the use of a boat for both diving and surface collecting (a whaler, as mentioned in the museum budget, would be perfect).

We would also need transportation to Road Town for air fills and for other business.

5) To facilitate the diverse aspects of our proposed work on Guana, we wish to establish a natural history library to be used by us, other scientists, and interested guests. This library would be set up in conjunction with the natural history museum (see below) and would include field guides, descriptions, and taxonomic keys for identifying the local biota. These materials would be in the form of reference books, descriptive books, and primary literature. We hope to acquire material relevant to the identification and natural history of all the major groups of plants, animals, and marine life represented on Guana. This library will serve as a reference for anyone wishing to identify organisms or to learn more about a particular organism. Without a good reference library, we feel we will be unable to adequately pursue the other projects we propose.

The following is a list of some books we are currently aware of that would be included in this library. Others certainly exist and could be added should we find them to be of use. We are continuing to seek the advice of experts on these various topics to recommend books appropriate for the library. In addition, we will accumulate reprints and xeroxes of any important primary literature relevant to the natural history of Guana Island.

Plants:

Common Trees of Puerto Rico and the Virgin Islands. volume 1, 1964. by Little, Woodbury and Wadsworth. U.S. Department of Agriculture, Forest Service

Trees of Puerto Rico and the Virgin Islands. volume 2, 1974 by Little, Woodbury and Wadsworth, U.S. Department of Agriculture, Forest Service [if these two are still in print they will be very inexpensive--$10-15--otherwise we could photocopy and bind them, which would probably cost around $100 for both (700 pages)]

Ferns or Puerto Rico and the Virgin Islands. 1989, by Proctor, GP. New York Botanical Garden Memoir 53: 389pp.

Vascular Plant Families. 1977 by John Payne Smith. Mad River Press Inc. ($20)

Flora of the Lesser Antillean Islands. 1989-90. 7 volumes (about $80 each)

Botany of Porto Rico and the Virgin Islands: scientific survey of of Puerto Rico and the Virgin Islands. 1923-30, by Britton, Wilson, and Percy. New York Academy of Science 5-6 (this is out of print but we may be able to have it photocopied and bound. Despite it's age it is still a very useful book since it covers many species lacking in other books on the Caribbean flora.)

Genera Palmarum. by Uhl and Dransfield

Also, Dr. Walter Judd at the University of Florida Botany Department suggested photocopying herbarium specimens of plants found on Guana (i.e. make our own field guide). He showed us some examples that he had done and they were very clear and showed much detail. However it will be difficult to get permision to handle the herbarium specimens here since neither Fred nor I have formal botanical training. Perhaps we can get George Proctor in Puerto Rico to do it for us.

Insects:
We will consult Scott Miller for advice on the best guides to BVI insects, arachnids, and myriapods

Herpetofauna:
Reptiles of the West Indies by Schwartz and Thomas (two books: $60)
We will probably have to consult the primary literature for good descriptions of Virgin Island amphibians (and also for bats)

Birds:
Birds of Puerto Rico and the VI: already in the Guana library (donated by Skip)

Marine:
Marine Fauna and Flora of Bermuda. edited by Wolfgang Sterrer. John Wiley and Sons
Seashore Life of Florida and the Caribbean
The shallow-water octocorallia of the West Indies Region. by Bayer.
American Seashells 1974. by Abott
Caribbean Seashells 1958. by Warmke and Abbott
Ascidians of the West Indian region and the southeastern United States. by Van Name.1921. Bull. Am. Mus. Nat. His. 44:283-494.

The Invertebrates: smaller coelomate groups. Volume V. Hymen, LH 1959. McGraw-Hill Book Co. Inc. N.Y. 783 p.
Starfishes from the Carribean and the Gulf of Mexico. by Downy, ME. 1973. Smithson. Contrib. Zool. 126, 158p.
A discussion of the sponge fauna of the Dry Tortugas in particular and the West Indies in general, with material for a revision of the families and orders of the Porifera. 1936. by de Laubenfels, MW. Carnegie Inst. Wash. Publ.467. 225 p.
A manual for the study of meiofauna. by Hullings and Gray, 1971. Smithson. Contrib. Zool. 78, 84 p.
Atlantic Reef Corals. 2nd edition. by Smith, FGW 1971. University of Miami Press. Coral Gables, Florida. 164 p., 48 plates.
Patch reef coral communities of southern British Honduras and Illustrated Catalogue of Common British Honduras Corals. by York, M. 1971. In A Guidebook for the Field Trip to the Southern Shelf of British Honduras.

