Herpetofaunal Inventories of the National Parks of South Florida and the Caribbean: Volume II. Virgin Islands National Park

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Conversion Factors

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
kilometer (km)	0.5400	mile, nautical (nmi)
meter (m)	1.094	yard (yd)
	Area	
square meter (m^2)	0.0002471	acre
hectare (ha)	2.471	acre

Acronyms

AIC	Akaike's Information Criterion
VINP	Virgin Islands National Park
CI	Confidence interval
ENP	Everglades National Park
GIS	Geographic information system
ORV	off-road vehicle
PAO	proportion of area occupied
SD	standard deviation
SE	standard error
SVL	snout-vent length
VES	visual encounter surveys

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Abstract

Amphibian declines and extinctions have been documented around the world, often in protected natural areas. Concern for this alarming trend has focused attention on the need to document all species of amphibians that occur within U.S. National Parks and to search for any signs that amphibians may be declining. This study, an inventory of amphibian species in Virgin Islands National Park, was conducted from 2001 to 2003. The goals of the project were to create a georeferenced inventory of amphibian species, use new analytical techniques to estimate proportion of sites occupied by each species, look for any signs of amphibian decline (missing species, disease, die-offs, etc.), and to establish a protocol that could be used for future monitoring efforts.

Several sampling methods were used to accomplish these goals. Visual encounter surveys and anuran vocalization surveys were conducted in all habitats throughout the park to estimate the proportion of sites or proportion of area occupied (PAO) by amphibian species in each habitat. Line transect methods were used to estimate density of some amphibian species and double observer analysis was used to refine counts based on detection probabilities. Opportunistic collections were used to augment the visual encounter methods for rare species. Data were collected during four sampling periods and every major trail system throughout the park was surveyed.

All of the amphibian species believed to occur on St. John were detected during these surveys. One species not previously reported, the Cuban treefrog (*Osteopilus septentrionalis*), was also added to the species list. That species and two others (*Eleutherodactylus coqui* and *Eleutherodactylus lentus*) bring the total number of introduced amphibians on St. John to three. We detected most of the reptile species thought to occur on St. John, but our methods were less suitable for reptiles compared to amphibians.

No amphibian species appear to be in decline at this time. We found no evidence of disease or of malformations. Our surveys provide a snapshot picture of the status of the amphibian species, so continued monitoring would be necessary to determine long-term trends, but several potential threats to amphibians were identified. Invasive species, especially the Cuban treefrog, have the potential to decrease populations of native amphibians. Introduced mammalian predators are also a potential threat, especially to the reptiles of St. John, and mammalian grazers might have indirect effects on amphibians and reptiles through habitat modification. Finally, loss of habitat to development outside the park boundary could harm some important populations of amphibians and reptiles on the island.

Introduction

Declines in amphibian populations have been documented worldwide from many regions and habitat types (Alford and Richards, 1999). No single cause for declines has been demonstrated, and it seems likely that several factors may interact to threaten populations (Carey and Bryant, 1995). In response to concerns about amphibian population declines, the Department of Interior (DOI) received funding from Congress to institute long-term surveys of the status and trends of amphibians on DOI lands. This report describes an inventory of the amphibians and reptiles of Virgin Islands National Park that was conducted from 2001 to 2003. This study focused primarily on amphibians, and our methods were designed to be most effective for those species. However, many species of reptiles are also readily sampled using these methods, and we include data collected about that class in this report. This study did not attempt to survey marine turtles and, therefore, they are excluded from species lists presented in this report.

Virgin Islands National Park (VINP) encompasses 2,816 ha of land on St. John, and also protects another 2,287 ha of water around the island. St. John, the smallest of the three U.S. Virgin Islands, is part of the Lesser Antilles and lies near the tropic of cancer about 112 km east of Puerto Rico (Figure 1). This area, known as the Puerto Rican bank, includes both the U.S. and British Virgin Islands. The National Park includes the majority of St. John (Figure 2), and consists of three primary terrestrial habitats. The first of these, moist forest, may receive up to 173 cm of rainfall per year. Moist forest vegetation includes West Indian locust (*Hymenaea courbaril*), sandbox (*Hura crepitans*), kapok (*Ceiba pentandra*), mango (*Mangifera indica*), strangler fig (*Ficus aurea*), and hogplum (*Spondias mombin*). Understory vegetation consists of various shrubs along with bromeliads and ferns. The second major terrestrial habitat type in the park is dry forest. Dry forests and associated dry scrub areas may consist of gumbo limbo (*Bursera simaruba*), mampoo (*Buapira fragrans*), acacia (*Acacia* spp.), and white cedar (*Tabebuia heterophylla*). Organ pipe (*Pilosocereus royenii*) and Turk's cap (*Melocactus azureus*) cacti are also found in these areas. Mangrove forests, the third major habitat type in the park, line the periphery of bays and salt ponds. Three species of mangrove-red (*Rhizophora mangle*), black (*Avicennia germinans*), and white (*Laguncularia racemosa*)-are found in the park. In addition to the three major habitat types, the park contains coastal communities, natural salt ponds, and guts (intermittent stream beds lined with boulders). The guts appear to be very important for aquatic and semiaquatic species, as they may be the only natural source of permanent fresh water. Primary vegetation on St. John was mapped using the habitat designations of the University of the Virgin Islands (2000; Figure 3).

Dumeril and Bibron first described the herpetofauna of the Puerto Rican bank (Schwartz and Henderson, 1991). Their discoveries, along with other contributions, have documented about 80 species of amphibians and reptiles from the region. However, species diversity decreases eastward from Puerto Rico to the Virgin Islands. Each island contains approximately 14 to 19 amphibian and reptile species, and moisture is a major determining factor in their distribution (Thomas, 1999). Because of the unique natural and cultural history of the Virgin Islands, the origins of some amphibian and reptile species occurring in the region have been debated (MacLean, 1982).

MacLean (1982) listed 4 species of amphibians as being present on St. John. Since that time, new discoveries and introductions of several exotic species have increased the number of amphibian species potentially occurring on the island to eight. Our survey has documented 6 of these 8 amphibian species, including 3 introduced species, *Eleuthrodactylus coqui, Eleuthrodactylus lentus,* and *Osteopilus septentrionalis*. MacLean (1982) also listed 13 species of reptiles (excluding sea turtles) for St. John; we have documented the existence of 9 of those species, including 2 exotic lizards.

Survey Methods

We used several different methods to sample for amphibians at sites throughout VINP. Our two primary survey methods were nocturnal visual encounter surveys (VES) and vocalization surveys; both methods are described in detail below. We also recorded any opportunistic encounters with amphibians and reptiles, including details on locations of captures and physical data (when possible) on each individual animal. Most of the data used in this report come from samples made during trips in February 2001, October 2001, and May 2002. All transect data from a sampling trip in June 2001 were stolen, but voucher specimens were collected from this trip.

Data collection techniques for visual encounter surveys were designed to utilize three methods of population analysis. First, we were able to determine frog densities from VES transect data. In addition to providing density estimates, our nighttime surveys were designed around both a double observer method and PAO analysis (see Data Analysis below). These two methods allowed us to estimate the number of amphibians present in an area and to estimate the probability of finding certain species within each habitat.

Lastly, we collected voucher specimens to formally document the occurrence of some species. Voucher specimens were collected from opportunistic encounters throughout the island. Specimens were sacrificed using Benzocaine (Ora-Gel™; Chen and Combs, 1999), fixed in 10 percent formalin, and preserved in 70 percent ethanol. Localities for all collected specimens were recorded, along with collector name, and any relevant notes. These specimens have been accessioned into the NPS collections database and are cataloged as collection numbers VIIS-0001535 to VIIS-0001675. They will be permanently housed at VINP. Data collected from all methods used during this survey were recorded for storage into a Microsoft Access database and will be made available as a supplement to this report.

Site Selection

Transects for this survey were chosen along existing trails within VINP. The trails were used in an effort to adequately sample as much of the park as possible within our time constraints. For purposes of this study, the park was divided into five habitat types; moist forest, dry forest, and scrubland, developed land, and guts. Each trail used in this study was plotted on the vegetation map to determine the dominant habitat type of the trail (Table 1; Figure 4).

Visual Encounter Surveys

Our primary method of sampling was a standard VES (Heyer and others, 1994) conducted for at least 30 minutes along transects within the park. All VES began at least 30 minutes after sunset to maximize the probability that amphibians would be active. Two experienced observers conducted each VES using 6-volt spotlights with halogen bulbs. The goal was to find as many individuals as possible during the time allotted. Transects were thoroughly searched, including trees and other vegetation as well as bare ground and leaf litter.

We attempted to capture each amphibian or reptile that was observed during a VES. The animals were identified and recorded as to species, sex (if possible), and age/life stage (for example, juvenile, adult, larva, and so forth). The snout-to-vent length (SVL) of each animal captured was measured in mm. The substrate on which each individual was first observed and the perch height (estimated to the nearest 10 cm) was also noted. For line transect density estimation, the perpendicular distance from the edge of the trail to the location of the animal was estimated to the nearest 10 cm and recorded.

In addition to the biological data collected during a VES, we also collected some key environmental data in the field at the time of the survey. We measured the air temperature and relative humidity using a digital thermohygrometer, and classified the weather into one of five categories: clear, partly cloudy, cloudy, rain, or fog. Wind speed was classified as none, light, moderate, or strong. The date and time of the sample, as well as the observers present were recorded.

Vocalization Surveys

At the beginning of each VES transect, we conducted a 10-minute call count survey. During this period, we noted all species of frogs that were heard vocalizing. The abundance of vocalizing individuals was estimated and placed into one of the following five categories: 1, 2 to 5, 6 to 10, greater than 10, or large chorus. In addition, the frequency of calling by each species was categorized as occasional, frequent, or continuous. These categories were discussed with newer observers in the field so that a consensus could be reached on which category to place the abundance and frequency of calls.

Data Analysis

During attempts to visually locate animals, many of the individuals present typically are not observed (Williams and others, 2002; Schmidt, 2003). This can be due to a variety of factors including an animal's behavior, cryptic coloration, weather conditions, or just chance. Many frogs are difficult to observe directly at night using handheld lights (Heyer and others, 1994). For this reason, we did not consider counts of individuals from transects as indicative of the actual numbers present at sites. In addition, we did not accept these counts as an index and assume that all factors affecting sighting probability are equal at each sample at each site. Instead, we directly estimated the number of frogs missed during a visual encounter survey using a two-observer approach (Nichols and others, 2000), or we estimated the proportion of sites occupied by a species using multiple visits to the same site (MacKenzie and others, 2002).

Density Estimation

Our line transect sampling data were used with the DISTANCE program to estimate the density of frogs (Thomas and others, 2003). We used DISTANCE to estimate the density of animals by species throughout VINP. DISTANCE facilitates choosing and testing several detection functions for fit against the observed data. The density of individuals (per ha) was then estimated by applying the detection function to the data. Because of the scarcity of data available for analysis, we collapsed the habitat categories into two: dry forest (including scrubland habitat) and moist forest (including gut habitat). Developed land was not included in this analysis.

