THE FAUNA OF
DOLPHIN HEAD, JAMAICA

A Report on the Status of Wildlife Diversity and the Effects of Habitat Modifications on Ecological Communities, Dolphin Head Environs

for

Dolphin Head Trust

United Nations Development Programme

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ACRONYMS

ANOVA	Analysis of Variance
CBD	Convention on Biological Diversity
CHM	Clearing House Mechanism
CIDA	Canadian International Development Agency
DH	Dolphin Head
FD	Forestry Department
GoJ	Government of Jamaica
IoJ	Institute of Jamaica
MYA	Million Years Ago
NEPA	National Environment and Planning Agency
NRCA	Natural Resources Conservation Authority
NGO	Non-Governmental Organization(s)
SE	Standard Error
UNDP	United Nations Development Programme

ACKNOWLEDGMENTS

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EXECUTIVE SUMMARY

Dolphin Head and adjacent mountains represent a nationally- and globally unique ecosystem, noted particularly for their extraordinarily high levels of endemism among plant species. The forests support a rich and diverse wildlife community of nearly 150 species, representing 61 families in 10 classes of 4 phyla. Further research should add to this list, particularly for arboreal insects and land snails. At least 50 of the Dolphin Head species are endemic to Jamaica and a miminum four (1 freshwater crab *Sesarma dolphinium*, 2 Lampyridae fireflies, 1 species of Operculate snail) are endemic to Dolphin Head. These endemics are small animals with limited dispersal capabilities and, as seen with the crab, highly restricted habitat requirements. Indeed, *Sesarma dolphinium's* global range appears to be restricted to a small area of emergent springs in the cockpit-type karst of God Almighty Bridge, Askenish.

Dolphin Head further supports a diverse community of vertebrates, including nine of Jamaica's 22 endemic frogs (including two that are restricted to western Jamaica), four endemic *Anolis* lizards, several geckos, galliwasps and the small Black Groundsnake. Although no species of bird is restricted in range to Dolphin Head, 21 of Jamaica's 28 endemic land birds, 23 of 70 resident breeding birds and 11 migratory species occur across the gradient of available habitats. Forest-dependent birds include the endemic Ring-tailed Pigeon, Jamaican Elaenia, and the Arrow-headed Warbler. Similarly, no bat species is endemic solely to Dolphin Head. However, one of Jamaica's four endemic bats, the Jamaican Fig-eating Bat, occurs within the forested environs. This bat is the single species in its genus (i.e. the genus is endemic to Jamaica) and is listed as "Vulnerable" by the IUCN, meaning it faces a high risk of extinction in the wild in the medium-term. It was encountered only in the western portion of Dolphin Head, in the Retirement Forest and, like many of the large fruit-eating birds (e.g., White-crowned Pigeon), was seasonal in its movements, presumably following ephemeral food resources.

The forests and wildlife of Dolphin Head have been subjected to variable human pressures for the past four centuries. Large-scale conversion of natural forest for agriculture and rural settlements has isolated Dolphin Head from other remnants of broadleaf-forest-over-limestone and may have resulted in the extinction of endemic plants. Cleared forest patches are rapidly invaded by non-native plant species, which hinder natural forest regeneration. Introduced wildlife, such as the mongoose, move easily through the forest, while openings in the forest canopy facilitate the invasion of non-native frogs and toads. The effects such incursions have on wildlife communities are highly variable and depend upon the type and location of disturbance as well as the wildlife species of concern.

As areas become less diverse, both in terms of plant species composition and structure, wildlife diversity decreases. Habitats dominated by Bamboo, Red Bead Tree and Rose Apple represent biologically-sterile environments, hosting both low faunal diversity and abundance of individuals. This association was particularly salient for terrestrial invertebrates and bird species. When deforestation occurred on hilltops (as associated with clearing for marijuana cultivation), use of the habitat by birds declined significantly in comparison to closed-canopy minimally and moderately disturbed forest. Terrestrial invertebrate populations appeared to be less affected by this clearing location. Whether this was because natural conditions on hilltops fail to provide suitable microhabitats (e.g., soil formation is poor as substrate is acidic humus on limestone hilltops) for terrestrial invertebrates or because mongoose, which prey on invertebrates and vertebrates, were common on the surveyed hilltop is unknown. Additional sampling is needed. Terrestrial invertebrates, however, were affected by clearing of forest in low-lying areas, where good soil formation occurs. Millipedes served as suitable indicators of habitat degradation. As canopy cover was removed and soils were exposed to drying abiotic factors, millipede populations disappeared. The loss of these species, which assist in formation and aeration of soils, will impair ecosystem function.

Deforestation affects not only terrestrial biota but also subterranean ecosystems in limestone environments. Garbage and siltation have degraded Clifton Cave, the latter appearing to have affected the hydrology of the underground river, which feeds into the Lucea River. American cockroaches were abundant within the cave; in the absence of pre-introduction faunal surveys, it is impossible to quantify their effects on native cave-dwelling invertebrates. Removal of bat guano for fertilizer disturbs roosting and breeding bats, which are restricted to a few large, chambered caves.

The communities on the periphery of Dolphin Head express a strong connection with "The Dolphin." Effective protection and conservation of this unique ecosystem and the endemic biological diversity found within will be achieved only with their participation. In order to prevent the loss of further biodiversity, local community efforts should be directed towards:

- Preventing further clearing of natural forest to maintain the largest possible area of closed-canopy habitat for forest-dependent species; this strategy will serve further to protect endemic plants which depend upon wildlife for seed dispersal and pollination.

- Restore degraded hilltops and valleys that are dominated by non-native, invasive plant species (e.g., ferns) to prevent further encroachment into core forested areas; natural forest regeneration appears hindered in the absence of human intervention.

- Rehabilitate peripheral rural hillsides, notably those dominated by Bamboo, with forestry plantation and mixed-fruit tree species; this activity will provide viable habitat for resident and migrant species as well as provide long-term economic benefit from resource harvesting.

1.0 INTRODUCTION

The protection and conservation of the Dolphin Head limestone ecosystem, which is recognized nationally and globally for its unique biological diversity, requires an integrated management plan and the participation of all relevant stakeholders. Management should be directed towards:

1. Preventing further losses of natural forest in order to conserve the variety of life forms, their ecological functions, and the genetic diversity they contain;
2. Restoring degraded areas, particularly abandoned cultivations on hilltops within the core forested area;
3. Rehabilitating peripheral areas dominated by non-native plant species, particularly Bamboo (*Bambusa vulgaris*), to bring these lands back into productive use and expand the range of available habitat to native and migratory wildlife.

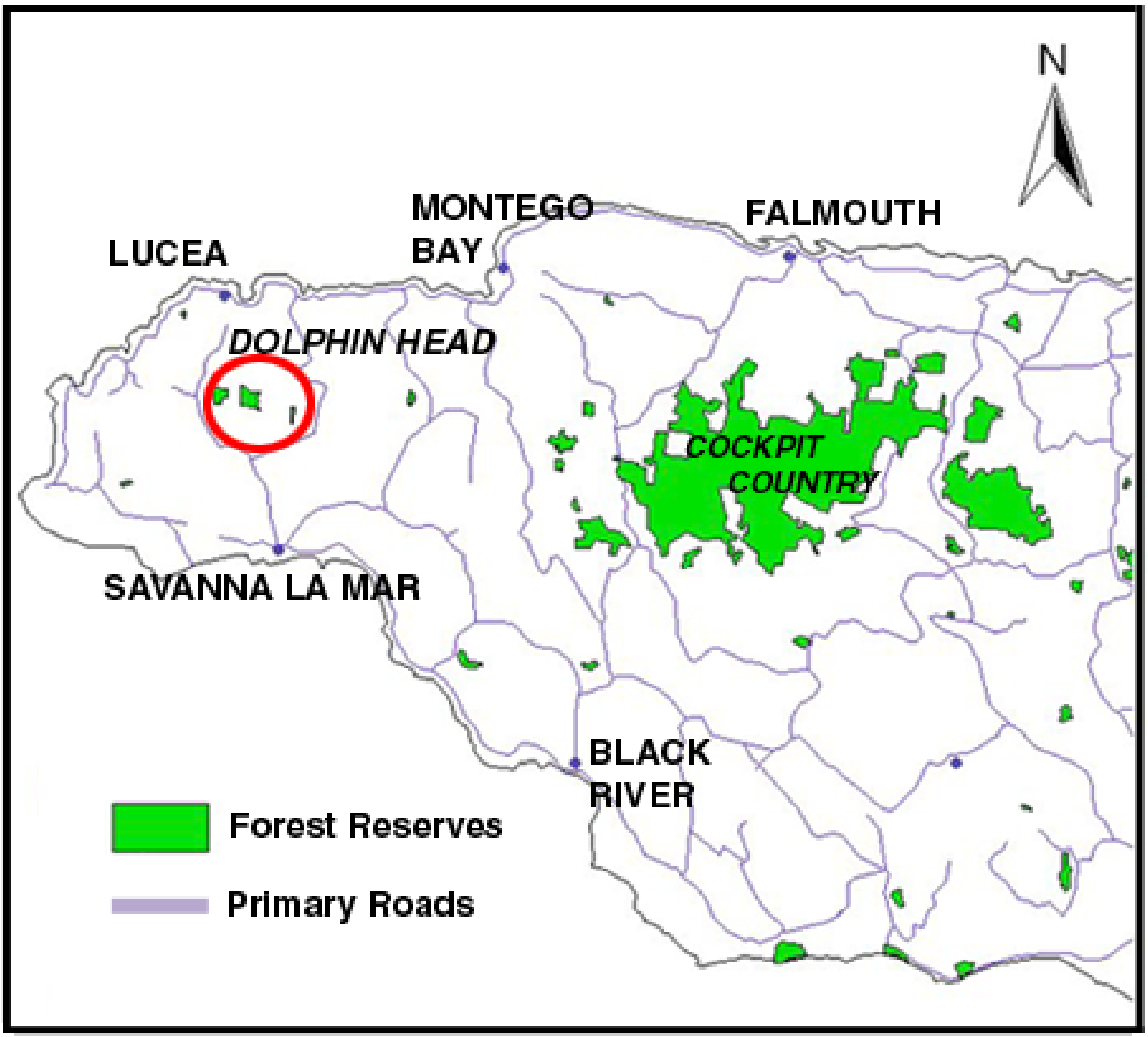
> *To understand and manage limestone areas requires seeing them as complex three-dimensional integrated natural systems. The features of limestone landscapes depend on the interaction between the components of the system: rock, water, air, soil, life (plant and animal), energy and time. The integrity of the systems depends on the preservation of this interaction. If the balance is upset by sudden changes in one or more components, the whole system may be disrupted.*
>
> *Gillieson 1996*

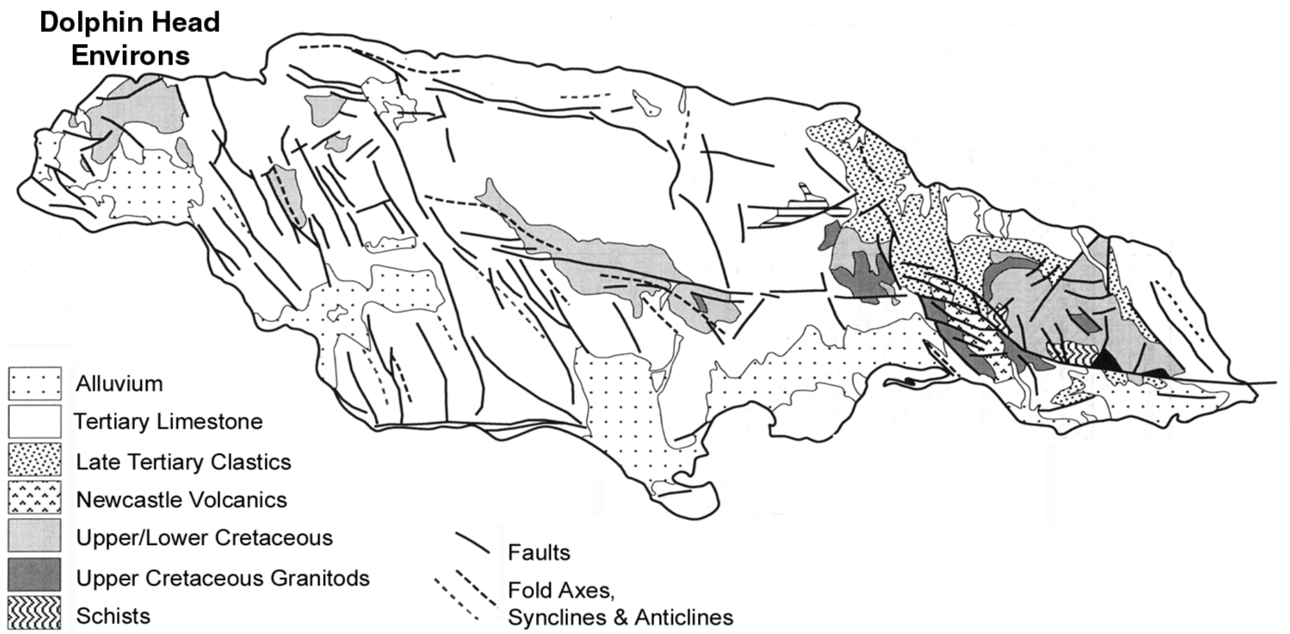
1.1 Site Description and Conservation Significance