Other:
Biogeography of the West Indies. 1990 by Charles Wood. ($98)

6) An integral part of conservation and science in general is education of the public. We wish to put together a small natural history museum to inform visitors of Guana's incredible biotic diversity as well as relevant ecological and behavioral interactions among the organisms they may encounter. We hope that this educational exhibit will give people a better understanding of Guana's species and their ecology, will inspire fascination with the intricate relationships between organisms, and will provoke admiration of the beauty and diversity of life that Guana's ecosystems support. This display would inform visitors of ongoing conservation and scientific projects on Guana and the importance of preserving Guana's natural state. It would show that Guana is currently among the last remaining Caribbean islands existing in a relatively natural state. For this reason it is among the most diverse Caribbean islands for its size, harboring a large number of rare species. In fact, several species endemic to the Greater Puerto Rican Bank may only be preserved on Guana Island. These unique attributes of Guana would be stressed to the public in the museum. Representative plants and animals from Guana's various ecosystems (including: forest, salt pond, and coral reef) would be identified and described both ecologically and behaviorally (where appropriate), with the intention of conveying the importance and nature of species interdependence. The museum would cover both the terrestrial and marine (including salt pond) ecosystems of Guana. It would emphasize the ecology, natural feedback systems, environmental complexity, and diversity of Guana's biota and ecosystems.

Most of the terrestrial display would consist of photographs. We would try to round up already-existing pictures of plants, animals, and vistas (from Tom, Didi, and Jan--the photographer Skip used to have accompany him) and complement these with our own photographs. A small mounted insect collection would also be included.

The marine ecosystems would be represented by both underwater photographs and specimens:

A) Underwater pictures would be taken with a Nikonos V, and most organisms could be represented using a 28 mm lens; however, some of the most impressive underwater photos include either wide-angle close-ups of large marine organisms or macro shots of small invertebrates. In either case, the quality is due to minimizing distance from the subject, which is particularly important underwater due to low light intensity and scattering of light by suspended particles. It would, therefore, be best to invest in a 15mm lens, a close-up extension tube set, and a second strobe. Very small animals, e.g. the copepods that are abundant in the salt pond, would be photographed through a microscope. Some really spectacular and enlightening pictures can be taken through a microscope, and these pictures may prove to be the most interesting. Magnified pictures give people the opportunity to view organisms they would probably otherwise never see.

B) Dried specimens would include shelled mollusks, echinoderms (starfish, brittle stars, and sea urchins), crustaceans, and sponges. Representatives of some other phyla (e.g. worms, sea cucumbers, unshelled mollusks) would be preserved in alcohol in glass jars. Collection of specimens would be coordinated with marine research. Fish, corals, anemones, jellyfish, and macro algae would be represented only by photographs.

This display would be oriented towards the general public and not necessarily toward biologically inclined individuals; however, it would be scientifically accurate. Therefore, efforts would be made to make it aesthetically pleasing, interesting, and understandable. The goal would be to give people a greater appreciation of the beauty and diversity of Guana Island and to demonstrate that the steps being taken to preserve Guana's natural state are essential to retaining that beauty and diversity.

Both this exhibit and the natural history library would probably fit nicely into the present library off of the lounge in the common building. The books that this room presently houses would have to be moved. This room would be an ideal place for the natural history display and library because of its central, but unimposing, location. Information on nature hikes, collections of Guana natural history photographs, and scientific publications resulting from research on Guana Island could be included in this room. Additionally, it may be appropriate to purchase a slide projector so that natural history talks can be presented to interested guests.