We tested two different detection functions (cosine and uniform) in DISTANCE, as well as models with and without habitat type as a factor. We also tested models both without truncation of the data for the longest distances and with truncation to 4 m. This cutoff was chosen based on visual interpretation of the data; all but the longest distances fell below this cutoff. A total of 8 different models were used in the comparison.

Double Observer

Sampling using the double observer method required one primary observer and one secondary observer (Nichols and others, 2000). The primary observer walked first along each transect, pointing out all frogs detected. The secondary observer followed close behind, recording the data and noting any additional frogs the primary observer missed. Halfway across each transect, the observers switched roles so that each had a turn as primary observer.

The data used for the analysis were the total number of frogs observed by both observers and the number of frogs observed by the primary observer. We used program SURVIV (White, 1992) to perform double observer data analyses. We tested two models, one in which each observer had individual probabilities of detecting an individual frog, and a more general model where the detection probability was pooled across observers. The best model was chosen using Akaike's Information Criterion (AIC), an information-theoretic approach (Burnham and Anderson, 1998).

The overall density of frogs along transects was estimated using the detection probability obtained in this analysis. The total number of frogs observed during all surveys was divided by the estimated detection probability to estimate the actual number of frogs present along the transects. The length (in m) of all trails surveyed was multiplied by 4 m per side of transect surveyed to calculate the total area surveyed. The estimate of the true number of frogs then was divided by the total area surveyed to produce an estimate of the overall density of frogs in VINP.

Proportion of Area Occupied (PAO)

Just as individuals may be missed when searching transects, so may entire species (MacKenzie and others, 2002). This problem is especially important for species that are found in low abundance where only one or two individuals are present along a given transect. If these individuals are missed, it is possible that the species will not be detected. The proportion of sites where the species is found is therefore less than the proportion of sites in which it occurs. The latter was estimated by repeated visits over time. We used the site occupancy modeling approach of MacKenzie and others, (2002) to directly estimate the proportion of area occupied (PAO) by a given species within a given habitat type.

We used detection data from each transect that was visited more than once to estimate the proportion of sites occupied by each species. The sites were classified into the two classes of habitats identified earlier: moist forest/gut and dry forest/shrubland. These classes represent the two ends of the moisture gradient on St. John. Data were analyzed with the PRESENCE program (MacKenzie and others, 2002) to obtain estimate of overall PAO. Model selection methods (see Double Observer) were used to determine if the best model included separate habitats (Burnham and Anderson, 1998).

Results

We surveyed 43 transects within VINP during 63 VES sampling events. We conducted vocalization surveys at the starting points of 39 separate transects. We encountered 216 individual amphibians and 38 individual reptiles during VES in VINP. In addition, we collected 58 individual amphibians and 10 reptile specimens as vouchers during opportunistic encounters. We have documented 6 of the 8 potential amphibian species on St. John, using all methods. In addition, we documented 9 reptile species from the island.

Density Estimation

Density estimation using line transect data was only performed for *Eleutherodactylus antilliensis* (Table 2). Other species were observed in low numbers and, therefore, the density of these species could not be estimated. All of the best models chosen using AIC for model selection were with the truncated data set (excluding observations greater then 4 m from the transects). Observations outside this range were rare and force the detection function into a shape that provides a very poor fit to the data.

The two best models were virtually indistinguishable using AIC. Both used the truncated data set and the uniform cosine detection function, but one was with the data stratified by habitat type and the other was without stratification. This indicates only weak support for the presence of habitat-related differences in density of *E. antilliensis*. Density estimates for these two best models were similar, 41.6 (CI 29.2-59.2) frogs/ha and 39.2 (CI 27.0-57.1) frogs/ha for un-stratified and stratified data, respectively. These results are the global estimate of density of *E. antilliensis* throughout VINP, and they are similar to the results obtained using the double observer method on the data from the same species (described next).

Double Observer

Double observer analysis was only possible for *Eleutherodactylus antilliensis* (Table 3). No other species were observed in sufficient numbers to permit this type of analysis. The estimation process is somewhat data intensive, especially for models where detection probabilities are estimated for individual observers. Of the two models tested, the more general model that estimates a common detection probability for all observers yielded the best results. This model had an AIC value of 50.81, compared to 59.12 for the model with individual estimates of detection probability. The likelihood ratio test also confirmed that there was not significant support for the reduced model (X^2=1.69, df=5, p=0.8897).

The common estimate of detection probability was 0.432 (SE=0.1097). This means our observers saw approximately 43 percent of the frogs that were actually visible along each transect. Individual estimates for observer detection rates ranged from 0.419 to 0.576. These results indicate that detection rates are fairly even across different observers, but less than half of the visible frogs were observed in an average sample. This information is important to consider in designing future monitoring projects.

The total area that was sampled during this project was 85,980 m^2, or 8.598 ha, and we observed 157 *E. antilliensis* during these surveys. Dividing this number by the common detection probability (0.432) we estimate that there were 363.4 individuals of *E. antilliensis* in the 8.598 ha that were sampled, or a density of 42.268 frogs per ha. This result is close to the estimate of 41.6 frogs per ha obtained using distance analysis. It is encouraging and somewhat intuitive that these results are so similar. Although they were obtained using different data and different survey techniques, both analytical methods address the same problem of undetectable animals. Either survey method appears to be appropriate for use on *E. antilliensis* on St. John. DISTANCE analysis requires recording perpendicular distances, and double observer analysis requires two individuals for each survey.

Proportion of Area Occupied (PAO)

Three amphibian species were detected in sufficient numbers to estimate the proportion of sites in which they occur. *Eleutherodactylus antilliensis* was the most commonly observed amphibian in our study, and was detected at 78.9 percent of the sites we sampled. Among the four models tested, no single model was clearly better than the others (using AIC model selection) (Table 4). Model selection indicates that occupancy rate may or may not be a function of habitat division, and detection rate may or may not be a function of air temperature. Results suggest the most parsimonious model is that detection is influenced by air temperature and occupancy is variable by habitat type. The overall estimate for the proportion of sites occupied by *E. antilliensis* using this model is 0.792 (SE=0.094), which is very similar to the initial estimate of 0.789. These results indicate that although counts may be unreliable for *E. antilliensis* (see Results: Double Observer above), presence of the species is readily detected. This is probably partly because the data from vocalizations and visual detection were combined for PAO analyses.

We also were able to estimate the proportion of sites occupied for *Eleutherodactylus cochranae* (Table 5), was detected at 26.3 percent of the sampled sites. Only the two occupancy models that included habitat type converged on a real estimate of site occupancy. The better of these two models includes temperature as a detection covariable. The estimate of sites occupied by this species is 0.782 (SE=0.206), which indicates that the species probably occupies a much larger number of sites than the number in which it was detected. This species is particularly small, and does not call as frequently as *E. antilliensis*, which may explain the low detection rates. The high variability of the site occupancy estimate makes it difficult to be certain of the true area occupied by the species, but it is certainly larger than 26 percent.

We also obtained site occupancy estimates for a third species, *Leptodactylus albilabris* (Table 6), which was detected at 42.1 percent of the sites we sampled. As was the case with *E. cochranae*, the only two models that converged were those that included habitat as an occupancy covariable. Like *E. cochranae*, detection of *L. albilabris* appears to be dependent on air temperature. The overall site occupancy estimate for this species is 0.782 (SE=0.206). Like the estimate for *E. cochranae*, it is much higher than the naïve occupancy rate, and it has a large amount of statistical variance. This may be due to the fact that the moist forest habitat category combines guts, which appear to have a very high occupancy rate, and gallery moist forest, which presumably has a lower occupancy rate. In general, *L. albilabris* is another species with low detection rates, complicating our ability to accurately estimate the total area occupied by this species.

Species Accounts - Anurans

During this study, we encountered 6 anuran species in VINP. Three of the species detected during this study are introduced on the island: the Cuban treefrog (*Osteopilus septentrionalis*), the common coqui (*Eleutherodactylus coqui*), and the mute frog (*Eleutherodactylus lentus*). The marine or cane toad (*Bufo marinus*), another exotic species potentially present on St. John, was not detected during this survey. The other three anuran species detected are native members of the family Leptodactylidae: the white-lipped frog (*Leptodactylus albilabris*), the Antillean frog (*Eleutherodactylus antilliensis*), and the whistling frog, *Eleutherodactylus cochranae*. The threatened Puerto Rican crested toad (*Bufo lemur*) was not found during this study.

Bufo marinus

Bufo marinus, also known as the cane, marine, or giant toad, is an exotic species in both the U.S and the West Indies that has been actively introduced in many areas to control pests in sugar cane fields (Conant and Collins, 1998). This large South American toad is tolerant of many different habitats, including both xeric and mesic areas. The species is an opportunistic feeder that actively preys on both invertebrates and small vertebrates (MacLean, 1982). In addition, *B. marinus* produces a *Bufo* toxin that may be harmful or fatal to potential predators of the species (Conant and Collins 1998).

Bufo marinus is known to occur on the nearby islands of St. Thomas, St. Croix, Puerto Rico, and Tortola, British Virgin Islands (MacLean, 1982; Schwartz and Henderson, 1991). Taking into consideration St. John's proximity to these islands and the dispersal ability of the species, it seems likely that *B. marinus* colonized St. John in the past. In addition, accounts from residents of St. John, including Rafe Boulon (VINP resource management, oral comm., 2005), indicate that *B. marinus* was present on the island at one time. However, no recent sightings of the species were communicated to us, and none of our contacts could remember seeing any individuals during the past several years. We did not detect any individuals of *B. marinus*, nor did we hear them vocalizing, even during the rain event of October 2001. This species either does not currently occupy St. John, or it may exist in very low numbers on the island. In the past, no collections of *B. marinus* have been made from St. John and no official records of this species on St. John have been published.

Bufo lemur

The Puerto Rican crested toad, *Bufo lemur*, is another member of the family Bufonidae that may be present on St. John. *B. lemur* occurs in semiarid rocky lowlands, seasonal evergreen forest, and in other rather mesic areas (Schwartz and Henderson, 1991). The known range of *B. lemur* includes Virgin Gorda in the British Virgin Islands and Puerto Rico, so the possibility exists that it may be present in other areas of the Puerto Rican bank. The presence of this species on St. John would be particularly important because the U.S. Fish and Wildlife Service lists the species as Threatened. One individual of this species was reported observed on St. John and then later identified, but no specimen or photograph was made as a voucher (Norton, 1997). The lack of a voucher or any subsequent sightings of this species call into question the occurrence of the species on St. John, but the crested toad is known to be secretive and is rarely active except in the wettest conditions (Rivero, 1978; Schwartz and Henderson, 1991). We therefore cannot conclude *Bufo lemur* is absent on St. John, but we consider it unlikely that a breeding population occurs on the island.

