The Conservation Agency

Exploration, Education, and Research

President
James D. Lazell, Ph.D.
401-423-2652

6 Swinburne Street
Conanicut Island
R.I. 02835 U.S.A.

January 22, 1987

Dr. Henry Jarecki
Byewood, Timber Trail
Rye, NY 10580

Dear Henry,

This year's Guana Report of works and progress comes in three parts:

1. The Guana Guide, which includes all the relevant recent advances in our knowledge and projects suitable for the popular press.

2. Flamingo Notes: a historical overview of that project; and

3. This letter, wherein I give shorter-than-usual summaries of the 1986 work because of the two previous submissions and the repetitious nature of some work (very necessary though!). I will outline the proposal for 1987 work.

THE BOOK

Island, An Introduction to Population Biology and Theoretical Ecology, is now on disks and can be readily accessed and updated. Michael Gibbons has begun his review process and is in frequent communication. Smithsonian Institution Press is interested, and E. J. Brill Co., Leiden, has nibbled. I believe the work will get better and better with time. Some of the results of long-term projects such as mine with Greg Mayer on Anolis lizards will dramatically enhance the whole. I am not now in a hurry to push for publication. The book can now be updated and polished at any moment - including posthumously for me - and be the best of its kind available; it can only get better.

SMITHSONIAN INSTITUTION

WASHINGTON, D. C. 20560

9 December 1986

Dr. James D. Lazell, Jr.
The Conservation Agency
6 Swinburne St.
Jamestown, RI 02835

Dear Skip,

Thanks for the visit and taking the time to explain some of the details of the Guana Island program. I am very interested in participating in your July, 1987 program and am enclosing a brief description of my proposed research and a copy of one of my publications.

I would like to continue some of my recent work on the population dynamics and life history of the stoplight parrotfish, Sparisoma viride. I made an extensive investigation of this species on Grand Turk, Turks and Caicos Islands, B.W.I. during 1985 and 1986. Results from this study revealed several interesting aspects of their biology and raised some interesting questions.

S. viride is a protogynous or sequentially hermaphroditic species, in which all individuals are born female. Males are derived from females, undergoing sex reversal at about 2 years of age. Although approximately one-half of the population undergoes sex reversal, it appears that most of the breeding is performed by the large adult males (5+ years) who control a group or harem of females.

During the time of sex reversal, males (termed "transitionals") contain functional testes with viable sperm. However, the secondary male sexual characteristics (color change) in this sexually dimorphic species, remain female in appearance for at an unknown period of time after the gonads have reversed from ovaries to testes. Females have heavier gonads relative to body weight (gonosomatic index) than fully transformed males. The gonosomatic index in transitionals is also characteristic of a female during this period. In other words, the testes regress in size sometime after sex reversal. Thus it appears that males have a very high reproductive potential at the point of sex reversal. Females, on the other hand, do not become sexually mature until age 3 or 4. Thus, males are capable of breeding at an earlier age than females. Moreover, all males sampled at Grand Turk were always ripe.

Although ripe males and females were collected on several occasions, spawning in the wild was never observed in the Grand Turk population. However, one interesting finding was that ripe individuals were only found off the ends of the island in high energy zones. Sampling within the lagoon showed that this area appears to be both a nursery ground and an area inhabited by non-breeding individuals. Studies with other species of Scarids suggest that spawning occurs in deeper water than that which was sampled in the Grand Turk studies.

Three lines of investigation are proposed for the Guana Island studies. First, to conduct a comparative study of the population age and structure. This would require spearfishing and a dissecting microscope and a compound microscope. Secondly, to observe the behavioral ecology of the spawning population to determine aspects of their breeding biology in general. Thirdly, since transitionals have been taken from groups in the wild containing ripe females and therefore, presumably, a breeding group, could the period of sex reversal be used by transitional males to gain access to females at an early age? In other words, can the period of sex reversal be used as a strategy to increase reproductive potential by allowing functional males to remain in the harem while they physically appear to be female, but "sneak" copulations as males? Although this strategy has been documented in other species, to my knowledge no one has investigated this in parrotfish.

I am looking forward to hearing from you and learning more about this year's proposed research. All the best in your travels and again, thanks.

Sincerely yours,

Karen N. Koltes

Karen H. Koltes, Ph.D.
Marine Systems Laboratory
NHB W-310
Smithsonian Institution
Washington, D.C. 20560
202/357-1860

MARINE SANCTUARY

I have heard nothing from Dr. Clarke or anyone else concerning our proposal. I cannot believe it would meet with serious objection, so must believe the problem is just the usual 18° lassitute....

Meantime I enclose a proposal from Dr. Karen Koltes to study parrotfish. I knew her when she was getting her doctorate at U.R.I. She is just the sort of person I had hoped to find for our marine aspect, and her project has just what I look for: spectacular animals, fascinating problem (sex), and will lead to readily publishable results. She sent along some reprints, so I know she can write scientific papers. I enthusiastically recommend her for next July.

HERPETOLOGY

Greg Mayer and I and assistants collected more than 500 specimens - mostly on Guana. Our purpose is to have statistically significant sample sizes to determine the extent of geographic variation within the Guana population. We expect Monkey Point lizards, for example, to be different from Guana Peak lizards in modal scale counts, just as Bill MacLean found them to be in physiology. Greg is in the throes of finishing his thesis and we have not had time to work up these data.

We got 12 mother-offspring sets for heritability assesments. These allow us to estimate the probability that a given character (scale count) is inherited. We need lots more of these mother-offspring sets, and they are difficult to produce. A palpably gravid female must be held in captivity until she lays her egg (only one at a time). She may simply resorb the egg if she is not healthy and content. Then the egg must be maintained at the right humidity and temperature until it hatches - in about two weeks.

Because we have needed large numbers of preserved specimens for variation analysis and diet studies (stomach contents), we have not been able to raise as many mother-offspring sets as we will be able to this year. Jenifer Bush, field assistant last year and student at U. Mass Amherst, is doing an analysis of reproduction in the slipperyback using all the old museum specimens from all over the Puerto Rico Bank and Mona. She should be able to tell us just what we need to find out next: is there a reproductive season? Do we need more material to prove it?

We got another Amphisbaena on Guana - with two lovely mites. All have been properly pickled and accessioned into the appropriate museums: MCZ and Bishop.

My former professor at U.R.I., Kerv Hyland, a well-known parasitologist, especially wanted to tackle the mites. Scott's letter to him follows. I am sure he will do a good job of identification and (probably) description of the predicted new species. All this leads right into the next section:

ENTOMOLOGY

BISHOP MUSEUM
1525 BERNICE STREET • P.O. BOX 19000-A • HONOLULU, HAWAI'I • 96817 0916 • (808) 847-3511

December 18, 1986

Dr. K.E. Hyland
Department of Zoology
University of Rhode Island
Kingston, RI 02881-0816

Dear Dr. Hyland:

I must apologize for my delays in contacting you about the mites from Amphisbaena fenestrata from the British Virgin Islands. The last year has been a hectic one for me, especially with the move here to Hawaii.

In the meantime, we have collected another lot of these mites, so I am now sending both lots (under separate cover) to you.

We look forward to your comments. If you wish to publish on them, we have some funds available for the preparation of illustrations of BVI material.

Sincerely,

Scott E. Miller
Chairman
Department of Entomology

SEM:ln

cc: J. Lazell

enclosure

BISHOP MUSEUM
1525 BERNICE STREET • P.O. BOX 19000-A • HONOLULU, HAWAI'I • 96817 0916 • (808) 847-3511

December 19, 1986

Dr. James Lazell
c/o Taylor
6512 Sky Farm Drive
San Jose, CA 95120

Dear Skip:

As requested, here is my report for the 1986 Guana Island field season. This report covers the "general entomology" activities of Mike Pogue and I. I assume that Margaret Collins is submitting a separate report on her termite research.

This season was very successful in terms of general collecting. We collected something on the order of 8000 specimens, which should be prepared, counted, and accessioned by the Smithsonian by the end of the year. Conditions were good for collecting on Guana, and we picked up many species not seen on the island before. We concentrated our efforts on Microlepidoptera (small moths), because they are of special interest to Mike and I (and our colleagues) and they are very poorly represented in collections.

A highlight of the trip was the opportunity to run blacklight traps two nights each in the moist forests on the tops of Virgin Gorda and Tortola. This produced valuable comparative material, which included some real surprises since these localities had never been adequately sampled.

As soon as the specimens have been labelled, they will be distributed to the developing group of collaborating specialists. Most of these have been detailed in my previous reports, but I can add a few more:

Dr. K.V. Hyland, University of Rhode Island (mites)
Dr. S. Adams, Cornell University (noctuid moths)
Dr. G. Eickwort, Cornell University (halictid bees)
Dr. A.S. Menke, U.S. Dept. of Agriculture (sphecid wasps)
N. Evenhuis, Bishop Museum (bombyliid flies)
Dr. J.A. Powell, Univ. California (ethmiid moths)
D. Adamski, Mississippi State University (blastobasid moths)

A variety of papers are in preparation utilizing our BVI material, and some of these will include illustrations funded by the project (I enclose a few examples). Since we have just about used up the previous illustration allotment, can we request another $1200?

For next season, I think we should continue the same program. Margaret Collins should continue her termite work, and two other entomologists can profitably continue "general survey" work. As I have indicated previously, I will be happy to coordinate the entomology program for another season, although I cannot guarantee (due to responsibilities here) that I will be able to go myself. I will try to go, but if I cannot go to Guana myself, I will be able to send a substitute. Mike Pogue will probably be available to go again, although this will depend on his responsibilities at the Smithsonian. It would also be nice to have someone look into arachnids and myriopods in the future.

Thank you again for the opportunity to participate in this project.