Museum budget:

Photography:	
Film and developing:	$2000
Photography equipment:	
on land:	
Flash set up	$230
underwater:	
extension tube set	$240
15mm lens	$1650
second strobe with Y-adapter	$600
picture framing:	$1500
slide projector:	$350
glass cases (for insect and shell collections)	$1000
chemicals, vials, collecting equipment, probes, pins, plaques (miscellaneous)	$500
Zeiss stereoscope (dissecting microscope) with photo-tube, camera adapter, and fiber-optic bifurcating light source	$5000

Zeiss, which makes one of the highest quality microscopes available, is discontinuing all its stereoscopic models as of February and their sales people have been instructed to sell everything fast. Therefore, we will be able to purchase a demo scope (used about 20 times) with the accessories we want for considerably less than list price. The price indicated above is the marked down price quoted to us by a Zeiss representative. Since the microscope will be a permanent addition to the Guana science project, it will be essential to build a dessicator case to prevent corrosion by the salt air during long-term storage when the microscope cannot be regularly cleaned. This would require an additional couple hundred dollars.

Boat:

We will need use of a boat for much of the marine invertebrate collecting (which is necessary both for the natural history display and for marine research). Use of a whaler would be adequate.

7) In addition to the six projects outlined above, we will be available to

help out with species reintroductions initiated during our residence on Guana. We will also be willing to give talks at the community college on Tortola, if appropriate, and we will be willing to lead occasional hikes and snorkels and to give natural history slide shows on Guana.

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<u>SUMMARY BUDGET</u>

Sheep eradication	$4,400
Rare tree propagation and soil analysis	$1,000
Marine program:	$5,650
Microscope	$5,200
Natural history library:	$3,000
Museum:	$8,070
Other:	$3,000

this money will be used for preliminary research done in Florida, phone calls, general equipment not mentioned elsewhere, shipping personal gear and equipment to Tortola, etc.

Also required:

use of a whaler-sized boat;
occasional transportation to Road Town and other areas;
two round-trip air fares from Florida to Beef Island
one round-trip air ticket from Corvallis, Oregon to Beef Island for Bruce Coblentz.

Stipend: $500/month each for 6 months $6000

We can probably set up an account at the University of Florida and get 20% or higher discounts from Fischer Scientific on much of the equipment we would need. We will return to you any money not spent (excluding stipend money) and will keep expense records and receipts for you. Any major equipment bought for this project, e.g. microscope, weighing balance, water and soil chemistry equipment, etc. will be permanent additions to the Guana science project and will probably prove very useful in future research there.

We would be quite happy to live in the staff quarters on Guana, if this will be less of a burden on the hotel. We will, however, need some room for desk work (we will be bringing a computer) and lab work (microscope and chemistry).

One item of major concern: how will we get the .223 rifles onto Guana, now that firearms are illegal in the BVI? These rifles are absolutely necessary for the success of sheep eradication since the .22's already there are unreliable for killing large animals. We will need your help in getting these guns to Guana. It should be apparent that the entire purpose of this proposal, and that of most future ecological work on Guana, will be undermined without these guns.

Total cost: $36,320

CURRICULUM VITAE

December, 1990

LIANNA L. JARECKI

Department of Zoology
223 Bartram Hall
University of Florida
Gainesville, FL 32611

(904) 392-1107 (office)
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SSN 155-74-2176

PERSONAL

Born: December 3, 1966
Marital status: Single

EDUCATION

Cornell University, Ithaca, NY: B.S., 1988
Major: Biology, with concentration in Neurobiology and Behavior

RESEARCH EXPERIENCE

1989 - University of Florida, Department of Zoology, Gainseville, FL
M.S thesis research on ribosomal RNA secondary structure analysis and sequence comparisons to determine phylogenetic relationships within the Artiodactyl family Bovidae.

January - July 1989 Hawaii Institute of Marine Biology, Kaneohe, HI
Research Supervisor. Designed and supervised the construction of a shrimp culture system which maintained constant but adjustable temperature and salinity. Carried out growth experiments on juvenile shrimp raised at different temperatures and salinities.

October - December 1988 Cornell University, Department of Natural Resources, Ithaca, NY
Research Assistant. Assisted in a study of population genetics and reproductive behavior of Lake Trout in Lake Ontario and the Finger Lakes.

August
1988 Friday Harbor Marine Laboratory, Washington.
Research Assistant. Conducted bioassays of four species of brachiopods to determine the source and nature of a distasteful compound produced by brachiopods.

January - June,
1988 Cornell University, Department of Animal Science, Ithaca, NY.
Laboratory Technician. Analyzed the acrosome reaction of stallion sperm. Research techniques included cell staining, *in vitro* fertilization, and use of IBM motion analysis software on semen samples .