Eleutherodactylus antilliensis

The Antillean frog, *Eleutherodactylus antilliensis*, is a member of the family Leptodactylidae, and native to St. John. This species is found in primarily wooded habitats, including xeric forest. During the day, it hides in bromeliads, under the bark of trees, or in tarantula burrows (Schwartz and Henderson, 1991). This species was commonly found throughout the island during this study.

One hundred and fifty seven individual Antillean frogs were found during our nighttime transect surveys (Figure 5). Individuals were found on a variety of substrates, but were primarily found on palms or other trees (Table 7). We encountered the species in all major habitats; however, most individuals were found in forested habitats (Table 8). Measurements were taken from 58 of the 157 frogs captured during VES (Table 9). In addition, *E. antilliensis* was found opportunistically throughout the island. Eleven individuals were collected throughout the island as voucher specimens (Figure 6).

Eleutherodactylus cochranae

The whistling frog, *Eleutherodactylus cochranae*, is native to St. John, and is primarily found in xeric wooded areas where it uses bromeliads and coconut husks as diurnal retreats (Schwartz and Henderson, 1991). This species was commonly found throughout the island during our nocturnal surveys (Figure 7), primarily in bromeliads or on tree branches and leaves (Table 7). A total of 25 individuals were found, and SVL of 7 were measured (Table 9), and 4 individuals were collected as voucher specimens (Figure 8).

Eleutherodactylus coqui

Another member of Leptodactylidae, the Puerto Rican or common coqui (*Eleutherodactylus coqui*) has been introduced onto St. John. While the natural range of this species includes only Puerto Rico, introductions have been documented in south Florida, St. Thomas and adjacent islands, and St. Croix (Conant and Collins, 1998; Schwartz and Henderson, 1991). The species is naturally found in mesic habitats, and typical of the genus, does not require that eggs be deposited in a water source. This terrestrial reproduction strategy suggests that *E. coqui*, along with other introduced Leptodactylids, may thrive within VINP.

Vocalizations of E. coqui were detected at one of our survey transects (Figure 9). Three individual E. coqui were found and collected as voucher specimens during this study through opportunistic encounters at Westin Resort (Figure 10). This suggests that this species is currently associated with areas near disturbance on the island, and may not have widely spread into the natural areas of the park.

Eleutherodactylus lentus

Like the common coqui, the mute frog (*Eleutherodactylus lentus*) is introduced on St. John. This is a notable member of the family Leptodactylidae because unlike most other frogs, it is voiceless. *E. lentus* is believed to have evolved as an endemic on St. Croix. The species was later spread as an exotic to St. Thomas and St. John, probably through agricultural or horticultural products (MacLean, 1982).

As with the other introduced leptodactylid, *E. coqui*, mute frogs were not found in natural areas of VINP during our study. Six individual mute frogs were found and collected as voucher specimens at the Westin Resort (Figure 11).

Leptodactylus albilabris

The white-lipped frog (*Leptodactylus albilabris*) is native to both the U.S. and British Virgin Islands. Although it was not listed specifically for St. John by MacLean (1982), its occurrence on the island is believed to be natural. This species is semi-aquatic and is usually found in streams, guts, ditches, marshes, and other wet areas. After breeding, *L. albilabris* deposit their eggs in foam nests under surface debris. The tadpoles are later washed from these nests into temporary ponds (Schwartz and Henderson, 1991).

Consistent with the natural history of the species, we found that *L. albilabris* was common in guts throughout the island. A large majority of individuals encountered were found on the ground or on rocks within guts (Table 7). We found a total of 29 white-lipped frogs during our transect surveys (Figure 12), and measured SVL's of eleven of those individuals (Table 9). Eleven additional white-lipped frogs were collected as voucher specimens (Figure 13).

Osteopilus septentrionalis

The only hylid species encountered in VINP was the Cuban treefrog, *Osteopilus septentrionalis*. The Cuban treefrog is one of three members of the West Indian hylid genus *Osteopilus*, and is native to Cuba, Isla de Juventud, the Cayman Islands, and the Bahamas (Meshaka, 2001). Introductions of this species were previously recorded for Puerto Rico, St. Croix, and St. Thomas (Schwartz and Henderson, 1991; Meshaka, 2001). However, neither MacLean (1982) or Schwartz and Henderson (1991) listed the species from St. John. This study represents the first official documentation of *O. septentrionalis* from VINP. The presence of this exotic on St. John may be significant to other wildlife, as this species is a known predator of frogs and other small vertebrates (Meshaka, 2001).

Four specimens of *O. septentrionalis* were encountered during our transect surveys (Figure 14), but only two of those were captured for measurements. Although Cuban treefrogs were not frequently found during our transect surveys, many individuals were encountered opportunistically throughout the island and 22 *O. septentrionalis* were collected on St. John (Figure 15). Cuban treefrogs on St. John, as with other introduced populations of this hylid, appear to be largely associated with man-made structures and other disturbed areas.

Reptiles

During this study, our methods were designed primarily to sample amphibian species. However, many reptile species on the island were easily sampled using VES. We have included data in this report for reptile species encountered during the course of this study. The most abundant reptile found during VES was *Anolis cristatellus* or the Puerto Rican crested anole. Other species, including the green iguana (*Iguana iguana*) and garden snake (*Arrhyton exiguum exiguum*), were documented only from opportunistic encounters. In total, we found 38 individual reptiles of three species during transect surveys. Through opportunistic encounters, we documented 6 other reptiles, for a total of 9 species. This number includes the exotic *Hemidactylus mabouia*, the Amerafrican house gecko. Due to the structure of our methods, we were unable to document a few other reptiles known to occur on the island, including the red-footed tortoise and the common worm snake.

Anolis cristatellus

The Puerto Rican crested anole, *Anolis cristatellus*, is widespread throughout the Puerto Rican bank. The species occurs in a variety of habitats, and was found throughout the island during our study. Individuals were commonly found resting on tree branches and shrubs during our nighttime VES. In total, we found 30 *A. cristatellus* during our transect surveys. We collected two individuals as voucher specimens during opportunistic encounters (Figure 16).

Anolis pulchellus

Another native anole, the sharp-mouthed lizard (*Anolis pulchellus*), was also very common throughout St. John. Unlike the other anole species on the island, this species prefers grassy habitat and has also been referred to as the grass anole (MacLean, 1982). Individuals are typically located on the stems of small shrubs, dead twigs, or grass blades (Schwartz and Henderson, 1991). While we did not find this species during our nocturnal transect surveys, we did frequently encounter it during daylight hours on the island. Two individuals were collected as voucher specimens (Figure 17).

Anolis stratulus

The least abundant anole found during our study was *Anolis stratulus*, the salmon lizard. The salmon lizard is primarily a trunk-crown dweller and is usually found high up in large trees, although it may sometimes be found on grasses or ground litter (Schwartz and Henderson, 1991). The natural history of the species may account for the fact that this was the least seen anole during our study. We observed only 4 individuals during our nighttime transect surveys, and collected two individuals to serve as voucher specimens (Figure 18).

Iguana iguana

The arrival and occurrence of the green iguana, *Iguana iguana*, in the Virgin Islands has received considerable discussion. This lizard is native to South America, and has been established on Puerto Rico in the last thirty years. However, *I. iguana* has occurred in the Virgin Islands much longer and the species' mode of arrival is debatable (Thomas, 1999). Some researchers have suggested that either Pre-Columbian Indians or Europeans brought green iguanas to the islands, while others maintain that the species is native (MacLean, 1982; Thomas, 1999). Since the species is diurnal and spends the day foraging and thermo regulating (MacLean, 1982), it is not surprising that *I. iguana* was not encountered during our nighttime VES. However, we did incidentally document the species from Cruz Bay during a daytime visit.

Hemidactylus mabouia

Hemidactylus mabouia, the Amerafrican house gecko, is found throughout St. John. In the past, some researchers have suggested that this species may be native to the region (Kluge, 1969). However, the more commonly accepted explanation of the origin of this species in the Virgin Islands is that *H. mabouia* were introduced to the area from Africa, arriving as passengers on slave ships (MacLean, 1982). We did not find this species during our transect surveys. However, we found these geckos in both natural areas and on buildings during opportunistic encounters. No specimens of *H. mabouia* were collected during this study.

Sphaerodactylus macrolepsis

The common dwarf gecko (*Sphaerodactylus macrolepis*) is native to St. John. This species is small, with adults usually only reaching 34-35 mm SVL. *S. macrolepis* is primarily terrestrial, and individuals can normally be found foraging in leaf litter (MacLean, 1982; Schwartz and Henderson, 1991). The small size of *S. macrolepis*, combined with its terrestrial habits, may make the species difficult to detect. However, we found the species to be common throughout the island. Four individuals were found during VES, and three specimens were taken as vouchers (Figure 19).

Ameiva exsul

The common ground lizard (*Ameiva exsul*) is a diurnal lizard species native to St. John. These lizards can commonly be found in sandy open areas including lawns, parks, and roadsides (Schwartz and Henderson, 1991). Because of its natural history, this species was not found during our nighttime VES surveys; however, we did observe *A. exsul* occasionally in the town of Cruz Bay. No specimens of *A. exsul* were collected during this study.

Amphisbaena fenestrata

Despite its name, the Virgin Islands blind snake (*Amphisbaena fenestrata*) is actually not a snake. It is the only member of order Amphisbaena to occur on the island, and may be found in a wide variety of habitats. However, *A. fenestrata* is a burrower and is almost always found under rocks, debris, or in small holes (MacLean, 1982; Schwartz and Henderson, 1991). We did not find this species during our nighttime VES, although it is active nocturnally. We did, however, collect one specimen from the Lameshur Bay area (Figure 20). This individual was preserved as a voucher specimen.

Arrhyton exiguum exiguum

The garden snake (*Arrhyton exiguum exiguum)* is a small non-venomous snake that feeds primarily on lizards and frogs. The species is probably diurnal (Schwartz and Henderson, 1991), and, as expected, we did not encounter this species during nighttime VES. Unfortunately, we did not encounter the species opportunistically on the island. However, Rafe Boulon (VINP resource management, oral comm., 2005) has two preserved specimens collected from St. John.

Typhlops richardi

We did not detect any individuals of the common worm snake (*Typhlops richardi*) during this study. This species is one of a few endemics in the eastern part of the Puerto Rican bank, and is not found on Puerto Rico itself (Thomas, 1999). The species is typical of the genus in that it is fossorial, spending the majority of its time underground. As a consequence, our survey methods were not effective for this particular snake. Rafe Boulon (VINP resource management, oral comm., 2005) has found *Typhlops richardi* while digging in areas adjacent to VINP.

Geochelone carbonaria

Geochelone carbonaria, the red-footed tortoise, is the only tortoise found on St. John. The origin of this species in the Virgin Islands, like that of the green iguana, is debatable. *G. carbonaria* are used as a food source by many people, and may have arrived in the West Indies by both natural means and introductions (Thomas, 1999; Schwartz and Henderson, 1991). We did not detect this species in VINP during either our VES surveys or opportunistic encounters.