Best regards,

Scott

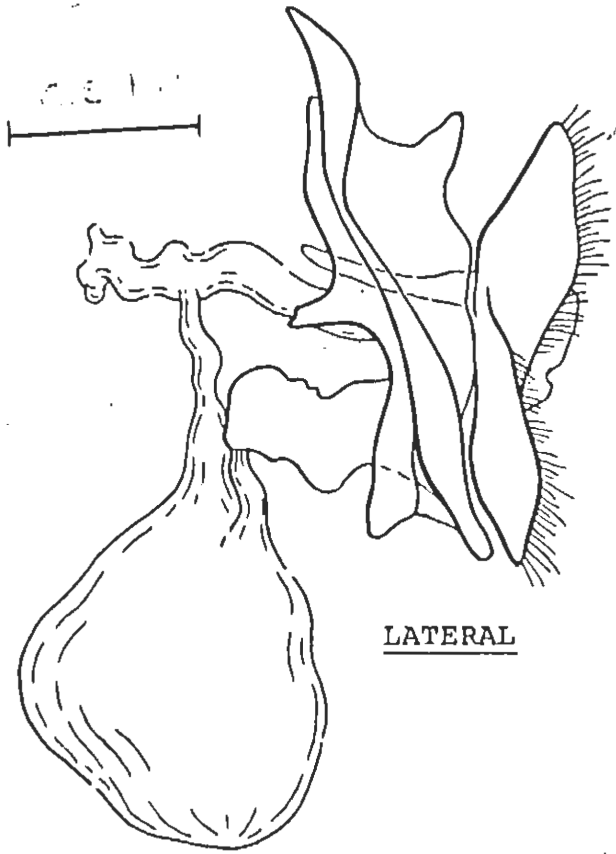
Scott E. Miller
Chairman
Department of Entomology

SEM:ln

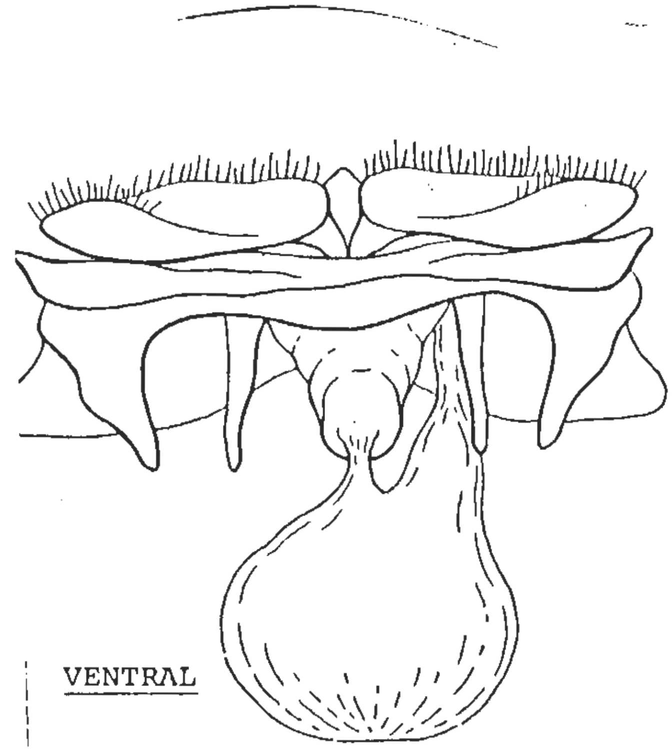
cc: Dr. M. Collins
Dr. M.G. Pogue

P.S. Another paper citing our Guana Island specimens:

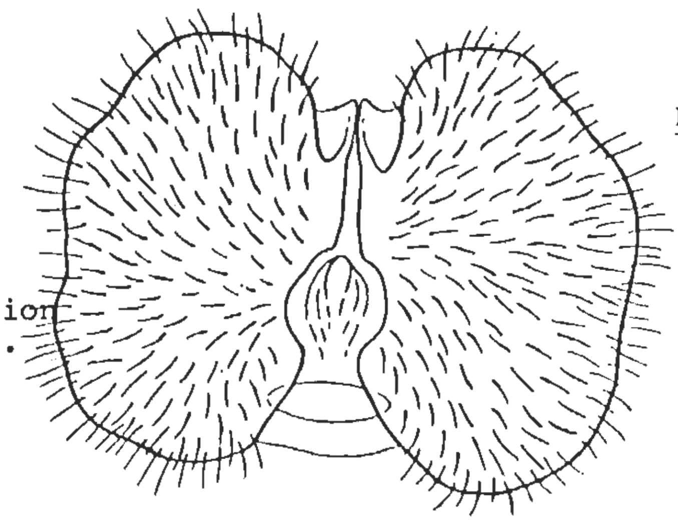
Menke, A.S. 1986. A new Pachodynerus from Mayaguana Island, Bahamas, and a key to the West Indian species of the genus (Hymenoptera: Vespidae: Eumeninae). Proc. Entomol. Soc. Wash. 88: 650-665.



LATERAL



VENTRAL



POSTERIOR

Illustrations of the female genitalia of *Heuretes picticornis* (endemic to the Virgin Islands and Puerto Rico) prepared for a paper in preparation by Scott Miller and Marc Epstein. The paper includes the first illustrations ever published of the genus!

Examples of how the final published illustrations will look (these are not BVI specimens and not paid for by TCA, just examples)...

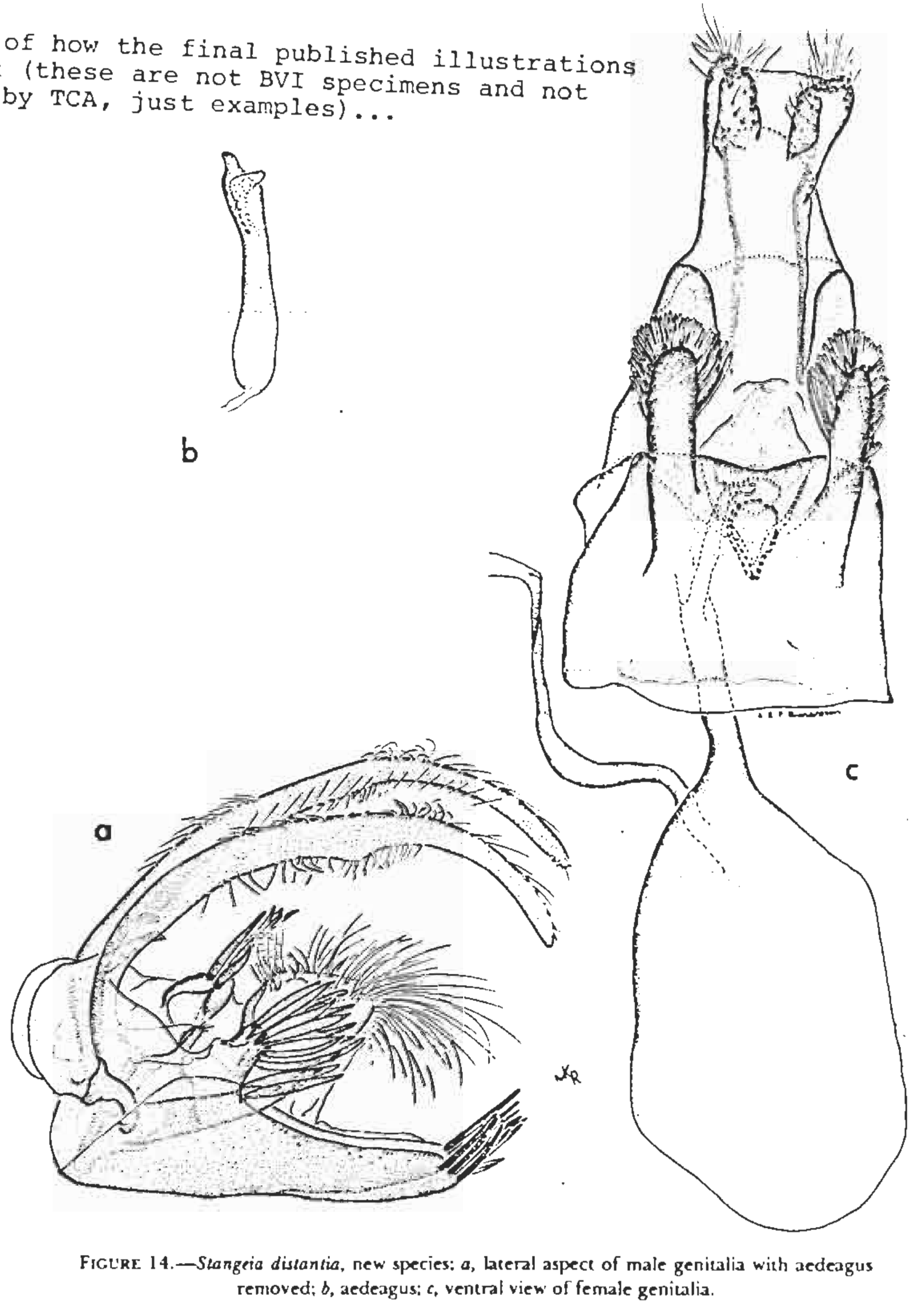


FIGURE 14.—*Stangeia distantia*, new species: *a*, lateral aspect of male genitalia with aedeagus removed; *b*, aedeagus; *c*, ventral view of female genitalia.

BISHOP MUSEUM

1525 BERNICE STREET • P.O. BOX 19000-A • HONOLULU, HAWAI'I • 96817-0916 • (808) 847-3511

December 29, 1986

Dr. James Lazell
c/o Taylor
6512 Sky Farm Drive
San Jose, CA 95120

Dear Skip:

I just received another request for illustration support. The basic $250 can be covered from the money I have, but you need to decide about funding for publishing a color plate. Please let me know and I'll forward your response to Ivie.

Al Samuelson is back from the mainland and I reminded him about your beetle photograph.

I spoke recently to Margaret Collins and she said she would send you an "annual report" letter in the same style as mine.

Happy new year,

Scott E. Miller

Scott E. Miller
Chairman
Department of Entomology

SEM:ln

Montana State University
Bozeman, Montana 59717-0002

Department of Entomology
College of Agriculture

Telephone (406) 994-3860

16 December 1986

Dr. Scott Miller
Department of Entomology
Bishop Museum
P. O. Box 19000-A
Honolulu, HI 96819

Dear Scott,

It was good to see you in Reno, hope you are feeling better by now. I have checked a bit more on some of the Guana Is. material, and the clerid I mentioned is definitly undescribed. Since the Cleridae of the Puerto Rican Bank is currently under way, I would like to get an illustration done of the n. sp. asap. You mentioned that you might be able to arrainge for illustration funds. My standard artist has agreed to a contract price of $250 for a full habitus and necessary line drawings needed for this description. She will do either a black and white or color for this price. If your patron is interested in having the beast done in color (it is a pretty little thing, with a red head and pronotum) and will pay the extra publication costs, we can go that way.

Basically I am requesting $250 for illustration preparation. If additional funds are available for publication costs, I would ask first for funds for a color plate, then page fees. The description will be included in a paper on all Virgin Island and Puerto Rican Cleridae, not just the Guana material.

Hope this is the information you need, and that it can be arrainged to honor this request. Please let me know.

Have a nice holiday season.

Yours,

Michael A. Ivie

Phone: (406) 994-4610 (office)
994-4943 (lab)
587-0211 (home)

BISHOP MUSEUM
1525 BERNICE STREET • P.O. BOX 19000-A • HONOLULU, HAWAI'I • 96817 0916 • (808) 847-3511

December 29, 1986

Dr. Michael A. Ivie
Department of Entomology
Montana State University
Bozeman, MT 59717

Dear Mike:

Thanks very much for your letter re illustrations of the Guana Island clerid. I can answer two questions now: we can pay $250 for the illustrations, and we cannot pay page charges.