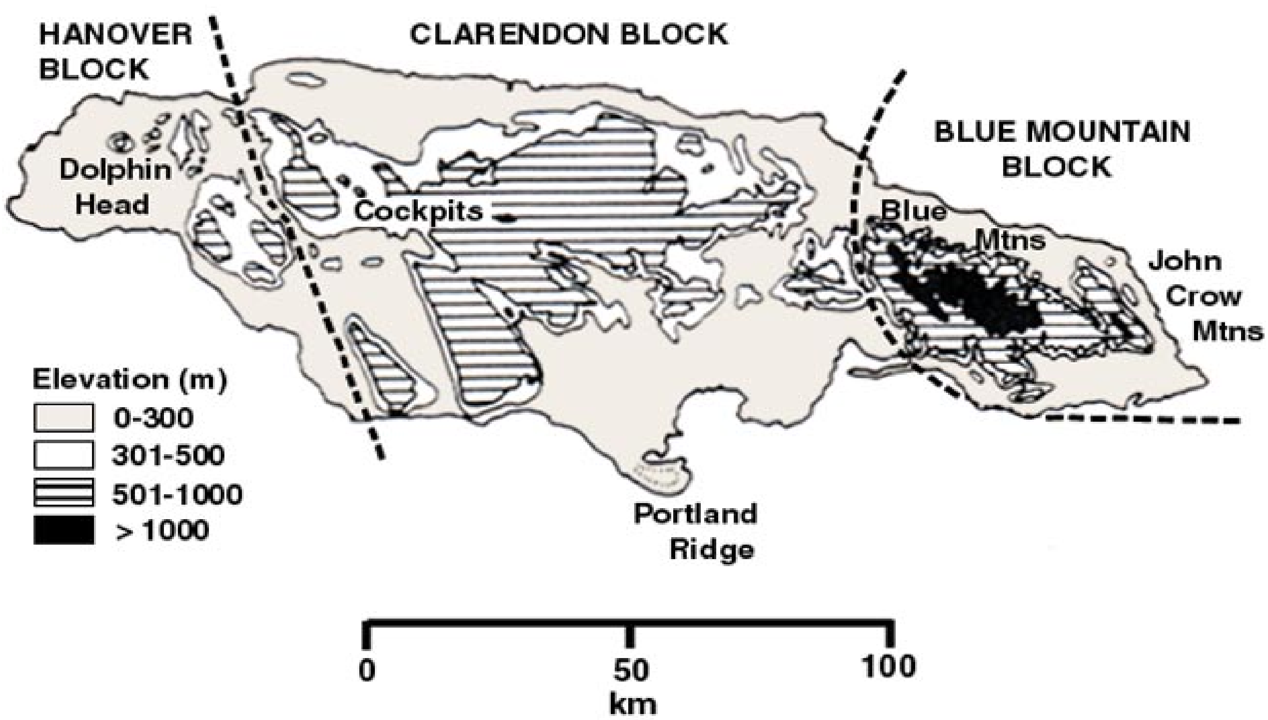
1.1.1 Dolphin Head - An Island Within An Island

Dolphin Head and adjacent forested mountains (hereafter referred collectively as Dolphin Head [DH]) are located at the western end of Jamaica between latitude $18^{0}21'$ to $18^{0}25'$ and longitude $78^{0}08'$ to $78^{0}13'$ west longitude (Figure 1). The area is recognized as the western-most portion of the mountainous spine stretching across Jamaica from the John Crow Mountains (limestone) and Blue Mountains (igneous shales) in the East through Mount Diablo and Cockpit Country (limestone) and igneous Central Inlier of the Central Plateau, to the limestone-over-shale Dolphin Head mountains of the Hanover Block in the West. The white limestones of the Central Plateau and Dolphin Head-Hanover Block were deposited during the lower and middle Tertiary Period (65-25 million years ago [MYA]), when large-scale subsidence left Jamaica fully submerged by 1-2 kilometers or more (Steineck 1974). Beginning in the late Oligocene or early Miocene epochs (25 MYA), Jamaica began to emerge via tectonic uplift. North-central Jamaica appeared first, soon followed by the eastern Blue Mountains and the highest peaks of extreme western Jamaica (Figure 2). As uplift continued, these "islands" eventually coalesced, but the present configuration of Jamaica was not reached until the late Miocene (8 MYA). Consequently, the earliest plants and animals that arrived to colonize western Jamaica may have been isolated for more than 10 million years before a "landbridge" with the Central Plateau enabled interactions among many terrestrial species.

Figure 1. Dolphin Head within its regional context of western Jamaica.







Figures 2a & 2b. Geologic and topographic maps of Jamaica highlighting the geologic discontinuity of Dolphin Head environs (limestone escarpment surrounded by shale and alluvium) and the three structural blocks that form the island. As Jamaica was uplifted from the ocean 25 million years ago, the white limestone of north central Jamaica was the first land to emerge. The eastern Blue Mountain Block soon followed, but probably as an island separated from the Clarendon Block by the Wagwater Trough. Extreme western Jamaica (Hanover Block) is thought to have initially been a third island separated from the Clarendon Block by the Montpelier-Newmarket graben. As uplift continued, these islands coalesced to the present configuration, although not until the late Miocene (8 MYA). Thus, some of the flora and fauna of Dolphin Head may have evolved in relative isolation for up to 10-15 million years. Maps adapted from Fincham (1997) and Hedges (1989).

Jamaica has not been attached to any other island or continent since its Miocene emergence and, consequently, the entire terrestrial biota had its origin by dispersal over the marine barrier within the last 25 million years (Buskirk 1985). Because of this isolation, species diversity on Jamaica is typical of an oceanic island. Compared to a mainland area of comparable size and latitude, the species richness is depauperate, with many taxonomic groups of poor over-water dispersal ability absent from the biota. However, for the successful colonizing species, Jamaica's size (11,290 km^2), diverse physical features (sea level - 2255m), and climate (rainfall 0 – 500+ cm per annum) provided a wide range of microhabitats that facilitated within-island radiation and speciation. The present composition of species represents some of the highest rates of endemism in the world, recognized particularly for ferns and flowering plants, birds, reptiles, frogs and land snails (Proctor 1985, Lack 1976, Schwartz and Henderson 1991, Kay 1995).

The limestone mantle of Jamaica is one important feature that contributed to the island's extraordinary patterns of endemism. Tropical limestone areas present extreme and diverse environmental conditions, including:

- high concentrations of calcium and magnesium
- local topographic variation of steep-sided, rocky hills and cliffs, which have poor or no soil formation, valleys with deep alkaline soils, and hilltops with acidic humus
- extreme climatic conditions, such as exposure to strong tropical sun or torrential rains followed by near-drought conditions because of a very efficient underground drainage system

These conditions exert strong ecological pressure on species, particularly on sessile organisms (such as plants or animals with limited mobility). Species either adapt quickly (accelerated evolution) to local conditions or they go extinct. By this process, isolated populations evolve into distinct species. Some species adapt so thoroughly to a limestone substrate that any non-limestone habitat surrounding them becomes uninhabitable. In the case of Dolphin Head, many species adapted to the unique ecological conditions of the elevated limestone cap may find the surrounding shale and alluvium substrates to be barriers to dispersal that are as formidable as the Caribbean Sea. This geologic discontinuity and isolation is exacerbated by the large-scale conversion of natural forest to agriculture and rural settlements in the areas surrounding Dolphin Head. For the many site- and island-endemic species unable to adapt to this surrounding modified environment, the forests of Dolphin Head represent a last refuge. In the heavily fragmented landscape, Dolphin Head is '*an island within an island*.'

1.1.2. Forest ecosystems of Dolphin Head

The forests of Dolphin Head have been broadly classified as evergreen seasonal and closed broadleaf forest (Beard 1955, Forestry Department 2001). This formation is known also as subtropical rainforest over limestone (Kelly 1988), or moist limestone forest (Haynes-Sutton and Proctor 1992; see also Asprey and Robbins 1953). Isolated remnants of this mid-elevation, moist limestone forest-type are seen in central Jamaica (e.g., Cockpit Country, Mount Diablo), while the limestone forest of the John Crow Mountains, with its greater rainfall, is classified as wet montane limestone.

Although the forest of Dolphin Head falls into the same category of moist limestone forest and is similar in structure and regeneration patterns (e.g., gaps, building phase of pioneer species, mature phase of climax species) to the Cockpit Country (Proctor 1986, Boyd 1999), Dolphin Head's isolation from other mid-elevation limestone forests has generated a unique flora. Indeed, this forest-type designation fails to capture the uniqueness of the area's geology and terrestrial flora, both in relationship to other remnant moist limestone forests on Jamaica as well as within a global context. Botanic research thus far has identified 410 vascular plant species in the peripheral forest, 115 of which are endemic to Jamaica and 21 of which are restricted to Dolphin Head (G. Proctor pers. comm). Dolphin Head supports the highest density of endemic plant species and rare or threatened species per unit area for Jamaica. For most plant species, basic ecological information (e.g., microclimate requirements, pollinators, seed dispersers, abiotic or biotic factors limiting species range) has not been collected. Consequently, the direct and indirect effects of uncontrolled human activities on the persistence of these unique species and the disruption of ecological processes cannot be fully assessed.

1.1.3 Current status

Dolphin Head includes a core area consisting of two Forest Reserves (Raglan Mtn. and Bath Mtn.), Crown Lands managed by the Forestry Department (FD), and privately-owned lands of natural, closed- and disturbed broadleaf forests and forestry plantations. Surrounding this core is a mosaic of mixed- and non-forest land use, including bamboo, sugarcane, pasture, small family farms of yam, banana, and fruit trees, and rural communities. The remnant forest has been depleted for more than 300 years by the harvesting of valuable timber species and for fuelwood associated with sugarcane and slaked lime production. Illegal timber harvesting and clearing of hilltops for marijuana (*Cannabis sativa*) cultivation occurs within the Forest Reserves and on private lands. This latter activity facilitates invasion by non-native plant species, which hinders natural forest regeneration. While botanists consider much of the forest to be affected by human activities (past and present), it is believed that most plant species are still present as young source stock (G. Proctor, pers. comm).

The largest block of privately held forest land is owned by the Samuels family, who use the forest mainly for selective timber harvesting and grant rights to harvest timber and burn charcoal in return for a small percentage of the profits ("T" Samuels, pers. comm.). Decision-making is divided across three senior family members, but there is clear tension as to the scope of activities considered permissible, including tolerance for small-scale clearing of forest for marijuana cultivation by one elderly member of the family. Younger members support protection efforts. All members of the Samuels family and other residents with smaller landholdings express concern for government acquisition of lands and an expected increase in illegal squatting associated with limited enforcement (N. Samuels, R. Esty, pers. comm.).

Because of its high botanical diversity, Dolphin Head is ranked “Priority 1 – High Ecological Value” in the Green Paper System of Parks and Protected Areas. In accordance with the United Nations Convention on Biological Diversity (CBD), to which Jamaica is signatory, this high priority ranking recognizes that biological diversity should be conserved for its intrinsic value and its importance for the sustainable functioning of the biosphere, not primarily for its economic exploitation (United Nations 1982, 1994). Although the area is proposed as candidate to the National System of Protected Areas (NRCA/NEPA 2001), the most appropriate Protected

Areas Classification (e.g., National Nature Reserve, National Park, Habitat/Species Management Area) and consequent habitat conservation and management plan which will protect species and ecological processes has yet to be defined.

1.2 Study Aims and Objectives:

The current research was undertaken to assist in the development of a management plan for the proposed Dolphin Head Nation Park to ensure long-term conservation and protection of this nationally- and globally unique limestone ecosystem. It is recognized that local stakeholders play an important role in the Dolphin Head ecosystem, both in their abilities to protect and use sustainably the natural resources and in their abilities to damage irreparably the ecosystem. Identifying the stresses on individual species and ecosystem function is critical to developing and implementing effective mitigation strategies.

The objectives of the research were:

1. Develop a preliminary inventory of wildlife species present in the area
2. Compare the spatial and temporal distribution patterns of species across the gradient of habitats in the area, including disturbed edge and agriculture habitats, regenerating edge forest, and minimally disturbed interior forest
3. Identify specific habitat features and resources – both biotic and abiotic -- that may directly influence species distributions and their demography (survival and reproduction)
4. Develop hypotheses defining the relationships among wildlife and their environment, based on the aforementioned quantified parameters. From these hypotheses, it will be possible in the future to test predictions of the direct and indirect effects of human activities on these relationships. Directed questions include:
    - what level of disturbance can be tolerated (species or ecosystem resistance to disturbance)
    - what is the species composition following disturbance (species or ecosystem resilience) in the presence or absence of human interventions (i.e., management strategies)
5. Prioritize critical areas under greatest threat, incorporating:
    - species diversity
    - endemism
    - degree of threat
    - level of vulnerability

2. METHODOLOGY

2.1 Literature review

A preliminary faunal list documenting species richness was prepared using reference materials available on Jamaica, including collections at the Institute of Jamaica, published field guides, peer-reviewed journal articles, and technical reports. Two on-line biological abstract services were queried: BIOSIS, which provides citations for major ecological journals published in the United States, and Web of Science, which provides citations of European-based journals.