Summary and Conclusions

This report provides the first complete inventory of the amphibians of Virgin Islands National Park. It is meant to serve as a complete list of the amphibian species known to occur on the island of St. John, as well as to provide as much information as possible about the population status of each species within the boundaries of VINP. In addition, information gathered through literature review and during trips to St. John on reptiles in the park is included. We lack population status information for reptiles, as this was outside the scope of this study, but we feel the additional information we provide will be useful as a species list of reptiles for the park.

In general, amphibian populations in VINP appear to be very healthy. All of the native species of anurans were found throughout the park. *Eleutherodactylus antilliensis* and *Eleutherodactylus cochranae* appear to be habitat generalists. *E. antilliensis* was often heard calling from disturbed areas in suburban Cruz Bay. *Leptodactylus albilabris* appears to be primarily restricted to the guts (rocky beds of intermittent streams) throughout the island. We found this species in every such gut in which we searched. No evidence of disease or malformations was found on the island, and all species were heard vocalizing, so we presume reproduction is taking place. The Puerto Rican crested toad (*Bufo lemur*) was not found during this study, but its presence as a native species on St. John has never been definitively proven.

Three anuran species introduced on St. John were encountered in this study: the Cuban treefrog (*Osteopilus septentrionalis*), the common coqui (*Eleutherodactylus coqui*), and the mute frog (*Eleutherodactylus lentus*). The coqui was only detected once away from the suburban area of Cruz Bay, and the mute frog was only seen at one site in Cruz Bay. Both of these species probably came to St. John on horticultural material, and both seem to thrive in the artificially irrigated landscaped areas around the Westin resort hotel.

Unlike the coqui and the mute frog, the Cuban treefrog was found in natural areas throughout the park. The Cuban treefrog is well known as a colonizer of disturbed places, and it seems to have a wide range of tolerance for various habitats (Meshaka, 2001). The presence of Cuban treefrogs on the island may present the biggest potential detriment to natural areas on St. John because of the invasive and predatory nature of the species. Cuban treefrogs are a known predator of other frogs and have the potential to out-compete other species for limited food supplies (Meshaka, 2001). It is likely that the population of Cuban treefrogs on St. John will continue to increase, and the species appears to be spreading to all corners of the island. This species should be monitored to determine what effect it will have on the native frogs of St. John.

There are few other threats to the native amphibians of St. John. Populations within VINP are protected from development, and introduced mammalian fauna do not appear to directly impact the amphibian species (for example, predation). In addition, indirect effects (that is habitat disturbance) did not have a noticeable effect on the native anurans. Loss of habitat due to the encroachment of human development is problematic, but this will be limited to areas outside of the park boundary. In general, the amphibian fauna of VINP seems healthy and appears to have good prospects for remaining much as it is.

The reptile fauna of St. John and VINP require further study and monitoring. The status of several species believed to occur on the island is unsure, because they were not seen at all during our surveys, perhaps due to the nature of the sampling methods used. Both species of snakes native to St. John, *Arrhyton exiguum exiguum* and *Typhlops richardi*, appear to be rare. Only one person we spoke to remembered seeing a snake on the island. It is well known that feral cats, mongoose, and rats are predators of both of these small, non-venomous snakes. They are probably not adapted to escaping mammalian predators and are therefore vulnerable to predation.

The three *Anolis* lizard species present on the island were seen throughout the park and appear to be common. Likewise, *Sphaerodactylus macrolepis* was found in the leaf litter throughout the park. The only other native lizard on the island, *Ameiva exsul*, was found in landscaped areas near Cruz Bay. Why this species was not observed in natural areas is not clear, and may warrant more study. Two species of lizards are introduced to St. John. The green iguana was observed in Cruz Bay, and may be restricted to areas near human landscapes. The other introduced lizard is *Hemidactylus mabouia*, a ubiquitous gecko found throughout the Caribbean. Neither of these species appears to be a threat to the native flora or fauna.

The amphisbaenid native to St. John, *Amphisbaena fenestrata*, was detected during an opportunistic encounter. This was somewhat exciting as the fossorial nature of this species makes it generally difficult to find. It provides encouragement that the species is surviving on the island despite the effects of exotic mammalian predators. We did not detect it ourselves, but during the course of our surveys, we received credible reports of red-footed tortoises on St. John. This species was introduced on the island, probably as a food source, and appears to occur in low numbers today. It is probably not a threat to the native flora.

The main threat to reptiles on St. John is likely the presence of mammalian predators. The park managers have started reducing the populations of rats, cats, mongoose, wild hogs, goats and sheep from the park. Certainly the great reduction of cats, and probably mongoose, will benefit the amphibians and reptiles in the park. There are few species of introduced reptiles, but none have the potential of the Cuban treefrog to cause harm to the native fauna.

Future research needs on the amphibians and reptiles of St. John center around the need for continued population monitoring. Our work provided a snapshot of species occurrence and only provides abundance estimates for the more common species. Continued monitoring of amphibians using the protocols of this study or similar methods could provide data on the long-term trends of amphibian populations in the park. Studies on the effects of perturbations such as exotic predators and disturbance to the vegetation would also provide useful data on how these potential threats could impact amphibian and reptile populations on St. John in the future.

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Tables

Table 1. List of trails and habitat types used as transects for herpetofaunal surveys in Virgin Islands National Park. Trail numbers correspond to number on map of trails in Figure 4.

Trail name	Habitat type	Trail number
Bordeaux Mountain Road	Moist Forest	21-22
Bordeaux Mountain Trail	Dry Forest	19
Brown Bay Trail	Shrubland	1
Caneel Hill Trail	Dry Forest	5-8
Cinnamon Bay Self Guided Trail	Moist Forest	26
Cinnamon Bay Trail	Dry Forest	25-30
Concordia Farm Pond	Shrubland	17
Fish Bay Gut	Gut	10
Fish Bay Road	Shrubland	11-12
Francis Bay Trail	Shrubland	24
Gut at Virgin Islands Ecological Research Station	Gut	18
Johnny Horn Trail	Shrubland	3
Lameshur Bay Trail	Moist Forest	20
Leinster Bay Road	Shrubland	2
Lind Point Trail	Shrubland	4
Little Fish Bay Gut Farm Pond	Shrubland	13
Ram Head Trail	Shrubland	14-15
Reef Bay Trail	Dry Forest	23
Susanberg Sugar Mill	Dry Forest	9
Trail at Virgin Islands Ecological Research Station	Moist Forest	18
Westin Resort	Developed	27

Table 2. Results of DISTANCE analysis for *E. antilliensis* in Virgin Islands National Park.

[AIC, Akaike's Information Criterion]

Mode	No. of parameters	AIC	ΔAIC	Density	Lower confidence limit	Upper confidence limit
Uniform Cosine Detection / No Habitat Stratification / Truncated at 4m	2	1175.863	0	41.59	29.22	59.21
Uniform Cosine Detection / Habitat Stratification / Truncated at 4m	3	1176.601	0.738	39.22	26.95	57.09
Half-Normal Cosine Detection / No Habitat Stratification / Truncated at 4m	3	1180.416	4.553	39.30	25.77	59.96
Half-Normal Cosine Detection / Habitat Stratification / Truncated at 4m	4	1180.856	4.993	40.70	26.65	62.14
Half-Normal Cosine Detection / No Habitat Stratification / Not Truncated	4	1268.31	92.447	46.15	32.57	65.39
Half-Normal Cosine Detection / Habitat Stratification / Not Truncated	6	1269.138	93.275	44.20	30.48	64.09
Uniform Cosine Detection / No Habitat Stratification / Not Truncated	3	1280.451	104.588	31.29	22.52	43.47
Uniform Cosine Detection / Habitat Stratification / Not Truncated	6	1285.08	109.217	30.95	21.86	43.81

Table 3. Results of double observer analysis for *Eleutherodactylus antilliensis* within Virgin Islands National Park.

[AIC, Akaike's Information Criterion; SE, standard error]

Model	No. of parameters	AIC	ΔAIC	Detection probability	SE
Constant Detection	1	50.818	0	0.432	0.110
Observer Dependent Detection	6	59.125	8.307	0.419 to 0.577	0.123 to 0.168

Table 4. Results of PAO analysis for *E. antilliensis* in Virgin Islands National Park.

[AIC, Akaike's Information Criterion; ψ, proportion of sites occupied; SE, standard error]

Model	No. of parameters	AIC	ΔAIC	ψ	SE
Uniform detection, habitat specific occupancy	3	37.34	0.00	0.791	0.084
Uniform detection and occupancy	2	38.43	1.09	0.792	0.094
Temperature dependent detection, habitat specific occupancy	5	39.07	1.73	0.791	0.404
Temperature dependent detection, uniform occupancy	3	40.15	2.81	0.792	0.289

Table 5. Results of PAO analysis for *E. cochranae* in Virgin Islands National Park.

[AIC, Akaike's Information Criterion; ψ, proportion of sites occupied; SE, standard error]

Model	No. of parameters	AIC	ΔAIC	ψ	SE
Temperature dependent detection, habitat specific occupancy	5	34.92	0.00	0.782	0.206
Uniform detection, habitat specific occupancy	3	37.58	2.66	0.761	0.187
Uniform detection and occupancy	2	----	----	Failed to converge	----
Temperature dependent detection, uniform occupancy	3	----	----	Failed to converge	----

Table 6. Results of PAO analysis for *L. albilabris* in Virgin Islands National Park.

[AIC, Akaike's Information Criterion; ψ, proportion of sites occupied; SE, standard error]

Model	No. of parameters	AIC	ΔAIC	ψ	SE
Temperature dependent detection, habitat specific occupancy	5	41.97	0.00	0.724	0.168
Uniform detection, habitat specific occupancy	3	47.57	5.60	0.760	0.198
Uniform detection and occupancy	2	----	----	Failed to converge	----
Temperature dependent detection, uniform occupancy	3	----	----	Failed to converge	----

Table 7. Numbers of amphibians found during visual encounter surveys in Virgin Islands National Park listed by substrate.

Substrate category	Species observed			
	O. septentrionalis	***E. antilliensis***	***E. cochranae***	***L. albilabris***
Agave	-	8	4	-
Bare Ground/Rock	-	9	-	24
Bromeliad	-	14	8	-
Litter	-	4	-	3
Palm Leaf	-	52	4	-
Shrub	-	4	-	-
Tree Branch	-	7	2	-
Tree Leaf	-	28	1	-
Tree Trunk	1	10	-	-
Not Recorded	4	21	6	2
Total Individuals	5	157	25	29

Table 8. Numbers of amphibians found during visual encounter surveys in Virgin Islands National Park listed by habitat.