I am not sure about funding for a color plate, although it is possible. I am writing the project director, James Lazell, about this. Do you have any idea what the extra cost would be?

I will be back in contact soon.

Happy new year,

Scott E. Miller

Scott E. Miller
Chairman
Department of Entomology

SEM:ln

SMITHSONIAN INSTITUTION
UNITED STATES NATIONAL MUSEUM
WASHINGTON, D. C. 20560

January 11, 1987

Dr. James Lazell
c/o Taylor
6512 Sky Farm Drive
San Jose, CA 95120

Dear Skip :

Following please find a report on termite collecting during the 1986 field season on Guana Island.

Samples drawn from 75 colonies of termites of three families contained at least seven different genera; collections were made by J. Bush, S. Lazell, G. Meyer and M.S. Collins. The localities and numbers of samples taken are as follows : Guana, 66 ; Virgin Gorda, 10 ; Tortola, 12; Cooper,1 ;and St. Thomas, 9.

Preliminary identifications suggest that Guana has the richest fauna of the islands sampled, possibly due to its origin and proximity to Puerto Rico, for which 15 different species have been recorded. The absence of extensive agricultural operations and habitat destruction observed on the larger islands of Tortola and St. Thomas may play a role in the comparative richness of Guana, also.

Identification to species will require comparisons with type material, as the available key to the West Indian fauna needs modification. A species of Parvitermes not previously recorded from St. Thomas was obtained from the rain forest area owned and protected by the MacLeans; it may be identical with a form taken from Guana.

The varietal richness and accessibility of the termites of Guana make this a favorable site for investigations on foraging ecology, defensive behavior, rate of colony growth and other problems. Further, studies on utilization of termites and investigations of the role termites play in maintaining healthful diversity in the plant communities could be pursued here.

The collection will play an important role in our projected upgrading of keys to the termites of the Caribbean, to be begun after completion of "The Termites of North America, Canada through Panama". Duplicate specimens will be provided to the American Museum of Natural History and the Museum of Comparative Zoology at Harvard, while the rest of the collection will remain at the Smithsonian. Reference specimens, descriptions and illustrations will be made available to agencies desiring such in the BVI's. A travelling exhibit describing the role of termites in communities suitable for high schools can be prepared for the next season.

Further work on Guana is desirable- to complete the collection by the addition of winged forms to those samples that contained only soldiers, and descriptions of habitats and habits. If termites are to be treated as the valuable renewable resource they could be, data need to be obtained on rate of colony growth for selected species of carton-nest builders. Flight cages would allow harvesting of reproductives for use as human food, as a source of cooking oil, or as food for fish and poultry. Carton nest material has been employed as fertilizer (soil conditioner and nitrogen source), and, when allowed to dry and burn slowly, as a non-toxic insect repellent.

It has become increasingly evident that temperate and tropical forest and grassland communities depend heavily on termite activity for their continued existence. Analyses of interactions between termites and other elements of the community could be carried out effectively in a situation that combines accessibility, simplicity, favorable living conditions, and a diverse, but not overwhelming, termite fauna.

Studies of animals and plants that survive well on islands may provide important clues for investigators developing closed systems for space stations or undersea communities.

The most intriguing question of all remains identification of the factors involved in the great diversity that obtains on such a small island as Guana. Check lists of the plants of Guana and near-by islands of similar history, along with exhaustive collecting, may provide some clues.

I am grateful for the opportunity to participate in the entomological survey of Guana, and would like to extend these observations to other adjacent islands. Identification of collected materials prior to projected return in July,1987, will facilitate gathering of distribution and density data.

Thank you for the opportunity to participate in this project.

Sincerely,

Margaret S. Collins

Margaret S. Collins

CC : Dr. Scott Miller

California Academy of Sciences

Natural History Museum & Aquarium

Dec. 24, 1986

Department of Entomology

Dear Scott:

Thanks for sending the embiids from the Virgin Is. Most were conspecific with species of Oligembia previously collected. However, there is a single male (has jet-black head rather than amber + other characteristics) I have not seen before. These are all light-bodied species subject, perhaps, to aerial dispersal from island to island.

It would be interesting to visit these islands while taking the opportunity to go to some of the larger islands which retain a more diverse fauna of embiids. We will have a visit from Skip about Jan 12th and will discuss plans.

Almost the same day I will depart for a month in Panama. During a return-stop-over in Miami I may back-track to Dominican Republic for a few days.

I will certainly share specimens with USNM and Bishop museum.

Happy Holidays,

Sincerely,

Ed

Congratulations on your new position. Lin Gressitt was an old classmate of mine at U.C.

Golden Gate Park San Francisco, California 94118 (415) 750-7227

ORNITHOLOGY

Chip's report on his quail dove study follows. We have submitted a paper updating known BVI bird distributions to American Birds, along with Didi's photos of bridled quail dove we hope might provide a cover for them. Their Caribbean editor, Rob Norton (of Halewyn and Norton, cited p. 4 of Guana Guide), writes back that he would like to join us as third author and throw in some records of his own. We are enthusiastic; the result should be the best possible paper.

Liao is extremely excited about being able to spend an entire year chronicalling Guana's birds and both Chip (following report) and I concur that it will be a very useful project. As Chip notes, we know next to nothing about migrants because we are never there at the relevant times. Liao should also be able to census our nesting roseate terns, last done in 1976, and assess any cat predation problems.

Liao will also be able to aid the herpetological effort by collecting sets of lizards at times of year for which we have no reproductive data.

A formal proposal has been sent Richard Branson for investigating Necker Island with an eye toward developing flamingo habitat. If that worked out, we could bring in more flamingos at a reduced cost. The flamingo project cannot really be counted a success until they breed, and the most likely place for that is Anegada. We need lots more birds, and that will take years.

* * * * *

Following Chip's report is Michael's highly provocative one. I look forward to seeing the evidence of his faunule with three and four lizard species. Since there are now eight species on Guana, and since I believe all are native, I suspect his faunule gives an incomplete picture of the diversity present at any specific time horizon. All good fun, though.

The Nature Conservancy

1800 North Kent Street, Arlington, Virginia 22209
(703) 841-5300

January 6, 1987

Dr. James D. Lazell, Jr.
The Conservation Agency
6 Swinburne Street
Conanicut Island, RI 02835

Dear Skip:

The 1986 field season on Guana was the best ever in terms of the quail dove study. First, we were able to net and band 15 birds, many more than in the previous year. From the reobservation of marked birds, I feel considerably more confident in my estimate of 50 - 75 individuals on the island. Second, due to the fact that the radios functioned much better, I was able to locate two nests--this was most fortunate, since nests of the quail dove are extremely difficult to find; a study of the bird on St. John was unable to locate a single one. As a result, I was able to make interesting and valuable observations on the nesting behavior of the species.

As for next field season, I would like to visit the nest sites (both are well marked with trails leading up from Quail Dove Ghut) to see if renesting occurs in the same place. Also enough birds were marked that, based on reobservation plus a reliable estimate of the total number of birds on the island, I should be able to estimate how many of the marked birds are still present on the island after a year. Marking next field season will be with a different combination of bands so we will always be able to tell which year an observed marked bird was banded. We should discuss the possibility of again using transmitters and how that aspect of the study might be improved. For example, I think a lighter radio would function better; in two cases, the radios fell off the birds after about a week. Should we receive funding to pay for more transmitters, I think we have a good chance of discovering more nests--particularly significant in that Dr. Liao will have the chance to make extended observations on nests sites. Under the present arrangement, however, I am borrowing the receiver from a contact in the U. S. Army; this means that I must return it at the end of my stay on Guana and it would not be available for Dr. Liao to use on his own. We could look in to buying a receiver, though it has been a considerable saving to be able to borrow one.

Other observations last season have added to our knowledge of the bird fauna of Guana Island. Of especial interest has been the change in species components nesting around the Salt Pond from one season to the next. The project reintroducing flamingoes to the British Virgin Islands is both interesting and valuable and will require study and monitoring to assure its success.

I am particularly interested in the proposal that Dr. Liao spent several months on the island studying the avifauna. If he is to do so, I think it is important to get him off to a good start. I look forward very much to working with him, especially in learning more through his work about the migratory and wintering species using the island.

Thanks again to you and the Jareckis for making our ongoing scientific and conservation project possible.

Yours sincerely,

Chip

Robert M. Chipley
Director, Preserve Selection
and Design

P.S all photos got here.

Guana Island Technical Letter

Gibbons 20 December 1986.

Dr. James D. Lazell
President
The Conservation Agency
6 Swinburne Street
Conanicut Island
Rhode Island 02835.

Dear Skip:

Once again, please accept my thanks and extend them to Mocatta Metals for the opportunity of doing field work on Guana Island. Last Year, I divided my letter into areas related to the kinds of investigations that I had conducted on the island. The areas were: Historical Archeology, Prehistory, Subfossil and Recent Bony Remains, and some overall ecological observations. This year I will use the same divisions.

HISTORICAL ARCHEOLOGY.

I noted that Guana was wetter this year than in the last two. Under these wetter conditions, the Island's ruins were much more friable than I had noted in the past. They were more delicate in most instances. I found that the remains of the various sites, such as the rum mill, are being reduced to rubble at a more rapid rate than I had estimated in 1985.

While it is true that investigation using the techniques of Historical Archeology can be done at any time, the earlier the better.....if one intends to do such investigation at all.

The question now becomes whether the ruins on the Island should be investigated from an Historical Archeology perspective. Given other such investigations in the Caribbean, Guana's ruins and their associated artifacts are not unique. I am not saying that the remains of rum mills and cane plantations are many because they are not. But, the overall nature of these operations are well documented from other sites, some of which are functioning mills and plantations to this day. I do not expect that anything particularly new would be discovered at Guana.

Another point against Historical Archeology investigation on Guana is that such an investigation, and its accompanying excavation, sometimes does more damage than the resulting knowledge is worth. Given the Guana Island Club and its guests, the ruins add to the aesthetic experience of Guana. As such, they should be left intact.

This statement could get me into a lot of trouble with a professiona Historical Archeologist who would probably argue that the profession is more geared to preservation than I have suggested. Under ideal conditions this may be true. Excavating on Guana, however would be under non-standard conditions. The field season is very short there: three weeks or a month. This time would allow for some digging but not for backfilling and reconstructive work all of which is more time consuming than the basic excavation.

Surface collecting (without excavating) by a professional may come up with enough artifacts to produce a display and this would be minimally disruptive to the sites. It is my impression, though, that the surfaces of most sites have been thoroughly picked over in the last fifty or sixty years. This impression is based on the fact that Johnny, who is a very talented amateur, has only come up with a handful of artifacts in two years on the Island. In addition Johnny and I pumped out the well at the rum mill and found nothing at its bottom.