June - August
1987 and 88 Guana Island Wildlife Sanctuary, British Virgin Islands.
Research Associate. Conducted a survey of the hypersaline pond fauna of five British Virgin Islands to assess their suitability for flamingo reintroduction. Assisted in data collection for a study of parrot fish spawning behavior.

June - August
1986 National Oceanic and Atmospheric Administration, Sandy Hook, NJ.
Research Assistant. Executed experiments concerning the effects of pollution on the behavior and survival of young winter flounder in the New York Bight.

TEACHING EXPERIENCE

1989-90 Teaching Assistant at University of Florida for:
Introductory Biological Sciences: Integrated Sequence II
Evolution, Ecology, and Behavior

GRANTS

1990 Division of Sponsored Research, University of Florida ($7,905)
Graduate Research Assistantship

SOCIETY MEMBERSHIPS

American Association for the Advancement of Science
American Museum of Natural History
Genetics Society of America
Society for the Study of Evolution

SERVICE AT THE UNIVERSITY OF FLORIDA

Search committee member for population geneticist faculty position.
Department representative to the Graduate Student Council.
Assistant editor of the Graduate Student Council newsletter.

CERTIFICATIONS

Search and Rescue SCUBA certification.
Hyperbaric Chamber Attendant certification from the Jerome Johns Hyperbaric Facility at Shands Hospital, University of Florida.
American Red Cross CPR and Emergency First Aid

PUBLICATIONS

Jarecki, Lianna and J. D. Lazell Jr., 1987. Zur Grosse und Dichte einer Population von *Lepidactylus lugubris* in Aiea, Hawaii (Sauria:Gekkonidae). Salamandra. 23:176-178.

Lazell, James D. Jr. and Lianna Jarecki, 1985. Bats of Guana, British Virgin Islands. American Museum of Natural History: Novitates. 28 (19):1-7.

PAPERS IN PROGRESS

Kraus, F., L. Jarecki, and M.M. Miyamoto, S.M. Tanhauser, and P.J. Laipis. Mutational compensation within double--stranded ribosomal RNA.

CURRICULUM VITAE

FRED KRAUS

BIRTH DATE June 12, 1959

DEGREES

B.S. in Biology, University of Toledo, 1980
Ph.D. in Biology, University of Michigan, 1987

DISSERTATION TITLE

An evaluation of the ontogeny polarization criterion in phylogenetic inference: a case study using the salamander genus *Ambystoma* .

POSITIONS

Postdoctoral Research Associate, University of Florida, 1988-1990
Teaching Assistant, University of Michigan, 1980-81, 1984, 1986
Research Assistant, University of Michigan, 1983, 1984-85
Field Biologist, Ohio Dept. of Natural Resources, 1980

SCHOLARSHIPS AND GRANTS

1) NSF Predoctoral Fellowship, 1981-1984
2) Edwin H. Edwards Scholarship, Univ. of Michigan, 1983
3) Rackham Block Grant, Univ. of Michigan, 1983, 1985
4) Walker-Hinsdale Grant, Univ. of Michigan, 1984, 1985
5) Rackham Dissertation Grant, Univ. of Michigan, 1985
6) Cleveland Museum of Natural History Research Grant, 1985
7) Rackham Predoctoral Fellowship, Univ. of Michigan, 1986
8) State of Michigan Non-game Species Research Grant, 1988

MEMBERSHIPS

1) Society for the Study of Evolution
2) Society of Systematic Zoology

3) American Society of Ichthyologists and Herpetologists
4) Herpetologists' League
5) Society for the Study of Amphibians and Reptiles
6) Willi Hennig Society

INVITED TALKS

University of Toledo, Dept. of Biology, November 1986

American Society of Ichthyologists and Herpetologists, symposium on biology of unisexual vertebrates, Albany, NY, June 1987

University of Florida, Dept. of Zoology, October 1988

First World Congress of Herpetology, symposium on unisexual reptiles and amphibians, Canterbury, England, September 1989

International Congress of Systematic and Evolutionary Biology, symposium on phylogenetic analysis of sequence data, College Park, MD, July 1990