Species	Common name	Dry forest habitat	Shrubland	Moist forest habitat	Gut habitat	Developed land	Total
Osteopilus septentrionalis	Cuban treefrog	4	1	-	-	-	5
Eleutherodactylus antilliensis	Antillean frog	91	21	36	8	1	157
Eleutherodactylus cochranae	whistling frog	12	8	4	-	1	25
Leptodactylus albilabris	white-lipped frog	1	6	12	10	-	29

Table 9. Snout-vent length of amphibians found during visual encounter surveys within Virgin Islands National Park.

[SVL, Snout-vent length]

Species	No. of individuals measured	Maximum SVL	Minimum SVL	Mean SVL	Standard deviation
Osteopilus septentrionalis	2	72	57	64.5	10.61
Eleutherodactylus antilliensis	58	41	14	27.59	7.15
Eleutherodactylus cochranae	7	20	17	18.86	1.07
Leptodactylus albilabris	11	25	48	38.45	8.3

Figures

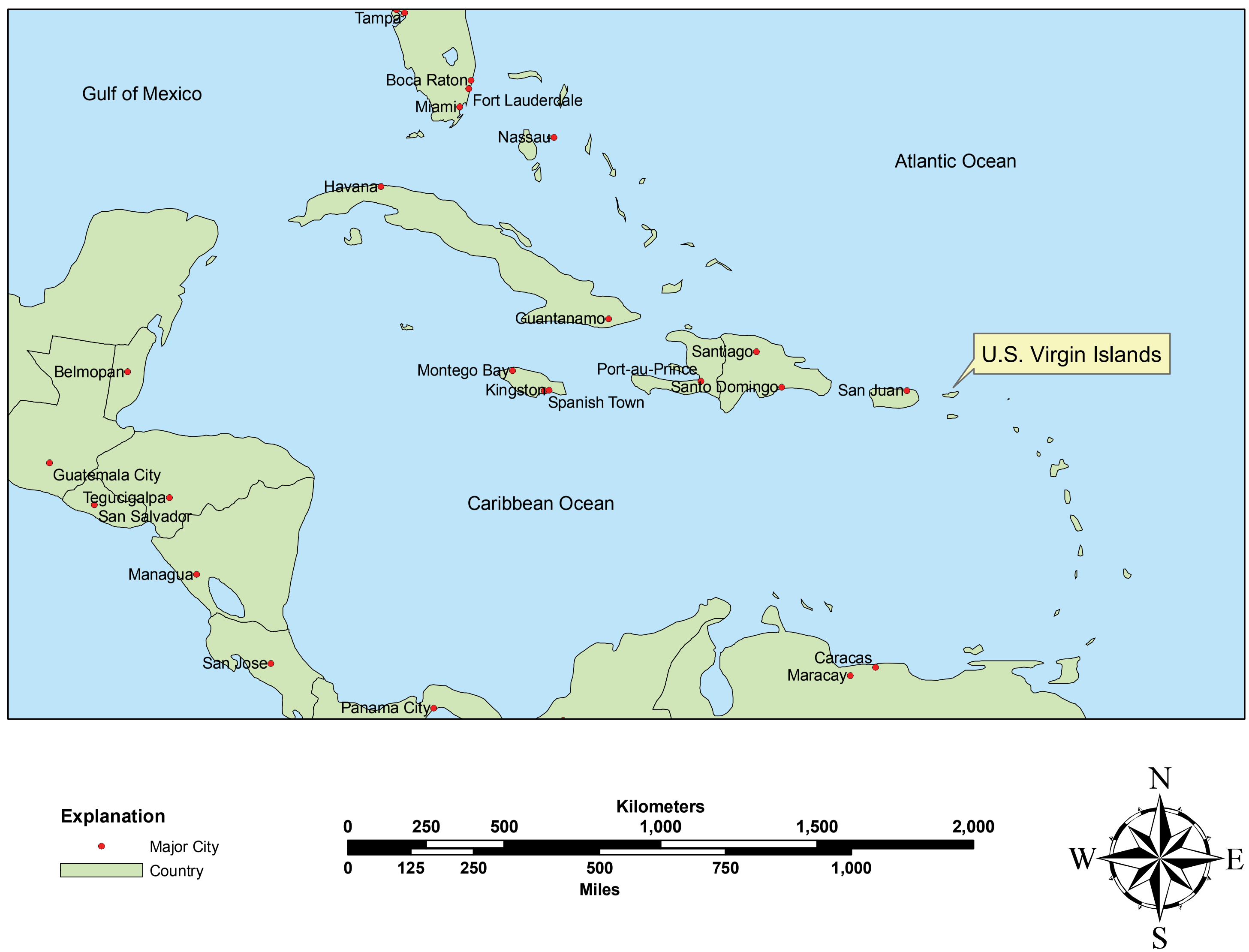

Figure 1. General locator map for U.S. Virgin Islands.

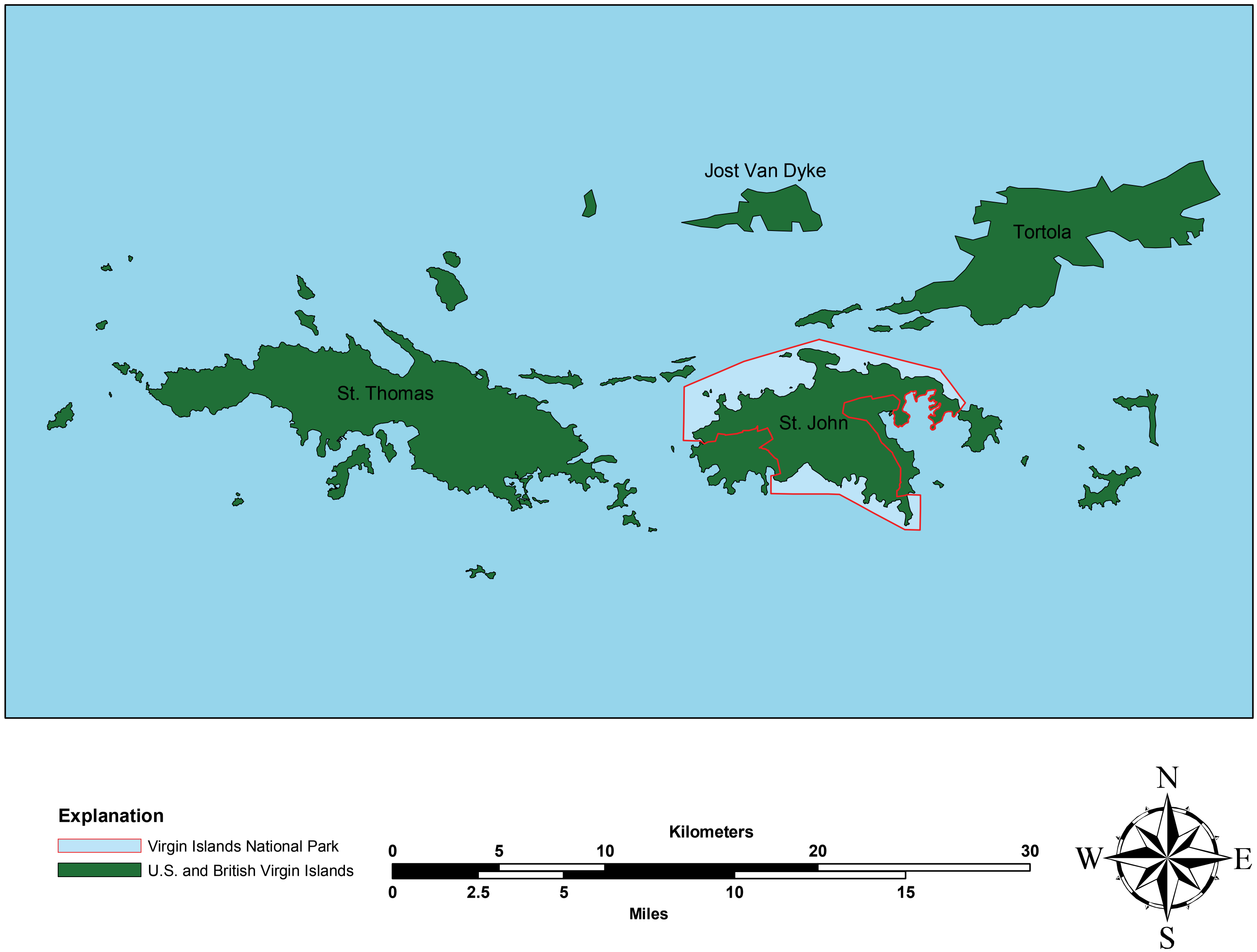

Figure 2. Location of Virgin Islands National Park on St. John, U.S. Virgin Islands.

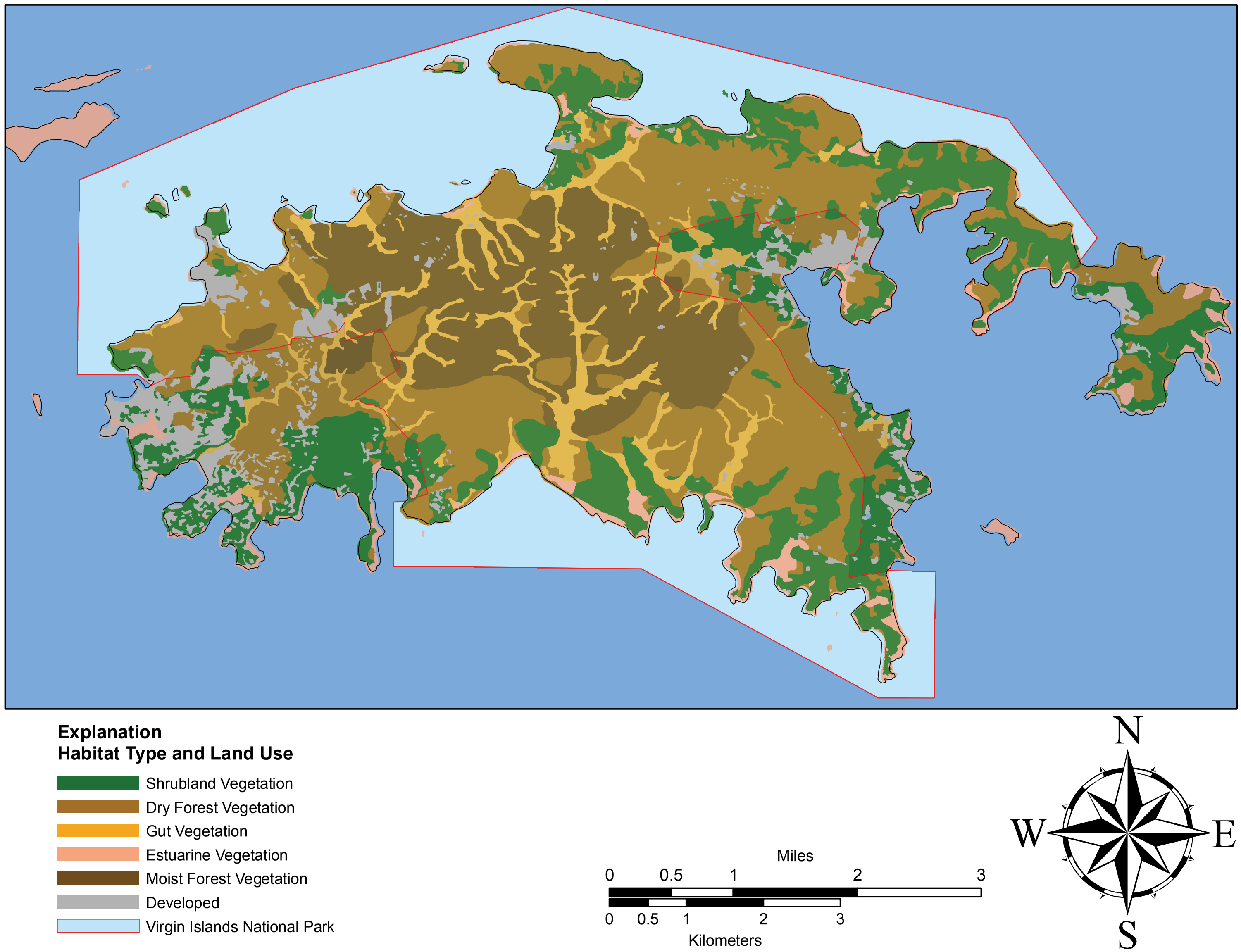

Figure 3. Major vegetation types found on St. John.