To address the issue of why an Historical Archeologist at all: In my 1985 letter, I mentioned that there may be some undiscovered sites that an Archeologist might uncover, and that examination of these sites would provide material that would illuminate the history of habitat disruption over the last 400 years. Last summer (1986), I walked the Island specifically looking for such sites and found none that were not already known. I thought that I had a new one from about half-way up Palm Ghut, but Johnny had already been there and had one artifact from the area.

With respect to the value of any excavation illuminating habitat disruption during the historical period, the sites might prove useful, but the dates coming out of the excavation of the main bat cave for the faunal remains and artifacts found there are sufficient for our present needs. In 1985, when I wrote that archeological excavation would be useful, I had no dates from the bat cave excavation.

It is now my feeling that the archeological sites on Guana are not unique and since successful dates are coming out of the cave, much of what an Historical Archeologist could add would be redundant.

There is one area in which a laudatory report from an Historical Archeologist would be useful. Such a report could further make the point that Guana is a sanctuary. Not only are the remains aesthetically pleasing to the guests of the Guana Island Club, but the point can be made that they contribute to the history of the British Virgin Islands in general.

PREHISTORY.

No new artifacts were found in the cave this summer, probably because we were digging at levels that were laid down prior to extensive human use of the Island. However, some comment on the arrowhead found in 1985 is in order here. The arrowhead was discovered in the main bat cave at a time horizon (level) that has been dated at between 1300 and 1500 A.D. Since the arrrowhead is made of chert, it was my early conclusion that the material for the arrowhead, if not the arrowhead itself, was imported to the area of the BVI from elsewhere. It is commonly thought that there is no chert source within 1000 miles of Guana Island. Prior to this summer (1986), it was my assumption that the arrowhead was made from chert from a source in central Florida.

In discussion with Jill Tattersall at the Guana Island Wildlife Sanctuary and The Conservation Agency's presentation on Tortola this summer (1986), she suggested that there may be a chert vein in the Towers Limestone on Tortola's West End and on Great Thatch Island. These limestone formations are typical of geological formations in which chert is found. A brief excursion next summer would quickly determine whether the arrowhead could have been made locally or not. If it were, I think that it would be the first such find in this area of the Caribbean.

Based on the artifacts that the Guana Island Club and its guests have collected over the years, and on those that I have found and dated, I propose the following chronology. I have geared it to the rest of the Caribbean in the titles of the periods, but the proposed dates are my own.

ARCHAIC PERIOD:
This was largely a shell culture and the settlements were probably restricted to the beaches (littoral). This suggests that they were temporary and that Archaic Indian groups used Guana as a shellfish collecting base. There is no evidence of fire on Guana during this period.

LATER ARCHAIC:
This period saw hunters and gatherers on Guana. The earliest cultural remains from the cave come from this period. The Indians seem to have been exploring Guana quite thoroughly during this time and there is evidence of their occupation from most parts of the Island. The polished stone axehead that Johnny found is probably from the Later Archaic. Now, no fire has been reported from Tortola for this period, but the earliest charcoal from the cave is this old. The tentative date from this time horizon in the BVI (specifically Guana Island), then, may be established at 2000 to 1500 years before the present B.P.

SAUDOID PERIOD:
There is evidence of Arawak agriculture in other parts of the BVI during this period, but not on Guana. Some fish remains and associated charcoal come from this time on Guana. These fish are a consistent source of food. See the attached newspaper clipping. (The clipping dates this fish barbecue at 1000 years ago, I would like to modify that to read 1500 B.P. here.)

BARANCOID:
This is probably continued Arawak and can be dated between 1200 and 600 B.P. There is little evidence for this time period from the cave. On other parts of the BVI, however, coarse pottery that has been sculpted, but not painted, along with adorned tool handles and wooden, stone and shell tools have been found.

Around 600 years ago, the first evidence of bow and arrow appears in the BVI, along with fine woven cloth and some baskets. This is thought to have been the period during which the Caribs made slaves of the Arawak. There is no direct evidence for this on Guana, but the chert arrowhead comes from a layer (time horizon) in the cave that is post-Barancoid. Further identification of the arrowhead will have to await comparison with established collections of Carib artifacts.

SUBFOSSIL AND RECENT BONY REMAINS.

The term subfossil here refers to remaians that have been partially permineralized. This year (1986), I had a full-time field assistant (Paula Bonarrigo) and we found over 200 catalogable sspecimens from various time horizons. These specimens are still being analyzed, but the preliminary indicationsare thought provoking. In brief, the variety of species is greated after 300 B.P. than it is prior to 400 B.P. These dates are tentative as it is difficult to distinguish such small time increments given the rubble-like nature of the cave floor. Suffice it to say here that there is less variety before the period of extensive European agriculture than there is after it.

The nature of this subfossil faunule suggests that the ecological nature of Guana changed after the period of European agriculture. This agriculture would have disrupted much of the Island ecosystem.

My explanation for the increase in faunal variety since the intensive European agriculture is that the environment on Guana is not in equilibrium. This means that the number of habitats on the Island is likely to be greater than when the ecosystem is more stable. Generally, more habitats mean a greater variety of species. I must point out here that this is a preliminary impression, and for the following reasons:

a) The data are only preliminarily analyzed,
b) In the cave, we are only sampling a faunule and it may be argued that a faunule is not representative of a complete fauna.
c) The dates are based on relative chronology and not on an absolute one. This means that, although the baseline for the time sequences in the cave is radiometrically based, the later dates are reconstructed using a modified principle of superposition. In short, the accuracy of the dating may be off by a factor of 30 percent.

Now, this may not affect the basic conclusion about an early lack of variety and a later increase, but it could exclude the European agriculture as a factor.

Still, despite the preliminary nature of the analysis, there is one thing that is clear: in the preagricultural strata (sediments), there are three species of lizards, and in the post-agricultural ones, there are four species. The specifics on these species will follow in a later report.

SOME OVERALL OBSERVATIONS.

MacArthur and Wilson have a formula that, when imposed on Guana Island, predicts around four primary species there. Guana seems to have around twelve. In planar measurement, Guana Island is roughly 800 acres. If vertical considerations are added to the planar ones, Guana is closer to 1000 or 1100 acres in size. This is roughly a 25 percent increase, but one which only changes the MacArthur/Wilson estimate by one species (5 primary species).

The explanation for Guana's unexpected variety may be because of the aforementioned lack of environmental equilibrium. At least the nature of the subfossil faunule from the cave is beginning to suggest this possibility.

TIME SCALES AND ENVIRONMENTAL CHANGE ON GUANA ISLAND.

Not only is Guana Island unusual in its variety, but there is beginning to be some evidence that evolution may be occuring quite rapidly there. I have proposed above that species variation of Guana may be due to habitat variation and that the habitat variation is the result of overall environmental instability. Well, it's a little more complicated than that. The results of habitat variation within any environment depends on the time scale over which the variable exists. Guana seems to have accomplished much in a relatively short time. It is too early to be certain, but I am going to suggest here that Guana's ecological time scale has telescoped and that the variation that the cave faunule is sampling is actually changes in population density as habitats shift in the process of the ecosystem recovering. This does not mean that the material we are sampling from the cave is unreliable or that we are sampling changes that are less than a generation in length, but it does imply that the populations of the primary species on Guana are succeeding one another more rapidly than is usual on small tropical islands -- even one with a disrupted ecology. Further, the preliminary data suggest that populations on Guana may simply move around a lot with subtle habitat changes: something akin to seasonality.

ARAWAKS' DIET INCLUDED LOCAL FRESH-WATER FISH

The Island Sun
7/23/86
Tortola, BVI

By Vernon Pickering

The Leader of the Opposition, Hon H. Lavity Stoutt photographed at the Scientific Symposium held on Monday, July 21, at Government House while discussing with Mrs. Jarecki. (Photo by Vernon).

Fossilized remains of a primitive barbecue have revealed that Arawaks living in the islands over 1,000 years ago had local fresh-water fish caught in ponds as part of their regular diet. This information was received only a few days ago by Professor Michael Gibbons, a visiting scientist, from his laboratory assistant in Massachussets.

Analysis of fossils and sub-fossils remains discovered by Prof. Gibbons a year ago in a rock shelter in Guana Island revealed that approximately 1,000 years ago there were fair numbers of fresh-water fish on that island: "We have a charcoal that has been dated 1,000 years ago (+ or - 250 years); the fish has been identified as a fresh-water variety, the exact species is still under analysis", the scientist said.

The dating done by an organization in Massachussets is about 80 percent accurate; the average length of the fresh-water fish is about 6 to 8 inches. In speaking to the older folks of the islands Gibbons discovered that Tortola had standing waterfalls as recently as 1940. According to the scientist this means that there were presumably greater and year-round sources of fresh-water and this source has now begun to diminish: "This does tend to fit the general cooling and drying curve that we are seeing for this part of the world," Gibbons said.

Professor Michael Gibbons, Laboratory of Primate Anatomy (Paleontology-Antropology), 4th Professor at the University of Massachussets in Boston, is a member of a team of visiting scientists.

Since 1980, Dr. and Mrs. Henry Jarecki have invited scientists from all parts of the world to visit the BVI to study the local flora and fauna.

BOTANY

George Proctor has, I believe, been working right along on this. He has sent lists of specimens collected, but his overall report probably will not be presentable until next year. I believe he will be huge help to us zoologists next July.

PROPOSAL: 1987

Most of us hope to continue right along with our projects. Scott Miller's role may decline, at least in the field, because of his move to mid-Pacific. Dr. Ed Ross, California Academy of Sciences, has to fit Guana into other field trips; he couldn't make it last year and might not this year. Some year he definitely will come, he says.

Our only new project then is Karen Koltes on parrotfish. I think this is a dandy; perhaps Lianna will work as her assistant.

Proposed 1987 Scientific team (days in parentheses):

PI	Assistants, R & B	Paying
Lazell (34)*	Bush (34)*	
Mayer (30)*	Jenkins (30)	
Miller (30)*	Walsh (30)	
Poque (30)*	Villars (30)	
Chipley (21)*	Giovannone (30)	
Lido (365)*	Azavedo (30)	
Gibbons (21)	Bonarrigo (21)	Virginia (21)
Collins (30)	Lianna (30)	
Proctor (7,7,10 = 24)*	Nameless (30)	
MacLean, Wm. (7)	MacLean, E. (7)	
Ross, Ed (7)	Ross, Sandy (7)	
Koltes, Karen (30)	BVI Students	

* We pay airfare (all others pay their own).

Total airfares at ca $ 400 each (8)	$ 3,200
Total person days (not including Virginia)	908
Slush fund	$ 1,000
Boat days	5
Illustration costs	$ 1,200

Sally Taylor and I are working up the accounts to date and will send these along to Gloria directly. Everything seems to be well within expectations.