Information collected from the reference material included (a) species identity, (b) collection location and date, and (c) ecological information, such as microhabitat descriptions. While not an exhaustive search (e.g., international museum collections were not surveyed), the list provides the foundation for a reference database for managing agencies (e.g., FD, National Environment and Planning Agency (NEPA), local NGO) and national archives (Clearing House Mechanism (CHM), Institute of Jamaica (IoJ)).

2.2 Field assessments

2.2.1 Focal species

The literature-based faunal list was augmented by *ad libitum* recording of species encountered within the proposed boundaries of the Dolphin Head National Park. While location and habitat characteristics were recorded, no comparisons were made with respect to habitat associations or population densities because of the lack of random sampling and detection bias skewed to more conspicuous species.

A complete taxonomic inventory of Dolphin Head will require years of field research. Because of temporal variation in habitat use associated with resource availability and life history traits (e.g., breeding and non-breeding seasons, migrant and resident species, active and aestivation periods), it was recognized that all taxa in all habitats could not be evaluated with equal success, particularly under the project's short duration and limited human resources of the Study Team. Further, the development of a management plan need not be hindered by an incomplete taxonomic list as long as important conservation targets are identified and monitored. Therefore, several conspicuous faunal groups were selected based on their ecological value as:

- Indicator species, which are characteristic of particular climate, soil or vegetation regimes and which reflect the presence of particular ecological conditions; if these conditions change the species concerned may respond by changing its abundance, thus reflecting the 'health' of the community or habitat.
- Species with direct economic value, such as pollinators and seed dispersers of important commercial crops or consumers of pests
- Umbrella species, whose wide ecological requirements confer benefits to other species via conservation of larger habitats.

Comparisons were made among these focal species in order to delineate natural patterns, define habitat associations, and develop an understanding of how habitat modifications affect local populations. The major taxonomic groups surveyed included: terrestrial invertebrates (excluding molluscs), arboreal invertebrates (lepidoptera), amphibians, reptiles, birds and mammals. Aquatic systems were not surveyed systematically, but macrofauna were identified *ad libitum*. Field research was conducted in January-February and May-June 2001.

2.2.1 Vegetation Assessment and Habitat Structure

Faunal surveys were conducted in conjunction with a biophysical survey undertaken by the Forestry Department, Government of Jamaica (GoJ), with support from the Canadian International Development Agency (CIDA)-funded Trees for Tomorrow Project. Forestry Department established eight transects within the major land use/cover type classifications of the Dolphin Head area, with transects oriented to sample topograhic variation (i.e., break of slope, hillside and hilltop). Along each transect, 20 m x 25 m quadrats were established at 100 m intervals and surveyed for a number of biotic and abiotic variables, including tree species composition and soil type (see Biophysical Inventory Manual, FD 2000 for complete descriptions of data collection). Faunal surveys were completed in a subset of FD quadrats, along trails and roads in proximity to FD transects, and in selected caves (Figure 3).

Slight modification was made to the FD classification to enable greater distinction among human-related alteration patterns (i.e. to determine the effects of variable human-related disturbance on wildlife communities). Six different habitats were defined:

1. Closed broadleaf of moderate disturbance; if accessed by trail, canopy cover > 80% over trail
2. Disturbed broadleaf -- open canopy over access road or at break of slope (e.g., as when drainage bottoms or sinks are cleared while adjacent hillsides are left forested)
3. Disturbed broadleaf -- open canopy on hill top, slopes under forest cover
4. Disturbed broadleaf and plantations of blue mahoe (*Hibiscus elatus*)
5. Dominated by non-native plant species (i.e. > 75% plant biomass identified as non-native and invasive, notably Bamboo, Red Bead (*Adenanthera pavonina*), Rose Apple (*Syzygium jambos*)
6. Active farm (e.g., yam, banana, fruit trees) adjacent to closed-canopy forest

A distinction was made between disturbance patterns (2) and (3) because of observed differences in forest regeneration on cleared hilltops when compared to cleared sinks, valleys and roads. Deforested hilltops will have greater exposure to direct solar radiation and wind and possibly experience greater changes in microclimate in the absence of canopy cover compared to small sinks and valleys, which receive shading from adjacent hillsides. A low-lying cleared area may also be in a better position to intercept pollinators and seed-dispersing fauna because of its relationship to forest edge. Other factors of tropical limestone, such as how topography influences soil condition (e.g., acidic humus on hilltops, alkaline soils in valleys) and hydrology, may also be relevant (Vermeulen and Whitten 1999). While examining these factors was beyond the scope of this study, the preference of marijuana farmers to clear hilltops required a baseline assessment of how this location preference might affect wildlife populations.

2.2.2 Terrestrial Invertebrates, Reptiles, and Amphibians

Twelve FD quadrats, located along five transects, were surveyed in January-February for terrestrial invertebrates (excluding mollusks), amphibians and reptiles. An additional eight quadrats (20 m x 25 m) were established to sample faunal richness and abundance in areas dominated by non-native, invasive plant species (above-described Habitat 5), areas currently under marijuana cultivation (with farmer permission) and farms abandoned for more than one year (i.e. Habitat 3) (Anonymous, pers. comm.) (Figure 3; Table 1).

Sample quadrats were searched systematically by two persons -- the author and one of four local field assistants on a rotating team. Assistants' abilities to capture invertebrate and vertebrate wildlife varied, but physical descriptions of animals enabled identification to genus in most instances.

Figure 3. Dolphin Head faunal survey locations, supplemented to Forestry Department quadrats (not shown). In addition to FD quadrats identified in Appendix V, invertebrate and herptile surveys were conducted on cleared hilltops, areas dominated by bamboo and within the God Almighty Bridge area, which was dominated by Rose Apple. Birds and butterflies were surveyed along roads and trails, cleared hilltops, bamboo areas and within God Almighty Bridge. Bats were surveyed at cave entrances and along roads.

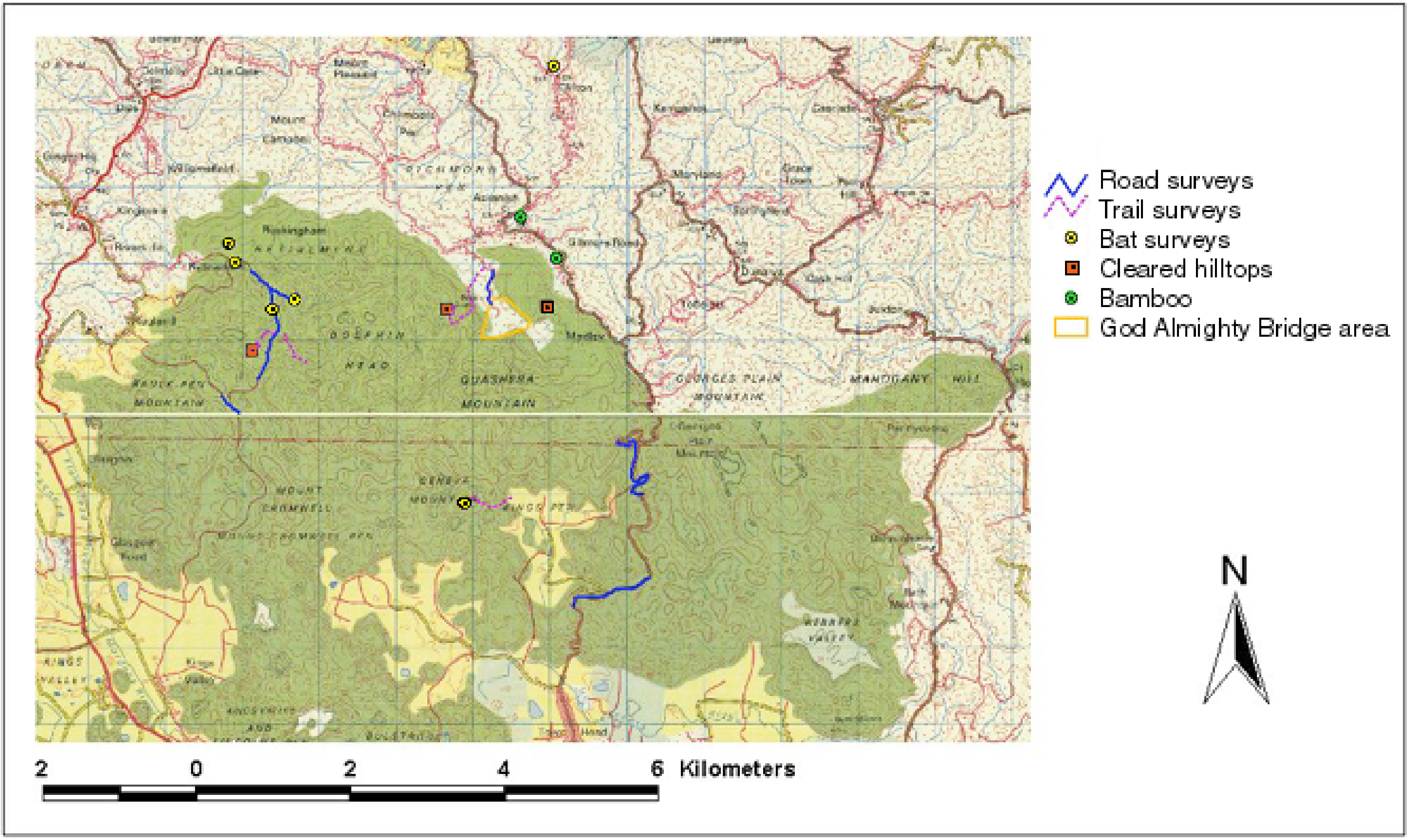


Table 1. Number of quadrats surveyed for terrestrial invertebrates and reptiles in each topographic setting and habitat structure, Dolphin Head environs, Hanover and Westmoreland, Jan-Feb 2001.

Habitat Description	**No. Surveyed**
A. Base of hill or saddle/corridor between hills with closed-canopy forest	2
B. Hill slope	7
C. Hill top with closed-canopy forest	2
D. Hill top with open-canopy	3
E. Closed-canopy, non-native plant species monoculture	5

Surveys were conducted for a period of three hours per plot. Morning surveys were initiated 30 minutes before sunrise and evening surveys continued for 30 minutes after sunset to include acoustic surveys of amphibians. Animals were collected (or presence recorded) by turning rocks and decaying logs, sifting leaf litter, examining bromeliads that were < 2 meters above the ground, and visually scanning perch sites that were < 5 meters above the ground. Canopy surveys were not conducted systematically. However, vocalizations (e.g., geckos) were recorded for the species composition list.

Acoustic surveys were conducted to record presence/absence of frogs. Vocalizing (i.e., detectable) males increased dramatically following episodic rain events. Therefore, while species composition was recorded in sample quadrats, comparisons of abundance were not performed. Reliable estimates of relative abundance will require repeated surveys throughout the breeding season to control for meteorological effects.

The amount of moisture in the soil, leaf litter and other woody debris is frequently an important microenvironmental factor for small terrestrial arthropods and amphibians inhabiting a forest floor. Distributions may be limited by annual precipitation, seasonal distribution of rainfall, evaporation, water-retention capacity, and surface and subsurface drainage. During May-June, soil moisture was measured in the sample quadrats using a Watermark Sensor attached to a Watermark Soil Moisture Meter (Forestry Suppliers, Inc.). The probe was inserted 15-20 cm into the soil and a reading taken after 10 minutes. Four measurements were collected per quadrat and the mean (± standard error (SE)) calculated. Pilot research indicated that time of day had less effect on soil moisture than if heavy rain fell in the hour preceding data collection. Gauges to measure daily rainfall were established in Askenish, Hanover.

Species were identified with reference to Loomis (1973), Sims (1987), Schwartz and Henderson (1991), Peck 1992, Hogue (1993), Schubart *et al.* (1997), Hedges (*in prep.*), IoJ museum specimens, R. Diesel pers. comm., and E. Garraway pers. comm.

2.2.3 Arboreal invertebrates – Lepidoptera

Fixed-speed transects (e.g., 100 m traversed in 10 min; see New 1997) were walked along major trails and roads of the study area to survey the six land use/habitat types for butterfly species (Figure 3). The author alone recorded sighting data. Although it would have been preferable to follow the FD transects in order to associate butterfly species with the vegetation composition and structure, these transects did not follow the contours of talus hillslopes. The consequent poor footing meant more attention was focused on the ground rather than in the canopy or observing adults as they were flushed from perches.

Observations were initiated after 1000hr and terminated before 1500hr, in accordance with diurnal activity rhythms. Transects were walked for two hours and all individuals observed within a distance of 5 m were recorded. Observations were suspended or terminated if cloud cover exceeded 75% or if wind speed exceeded 15km/hr (Beaufort Number 5; small trees in leaf begin to sway) for more than 15 minutes.

Only three surveys were conducted during January-February. It was quickly recognized that few adults of any species were flying during this winter period and it was concluded to be an inefficient use of limited manpower to be surveying for butterflies. Additionally, no caterpillars were observed during the terrestrial arthropod surveys. During the May-June period, however, butterflies had become emergent. These surveys enabled compilation of a species inventory but did not allow for rigorous comparisons of distribution and abundance patterns because of inadequate sample sizes among the habitat types. Documenting natural monthly and seasonal emergence patterns will be important, however, if butterflies are used as indicator species for monitoring the effects of habitat management strategies.