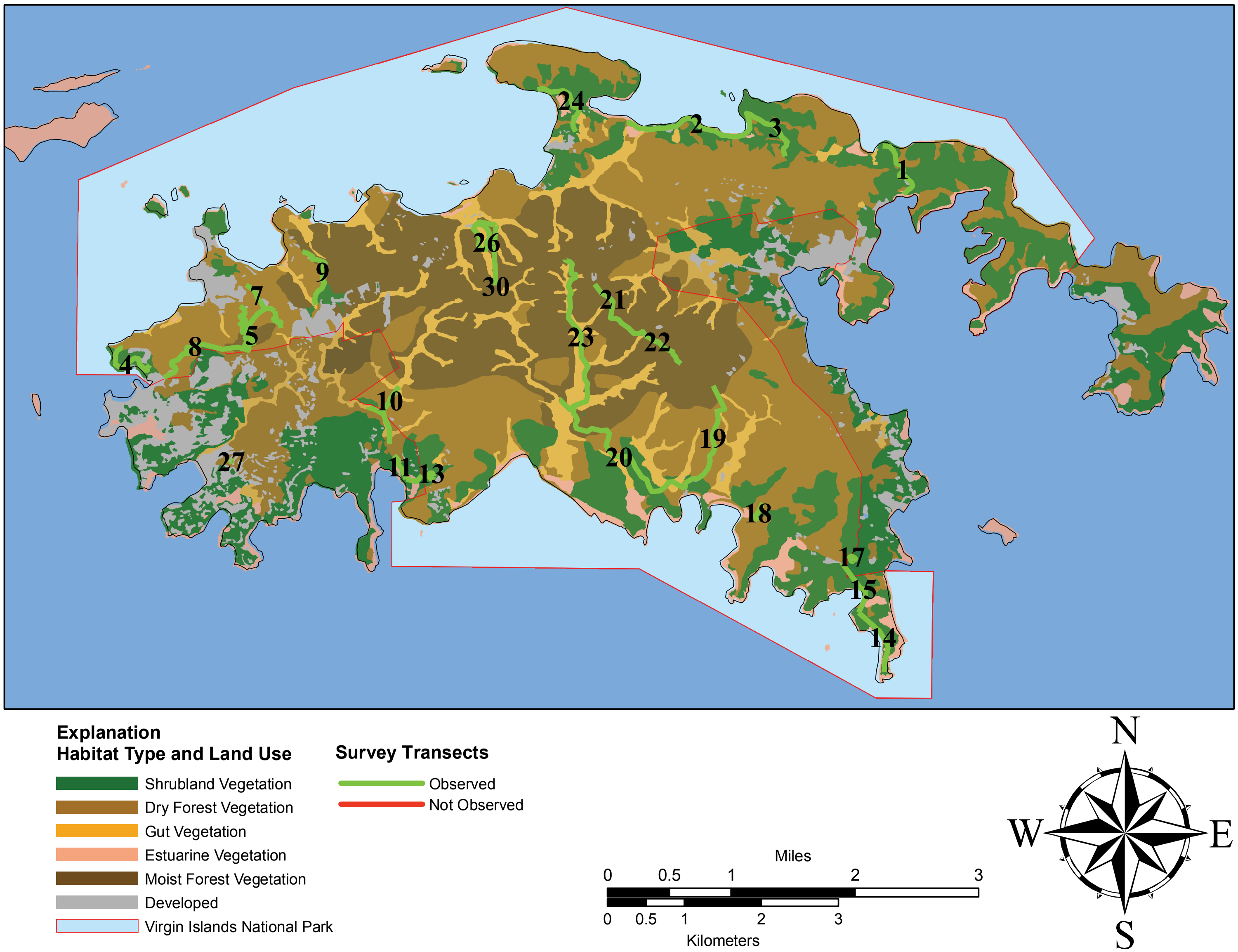

Figure 4. Location of transects used for amphibian surveys of VINP. Numbers indicate trail listed in *Table 1*

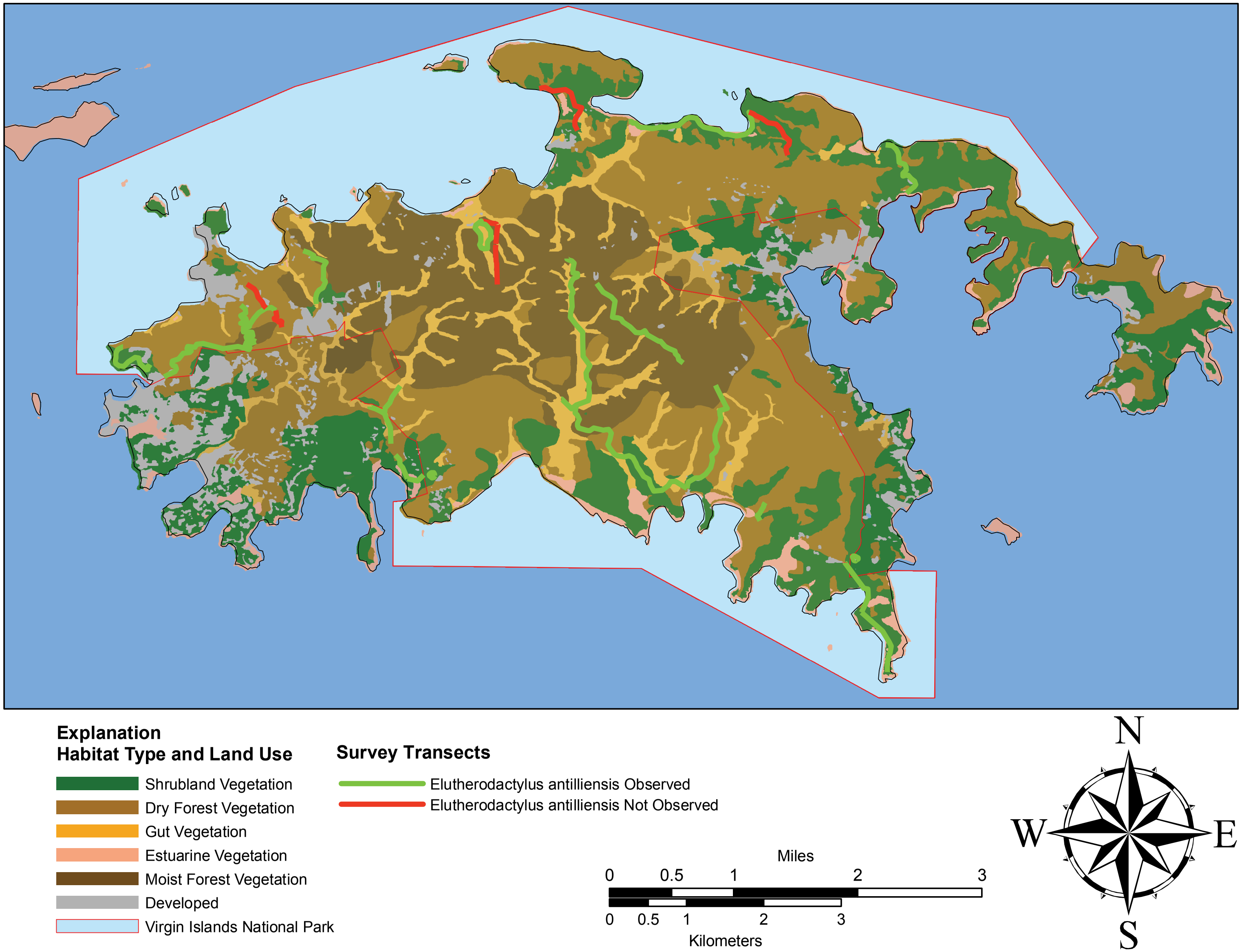

Figure 5. Locations of survey transects within VINP where *E. antilliensis* were observed.