I can be reached during February:

c/o Tod Lum, Fish & Game
1151 Punchbowl St.
Honolulu, HI 96813

and all of March:

c/o Fr. Anthony Bogadek
St. Louis School
179 Third St.
West Point, HONG KONG

Thereafter until June c/o Liao in China. I'll call as soon as I get back. Louis Potter is hunting up more students. He wants to do a less formal evening presentation this year, open to the public. Suits me; perhaps we should do two: one on Guana for the Jarecki's and guests, one on Tortola wherever Louis wants it.

All the best,

James D. Lazell, Ph.D.

P.S.: Appended article puts us in perspective.

JDL:lr

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THE FUTURE OF TROPICAL ECOLOGY

Daniel H. Janzen

Department of Biology, University of Pennsylvania, Philadelphia, Pennsylvania 19104

INTRODUCTION

Whether there is a future for tropical ecology, and of what it will consist, does not lie in the unveiling of yet another intricate animal-plant interaction, in the application of technological marvels, or in the discovery of a crop plant that can be grown with high yield on rainforest soils. The answer does not lie in meticulous analysis of what we know to date.

Yes, we need these things. But the real future of tropical ecology lies in whether, within our generation, the academic, social and commercial sectors can collaboratively preserve even small portions of tropical wildlands to be studied and used for understanding, for material gain, and for the intellectual development of the society in which the wildland is embedded. The tropical ecologist has a clear mandate to be a prominent guide and glue in this collaboration. Ecologists are specialists at understanding interactions between complex units and their environments; the future of tropical ecology lies, above all, in the interface between humanity and the tropical nature that humanity has corralled. It is this generation of ecologists who will determine whether the tropical agroscape is to be populated only by humans and their mutualists, commensals, and parasites, or whether it will also contain some islands of the greater nature—the nature that spawned humans yet has been vanquished by them. An ocean of oil palm plantations, no matter how sustained the yield and no matter how well-fed the caretakers, is no more human destiny, nor is it of more ecological interest, than is any other assembly line.

My goal here, then, is not to review the trajectory of the literature generated by studies of tropical ecology and biology, but rather to outline what is clearly becoming the structure of tropical ecology's future. My inferences and guid-

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ing examples are not drawn from a thoroughly studied tropical world and an illuminating tropical literature; neither exists. Instead, my thoughts derive from a blurry mosaic of field observations by myself and others, overlain, and therefore sometimes obscured, by an even more blurry literature—a cultural hybrid, debilitatingly inbred and of highly variable precision. Worse yet, tropical ecology's clergymen and their congregations usually do not share a common set of experiences and have not therefore evolved either a language in common nor closely congruent different languages.

Engineers build bridges, writers weave words, and biologists are the representatives of the natural world. If biologists want a tropics in which to biologize, they are going to have to buy it with care, energy, effort, strategy, tactics, time, and cash. And I cannot overemphasize the urgency as well as the responsibility. Within the next 10–30 years (depending on where you are), whatever tropical nature has not become embedded in the cultural consciousness of local and distant societies will be obliterated to make way for biological machines that produce physical goods for direct human consumption. In short, biologists are in charge of the future of tropical ecology. If the tropics of the world go under, biologists of the world will have no one but themselves to blame. We can see very clearly what is happening, what will be the irreversible consequences for biology and humanity, and how the solutions must be constructed. An active as well as a passive audience is there. It is up to us to make the world conscious of its interactions with the tropical living world. If we cannot set aside our personal interests, research, and development, and put our entire effort to affixing permanently some of tropical nature, then we have sold the tropics' long-term fitness for a handful of instant gratification. We are the generation for whom the only message for a tropical biologist is: *Set aside your random research and devote your life to activities that will bring the world to understand that tropical nature is an integral part of human life*. If our generation does not do it, it won't be there for the next. Feel uneasy? You had better. There are no bad guys in the next village. They is us.

THE BIOLOGY OF THE SURVIVORS

Tropical ecology is the biology of the interactions of things that live between the Tropics of Cancer and Capricorn. Understanding interactions requires understanding the interactants. The future of the tropics dates not from today but from the time when a pernicious ape evolved the use of tools, fire, and the division of labor. For at least 90% of the 5–10 million species that live in the tropics, the geographic and demographic structure of the ecological future (within the next 30 years) is extinction or restriction to wildland reserves totalling less than 10% of the tropical land surface. The future of tropical ecology is thus inextricably embedded in the biology of the consequences of this event for the survivors, in the intense study and manipulation of the survivors to see what they offer humanity, and in the exposition of both of these things to humanity near and far. Where neither gain nor any exposition is forthcoming, the future of most survivors of insularization will likewise be extinction through island eradication at a slightly later date.

The driving force for this reduction of the tropical world is human selfishness, human numbers, human ignorance of its own needs, and the acquisitive nature of life itself, applied at all levels. A seeming goal of humanity is to convert the world to a pasture designed to produce and sustain humans as draught animals. The challenge, in which the tropical ecologist is a general, knight, foot soldier, and technical specialist, is to prevent humanity from reaching this goal. The true battle is, however, to reprogram humanity to a different goal. The battle is being fought by many more kinds of professionals than just ecologists; however, it is a battle over the control of interactions, and by definition, the person competent at recognizing, understanding, and manipulating interactions is an ecologist.

I intend to discuss the traits of the two primary kinds of survivors that we will have in the immediate future of the tropics. There will be those in managed habitats and those in wildland preserves (preserves by design or by default—the humans have just not gotten around to harvesting the latter). What tropical species have to offer humanity is outlined in the third section in this essay.

Species Occurring in Managed Habitats

A tropical landscape is not (yet) an uninterrupted sheet of rice, pasture, and tree plantings. The agronomic factory is still dotted here and there with wild things. The free-living wild things are of two kinds: There are those that are standing, living and breathing, but as dead as is the litter, since they have no reproductive future. They are the living dead. The living dead range from strays to wild species—persisting as adults but going extinct through lack of reproduction—to crop species unable to survive on their own. Then there are those species that seem to be breeding populations, the species that find this novel combination of resources usable and the challenges surmountable. And there are the crop organisms. A major role for traditional biology in the future of tropical ecology lies in telling us about these three groups of organisms—how they interact, what sorts of habitats they come from, how they respond to change, how they can be manipulated and how they have changed.

The Living Dead

The living dead show us what once was. A pasture bears a straight, 45-m-tall rainforest tree. Such an organism is produced only by intact rain forest. As we stand in the withering wind and sun and gaze at that tree, we know better than we ever could from any weather or soil analysis what once grew in the green desert at our feet.

The living dead are food and shelter for some of the breeding populations. There are many breeding populations on managed lands that do not so much survive on new resources as persist on scraps of the old. Each collection of organisms represented by a pasture, a plantation, a newly fired corn field, has not yet reached the asymptote of its extinction curve, even for its breeding populations.

The living dead allow a survey of the flora and fauna of an agroecosystem under construction to "show" that much of nature is still present. They allow a father to clear a forest, yet show trees to his daughter—a cruel deception. They allow the tropical farmer to live on his ranch, yet not be consigned to the most boring habitat on earth. If the tropics had, on the one hand, only wildlands and on the other, agroecosystems with their living dead buried, the ecologists' task at public education would be much simpler. As many as 50%–90% of the wild species in tropical agroecosystems may be living dead, and these wild species may be as many as 20%–40% of the resident species that occupied the area when it was a wildland.

The living dead tend to be species with individuals that are tough and/or long lived, or not-so-tough but surviving through caprice, or those that propagate asexually, or that have large and/or persistent soil seed banks. While such plants survive longer in situ than do living dead animals, the latter may persist a long time, owing to their mobility. A habitat constituted largely of living dead obtains its structure by stochastic and dependency-linked decay of species arrays built up originally by both invasion and evolution.

Living dead plants are often prominent in biomass, species and numbers of individuals in contemporary slash-burn agriculture; yet such plants no longer place offspring in habitats adequate for population recruitment. Cleverly managed, they may be an integral part of soil, water, and crop management, since many species of tropical perennials have individuals that can propagate vegetatively for centuries in the right circumstances. They are also prominent as crops and tree plantations, and it is clear that ecologically tree plantations are not reforestation but rather, the living dead.

The living dead do not all live in the managed portion of the agroecosystem. Forest occupied by humans will contain individuals that persist though they are dead for the same reason as the trees left in pastures. For example, when seed dispersal agents are hunted out of a forest, a tree species may begin a downward demographic slide, though it persists until the last seed in the soil has germinated and grown through senescence (several life spans later). I suspect that many species-rich tropical wildlands are now rich in living extinct species. Where wildlands are near managed lands with extensive wild breeding populations, wildlands are often rich in living-dead individuals that flow into them from the managed land. These species are especially difficult to interpret when they are ruderals and grow up in natural disturbance sites in wildlands.

Contemporary tropical agroecosystems are rich in transient living dead. These are the species that pass through but would die if forced to stay, by elimination of their source or sink. A bird list, a moth list, a mammal list for an agroecosystem contains many species that are neither living dead nor breeding populations. There are even such transient living dead plants; dispersed out of the forest and into the agroecosystem, they grow and die but do not recruit. True migrants, animals whose presence depends on far-distant breeding grounds as well as on the tropical overwintering ground, are often transient living dead. In addition, there are the transient species that customarily cross the sea of agricultural desert between wildlands islands; their abundance is not so much a function of the amount of managed habitat overall as of the amount and proximity of wildlands.

Wild Breeding Populations

Many wild breeding populations in agroecosystems persist on the resource base constituted of living dead. A row of living dead fencerow trees may support a breeding epiphyte population and a breeding population of amphibians and ants, much of whose food may be transient living-dead insects. Such breeding populations are often a capricious subset of the original species on the site, a subset that just happens to find enough essential strands of the ecosystem for persistence. Ironically, some of these breeding species may well survive because the agroecosystem modifies some of the biotic and physical challenges. Some forest species are favored by the fact that a field is sunnier and drier than was the rain forest which it displaced.

A wild breeding population in an agroecosystem may itself be a living-dead population. Breeding persistence may occur only through a capricious series of favorable circumstances. Since agriculturization homogenizes habitat diversity, a population that has been locally extinguished by a break in the series has less chance of reestablishment through immigration than it would in a wildland. Likewise, wild populations in agricultural land are insular in their spatial demography (no matter how thoroughly their distribution maps appear to cover the countryside), a fact that has not escaped any farmer using crop rotation and crop moratoria for pest control.

A portion of the breeding population's resource base is often the crop itself. The caprice of crop choice then leads to extinctions. When a Costa Rican rancher converts from cattle to sorghum, the change is devastating to the vampire bat population.

Some agroecosystem wild breeding populations are maintained by the combination of the managed habitats and wildlands. The small frugivorous birds and bats dispersing early successional tree seeds throughout short-cycle field-fallow systems may well be roosting or nesting in nearby wildland forest.