Species were identified on the wing or from collected voucher specimens with reference to Brown and Heineman (1972) and Riley (1975).

2.2.4 Birds

Bird surveys were conducted during both the January-February and May-June field research periods. These periods corresponded to the winter/dry season, when the majority of resident species were not engaged in breeding activities and Neotropical wintering migrant species were present, and the summer/wet season, when resident and summer migrant birds were breeding. Birds were counted using the fixed-radius point count censusing technique of Hutto *et al.* (1986). All birds seen or heard within a radius of 25 m were recorded during a 10-min period at each point (see Wunderle *et al.* 1992, Wunderle 1994). The size of the radius was selected based on several pilot surveys conducted in the dense, closed-canopy habitat in which the distance of birds (detected visually and aurally) was estimated in conjunction with a 50 m measuring tape placed on the ground. Beyond 25 m, cryptic birds and those with soft or high frequency calls were difficult to detect, particularly canopy-dwelling species.

Bird surveys were conducted during early morning and late afternoon hours. Counts initiated at sunrise were terminated after three hours of sampling, the time when avian activity (e.g., dawn chorus and first feeding of the day) noticeably decreased. Afternoon sessions were initiated three hours before sunset and were terminated 30 minutes before sunset as ambient light conditions became poor. Each point was at least 100 m from all others. Surveys were conducted in areas adjacent to FD vegetation plots, along existing roads and trails, to obtain a minimum of four point counts for each habitat type (Figure 3). A total of 106 points were surveyed during the study period (Table 2).

Table 2. Number of fixed-radius point counts completed in each habitat of Dolphin Head environs, Jan - June 2001. The greater number of summer points in Habitat 2 resulted from an added survey along the

road between Askenish and Frome, where there is increasing forest clearance by the owner of Mahogany Estate and, consequently, a need for baseline survey data.

	Survey Period	
Habitat Type	**Winter**	**Summer**
1. Closed broadleaf	18	18
2. Disturbed broadleaf		
Road or open canopy at base of hill	11	21
3. Disturbed broadleaf		
Open canopy on hilltop	4	4
4. Forestry plantation	4	4
5. Non-native, invasive monoculture	5	5
6. Active farm	6	6
Total	48	58

Birds were identified using *A guide to the birds of the West Indies* (Raffaele *et al.* 1998), *Field guide to the birds of North America* (National Geographic Society 1987), and *Bird songs in Jamaica* (Reynard and Sutton 2000).

2.2.4 Mammals

2.2.4.1. Native mammals

Documented caves, including Busha Mouth Cave (also known as Medley Cave) (Askenish), Baulk Mountain Caves (Glascow), and Clifton Cave (Clifton) (see Fincham 1997) and unmapped caves, as reported by local residents, were inspected for bat colonies or evidence of historic occupancy (i.e., guano deposits). Where resident colonies were confirmed, mist nets (2.6 x 6 mm, 38 mm mesh, 4 shelf) were placed near cave openings at dusk to determine species composition, age (juvenile, subadult, adult) and reproductive status of individuals. In addition to cave assessments, nets were deployed in two locations in the Retirement Reserve along flight lines that were detected during herptile and avian sampling efforts.

Species were identified with reference to Baker *et al*. (1984).

2.2.4.2 Non-native mammals

Non-native mammals (rats, cats, mongoose) were recorded *ad libitum* within the proposed National Park boundaries. Unstructured interviews were conducted with local residents, including persons encountered along trails and marijuana farmers, to obtain crude estimates of the distance non-native species have penetrated the interior forest.

2.3 Statistical Analyses

Species diversity is a dual concept that includes the number of species in the community (richness) and the evenness with which the individuals are divided among the species. Together, these two terms represent the heterogeneity of the community. If, for example, a community has

10 equally abundant species, it is not considered to have the same diversity as another community with 10 species but where one species makes up 99% of the total individuals. Some communities are simple enough to permit a complete count of the number of species. This measure of species richness can often be done on bird communities in small habitat blocks. For many communities, such as insects, soil invertebrates and amphibians, it is often impossible to enumerate every species. Estimates of community richness, however, may be derived based on sampling within the population. By quantifying species richness and evenness, meaningful comparisons may then be made among communities in differing habitats.

2.3.1 *Terrestrial Invertebrates and Reptiles (Amphibians* excluded)

Species richness was estimated for terrestrial arthropods and reptiles using the Jackknife Estimate. This estimate is based on the observed frequency of rare (i.e., unique) species (defined as a species that occurs in one and only one quadrat) and was calculated from the equation

$$S = s + [(n - 1) / n]^k$$

where S = Jackknife estimate of species richness
s = Observed total number of species present in k quadrats
n = Total number of quadrats sampled
k = Number of unique species

The variance of this Jackknife Estimate of species richness was given by

$$\mathrm{var}(S) = [(n - 1) / n] * [\ \mathrm{j}_{\ j=1} (j^2 f_j - (k^2 / n))]$$

where var(S) = Variance of jackknife estimate of species richness
f_j = Number of quadrats containing j unique species
k = Number of unique species
n = Total number of quadrats sampled

Community heterogeneity of terrestrial arthropods and reptiles was assessed by Simpson's Index

$$D = \mathrm{j}\ \ p^2{}_i$$

where D = Simpson's Index
p_i = Proportion of species in the i community

One important index of diversity derived from the above equation is

$$1 - D$$

which measures the probability that two individuals chosen at random will be different species.

Finally, the spatial distribution of terrestrial arthropods and reptiles was examined to identify habitat associations, with the recognition that species which have high tolerance for conspecifics, form large social congregations, or defend large home ranges may bias habitat preference analyses. There are three possible types of spatial patterning of individual animals in a population: *uniform, random*, or *aggregated*. If individuals are randomly spaced throughout quadrat samples, the Poisson distribution describes appropriately their frequency distributions (Krebs 1989). Deviation from randomness is tested by the goodness of fit of the Poisson distribution. Because the number of quadrats sampled was < 51, the Index of Dispersion test was used

$$I = s^2 / 0$$

where I = Index of Dispersion
s = Observed variance
0 = Observed mean

For the theoretical Poisson distribution, the variance equals the mean and so the expected value of I is always 1.0. Two-tailed Chi-square is then the simplest test statistic for the Index of Dispersion

$$P^2 = I\,(n - 1)$$

where I = Index of Dispersion
n = Number of quadrats counted
0 = Value of chi-square with $n - 1$ degrees of freedom

2.3.2 Arboreal invertebrates -- Lepidoptera

No statistical comparisons were made on butterfly distribution patterns because of low sighting records. Species composition is presented.

2.3.3 Birds

Indices were calculated to compare differences in (1) the mean number of species and (2) the mean abundance of individuals (species data pooled) among the six habitat types surveyed for birds. Species were segregated by their status as either resident or migratory. An exploratory analysis of variance (ANOVA) was performed to examine the relationships between each index and habitat type by season. However, the low numbers of point counts in Habitats 3, 4, 5, and 6 (Table 2) restricted comparisons with Habitats 1 and 2. Consequently, analyses of the effects of habitat type and season on bird communities were limited to pairwise comparisons with a Student's t-test or, when data where not normally distributed, with Mann-Whitney U-test. Migratory species were excluded from between-season comparisons because the potential source-pool/number of migratory species and their diet preferences/foraging strategies differed between winter and summer. To compare seasonal changes in presence and abundance of resident species within each habitat, the mean number of detections was calculated for each species and tested with a Student's *t*-test, except for Habitats 1 and 2, where ANOVA was used to examine habitat by season effects.

2.3.4 Mammals
Sampling of mammalian communities was not random. Species composition is presented for: (a) mist-netting efforts along bat flight lines and caves; (b) unstructured interviews with community residents; and (c) *ad libitum* observations

Analyses were done using SYSTAT 5.0 (Wilkinson 1989). A probability of type I error (alpha) of 0.05 was accepted as significant, although greater values were presented for descriptive purposes. Throughout this report, standard error is used to describe variation around the mean.

3. RESULTS
3.1 Species richness
Nearly 150 species, representing 61 families in 10 classes of 4 phyla, have been reported historically or were observed in the present study in the Dolphin Head Area (Table 3; Appendices 1, 2, 3, & 4). At least 50 of these species are endemic to Jamaica and a minimum four (1 *Sesarma* freshwater crab, 2 Lampyridae fireflies, 1 species of Operculate snail) are endemic to Dolphin Head. Identification of several unknown species of earthworms (Class Oligochaeta), cricket (Order Grylloptera), and grasshopper (Order Orthoptera) may increase the number of localized endemic species. The species endemic to Dolphin Head are relatively small animals with limited dispersal capabilities and predicted small home ranges. To contrast, there were no birds or bats whose ranges were restricted to this relatively small area. However, 21 of Jamaica's 28 endemic landbirds and one of four endemic bats were identified, thus contributing to the recognition of Dolphin Head as important habitat both nationally and globally.

3.2 Terrestrial Invertebrates, Reptiles and Amphibians
3.2.1 Terrestrial Invertebrates
Sixty species of invertebrates, the majority belonging to the class Insecta, have been recorded in the Dolphin Head environs (Table 3; Appendix 1). All of Dolphin Head's known endemic species are invertebrates and all are known from only one or two collecting locales. For example, the entire global range of the endemic freshwater crab, *Sesarma dolphinium*, as far as is known, is restricted to the few hectares of springs emerging in the area known as God Almighty Bridge (Figure 3).

Within the 20 systematically surveyed quadrats, 12 terrestrial invertebrate species were observed (Table 4; Appendix 5). Based on encounter rates of unique species within these sampling units, the Jackknife Estimate of species richness was 12 $\pm$ 9. That is, an additional nine terrestrial invertebrate species were predicted to be present. This Jackknife Estimate corresponds with the total species composition recorded from both the literature review and field surveys for Annelid Earthworms and Arthropods, excluding winged insects.

Table 3. Summary of Dolphin Head faunal species composition, compiled from literature review and field surveys. Total includes native and introduced species. *status requires species identification.

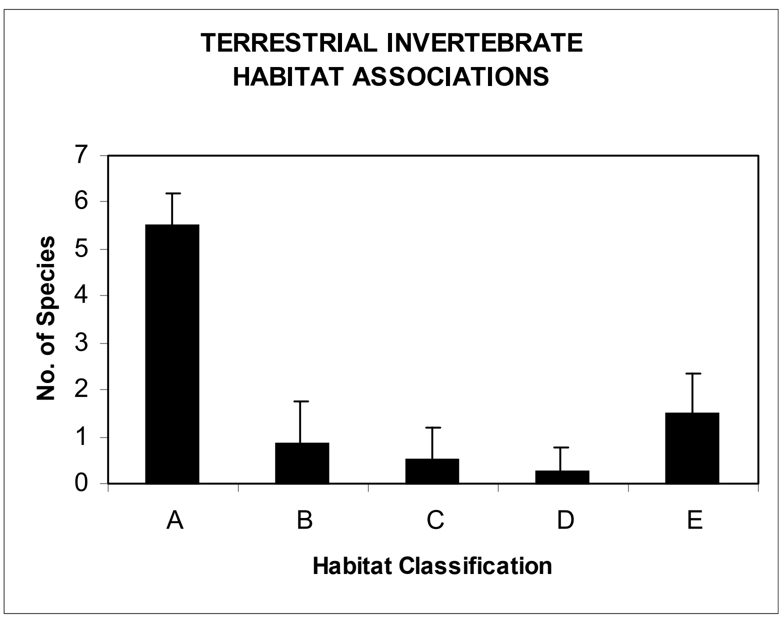
Phylum	Class	No. of Families	No. of Species	No. endemic to Jamaica	No. Endemic to Dolphin Head
Annelida					
	Oligochaeta	≥ 1	3	*	*
Arthropoda					
	Malacostraca	4	6	min. 3*	1
	Arachnida	7	8	0	0
	Myriapoda	2	4	*	*
	Insecta	14	34	4*	2*
Mollusca					
	Gastropoda	2	5	5	1
Chordata					
	Amphibia	3	12	9	0
	Reptilia	4	10	7	0
	Aves	20	57	21	0
	Mammalia	5	8	1	0
	Total	≥ 61	147	≥ 50	≥ 4

Table 4. Invertebrate species composition, total abundance and the degree of uniformity and aggregation patterns observed within the Dolphin Head study quadrats. Increasing Index of Dispersion values increase signify spatial patterning of individual animals changing from uniform to random to aggregated (see also Figure 4).