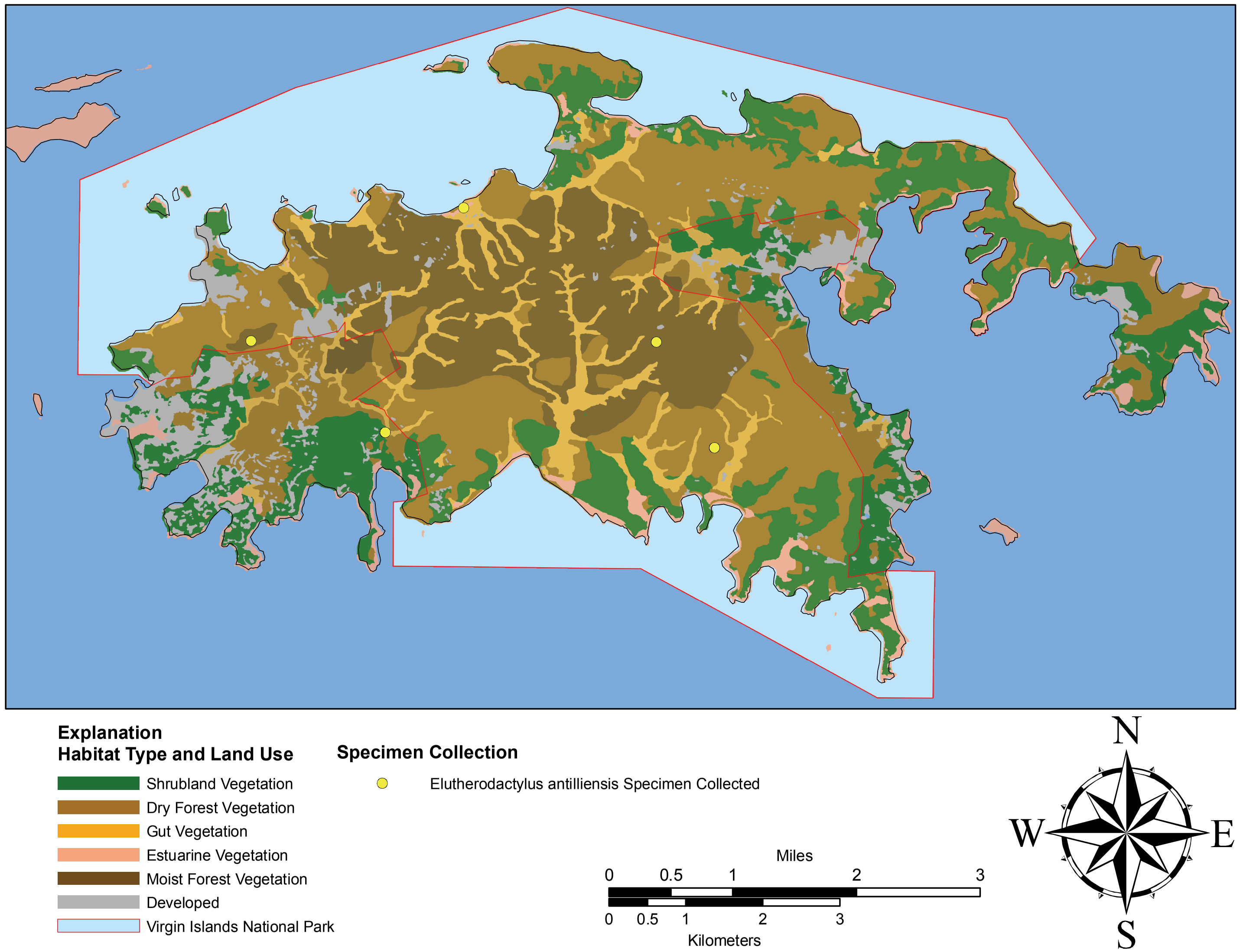

Figure 6. Locations where voucher specimens of *E. antilliensis* were collected.
*Note: Multiple individuals may have been collected from the points shown in Figure 6.

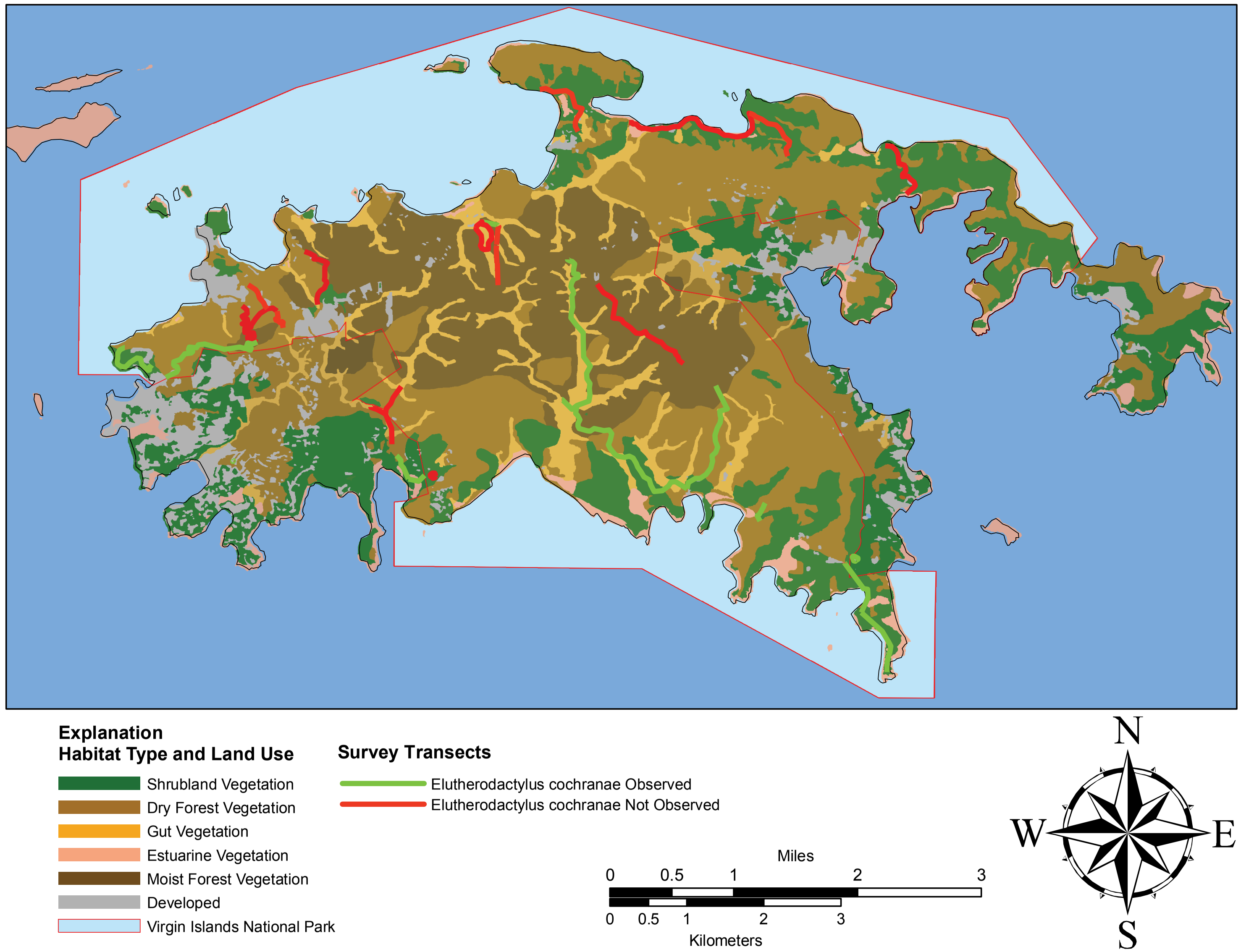

Figure 7. Locations of survey transects within VINP where *E. cochranae* were observed.

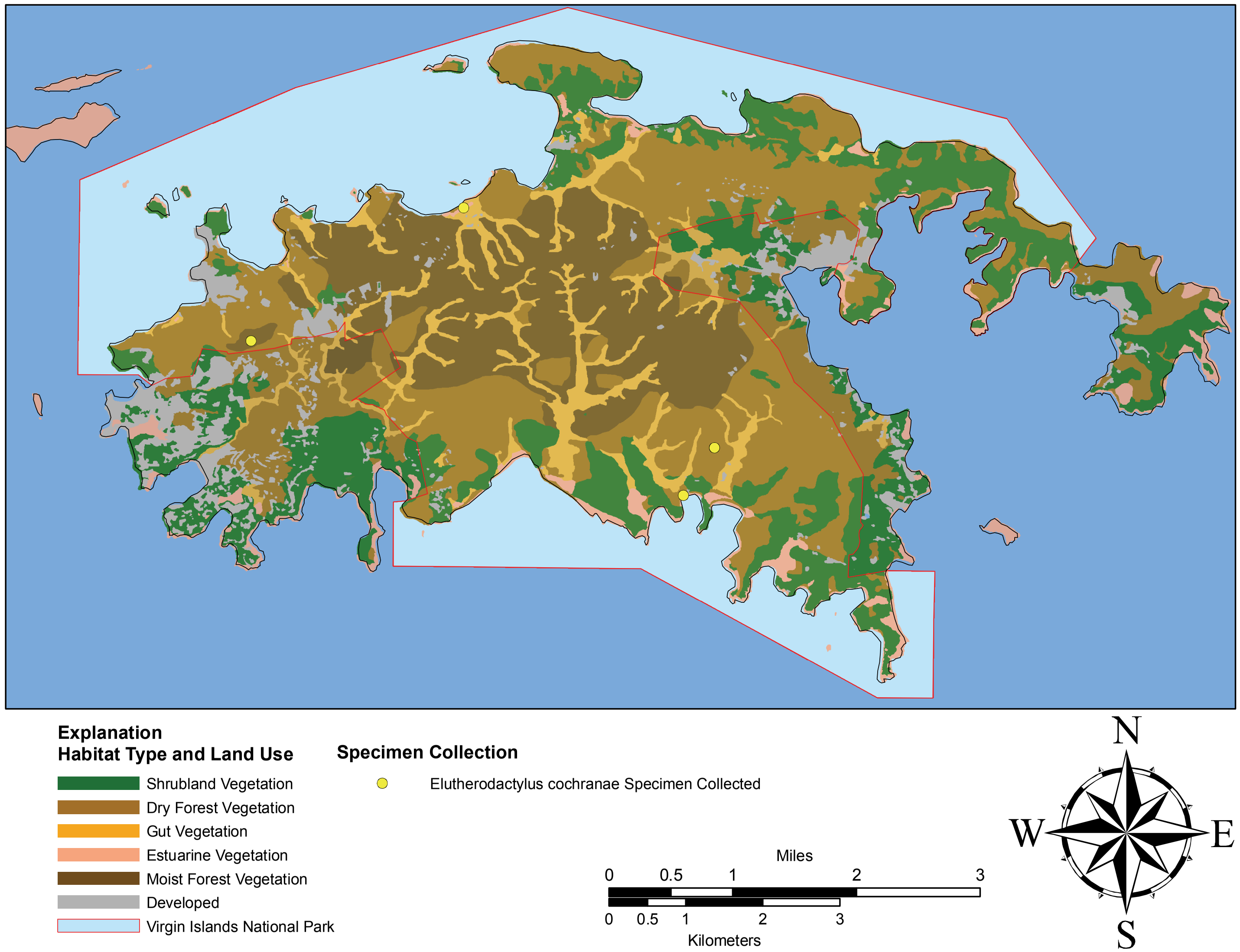

Figure 8. Locations where voucher specimens of *E. cochranae* were collected.
*Note: Multiple individuals may have been collected from the points shown in Figure 10.