Wild breeding populations may be viewed as a crop threat, and thereby become subject to biotic challenges that alter the gene pool (e.g. that select for pesticide resistance) or extinguish populations. If paleohunters had not eliminated the neotropical Pleistocene herbivorous megafauna, their more agricultural successors would surely have done so; glyptodonts and cornfields are not compatible. Likewise, the catastrophic invasion of agroecosystems by biological control agents takes a direct toll of wild breeding populations.

Wild breeding populations will be genetically altered by crops and crop associates through gene flow and are unlikely to maintain their original genomes either in managed land or in nearby wildlands. The moths that follow neotropical cotton crops into newly cleared habitats are genetically distant from their wild conspecifics, and their wild conspecifics have little chance of maintaining a genetic identity in the presence of the crop associates.

Since the wild breeding population subsists on the crop, on the living dead, and on other wild breeding populations, it will inevitably be subject to dramatic and capricious fluctuations in these resources through ordinary management, with the consequence that major demographic shifts occur in the population. It is ironic that tropical populations, with their relatively predictable (even if fluctuating) resource bases, should be most susceptible to such fluctuations.

Wild breeding populations on managed lands are unlikely to have originated in the wildlands from which the managed lands were cleared. The same species of tropical weeds are found in old fields from high to low elevations, from rain forest to dry forest, from deserts to swamps. A field newly cleared from wildland forest often contains many local ruderals, but the vegetation quickly becomes dominated by an old field flora (and fauna). Managed lands are not rich in persistent local breeding populations of ruderals. Part of the cause is that many tropical ruderals are specialists on particular microsites that do not persist on managed land. Furthermore, many kinds of tropical agricultural lands are rarely perturbed enough for establishment of ruderals (e.g. pastures, oil palm and coffee plantations).

Some omnivores and other kinds of generalists are disproportionately well-represented among tropical wild breeding populations on managed lands, probably because they can survive over a large area, with almost every individual surviving on a somewhat different resource. On the other hand, the conspicuous absence of many species of omnivores from tropical managed lands makes it clear that omnivory itself is not an all-powerful shield against tropical agriculturization

The habitat structure of geographically congruent breeding populations in tropical agroecosystems is based largely if not entirely on the ecological rather than evolutionary fitting of invaders. (However, this is also probably true of most mainland wildland habitats.) A conspicuous exception is the case in which a breeding population is frequently subject to catastrophic selection during management eradication attempts, and these thereby lead to evolutionary fitting to a management challenge.

A conspicuous decline occurs with decreasing latitude, in the degree to which a resident wildland can be reconstituted from wild breeding populations (and even living dead) in managed land. There are at least three major causes. The tropical agriculturalized habitat is much more heavily hunted and plant harvested; it contains many more species whose presence is absolutely dependent on other species; and it draws its wild populations from a species pool that is much richer in habitat specialists—all relative to extratropical agroecosystems.

Managed tropical habitats are disproportionately rich in species that lack complicated life cycles. A trans-tropical migrant sphingid moth that feeds on flowers as an adult and feeds on leaves as a caterpillar is more in jeopardy from agriculturization than is a nonmigratory saturniid moth that feeds only as a caterpillar. On the other hand, some kinds of highly mobile animals can patch together a resource base in a large agroecosystem; for example, African finches that eat wild grass seeds follow ripening grain crops across many degrees of latitude, just as they once followed the latitudinal changes in the ripening time of wild grass seeds.

Wild breeding populations in managed lands are usually labeled with the same scientific names as are their conspecifics in wildlands. However, a population may be characterized as much by its interactions with other species as by its intrinsic traits. The interactions are grossly different in the two habitats, providing a problem that classical nomenclature cannot handle. An ephiphyte growing in the crown of a coconut palm in a plantation, even if it is a member of a wild breeding population, is demographically and physiologically very different from its conspecifics in the forest nearby. Gene flow proceeds with a different pace and pattern. Managed tropical habitats are rich in parasitoid-free insects, herbivore-free plants, fully sympatric carnivores with the same diets, plants lacking dispersers and pollinators, etc. Lizards and small snakes find a predator-free haven in African villages. Where a single organism is serviced by a species-rich coterie in a wildland habitat, it may be serviced by a few or none in a managed habitat. Even members of obligatory mutualisms may persist in wildland habitats that lack the challenge that gives the mutualism its significance. A small crop of self-pollinated seed may be quite adequate for persistence in a habitat that has been swept free of competitors and herbivores by the manager, yet such seed may not yield population persistence in intact wildlands.

Crop Organisms

Managed agricultural organisms have variously coevolved into mutualisms with humans and have therefore acquired humans as a bizarre phenotypic appendage because of some serendipitous trait. However, agricultural organisms are not featureless components of the tropical agroecosystem. They have many traits of importance to future tropical ecology and are about to acquire more such traits through the graces of genetic engineering.

Many tropical crops are absent from the habitat for months or years. Even when the species is present year-round, certain parts are carefully harvested rather than available for recruitment or food. Additionally, this absence often occurs during the harshest time of year. A wildland habitat may contain a dozen species of malvoid hosts on which cotton-stainer bugs feed sequentially through the year; the managed habitat may contain only cotton, and even that for only a few months or at intervals of several years.

Tropical crops are (or were) substantially more diverse within and between species and life forms than are extratropical crops. Given the same amount of management, tropical managed habitats can sustain substantially more species of animals than do their extratropical counterparts. However, the effect on conserving species-richness is less than one might expect because many tropical crops are (were) grown at very low density and in tiny patches. Thirty varieties of rice in a field carved out of a rain forest do not mean a proportional increase in carrying capacity for rice-eaters if many of the varieties occupy only a few m^2.

Many species of tropical crops are grown for drugs or wood products. These species have not been directly selected for lowered resistance to herbivores and therefore are relatively unavailable to dietary nonspecialists. This is also true of many tropical fruit and nut trees, except they may have small edible parts, only temporarily available. On the other hand, the tropical crop plants that are bred for overall edibility are subject to a much more species-rich herbivore array than is the case outside of the tropics. To complicate things further when wildlands are agriculturalized, many of the potential crop eaters are eliminated before they have the opportunity through evolution to move onto the crop, and this works against the accumulation of tropical herbivores on crop plants.

A multiplicity of human social processes led to great diversity of tropical agriculturalized habitats up until the last several hundred years. The contemporary homogenization of tropical agricultural habitats, from the gene to the habitat level, has substantially lowered both the intellectually stimulative power of agroecosystems and their carrying capacity for wild reproducing populations as well. Not only may tropical agriculture have to depend on classical gene banks for seed varieties lost through present-day homogenization of crops, but zoos and botanical gardens may turn out to be the only sources of certain wild animals and plants capable of surviving in agriculturalized habitats, once people decide they wish to reverse the trend toward homogenization.

Species of Wildlands and Their Restrictions To Reserves

Ecologists have been drawing major generalizations from small, island-like wildland reserves at least since Darwin built on the natural history of the Galapagos Islands. A wildland reserve is simply a relatively small area of habitat(s) surrounded by a major barrier to invasion, shielded from deliberate manipulation by humans, and prevented from expanding. Almost all true islands and many ecological islands originally fit this definition (though the extermination of island animals by seafaring peoples has been going on so long that oceanic isolation is certainly no guarantee of an intact habitat). However, until very recently much of tropical ecology has been based on biology occurring in widespread habitats rather than in small reserves, while the study and conceptualizations of evolution in nature have usually been based on the small populations characteristic of small reserves. Just at the time that tropical science is becoming aware of the distinctness of the ecology of widespread populations, these populations are being fragmented into tiny reserves.

Most tropical wildland reserves have one of two origins. They may be arbitrarily carved out of widespread habitats, as happened when the base of the Trinidad peninsula was inundated by a rising sea-level or when Barro Colorado Island in Panama was formed by the Gatun Lake impoundment. Almost all mainland national parks and other kinds of reserves have been formed by this process of fragmentation or severe shrinkage of widespread habitats. Thus, they arrive at their ecological structure by a process of species and habitat loss. The other kind of wildland reserve is formed by the colonization of a new substrate by immigrants. Such a biology is most pertinent to newly formed mainland reserves on agricultural land taken out of production and to the rare case where a true island is given reserve status.

The Formation Process

The ecology of reserve formation is long overdue as an explicit area of ecological study.

Regimes of reserve formation range from those in which the reserve is abruptly delimited and carved out of the forest (e.g. forest reserves left as islands in major timber clear-cutting operations) to those in which agricultural habitats have been in place for centuries and have gradually coalesced to surround the wildland reserve (the formation regime for many small tropical national parks). Abrupt reserve formation displays dramatically the decay of the habitat edges (e.g. tree death from wind and desiccation, influx of living dead, explosive expansion of ruderal populations, etc.), but these same processes also occur during more gradual reserve formation. The latter is, however, almost always unnoticed because the gradual changes lead local residents and biologists to view them as natural and because they are spread out in time and over many species. For example, it is difficult to convince the human population in a thoroughly pasturized tropical habitat that the annual grass fires were not part of the biology of the dry forest that once stood on the site.

Once a reserve is formed, it is characterized by frequent and/or severe changes in the general vicinity of the reserve. There are changes in local climate, changes in fire regime, plant and animal introductions from agriculturalized habitats, eliminations of sources and sinks for migrants, etc. Traditional dry forest preservelets in Australia, persisting under the care of Aboriginals for tens of thousands of years in a fire-rich habitat, are now being turned to ash by cattlemen's fires. Long-established lowland rainforest wildland reserves lose their cross-tropical migrants as the tropical highlands and tropical dry forests are cleared.

At the time of rapid reserve formation, the agricultural habitats in the vicinity are likely to be undergoing maximum and rapid swings in hospitability to reserve organisms. The secondary succession immediately following lumbering or slash/burn clearing is often extraordinarily rich in food for animals (thereby inundating the reserve with immigrants and living dead). Only a few years later the area becomes a pesticide-rich biological desert that absorbs reserve animals and invades the reserve's streams with the pesticide-rich runoff that follows agricultural intensification.

Established Wildland Reserves

Tropical wildland reserves generally have significantly fewer species in common with adjacent agriculturalized habitats than do extra-tropical reserves. This gradient derives both from the fact that tropical organisms are more habitat- and biotic-specialists than are extratropical organisms, and from differences in agricultural practices in the two regions. However, in the extreme, such as in fixed-field mechanized agriculture, the agriculturized habitats may have almost nothing in common with adjacent wildlands, whether they are in or out of the tropics.

Tropical wildland reserves are interlinked by migratory animals, just as were the large habitat expanses from which the reserves were designated. When a reserve is formed, migration becomes an act of island-hopping. Habitat fragmentation may have a lesser impact on migrant species that fly to a general area and then search for the best habitat than on species that simply arrive haphazardly. However, the reserve may also receive an overdose of searchers. Furthermore, diminution of migrant production by the reserve should lead to eventual diminution of arrivals of both kinds of migrants at the reserve.