Scientific Name	Common Name	Number of Plot Occurrences	Total Individuals Encountered	Index of Dispersion (*I*)	Chi-square
UI species 1	Earthworm	1	7	7.0	140
UI species 2	""	1	2	2.0	40
UI species 3	""	1	1	1.0	20
Sesarma jarvisi	Landcrab	1	5	5.0	100
UI species 1	Isopod Pillbug	3	4	1.4	27
Centruoides sp.	Scorpion	1	1	1.0	20
Scolopendra sp.	Blue-legged Centipede	4	6	1.4	29
Rhinocricus excisus	Large Millipede	8	78	19.8	396
Eurhinocricus sp.	Medium Millipede	5	47	30.7	615
UI species	Cricket	1	2	2.0	40
UI species	Grasshopper	1	2	2.0	40
UI species	Passalus beetle	2	2	0.9	19

Although low sample sizes precluded statistical comparisons, there was a trend for terrestrial invertebrate species richness to be greatest in low-lying areas and saddle corridors between hilltops under a closed-canopy forest (Figure 4). These areas were notable for their microclimates of deep, moist soils and decomposing woody vegetation. The most species-rich site for invertebrates was a saddle corridor located along the trail leading to Dolphin Head Monument ($18^0$22'15"N, $78^0$09'20"; elev. 520m). Six species of terrestrial invertebrates were found in this area, including four of the seven unique species (i.e., those species found in one and only one quadrat; Table 4). The slopes and tops of hills supported reduced communities of terrestrial invertebrates, regardless of presence/absence of forest canopy. Soils, if present were patchily located and often blanketed by a heavy layer of humus. Quadrats of Bamboo and Rose Apple, while located in low-lying areas with deep soil, hosted many fewer species compared to topographically-similar areas under native forest cover (mean species present = 1.6 $\pm$ 0.9 vs. 5.5 $\pm$ 0.7). Similarly, abundance of individuals was dramatically lower in areas dominated by these non-native plant species compared to native forest cover (mean abundance of terrestrial invertebrates = 2.0 $\pm$ 1.4 vs. 39.1 $\pm$ 5.7)

Figure 4. Mean ($\pm$ S.E.) number of terrestrial invertebrate species found in habitats located (A) at the base of hills or in saddle corridors with good soil formation and closed-canopy forest, (B) on hill slope, (C) on hill top with closed-canopy forest, (D) on hill top with open canopy, and (E) in low-lying areas dominated by non-native plant species.



The evenness of the terrestrial invertebrate community was skewed by the high relative abundance of millipedes (Figure 5). Consequently, the measure of community heterogeneity was low (D = 0.342). In addition to dominating the overall community composition, millipedes also were the most abundant biomass in every quadrat in which they occurred. The distribution pattern of millipedes, like the majority of terrestrial invertebrate species, was not random across the Dolphin Head environs, with individuals being strongly aggregated spatially (Table 4; Figure 6). As observed with the patterns of species richness, millipede abundance was greatest in areas of good soil formation and closed-canopy native forest.

Figure 5. Invertebrate community evenness as assessed by the relative abundance of individuals.

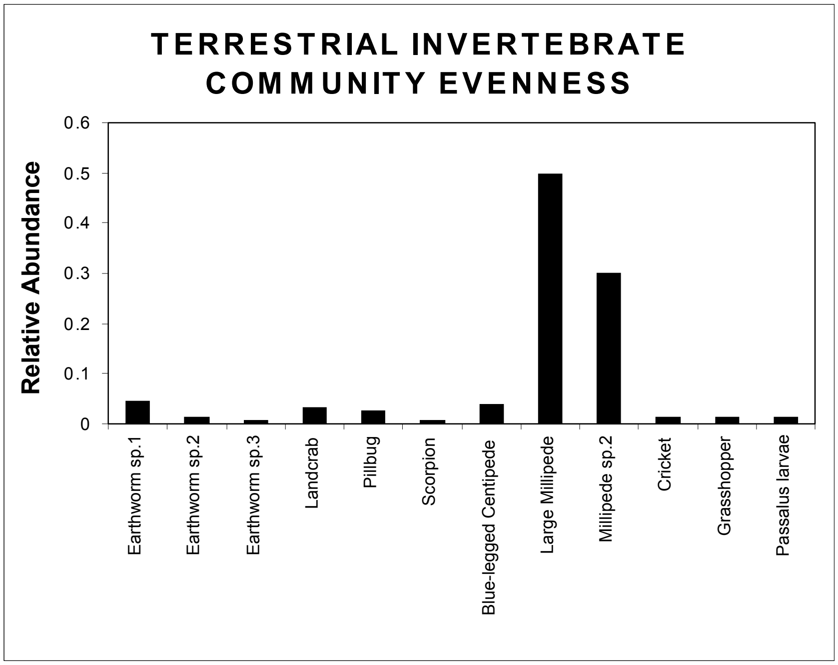
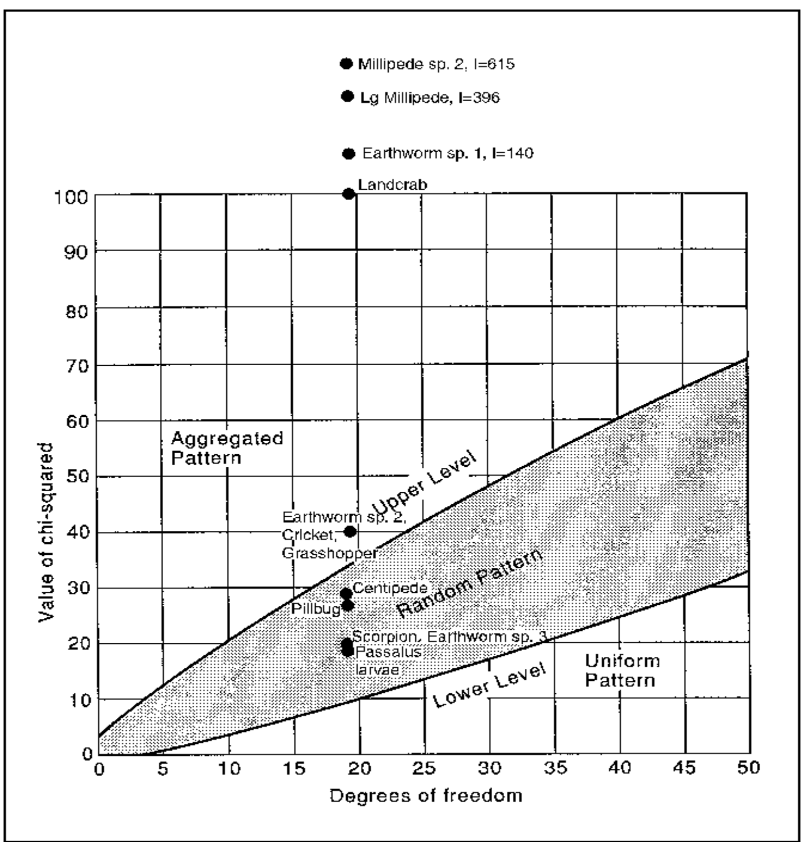


Figure 6. Spatial patterning of individuals among each invertebrate species encountered in the sample quadrats, as assessed by Chi-squared test of the Index of Dispersion (I) (After Elliott 1977).



Ecologically, millipedes play an important role as scavengers and primary decomposers. Most are herbivorous and their processing of organic matter assists in nutrient recycling. Further, as they force their way through soil, they maintain aeration necessary for fungal and plant growth. Across Jamaica, millipedes and the closely-related centipedes and isopods, are typically restricted to areas of limestone. They possess substantial calcium requirements for their exoskeletons (e.g., in some species calcium represents 50% of their dry biomass; McBrayer 1973) and their numbers are drastically limited at sites with low available calcium. DNA analyses of Jamaican millipedes is currently being conducted, but the geologic isolation of Dolphin Head's limestone cap quite likely resulted in the long-term isolation and speciation of the resident populations (J. Bond pers. comm.)

3.2.2 Reptiles

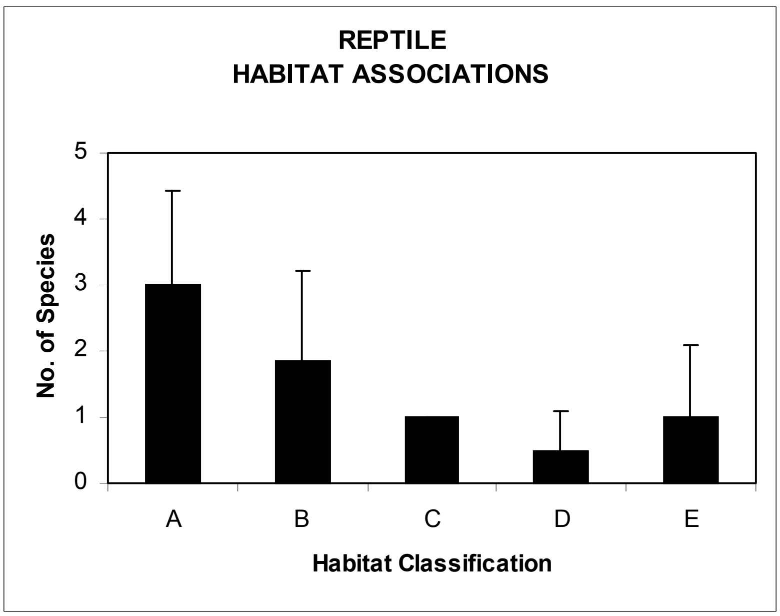
Of the 30 reptiles (1 turtle, 1 crocodile, 9 snakes, 28 lizards) found in Jamaica, the ranges of 10 (1 snake, 9 lizards) include Dolphin Head (Appendix 2). Seven of these 10 were observed during the present study within the 20 quadrats (Table 5). Based on encounter rates of unique species within these sampling units, the Jackknife Estimate of species richness was 8 $\pm$ 4. Three species were unique to one of three quadrats, including the Jamaican Black Groundsnake (*Arrhyton funereum*), which represents the first known sight-record for this small colubrid snake in Dolphin Head (see Schwartz and Henderson 1991). The most species-rich site for reptiles, which included the location of the Black Groundsnake, was the same saddle corridor located along the trail leading to Dolphin Head Monument where invertebrate species richness was highest.

Table 5. Reptile species composition, total abundance and the degree of uniformity and aggregation patterns observed within the Dolphin Head study quadrats.

Scientific Name	Common Name	Number of Plot Occurrences	Total Number Encountered	Index of Dispersion (*I*)	Chi-square
Anolis garmani	Giant Anole	5	7	1.6	32
A. grahami	Graham's Anole	4	5	1.2	24
A. lineatopus	Grey Anole	13	36	3.4	69
A. opalinus	Opal Anole	2	5	3.3	66
Aristellager praesignis	Croaking Gecko	1	3	3.0	60
Celestus crusculus	Galliwasp	1	1	1.0	20
Arrhyton funereum	Black Groundsnake	1	1	1.0	20

Habitat association patterns were not as strong for reptiles as they were for invertebrate species, although there was a trend for species richness to decline as forest canopy became more open or as plant species diversity became more homogenous (Figure 7). The Jamaican Grey Anole (*Anolis lineatopus*) was the most common member of the reptile community, both in terms of the number of quadrats in which in occurred and the number of individuals observed (Table 5; Figure 8). This species represents the "trunk-ground" ecomorph of Anoline lizards on Jamaica, foraging and perching on the ground or low on tree trunks (see Williams 1983). The other three *Anolis* lizards (Giant Green (*A. garmani*), Graham's (*A. grahami*), and Opal (*A. opalinus*)) forage primarily in the crown of trees or high on the trunk (trunk-crown ecomorph). Thus, a detection bias based on the search strategy may explain differences in abundance among species. However, these trunk-crown ecomorphs were discernibly absent from open-canopy habitats, either because of inadequate foraging substrates or because of higher predation risk associated with the open canopy. Where the Grey and Opal anoles occurred, there was a higher probability of finding a conspecific of each, respectively, than when one of the other two green anoles were present (Figure 9).

Figure 7. Mean (+ S.E.) number of reptile species found in habitats located (A) at the base of hills or in saddle corridors with good soil formation and closed-canopy forest, (B) on hill slope, (C) on hill top with closed-canopy forest, (D) on hill top with open canopy, and (E) in low-lying areas with good soil formation but dominated by non-native plant species.



3.2.3 Amphibians

Of Jamaica's 26 amphibians, twelve are known to occur in for Dolphin Head environs. Nine of the Dolphin Head species are endemic to Jamaica and three are introduced (Appendix 2). Although amphibian surveys were limited in their abilities to estimate species densities and habitat associations, they provided important information on the presence and habitat occupancy patterns of two non-native species. The Marine Toad (*Bufo marinus*) was reported by residents of Retirement and Askenish as "common on roads" during periods of prolonged rainfall. One large female (SVL 20 cm) was collected within the Retirement Forest Reserve on Transect 3, Plot 17. Stomach contents contained partially-digested fragments of arthropod species. Marine toads are voracious and equal-opportunity eaters. As noted by Zug (1983), "if it is bite-sized and animate, it is food, no matter how noxious, toxic, or biting/stinging." These toads eat small vertebrates and may be a controlling factor for Jamaica's smaller endemic frogs and reptiles. This species is a commensal of man and is common in converted habitats on Jamaica. Closed-canopy forest, in fact, appears to be an effective barrier to long-distance dispersal.

Figure 8. Reptile community evenness as assessed by the relative abundance of individual animals.