CONTRIBUTED TALKS

Society of Systematic Zoology, Boston, Massachusetts, December 1989

ACTIVE RESEARCH PROGRAMS

1) Phylogenetic relationships of ruminants and the evolution of their mitochondrial rRNA genes

2) Evolution and clonal structure of unisexual salamanders

3) Morphological and biochemical elucidation of a sibling species complex in the salamander genus *Ambystoma*

4) Phylogenetic relationships among the families of the salamander order Caudata

5) Biochemical systematics of the salamander genus *Ambystoma*

PUBLICATIONS

Kraus, F., and M. M. Miyamoto. In press. Rapid cladogenesis among the pecoran ruminants: evidence from mitochondrial DNA sequences. Syst. Zool.

Shaffer, H. B., J. M. Clark, and F. Kraus. In press. Where molecules and morphology clash: phylogenetic relationships among North American *Ambystoma* (Caudata: Ambystomatidae). Syst. Zool.

Miyamoto, M.M., F. Kraus, P.J. Laipis, S.M. Tanhauser, and S.D. Webb. In press. Mitochondrial DNA phylogenies of the eutherian order Artiodactyla. In: Comparative Analysis of Phylogenetic relationships among Mammals (F.S. Szalay, M.C. McKenna, and M.J. Novacek, eds.). Princeton University Press, Princeton.

Kraus, F. In press. Intra-individual ploidy consistency among unisexual *Ambystoma* . Copeia.

Miyamoto, M. M., F. Kraus, and O. Ryder. 1990. Phylogenetic relationships of antlered deer determined from mitochondrial DNA sequences. Proc. Nat. Acad. Sci., USA. 87: 6127-6131.

Kraus, F., and M. M. Miyamoto. 1990. The mitochondrial genotype of a unisexual salamander of hybrid origin is unrelated to either of its nuclear haplotypes. Proc. Nat. Acad. Sci., USA 87: 2235-2238.

Kraus, F., and J. W. Petranka. 1989. A new sibling species of *Ambystoma* from the Ohio River drainage. Copeia 1989: 94-110.

Kraus, F. 1989. Constraints on the evolutionary history of the unisexual salamanders of the *Ambystoma laterale-texanum* complex as revealed by mitochondrial DNA analysis. Pages 218-227 in Dawley, R.M., and J.P. Bogart (eds.), Evolution and Ecology of Unisexual Vertebrates, Bulletin, New York State Museum, Albany, New York.

Kraus, F., and R.A. Nussbaum. 1989. The status of the Mexican salamander *Ambystoma schmidti* Taylor. J. of Herpetology 23: 78-79.

Kraus, F. 1988. An empirical evaluation of the use of the ontogeny polarization criterion in phylogenetic inference. Syst. Zool. 37: 106-141.

Kraus, F. 1985. A new unisexual salamander from Ohio. Occ. Pap., Mus. Zool., Univ. of Michigan. No. 709: 1-24.

Kraus, F. 1985. Unisexual salamander lineages in northwestern Ohio and southeastern Michigan: a study of the consequences of hybridization. Copeia 1985: 309-324.

Goodman, S.M., F. Kraus, and S.M. Baha el Din. 1985. Records of terrestrial reptiles from Egyptian Red Sea Islands. Egypt, J. Wil. & Nat. Resources 6: 26-31.

Schuett, G.W., D.L. Clark, and F. Kraus. 1984. Feeding mimicry in the rattlesnake *Sistrurus catenatus*, with comments on the evolution of the rattle. Anim. Behav. 32: 625-626.

Kraus, F., and G.W. Schuett. 1982. A herpetofaunal survey of the coastal zone of northwest Ohio. Kirtlandia 36: 21-54.

Papers in Review:

Kraus, F., P. K. Ducey, P. Moler, and M. M. Miyamoto. Two new trihybrid unisexual *Ambystoma* from Ohio and Michigan. Submitted to Herpetologica.

Manuscripts in Preparation:

Kraus, F., and R. A. Nussbaum. Phylogenetic relationships among the salamanders, Order Caudata: a critical evaluation of the morphological evidence.

Kraus, F., L. Jarecki, M.M. Miyamoto, S.M. Tanhauser, and P.J. Laipis. Mutational compensation within double-stranded ribosomal RNA.