Wildland reserves on mainlands have many small populations carved from once widespread populations. Just as on real islands, these small populations are now prone to reduction in genetic diversity and evolutionary wandering. On the other hand, mainland reserves are much less depauperate in species and life forms than are islands (though in very small mainland reserves, species arrays can approach the distorted habitat-level structure characteristic of oceanic islands). The outcome should be less rapid and less divergent evolutionary change in the small populations in reserves than on oceanic islands, for example.

In contrast with many true islands, mainland wildland reserves are usually not surrounded by habitats the inhospitality of which is readily evident to wild animals. The reserve boundary becomes an absorbing edge for animals, a direct mortality agent rather than an electric fence. The same applies to plants, through the process of seed and pollen rain into agriculturalized habitats; these juveniles are the incoming living dead.

Wildland reserves of any size are subject to continuous invasion by competitors and consumers from agriculturalized habitats. Some invaders are native, some introduced. Wild native animals from reserves are often subsidized by nearby agriculturalized habitats, with the result that their density (and thus their impact) is far greater than the wildland can support without permanent habitat alteration. Similarly, the Indian mongoose introduced to Puerto Rico has swept El Yunque National Park as well as the rest of the island; African cattle egrets and Africanized honey bees are inside as well as outside the Central American national parks (though it is not likely that all introduced animals would have persisted in large areas of pristine vegetation). It is disturbing to think of what is going to happen when the African big game animals naturalized in Texas begin their southward movement.

Widespread habitats are large enough to influence regional climates; but small wildland reserves are not large enough to maintain such influence. A climatic change is no novelty for a tropical population or habitat. What is novel is that as the climate changes there is no adjacent wildland from which invasion of newly appropriate species can occur, or to which the habitat can move. A moist forest undergoing desertification does not accumulate arid land species from surrounding cotton fields.

The process of selection of wildland reserves gives us a biased sample of the tropics for our future ecological understanding and human use. Areas with high "endemism" are favorite targets of conservation efforts, yet the high endemism of such areas is a biological marker for being atypical of the vast bulk of tropical habitats. Habitats rich in birds and mammals are more likely to be saved than are those rich in insects and plants. The legitimate emphasis on avoiding extinction of species leads automatically to less concern over the ecologically spectacular but species-poor habitats (dry forest, swamps, high elevations, poor soils, etc). A habitat fragment is virtually never preserved by provision of adjacent land to reoccupy through expansive invasion, though this method of conservation is biologically highly feasible. Reserves are generally established where large blocks of forest still exist; these are often montane. Flatland forests tend to be destroyed well before those on steep hillsides. The result is that future tropical biologists may well be unduly influenced by ecological processes characteristic of steep slopes. Similarly, widespread and seemingly uniform tropical flatland widespread habitats are actually mosaics of many kinds of habitats; small reserves (e.g. several hundred km^2 or less) therefore are only a haphazard and randomly chosen subset of these habitats. Our future image of past widespread tropical habitats, as represented by the bits we save now, is in danger of being misrepresentative.

WHAT DO TROPICAL SPECIES OFFER HUMANITY?

Tropical species in wildlands offer intellectual stimulation and development (especially to those who live in the tropics), living examples pertinent to habitat manipulation, and direct goods. The future of tropical ecology rests on whether we set aside a small percentage of the wildland tropics for offerings other than presently harvested direct goods or whether we continue to mine the tropics for direct goods through wildland harvest and wildland conversion to biotic factories to feed human draught animals.

Direct Goods

What direct goods have the tropics provided? For a start, chickens, eggs, elephants, turkeys, beef, pyrethrum, corn, rice, coffee, corsage orchids, tea, chocolate, morphine, tobacco, cocaine, dahlias, cotton, marijuana, aquarium fish, marigolds, strychnine, parrots, bamboo, macadamia nuts, rum, pepper, honey bees, vanilla, milk, peppers, cinnamon, dates, quinine, rubber, gardenias, bananas, avocados, mahogany, pineapples, impatiens, humans, sorghum, rosewood, coconuts, Brazil nuts, peanuts, potatoes, sweet potatoes, manihot (tapioca), squash, chimpanzees, pumpkins, beans, cane sugar, molasses, tomatoes, cats, guinea pigs, citrus, white rats, palm oil, rhesus monkeys. How many potential polio victims realize that their vaccine was grown in a chicken egg, and chickens are nothing more than tropical pheasants specialized at preying on bamboo seed crops (which an Illinois farmer mimics with his chicken feed). The number one trade item between Russia and the United States in 1985 was a tropical crop, corn.

It is a useless conceit to think that our ancestors recognized more than a minute fraction of the useful products produced by the millions of species of organisms still surviving in tropical wildlands. Admittedly, when you take a bite out of a tropical forest, the most common flavor is somewhere between "ugh" and "gasp." However, the average taste of unprocessed olives, tobacco leaves, coffee seeds, chocolate beans and black beans is no better. Wild potatoes are so poisonous that they were originally eaten diced into a slurry of clay that absorbed the toxic alkaloids that protected them from digging herbivores.

What then do tropical wildlands offer in examples of goods? Put most simply, the tropics contain millions of species of organisms that could be managed to produce products of use to humanity. The realization of this potential requires nothing more than safety of the remaining wildlands they occupy, systematic and innovative curiosity about the traits of the organisms, data filing and retrieval systems for the accumulated information, and financed interest in moving ahead with the job. We need deliberate effort, imagination, selective breeding, genetic engineering, foresightful financing, innovative advertising, gene and species banks, and an understanding of tropical biology as an integral part of tropical schooling. There are no great intellectual barriers, though there are numerous social barriers, concerning what is a "good" tropical organism and what mixes of them we wish to have. The tropical ecologist has an obvious role.

The production of tropical goods is a very mixed blessing. The reason we still have some tropical wildlands to puzzle over is that humans have done so poorly at production, storage, and distribution in most parts of the tropics. If society had treated the potential crops of the Amazon basin as it did those of Illinois, the Amazon basin would look like Illinois or worse. We will never know what wildlands grew where today grow the tropical breadbaskets (mostly in seasonally dry forest and on midelevation gentle slopes). It is terrifying to think what will happen to the rain forest the day we come up with a high yield crop plant that grows well on rain forest soils and can be grown by everyone from the small farmer to corporations. The ecologist's role would be to negotiate a settlement with commercial interests and society at large, a settlement that contains guarantees that the mouth will not eat the hands.

The primary use of contemporary tropical agricultural output is direct sustenance of the laboring poor. These humans work for the most part in tropical agriculture or factories, and their surplus production goes to feed cities or to export. It has not been traditional in the tropics to work toward cultural enlightenment of these workers. If we use the remaining tropical wildlands simply to increase the numbers of humans supported by tropical habitats, we have done nothing but increase the volume of human misery. One hundred people planting rice by hand are as miserable as 25 doing the same. And, it does not matter if they are planting some newly domesticated rain forest vine that produces protein-rich seeds along with the rice. The tropics doesn't need more food. It needs cultural infrastructures that will manage what it does have so as to raise the quality of intellectual and physical life for its humans.

The blossoming legal argument over commercial possession of tropical genetic information has nothing to do with the tropics per se. It is one commercial enterprise vs another. Tropical enterprises characteristically lose to extratropical enterprises in these contests. This is not because they are tropical but because they are often incompetently organized and noncollaborative, and because many tropical countries are small, defined by historical politics rather than ecological coherence, and based on highly heterogeneous mosaics of high- and low-grade real estate and habitats. Furthermore, the production from such habitat mosaics favors grossly skewed distributions of wealth (though it is evident that other tropical conditions are also in part responsible for that).

It is much to the advantage of tropical populations to raise both their competence and real estate value; neither is accomplished by converting wildlands to food for humans. Improvement will not be brought about by the contemporary dilettante approach to tropical ecology, nor by the activities of those who are agriculturalizing the few remaining tropical wildlands. Both areas of endeavor include novices, incompetents, social outcasts, visitors, noncommunicators, social climbers, and do-gooders, and are sustained by trivial budgets. They present neither a collective vision nor a coherent and dignified future for portions or all of the tropics.

Technology of Goods and Habitat Manipulation

The ecologists have not been selling what they know to the enemy, and the agroecosystem planners have been disdainful of the field biologists. Both have good cause, in the narrow sense, for their isolationist attitudes, and both are responsible for the fact that at least 90% of current tropical agroecosystems are dysfunctional. In those cases where the organisms and management systems are traditional, they are embedded in disrupted and confused social systems that are in the process of being disassembled by commercialists engaged in retooling cultures to respond to external markets. And where the organisms and management are the products of modern crop selection and market design, the human participants have generally been pressed into the role of impoverished manual laborers. Tropical peoples have generally lost the cultural richness and modest agricultural production of their ancestors, and share only trivially in the cultural richness and overall higher cultural productivity of the distant social systems that they support as they tend cattle, mine gold, net fish, and pick cotton.

If the future of tropical peoples is to build their societies on the crop genes that have been captured to date, and on the known organism-organism interactions, their future is bleak. Their countries are consigned to being little more than monotonous, pesticide-rich, backwoods farming states in large industrial nations. If the highly divided tropical nations ever stood, divided they have already fallen. The industrialized nations hardly view it as useful to plan toward cultural enlightenment of tropical draught humans.

There appears to be an almost deliberate effort to hasten the decay of information about tropical wild systems, except where the information can be captured by a present-day commercial interest. I cannot name a single major harvester of any tropical product that has undertaken the long-term maintenance of a representative piece of wildland of the type from which the product's fields were cleared. A major part of the present tropical conservation effort is not home-grown (the once omnipresent indigenous rules regulating harvest intensity have for the most part died). But then again, most of the concern of the extratropical world for conservation of wildlands also has its roots deep in earlier cultures. Furthermore, the major impetus for conservation in the "developed" world has been the virtually total destruction of extratropical nature. The outstanding uniqueness of the tropics is not so much its diversity as the fact that there is still something in the tropics over which to make a conservation fuss. Where can you go in Europe or North America to establish a national park on 500 km^2 of relatively pristine forest vegetation?

Tropical benefits in the form of lessons and examples of habitat manipulation are more complex and difficult to describe than is the case with the direct goods mentioned earlier, but these benefits are equally rich. Agroecosystem design and management is essentially the art and science of constructing habitats according to this or that desired pattern of biological products. The essential requirement of a successful agroecosystem is that the persons influenced by it are in agreement over what is desired from it. Once this requirement has been met, humans are hobbled by their general incompetence at imagining the possible ways to fit things together. What wildlands offer, and humans have done very poorly at exploiting, are examples of how to fit complicated parts together to get this or that result.