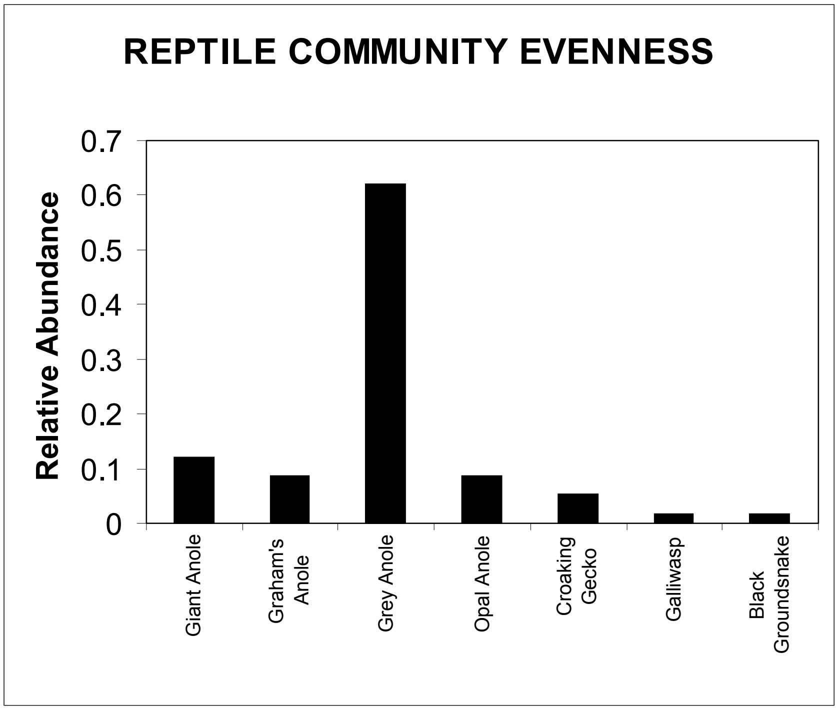
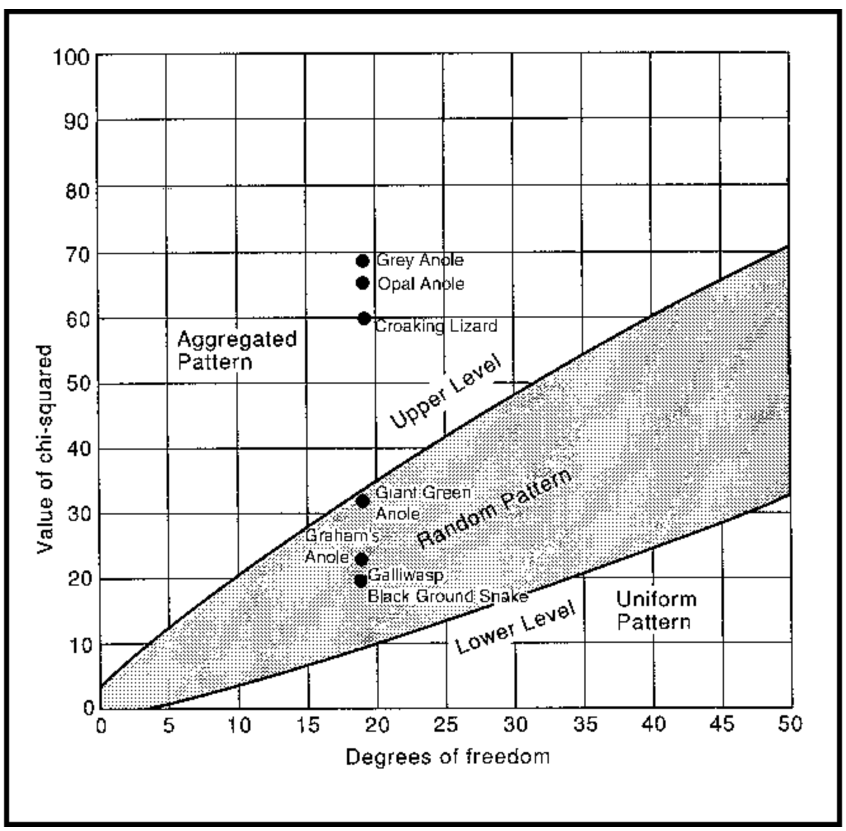


Figure 9. Spatial patterning of individuals among reptile species encountered in the sample quadrats, as assessed by Chi-squared test of the Index of Dispersion (I).



A second non-native invasive amphibian species detected in Dolphin Head environs was the Lesser Antillean Eleuth (*Eleutherodactylus johnstonei*). Introduced about 1890, this species has rapidly expanded throughout disturbed habitats of Jamaica. There is concern that it may displace endemic species, either through competitive exclusion or indirectly as females of local populations are unable to locate calling males because of the much louder calls of the Lesser Antillean Eleuth (Johnson 1988). It was the most conspicuous frog heard along the road from the coastal town of Lucea to Retirement via Kingsvale. Vocalizations ceased abruptly after passing the final house in the Reserve community, as one continued along the road into the Forest Reserve. The termination of vocalizations was associated with the closing of the forest canopy. The Lesser Antillean Eleuth was also found in Askenish and neighbouring communities. From reports by local residents, the distribution of this species has expanded into the pasture and farmlands adjacent to Dolphin Head Monument during the past ten years (N. Samuels, pers. comm.). Specimens were easily collected in the God Almighty Bridge Area during the summer survey period. As on the western Retirement side of the study area, the Lesser Antillean Eleuth was not detected in closed-canopy forest.

3.3 Arboreal Invertebrates - Lepidoptera

Fourteen butterfly species were observed, the majority during the summer survey period. This increases known species richness from two (Brown and Heineman 1972) to 16 for the Dolphin Head area (Appendix 1). Only one species, *Calisto zangis*, is endemic to Jamaica; all other species are widespread and common throughout the Americas. With the exception of *Calisto zangis*, all sightings were in converted habitat of pasture and along roadsides. The relatively low butterfly species richness in Dolphin Head and extreme western Jamaica has been commented upon by others (see Brown and Heineman 1972) and raises interesting ecological questions regarding functional processes and plant-animal interactions in this area compared with other wet limestone forests across Jamaica.

3.4 Birds

A total of 57 bird species, including 21 of Jamaica's 28 (72%) endemic species, 23 native resident species and 11 migratory species, were recorded in the forests and surrounding human-modified habitats of Dolphin Head (Appendix 3). Forty-five of these species occurred in at least three fixed-radius point counts, the minimum number of observations needed for inclusion in the distribution analyses.

3.4.1 Resident species

Among resident bird species, the mean number of species and the mean number of individuals detected per point count did not differ significantly among the habitats during the winter survey period (Table 6). A pattern that open hilltops (Habitat 3) and monocultures of non-native plant species (Habitat 5) supported less avian diversity and fewer individuals was not confirmed as statistical power was low because of the small number of point counts in Habitats 3, 4, 5 and 6. Because of the variance associated with the mean number of species per point count, a minimum 15-20 points would be required per habitat type to increase the confidence level of the analyses to detect differences where they exist.

Table 6. Mean (±SE) number of individuals and total number of species in fixed-radius point counts in Dolphin Head, Jan-Jun 2001. Comparison of seasonal changes in abundance and number, by habitat, was made of resident species. Non-native, invasive monocultures were habitats dominated (e.g., >75%) by Bamboo (*Bambusa vulgaris*), Red Bead Tree (*Adenanthera pavonina*), or Rose Apple (*Syzygium jambos*).

	Winter Season				Summer Season			
	Indiv. per point count		No. of species		Indiv. per point count		No. of species	
Habitat	**Resident**	**Migrant**	**Resident**	**Migrant**	**Resident**	**Migrant**	**Resident**	**Migrant**
1. Closed broadleaf	8.9 + 0.8	0.7 + 0.3[a]	6.6 + 0.5	0.5 + 0.2	8.2 + 1.0[e,f]	1.0 + 0.2	6.7 + 0.7[g]	0.9 + 0.1[h]
2. Disturbed broadleaf								
Road or open canopy base of hill	10.6 + 1.0	1.5 + 0.3[a,b,c]	8.2 + 0.7	1.4 + 0.3[d]	10.5 + 1.1[e,f]	1.8 + 0.2	8.0 + 0.8[g]	1.1+ 0.1[i]
3. Disturbed broadleaf								
Open canopy hilltop	6.3 ± 2.9	0.0 + 0.0[b]	5.3 + 2.0	0.0 + 0.0[d]	8.8 + 4.2[f]	2.2 + 0.6	6.3 + 2.6[g]	1.6 + 0.2[h,i]
4. Forestry plantation	9.5 + 0.5	1.0 + 1.0	7.0 + 0.3	1.0 + 0.6	8.8 + 3.2[f]	1.8 + 0.3	6.3 + 1.8[g]	1.3 + 0.3
5. Non-native, invasive monoculture	7.0 + 1.0	1.0 + 1.0	4.5 + 0.5	0.5 + 0.3	3.0 + 1.4[f]	1.5 + 0.3	3.0 + 1.0[g]	1.4 + 0.3
6. Active farm	14.0 + 5.5	0.3 + 0.3[c]	6.7 + 1.8	0.2 + 0.2	10.8 + 1.6[f]	1.8 + 0.4	7.4 + 0.3[g]	1.4 + 0.2

[a] $P = 0.09$
[b] $P = 0.07$
[c] $P = 0.09$
[d] $P = 0.07$
[e] $P = 0.06$
[f] Habitat 5 less than each other habitat $P < 0.05$
[g] Habitat 5 less than each other habitat $P < 0.06$
[h] $P = 0.02$
[i] $P = 0.07$

During the summer surveys, areas dominated by non-native invasive plants (Habitat 5) had significantly fewer individuals per point count compared with each of the other habitat types ($P < 0.05$); the lesser number of species per point count in Habitat 5 was nearly significant ($P < 0.06$) (Table 6). Excluding Habitat 5, there were no significant differences in the mean number of species among the other habitats. However, as with the winter survey, there was a marginally significant trend for a greater number of species to be detected per point count in the disturbed broadleaf/open canopy of Habitat 2 than in the closed broadleaf Habitat 1, which showed less structural diversity in the understory (e.g., less herbaceous ground cover) ($t = 2.08$; df = 17, $P = 0.06$; Table 6). The comparison of Habitat 1 to the farm environment of Habitat 6, which showed a similar number of individuals to Habitat 2, was hindered by the low sample size of Habitat 6.

Seasonally, the number of species detected within each habitat was the same. Despite the fact that resident birds were engaged in breeding activities during the summer surveys (e.g., nests were observed as well as fledglings) and, consequently greater numbers of individuals would be expected as young birds fledge from the nest, the mean abundance of individuals per point count was not significantly different between the winter and summer surveys for each habitat type.

While the mean number of species per point count was not significantly different among the majority of habitat types (the exception being fewer species in Habitat 5 during the summer survey), species composition varied among habitats (Table 7). Areas dominated by non-native plant species (Habitat 5) supported very low bird diversity. Had this habitat been further divided by plant species, diversity would have been even lower per site. For example, in point counts dominated by bamboo, only Yellow-faced grassquits (*Tiaris olivacea*) and Black-faced grassquits (*Tiaris bicolor*) were observed within the bamboo. Cave swallows (*Pterochelidon fulva*) were observed foraging for insects aerially, so their association with this habitat type was weak. The composition of bird species occurring on cleared hilltops similarly was dominated by the smaller species of aerial insectivores, several small frugivores and the ubiquitous endemic Red-billed Streamertail (*Trochilus polytmus*).

Habitat 1 (closed forest) and Habitat 6 (farm) were nearly identical in the number of endemic, resident, and migrant species detected, but there were several important differences in species composition (Table 7). The farm habitats supported nearly all species of aerial (flycatching) insectivores and the small, granivorous grassquits and introduced Green-rumped Parrotlet (*Forpus passerinus*). Although small flocks (2-6 birds) of this latter species were observed in-flight over disturbed forest habitats, they were not observed using forested areas for food or shelter. Notably absent from farm habitat and, indeed, from the heavily modified, open-canopy habitats 3 and 5, were the large, frugivorous Columbid pigeons (Table 8). The endemic Jamaican Woodpecker (*Melanerpes jamaicensis*), Jamaican Elaenia (*Elaenia fallux*), and Arrow-headed Warbler (*Dendroica phareta*) also demonstrated strong forest-dependence and avoided flying across open expanses.

Table 8. Habitats in which endemic (E), resident (R), introduced (I), natural range expansion (N), and migrants (WM – winter, SM – summer) bird species were detected in Dolphin Head environs, Jan – Jun 2001. Each bar represents a minimum of three detection events.