If one simply wants *n* kilos of rice per hectare, then wildlands have little to offer in examples of interactions. But if the goal is instead something like "take these 10,000 ha of flat swampy soil and maximize agroecosystem produce while minimizing human labor, use of fossil fuels, agrochemical contamination, soil degradation, market inflexibility, etc", then wildland wetland ecosystems have much to offer. The best system designer will be someone who has extensive experience with the mechanics of wild tropical wetland processes. The most likely person to anticipate the key (but seemingly minor) natural history details will be the person who has watched such details in operation. The tropical wetland is a rich storehouse of independent potential participants whose potential interactions are most evident when they are in fact interacting. A good carpenter has more than one kind of wood and nails at hand when he builds a house, and he learns much by studying houses constructed by other cultures. Africanized honey bees may well turn out to be the best honey-making machines for the neotropics. Water buffalo might well be the best beef-producers for tropical Australia. If the right seed dispersers are present, natural seed flow may give better tropical reforestation than will planting schemes. It is not encouraging to see major timber plantations, fuelwood plantings, and soil protection based on a few species of secondary fast-growing succession trees, rather than on the multitude of wildland trees with multiple beneficial traits and many combinatorial possibilities.

Barriers

What the tropics have to offer is evident, but there are some conspicuous barriers to realizing the potential inherent to incorporating wildland species and information into tropical agroecosystems. The future of tropical ecology lies in breaking down these barriers, and ecologists must become specialists at dealing with at least the following problems.

We learn directly or vicariously by watching someone else do something. Tropical peoples see extratropical cultures with products that they want. They therefore mime the resource harvest processes of extratropical cultures. However, extratropical cultures, based on species-poor habitats, think that wildlands have nothing to offer in material goods. No North American extratropical crop of contemporary significance is indigenous (except timber). Much of the success of extratropical crops comes about not only through massive extermination of wildland denizens, but because the crop is being grown in a habitat far from its origin (which is also true of the major tropical crops). In addition, extratropical crops are cared for during the winter, but their pests are not afforded such hospitality. Tropical agriculturalists are following the wrong examples of how to construct an agroecosystem.

We cannot communicate what we know and are finding out about the tropics without having names for the parts. Tropical wildlands are like enormous libraries with names on less than 20% of the books, almost no filing system or card catalogue for the books with names, and most of all the books arranged haphazardly on the shelves. Until there is a massive resource infusion into the taxonomy and classification of tropical organisms, the rate of acquisition, synthesis, and use of knowledge about tropical wildlands will stutter and move so slowly that the world at large can hardly be blamed for viewing wildlands as a featureless blot on the agroscape.

Mimicry of extratropical cultures by tropical peoples involves more than the nuts and bolts of agroecosystems. It occurs at all levels, from replacement of fresh oranges by pasteurized orange juice in paper containers to adoption of the National Park concept. The bad comes with the good. However, tropical agroecosystems are much more fragile in the face of new technology than are those of the developed world; the use of myrex, a pesticide for ants that is also very dangerous to wildlife, is effectively curbed by law in the United States and is only a minor nuisance in the swirl of political power and land use in Florida. In the less regulated Costa Rican countryside, when introduced to protect citrus groves from leaf-cutter ants, myrex is a serious threat and may never be effectively controlled.

Sparks of cultural generosity are no more abundant among the members of the power structure of indigenous tropical peoples than they are among the extratropical business world. The desire for short-term returns on invested funds steadily drives tropical agroecosystems towards maximization of marketable traits rather than to optimization of standard of living.

Each tropical country is busy inventing its own wheel. Does every tropical country have to discover for itself how to use fire in habitat control? Does each have to learn for itself what happens when you introduce large browsing mammals into wildlands? It is like having 35 small clothing stores all simultaneously going broke on the same street. A truly functional Latin American common market is difficult to envision. Poor countries squabble and look outside the tropics for strength, none feeling strong enough to be a solid partner. Each tropical experiment station is trying to invent the same pots, each search for pots of value to the extratropical markets, and almost none makes use of information, gathered in other countries, on wild organisms. There is almost no cross-tropical circulation of tropical journals, and little interest when one does arrive. There are small rays of hope scattered here and there, but almost no social links between them.

There are severe language barriers. The practice of field science takes place in habitats rich in the languages of rural areas, and there is much more intercountry diversity of rural languages in the tropics than extratropically. Furthermore, few of these rural languages are ones in which science is commonly discussed.

There is almost no cross-tropical exchange of young scientists, ecologists, or other kinds of agroecosystem planners. When senior personnel travel to foreign meetings, they spend their time in conference rooms and one-day excursions designed to be vacations; rather, their foreign experience should be as young field workers giving weeks or months of their lives to understanding other tropical agroecosystems.

The study of field biology and ecology is largely absent from the basic educational process in virtually all tropical countries. The fact that many rural children drop out of tropical schools after only a few years has much more to do with the absence of useful subject matter than it does with societal disinterest in learning per se or the learning capacity of the children. A theoretical and pragmatic understanding of how agroecosystems and their contained organisms function is of paramount importance to the people living in tropical agroecosystems; however, tropical school curricula generally mimic, poorly, the schools of developed countries rather than encourage home-grown efforts to produce humans who understand and control themselves and their environments.

Wildlands can be used to generate economic resources through ecotourism just as surely as, yet far more pleasantly and elegantly than, can more traditional kinds of tourist attractions. There is one clear way to raise the quality of tropical real estate. Develop a crop that pays better. And there are few tropical crops that pay better per hectare than does tourism. However, the tourist does not go to Kenya to see the airport, and sugar-cane fields are not a big tourist attraction in Brazil and Mexico.

Wildland tourism does have one peculiar trait. People have become so ignorant about living natural history that they have to be educated, so to speak, on the spot. The real future of wildland tourism is in visitor education, in the stimulation of emotional, physiological, and intellectual curiosity about wildlands, the back garden during 99% of human evolution. The world gets rapidly bored staring at crocodiles, eucalyptus trees, and koala bears. But, give watchers their ecological stories, and you gain not only their attention but a feeling of deep penetration and long duration of the value of wildland. In tourism, time on the site means income. Tropical wildlands desperately need to be made user-friendly.

Intellectual Stimulation

Tropical agroecosystems produce people. Wildland reserves are embedded in the agroecosystem, not perched on its margins. What will we do when we have captured all of a wildland's genetic information, used all of its examples? Do we then turn it into a few hectares of low-grade cropland? No, no more than we turn our brains into hamburger once computers begin to perform the bulk of the operations previously performed by the human brain. Wildlands must be used to raise the intellectual quality of life for those living in the agroecosystem.

People must be measured in something other than kilograms and body counts. I have already stressed that nobody worries about the quality of mental life for humans in the tropics, on the farm or in a city. But the planners will worry when it affects performance. One can train a human how to use a machine gun and hand grenade in an afternoon; it takes at least the first 20 years of life to teach him why that is not the solution. You may think that life in a midwestern corn field is boring, but it is an intellectual hotbed compared to life in an oil palm plantation or tropical cattle pasture (with no winter vacation to the Bahamas, no library, no car, no newspaper, no real schooling, no music, no university, no indigenous culture, and nowhere to go). Even the seasons are gone, since their biological manifestation has been obliterated. You may think immigrant labor sweatshops are appalling, but picking coffee or cotton at US $0.50 an hour in a country where gasoline costs $1.00 a liter and food staples cost as much as in the US supermarket is no better.

A functional agroecosystem has schools, entertainment, vacations, health care, good roads, emergency plans, etc. But if this is simply sandwiched into oceans of agricultural land, it's a green desert. Wildland reserves are a major and integral part of the effort that simply has to give tropical humanity (back) the same habitat diversity that the extratropical regions seek so desperately. It is not a mere fad that the US national parks are in such demand that you have to make a reservation to camp there. It is no accident that virtually every home in the United States has one or more representations of the natural world inside it. For many tropical agroecosystems, the cultural life offered by a small town and a large wildland reserve, if educationally user-friendly, is likely to be the only wall between mental survival and intellectual agroservitude. A person without the greater natural world to respond to and be stimulated by is as culturally deprived as someone whose hearing, sight, or reasoning power has been stripped away. And for the bargain hunters, I should mention that at all budgetary levels, wildlands are the best possible return on the dollar in efforts to raise the cultural quality of a region. Once established and widely experienced, their management costs are minimal.

I trust these arguments apply to those of tropical urban life and the world's culture overall, as well as to people living directly within the production component of tropical agroecosystems. The cultural importance of, say, North American tourist travel and learning within Europe is only a pale forerunner of the rich but undeveloped potential for cultural enlightenment of that same audience in the tropics' wildlands. Two ingredients are needed: wildlands and biologists/ecologists to prepare them for the stage.

IN CLOSING

Humans were invented in the tropics. Some left, and then some returned with a vengeance. The returnees come with the collective weight of world culture and technology on their backs and in their hands. They and the tropical residents are closing in at this moment on the world's last human-accessible frontier. We have less than one human lifespan to determine whether the tropics will be simply a very large pasture for human inhabitants, or whether it will also contain some rich and rewarding habitats in which humans can fully develop their mental and sensory potential. For most tropical peoples, wildlands are the closest there will ever be to libraries, concert halls, museums, universities, parks, and sports arenas. These wildlands are simultaneously gene, organism, and ecosystem banks. These wildlands offer far more examples of the interactions of complex units than humans will ever discover on their own; and recall, humans did not merely cerebrate their way to the moon. They built on many little lessons first learned by humans in wildlands and dutifully transmitted generation after generation to the present. It was an apple that fell on Newton's head, not a pop bottle from a passing airplane.

In the end, the future population of this earth will inherit and guard no more of tropical species and wildlands than we set aside in our lifetime. For the moment, the tropical ecologist fills the role of curator and champion of these patches of living knowledge. If the ecologist attempts to carry this burden alone, failure is guaranteed. The tropical ecologist can at best offer a temporary overview and some working guidelines to people in more specialized areas of human endeavor until the general population recognizes tropical wildlands as an integral part of humanity.

Wildlands are living seedbanks; ecologists should encourage and develop research on this resource. Wildlands are educational institutions; ecologists have the major responsibility to disseminate wildland knowledge into the neighboring community and the world at large, to make tropical wildlands user-friendly. Wildlands, and especially tropical ones, are living models of how complex organisms interact to produce larger collective structures; the ecologist is the professional at teasing out the ground rules of such interactions. Tropical agroecosystems and wildlands have many things in common with their extratropical parallels, yet they also differ in many ways; ecologists must become professional at telling when, how, and why this is so. And ecologists in their search for pattern and process must train themselves to apply what they discover in the tropics to the planning of its immediate future. Ecologists understand above all that to understand and maintain what is inside, you have to understand what is outside.

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