			Habitat Type					
Family	**Common Name**	**Status**	**1**	**2**	**3**	**4**	**5**	**6**
ARDEIDAE	Cattle Egret	N						■
FALCONIDAE	American Kestrel	R		■	■	■		■
COLUMBIDAE	White-crowned Pigeon	R	■	■		■		
	Ring-tailed Pigeon	E	■	■				
	Zenaida Dove	R	■	■				■
	Common Ground-Dove	R		■				■
	Caribbean Dove	R	■	■		■		
	Ruddy Quail Dove	R	■	■	■	■		
PSITTACIDAE	Olive-throated Parakeet	E	■	■	■			■
	Green-rumped Parrotlet	I						■
APODIDAE	Antillean Palm Swift	R						■
TROCHILIDAE	Jamaican Mango	E	■	■		■		■
	Red-billed Streamertail	E	■	■	■	■	■	■
	Vervain Hummingbird	R	■	■	■	■		■
TODIDAE	Jamaican Tody	E	■	■	■			■
PICIDAE	Jamaican Woodpecker	E	■	■		■		
TYRANNIDAE	Jamaican Elaenia	E	■	■				
	Greater Antillean Elaenia	R	■	■	■			
	Jamaican Pewee	E	■	■	■			■
	Sad Flycatcher	E	■	■				■
	Rufous-tailed Flycatcher	E	■	■		■		■
	Stolid Flycatcher	R		■				■
	Gray Kingbird	SM		■	■	■		■
	Loggerhead Kingbird	R		■				■
HIRUNDINIDAE	Cave Swallow	R		■	■		■	
MUSCICAPIDAE	Rufous-throated Solitaire	R	■	■				
	White-chinned Thrush	E	■	■		■	■	■
MIMIDAE	Northern Mockingbird	R						■
VIREONIDAE	Jamaican Vireo	E	■	■	■	■	■	■
	Black-whiskered Vireo	SM	■	■		■	■	■
EMBERIZIDAE	Northern Parula	WM		■				
	Black-throated Blue Warbler	WM	■	■			■	■
	Arrow-headed Warbler	E		■				
	Black-and-white Warbler	WM	■	■		■		
	American Redstart	WM	■	■		■		■
	Common Yellowthroat	WM	■	■				
	Bananaquit	R	■	■	■	■		■
	Jamaican Euphonia	E	■	■	■	■		■
	Jamaican Stripe-headed Tanager	E	■	■	■	■		■
	Yellow-faced Grassquit	R		■	■		■	■
	Black-faced Grassquit	R		■	■	■	■	■
	Yellow-shouldered Grassquit	E		■				■
	Greater Antillean Bullfinch	R		■			■	■
	Orangequit	E	■	■				■
	Jamaican Oriole	R	■	■	■	■		■
	Total number of endemic species		15	17	7	8	3	14
	Total number of resident species		9	17	9	8	4	14
	Total number of migrant species		5	7	1	4	2	4
	Total number of species		29	41	17	20	9	32

Table 8. Birds of Dolphin Head demonstrating the strongest closed-canopy forest dependence. Species are recognized as resident (R), endemic (E), or wintering Neotropical migrant (WM). No introduced or natural range expansion species were detected within natural forest. Habitat included closed-canopy broadleaf (1), disturbed broadleaf with road or open canopy at break of slope (2), disturbed broadleaf with open canopy on hilltop (3), forestry plantation (4), non-native monoculture (5), and agriculture (6).

			Habitat Type					
Family	**Common Name**	**Status**	**1**	**2**	**3**	**4**	**5**	**6**
COLUMBIDAE	White-crowned Pigeon	R	■	■		■		
	Ring-tailed Pigeon	E	■	■				
PICIDAE	Jamaican Woodpecker	E	■	■		■		
TYRANNIDAE	Jamaican Elaenia	E	■	■				
MUSCICAPIDAE	Rufous-throated Solitaire	R	■	■				
EMBERIZIDAE	Northern Parula	WM		■				
	Arrow-headed Warbler	E		■				
	Black-and-white Warbler	WM	■	■		■		
	Common Yellowthroat	WM	■	■				

Several resident and endemic species demonstrated seasonal differences in their use of habitats. The most distinctive was the White-crowned Pigeon (*Columba leucocephala*), which was rare in the winter months (4 detections within Habitats 1 and 2) but abundant in summer (47 detections; F = 35.72, $df_{1,28}$, $P < 0.001$). Few individuals were observed in flight during the winter, in marked contrast to summer. Consequently, it was assumed that the population migrated from lower elevation, wintering grounds rather than it being present but not detected in the winter. The Caribbean Dove (*Leptotila jamaicensis*), similarly, was detected in greater abundance in Habitats 1 and 2 in the summer than in the winter (mean winter abundance per point count = 0.06 $\pm$ 0.31 vs. summer 0.47 $\pm$ 0.52; F = 5.928, $df_{1,28}$, $P < 0.02$), while the Ruddy Quail Dove (*Geotrygon montana*) was marginally more abundant in the summer in these habitats (winter abundance per point count = 0.18 $\pm$ 0.48 vs. summer 0.46 $\pm$ 0.44; F = 3.635, $df_{1,28}$, $P < 0.06$). Additionally, the Ruddy Quail Dove expanded its use of habitat to include the forest edge of cleared hilltops (Habitat 3) and mixed forest/mahoe plantations (Habitat 4) in the summer. The Jamaican Euphonia (*Euphonia jamaica*) displayed a similar expansion to use habitats 3 and 4 in the summer while showing no significant seasonal differences in its mean abundances within habitats 1, 2 and 6. For all other resident species, no seasonal variation in abundance was detected across habitat types or, at best, variation occurred in only one habitat.

3.4.2 Migrant species

Among winter Neotropical migrant species, there was a trend that species were detected more often in the disturbed broadleaf/edge environment of Habitat 2, which represented the most structurally-diverse habitat (i.e., dense understory, herbaceous groundcover) (Tables 6). No winter migrants were observed or heard in the most open habitat, the cleared hilltop (Habitat 3) and only one species occurred in the monoculture Habitat 5 (Tables 6 & 7). Three species demonstrated a strong pattern of forest-dependence (Table

8). However, because of the low number of point counts in each habitat type, with perhaps the exceptions of Habitat 1 and Habitat 2, the statistical power to detect significant differences among habitat types was poor. With the largest standard deviation from a mean score equal to 1.4, a minimum of 15 point counts per habitat type would improve the confidence of the analyses.

The two summer migrant species were detected in all habitat types (Table 6). In contrast to the winter migrants, cleared hilltops (Habitat 3) were used, although only by the Grey Kingbird (*Tyrannus dominicensis*). Black-whiskered Vireos (*Vireo altiloquus*) were detected in all habitats except Habitat 3 (Table 7). Although the number of bird species in Habitat 3 was greater than in Habitat 1 ($P = 0.02$), this significance applies solely to the Grey Kingbird, which hunts from exposed perches (e.g., bare treetops, telephone lines).

3.5 Mammals

3.5.1 Bats

Of Jamaica's 21 bat species, five were identified during this survey (Appendix 4). Perhaps the most important new discovery of the field surveys with regards to wildlife was the identification of a large bat roosting and nursery chamber in King's Pen, Westmoreland (Line 9, Plot 49; $18^0$21'01"N, $78^0$09'14"W). This cave had been known by several local persons for more than 50 years, but it was not documented in the Jamaica Cave Registry. At least two species were resident in the cave, the Moustached Bat (*Pteronotus quadridens*) and the Leaf-chinned Bat (*Mormoops blainvillii*). Populations were estimated minimum 50,000 individuals each. Both of these species are insectivores and, based on their mass (8g and 10g respectively), a bat's capacity to consume its weight in insects nightly, and minimum estimated population size, this colony of bats would be capable of consuming approximately 330,000 tonnes of insects per annum. The current IUCN Red List of Threatened Species (IUCN 2000) lists *Mormoops blainvillii* and *Pteronotus quadridens* as "Near-Threatened," meaning they are not conservation dependent but are close to being considered "Vulnerable". Both of these species are endemic to the Greater Antilles. This cave represents the largest colony of roosting and breeding bats in the Dolphin Head environs identified thus far. Because of their biomass, the bats probably represent the most important consumers of insects in Dolphin Head.

As an additional note, the physical parameters of the cave remain to be surveyed before it may be registered. At the time species composition was determined (May), 75% of female Leaf-chinned Bats (n = 12 of 16) were pregnant. Prolonged human activity in the cave associated with a physical survey will disturb the bat colony and increase mortality risk of individuals, particularly of flightless pups. A survey with an experienced spelunker is tentatively scheduled for December 2001, outside of the bat breeding season.

In contrast to the King Pen cave, the next largest identified bat colony was found in Clifton Cave. Two species were present, the insectivorous Parnell's Moustached Bat (*Pteronotus parnellii*) and the frugivorous Jamaican Fruit Bat (*Artibeus jamaicensis*). Their populations were estimated to be fewer than 500 individuals. Occupancy of ceiling space was < 25%. It is not known whether this represents maximum capacity of the cave or whether repeated human disturbance suppresses the bat populations. Further, Clifton

Cave is badly degraded, as indicated by the presence of garbage and American cockroaches (*Periplaneta americana*); siltation from terrestrial erosion has altered the hydrology over the past 20 years, as reported by local residents.

The formation of large, chambered caves that represent potentially suitable roosting and breeding habitat for bats appeared to be restricted to the eastern mountains (i.e. Dolphin Pen, Quasheba, Bath, and Geneva). The northwestern region, including Retirement, was notably devoid of complex cave systems. "Caves," as identified by local persons, tended to be fracture slits, fault sumps, or small dissolution holes in escarpments that farmers identified because of their proximity to flight lines of bats observed at dusk. However, the forest of the western region provided foraging habitat for bats, including Parnell's Moustached Bat, the Long-tongued Bat (*Glossophaga soricina*; nectarivore), the Jamaican Fig-eating Bat (*Ariteus flavecens*; frugivore) and the Jamaican Fruit Bat. The first three species were netted in Retirement during the January survey while the Fruit Bat was the sole species netted in June. Mist nets were placed in the same locations for both surveys. Assessing spatial and temporal availability of food resources was beyond the scope of this research, but clearly this will have an effect on the distribution of foraging bats. This further emphasizes the importance of maintaining a large and heterogeneous forest to ensure food availability year-round frugivorous wildlife.

The Jamaican Fig-eating Bat is one of four bats endemic to Jamaica and is the sole species in the genus *Ariteus* (i.e. the genus is endemic to Jamaica). It is not believed to be a cave-dwelling bat, but most likely roosts and breeds in tree hollows. It is rare in collections and as early as 1942 was thought likely to become scarce because of intensive agricultural development. The Jamaican Fig-eating Bat is listed as "Vulnerable" by the IUCN, meaning it faces a high risk of extinction in the wild in the medium-term. Almost nothing is known of its ecology and habitat requirements.

3.5.2 Non-native mammals

Mongoose were reported as "common" by residents of Askenish and Retirement, both on their family farms as well as in marijuana plots located within the forest. Incidental trapping of three female mongoose on a farm near the Askenish/Clinton crossroad during a one-week period in June supported this claim. To what extent this insidious non-native species penetrated the forest was not assessed. However, direct sightings of four mongoose at Dolphin Head Peak were recorded on two separate occasions (Appendix 5). On Jamaica, the mongoose has been implicated in the extinctions of two endemic bird species and two reptiles.

Every marijuana farmer interviewed reported difficulties with rats destroying portions of his crop, particularly when the marijuana was cut and drying. Unfortunately, their preferred method of control may be equally as detrimental to native wildlife as the presence of the rats, which feed on birds and nest contents as well as on reptiles. Farmers carry cats to their plots, bringing food and water every few days to keep the cat in the area. However, the cats are not tended when farmers cease regular visits to their plots (e.g., during harvesting and replanting). It is assumed that, as has been documented on islands throughout the world where cats have been introduced, the primary prey base of these feral cats is native wildlife. Indeed, 26% of island bird extinctions are cat-caused and 54% by rats (King 1985).

4. THREATS TO THE BIODIVERSITY OF DOLPHIN HEAD

The forests, caves and surrounding human-modified habitats of Dolphin Head support diverse faunal communities, which include a minimum of 50 species endemic to Jamaica and four endemic to Dolphin Head. These species differ in their use of habitats, both spatially and temporally. While some species benefit from human modifications to the forest and landscape structure, others demonstrate greater sensitivity to degradation, fragmentation, and loss of natural forest cover. As a general trend, the endemic species were restricted to areas of closed-canopy or moderately disturbed forest, while introduced species were restricted to converted habitats. However, two harmful species, the mongoose and marine toad, have penetrated the closed-canopy forest. The results of this research reveal the importance of distinguishing not only the type of human modification but also the location of the disturbance in relation to forest cover in seeking to understand how habitat change affects different taxonomic groups of wildlife.

4.1 Clearing of forest patches

Removal of native forest cover will have variable effects on biodiversity. The topographic location of the clearing, viz. hill base/valley, slope, and top, is an important factor because of the natural spatial distributions of wildlife.

Direct effects may include:

- removal and possible extirpation of plant or animal species with highly restricted ranges
- removal of hunting and sleeping perches for wildlife, such as lizards and birds
- removal of the structurally complex environment which affords protection from predators
- alteration of microclimate, including temperature, relative humidity and soil moisture that precludes occupancy by terrestrial invertebrates

For birds, clearing of hilltops had a negative effect on species composition and abundance (Tables 6 and 7). This site location is preferred for marijuana cultivation because of the direct sunlight and pockets of soil, in contrast to hillsides with little soil formation or low-lying areas with soil but where sunlight is restricted. Of the four hilltops that were assessed for avian diversity, one was under cultivation while the other three had been abandoned for at least 10 years (Anonymous, pers. comm.). The abandoned hilltops were dominated by non-native fern and lantana. These patches showed low usage by both endemic and migratory birds (Table 7). With the exception of aerial hunters that perched on fire-burned snags, use of this habitat by other birds was restricted almost exclusively to the well-defined forest edge. Natural forest regeneration of these hilltops may be limited in the absence of human mitigation, particularly if the present vegetation either fails to attract seed-dispersing wildlife or competitively excludes native plant species.

Although there was a trend for cleared hilltops to have the lowest species richness for both terrestrial invertebrates and reptiles (Figures 4 and 7), the low sample sizes precluded statistical analyses. Further, it appears that hilltops and hillslopes may be naturally depauperate of terrestrial invertebrates, possibly because soil formation is inherently poor on these topographic locations. It should be noted, however, that the hilltops surveyed were located on Dolphin Head Peak, where mongoose were in apparent abundance and which may have been an important factor in the low observed frequency of ground-dwelling reptiles.

Clearing of saddles between hilltops or clearing of forested valleys, however, will affect species richness and individual abundances of reptiles and, especially, terrestrial invertebrates (Figures 5 and 8). Under closed-canopy forest cover, these areas provided microhabitats of moist soil and high relative humidity for invertebrates and diverse vegetative structure for Anoline lizards and other reptiles. Indeed, the area of overall greatest species richness for invertebrates and reptiles was the western saddle-corridor approaching Dolphin Head Monument. This area also held the most unique diversity, with four invertebrates (including a landcrab) and one reptile (the single sighting of a snake in Dolphin Head) found only in this location.

Avian diversity, in contrast, increased in valleys with disturbed broadleaf forest or when the forest canopy was kept open because of a road (that is, a gap was created, but unlike on hilltops, the gap was bounded by forest). This type of disturbance may even be seen as beneficial to bird diversity because of the regeneration of early succession herbaceous ground cover and understory, which supported the granivores and small frugivores, and by the maintenance of open gaps which are preferred by the larger species or aerial (flycatching) insectivores. The adjacent closed-canopy hillslopes supported the smaller aerial insectivores, many of which are endemic to Jamaica, and the larger frugivorous Columbids, which were restricted in their use to closed and minimally-open canopy.

Thus, conversion of forest affects taxonomic communities differently. Clearing for marijuana cultivation on hilltops has the greatest effect on avian diversity but apparently minimal effect on terrestrial invertebrates, which have low levels of natural occurrence on hilltops. Clearing in saddle-corridors or valleys, in contrast, will have an important negative effect on terrestrial invertebrates while being neutral or even positive for birds. In all instances of forest clearing, however, there is the risk of species extinctions, particularly for plants or other highly-localized fauna. Additionally, the opening of the forest canopy facilitates the spread of many non-native species, including the Marine Toad and the Lesser Antillean Eleuth.

4.2 Monocultures of non-native plant species

One consequence associated with the removal of native forest cover is the ease with which non-native species become established. As habitats became more homogenous, both in terms of plant species composition and structure, avian diversity decreased. Monoculture stands of non-native bamboo, red bead, and rose apple hosted the lowest number of resident species and abundances of individuals (Table 6). Perhaps more notable, species richness was 4-5 times lower across all classes of birds (endemics, residents and migrants) compared with the heterogeneous environment of broadleaf forest with road disturbance or clearing in small valleys and 2-3 times lower compared to moderately disturbed forest (Table 7). It was clear that food resources in these monocultures were highly seasonal. The only bird species that used this habitat were those which occur commonly in heavily modified environments across Jamaica.

All monocultures surveyed were located in low-lying valleys. Because of their topographic location, terrestrial and reptile would have been predicted to be 2-3 times greater (Figures 4 and 7). When compared to their closed-canopy, forested counterpart, stands of non-native plant species must be considered biologically sterile environments. This was particularly salient in the plots dominated by rose apple, which where located in the area known as "God Almighty Bridge" (Figure 3). A series of springs emerge and re-submerge to create a small area of cockpit-type sinks. Avian diversity was poor in plots where rose apple represented nearly 100% of the vegetative biomass. Similarly for terrestrial invertebrates, only a single insect larvae was located and that was in association with the lone Guava tree (*Psidium guajava*) surrounded by Rose Apple. However, as the area was traversed to the forested edge on the eastern boundary of the drainage system and native plant species became dominant, avian, reptile and terrestrial invertebrate diversity and abundance increased. It is not known to what extent the Rose Apple, which has come to dominate the area in the past 25 years (N. Samuels, pers. comm.), has affected the hydrology of the God Almighty Bridge, but it is within this series of springs that the freshwater crab endemic to Dolphin Head is located.

4.3. Degradation of cave systems

4.3.1 Above-ground activities

In karst landscapes, terrestrial and subterranean systems are linked directly. Deforestation results in increased water runoff and soil erosion, which may, in turn, contribute to sedimentation of caves, alteration of hydrologic regimes and deterioration of water quality. Siltation can, quite literally, raise the floor of the cave to the ceiling. Human waste and garbage are easily transported throughout the karst subterrain via the phreatic (river) system.

Examples of the above-degradation are evident in Clifton Cave. Siltation has elevated the floor of the river system 1-2 m in the past 20 years (Anonymous, pers. comm.) and garbage (e.g., diapers and plastic drink bottles) is accumulating throughout. American cockroaches (*Periplaneta americana*) are abundant, mostly likely having rafted in with the garbage. Unfortunately, Clifton Cave was not surveyed by Peck during the late 1960s and early 1970s (Peck 1992) so it is unknown to what extent these non-native cockroaches have affected the cave ecosystem.

4.3.2 Uncontrolled human visitation

Cave systems vary in their capacities to sustain human visitation and exploitation. Those with large rivers passing through underground caverns typically have the highest carrying capacities. "High energy" caves with guano deposits may be exploited but only if measures are taken to ensure the survival of the guano-dependent fauna and not disturb the bat colonies on the ceiling. Vermeulen and Whitten (1999) outlined risks that need to be understood in connection with human visitation of caves, including:

- Communities of soil-dwelling cave inhabitants can be trampled to extinction. Some may retreat to other suitable places, but others cannot move easily or are bound to their location because of extreme evolution to local conditions.
- Localized populations can be harvested to extinction. In the case of Clifton Cave, local people reported catching "blind, white fish" (i.e., a cave-adapted, non-pigmented fish), which they enjoyed roasting. These fish have not been seen in over 10 years. Based on their descriptions, it was quite likely endemic to the Clifton Cave river system and eaten to extinction.
- Guano extraction can result in the extinction of species that are guano-dependent. Further, frequent collecting visits may disturb the bat colony and cause them to abandon the cave. Because bats pollinate commercial fruit (e.g., mango, avocado) and other trees and are important pest control agents, their demise would cause both financial and ecological loss.
- Deliberate and/or unintentional persecution of wildlife. The culturally-ingrained Jamaican fear of many species of wildlife leads to unnecessary persecution. Bats, known locally as "ratbats" are one group of organisms that are disliked, particularly when a colony takes residence in a building. When visiting caves, some persons strike at bats as they fly past. During my survey in Clifton Cave, such action resulted in direct injury to and the humane euthanasia of a Moustached Bat.

4.4 Rehabilitation of the road from Medley to Frome

The peripheral communities of north-central Dolphin Head will benefit by the on-going restoration of the Medley to Frome road, particularly for accessing markets in Savanna-la-Mar, Westmoreland. This is the only driveable road through the mountains and one which provides a stunning view of the lesser-disturbed forest of Georges Plain Mountain and the south coast. This road and associated vehicular traffic, however, facilitates destructive human activities, including illegal extraction of timber products, clearing for agriculture/pasture in valleys and clearing for marijuana cultivation on hilltops. At present, there appears to be no monitoring of activities along this road and illegal activities (e.g. extraction of small trees for posts and new clearing for marijuana cultivation) were documented during the period of research. Harmful practices undertaken by private landowners along this road were also observed, notably the clearing of hillslopes exceeding 30^0 by the owner of Mahogany Estate. The clearing of hill slope is expected to lead to increased soil erosion and slope destabilization under the roadbed while clearing of low-lying areas is predicted to have an important effect on terrestrial invertebrates and reptiles.

5. RECOMMENDATIONS

1. The forest of the area collectively referred to as Dolphin Head represents a unique ecosystem, recognized both nationally and globally for its extraordinary plant endemism. Efforts should be directed to ensure that no large-scale clearing of natural forest occurs. A continued reduction of forest will eventually lead to the extinction of highly-localized endemic species. It also will lead to decline in population size of species that depend upon the closed-canopy forest, such as the large Columbid bird species and the IUCN-listed vulnerable Jamaican Fig-eating Bat. As forest area decreases or as forest becomes

more homogeneous, large frugivores are predicted to be the first species to disappear because of the reduction in available food resources. Monocultures of plants provide highly ephemeral food, as a function of their flowering and fruiting phenology, and would be inadequate to support frugivore populations year-round. Very little is known about the relationship of pollinators and seed dispersers of Dolphin Head's endemic flora, but the potential exists that the reduction or loss key wildlife may lead to the extinction of their dependent plants. Research should be directed to understanding the life histories of endemic plants species and their dependence upon wildlife for their populations to persist.

2. The trails and roads leading into the Forest Reserves (e.g., Retirement) and along the eastern boundary, particularly Askenish to Frome, provide a stunning view of the forest and south coast. Their value as nature walks should be assessed. However, these roads and trails also provide access for destructive human activities, including illegal extraction of timber products and clearing for agriculture. Any development along Askenish to Frome road should be restricted, particularly because of the steep hillslopes, erosion potential and disruption of ecological processes, but also because it will lead to the degradation of the "natural beauty." Bed-and-breakfast style accommodations in established communities (e.g., Medley, Askenish) would place visitors in close proximity to the nature walks along established roads. Based on observed current motorized vehicle, maintenance of the road for residents to conduct business on the south coast would not be expected to conflict with nature walks. The owner of Mahogany Estate should be contacted to discuss his activities in relation to Dolphin Head biodiversity and ecosystem health.

2. Caution is recommended in developing the trail to Dolphin Head Monument to increase visitor capacity. The present trail is in extremely poor condition, with much evidence of soil erosion and slope break-away. The trail appears to have been created for the shortest means of access to the peak, rather than following a course of switchbacks along contours. Major trail rehabilitation will be required if the number of visitors increases. Garbage already detracts from the natural environment and disposal of human waste will need to be addressed. Additionally, the most species rich and unique area surveyed during this research was in the upper saddle-corridor along the existing trail to the monument. Monitoring of visitor effects on biodiversity along this trail is critical.

3. If there is local community interest, hillsides dominated by bamboo along the periphery of Dolphin Head should be targeted for conversion to improve the health of these biologically sterile habitats. Research is needed to develop methods to eradicate this non-native, pervasive and insidious grass species. While restoration of these hillsides to natural forest may be difficult, the replacement of bamboo with mixed fruit trees or forestry plantations of local native tree species will create new habitat for many species, including resident and migratory birds and bats.

4. Similarly, the biologically sterile areas of "God Almighty Bridge," which are dominated by rose apple, should be targeted for rehabilitation. Remnant patches of natural forest persist in this geologically and hydrologically unique site of Dolphin Head

and the composition of plant species of these patches should be the foundation for restoration. Restoration will assist not only in the protection of endemic species, notably the Dolphin Head-endemic freshwater crab, but also in the protection of the watershed. The Samuels family recognizes the pervasive and harmful effects of rose apple, which has become established only in the past 30 years, and the younger family members would like to work with Forestry Department to rehabilitate this area. Rehabilitation could involve the creation of a "Living Herbarium" of Dolphin Head endemic plants, which will also serve to attract birds and native butterflies in a natural setting.

5. Although the cultivation of marijuana is illegal on Jamaica, this report recognizes the socio-economic realities of the communities in the Dolphin Head area. Law enforcement is difficult, particularly with market demand in the tourist area of Negril, and decriminalization or legalization (so that farmers can cultivate in their yard, rather than attempting to hide in forest patches) may not be politically viable. However, this activity has direct effects on wildlife communities and, ultimately, the health of the Dolphin Head ecosystem. The effects are seen with the direct extirpation of native plant species as hilltops are cleared and with the hindering of natural forest regeneration as non-native invasive plant species become established and form near-monocultures. These heavily modified areas offer poor habitat for resident and migratory species and, consequently, forest regeneration is further hindered by the lack of seed-dispersing birds and bats. The marijuana farmers first should be educated on the differences in "natural forest bush" and "bush, dominated by non-native species," classifications which they fail to distinguish as they abandon plots when productivity decreases. Second, the Forestry Department's policy of "no-net-loss" should be applied to these farmers, who are benefiting from the use of public lands but not compensating the owners (i.e., the Jamaican People). A nursery of early-succession plant species that are native to Dolphin Head (e.g., Piperaceae, Trumpet tree *Cecropia peltata*), and appropriate for the areas targeted for reforestation, should be established and the marijuana farmers required to initiate forest recovery when they abandon a hilltop. Finally, the consumers of marijuana, notably the tourist market in Negril, should be educated that their illegal activity is contributing to the extinction of endemic species that have existed on Jamaica for millions of years.

In accordance with the Convention on Biological Diversity, to which Jamaica is signatory, it is hoped that all stakeholders (local, national, international) in the Dolphin Head area will recognize that biological diversity should be conserved for its intrinsic value and its importance for the sustainable functioning of the biosphere, not primarily for its economic exploitation. The CBD expresses the concerns of the Conventions of Parties that biological diversity is being reduced at unprecedented rates and such losses will threaten not only the functioning of ecosystems but also human well-being via changes in aesthetic, health and cultural benefits as well as economic features. Although the value of biodiversity in maintaining ecosystem stability and function is understood poorly, "a lack of full scientific certainty should not be used as a reason for postponing measures to avoid or minimize threats of significant reduction or loss of the world's unique biodiversity.

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INSERT APPENDICES I, II, II, IV, & V from Excel Spreadsheets