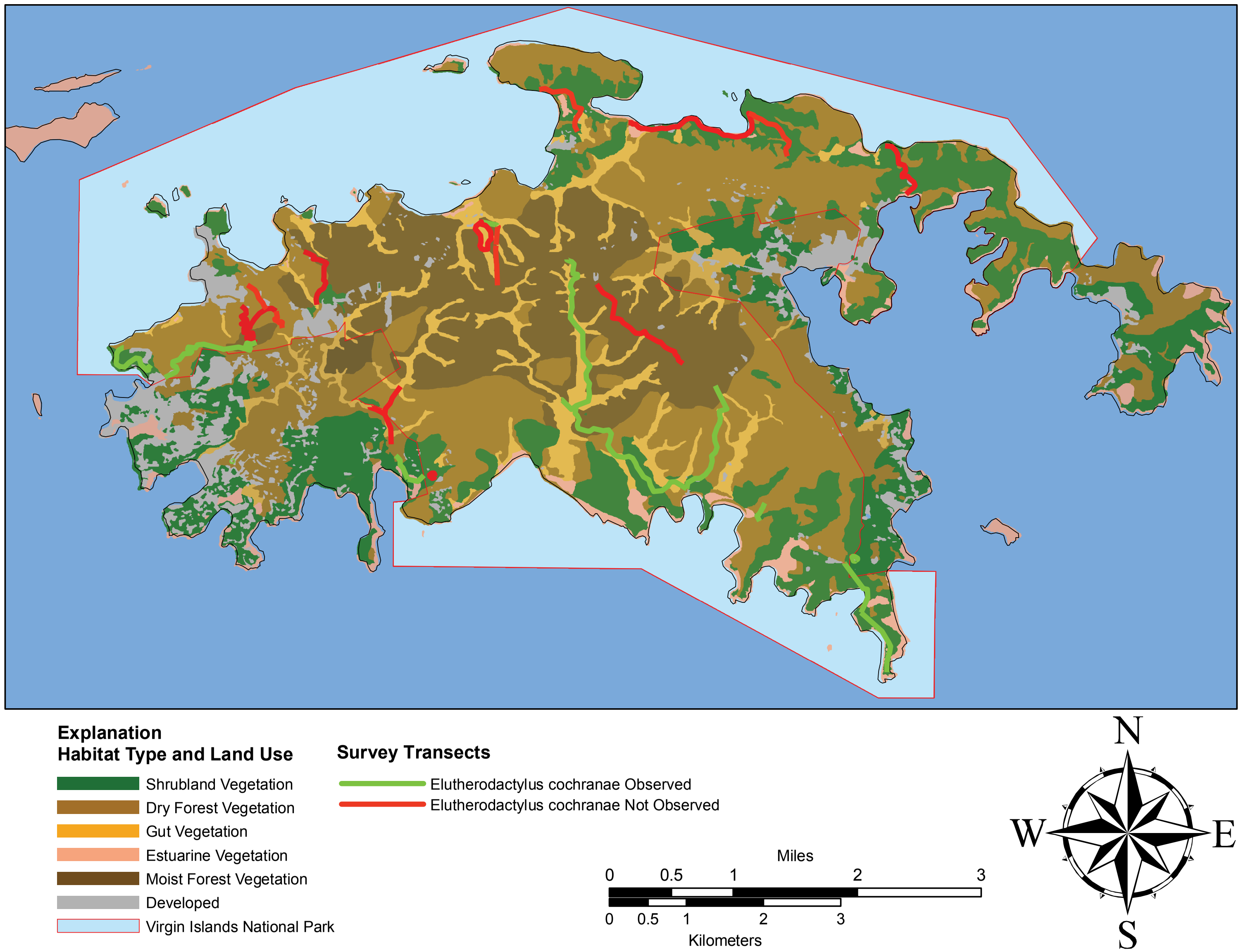

Figure 9. Locations of survey transects within VINP where *E. coqui* were observed.

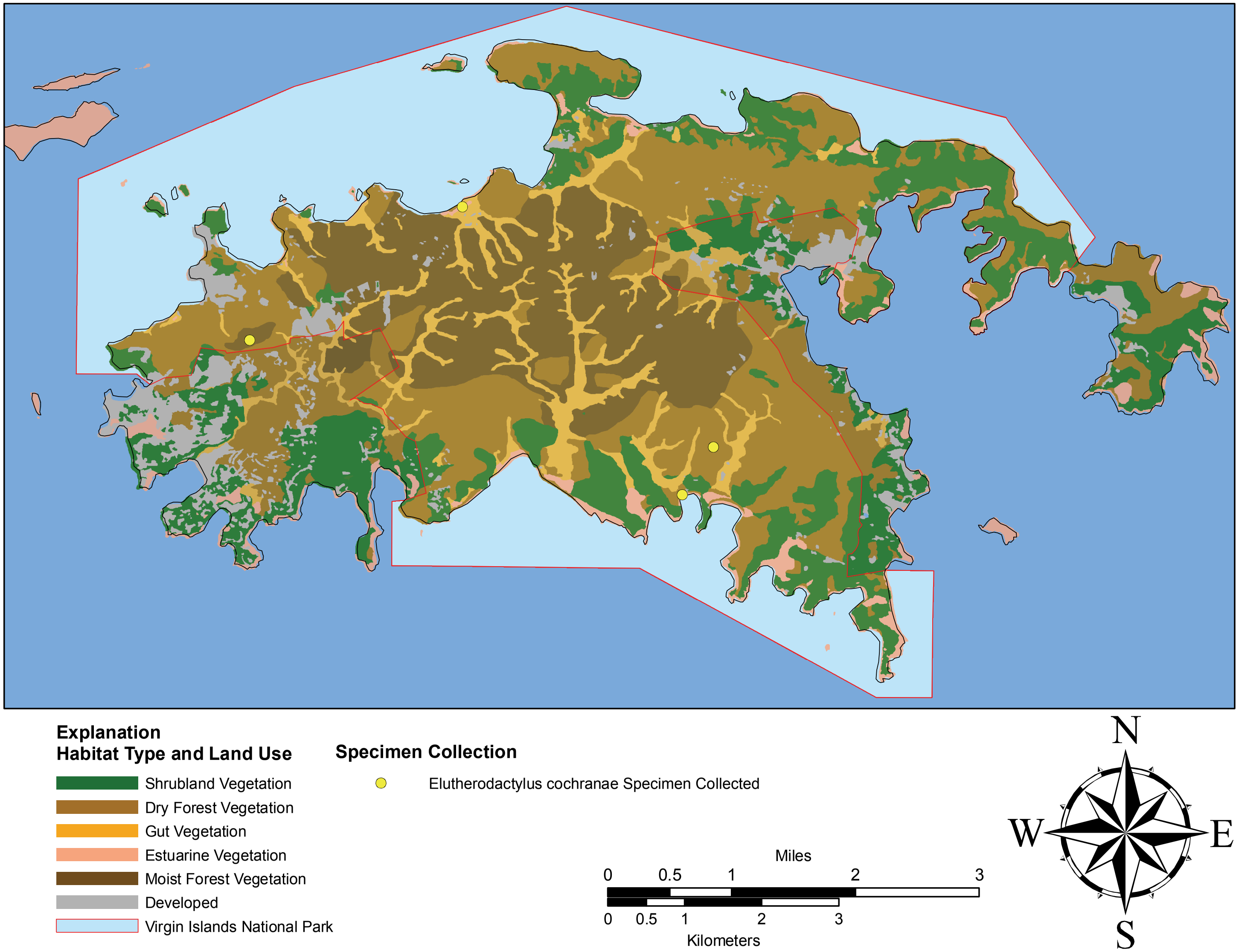

Figure 10. Locations where voucher specimens of *E. coqui* were collected.
*Note: Multiple individuals may have been collected from the points shown in Figure 8.

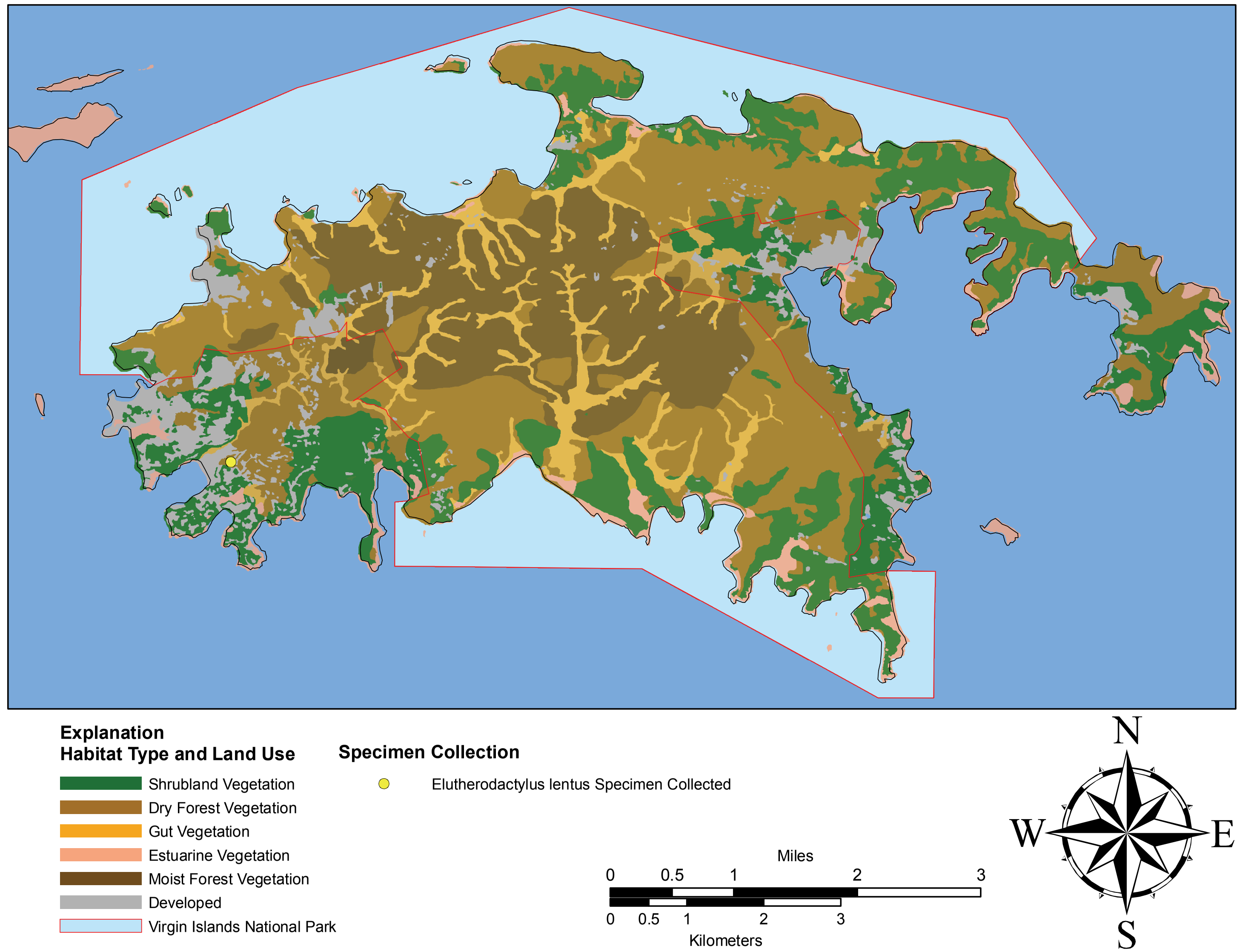

Figure 11. Location where voucher specimens of *E. lentus* were collected.
*Note: Multiple individuals may have been collected from the point shown in *Figure 11.*

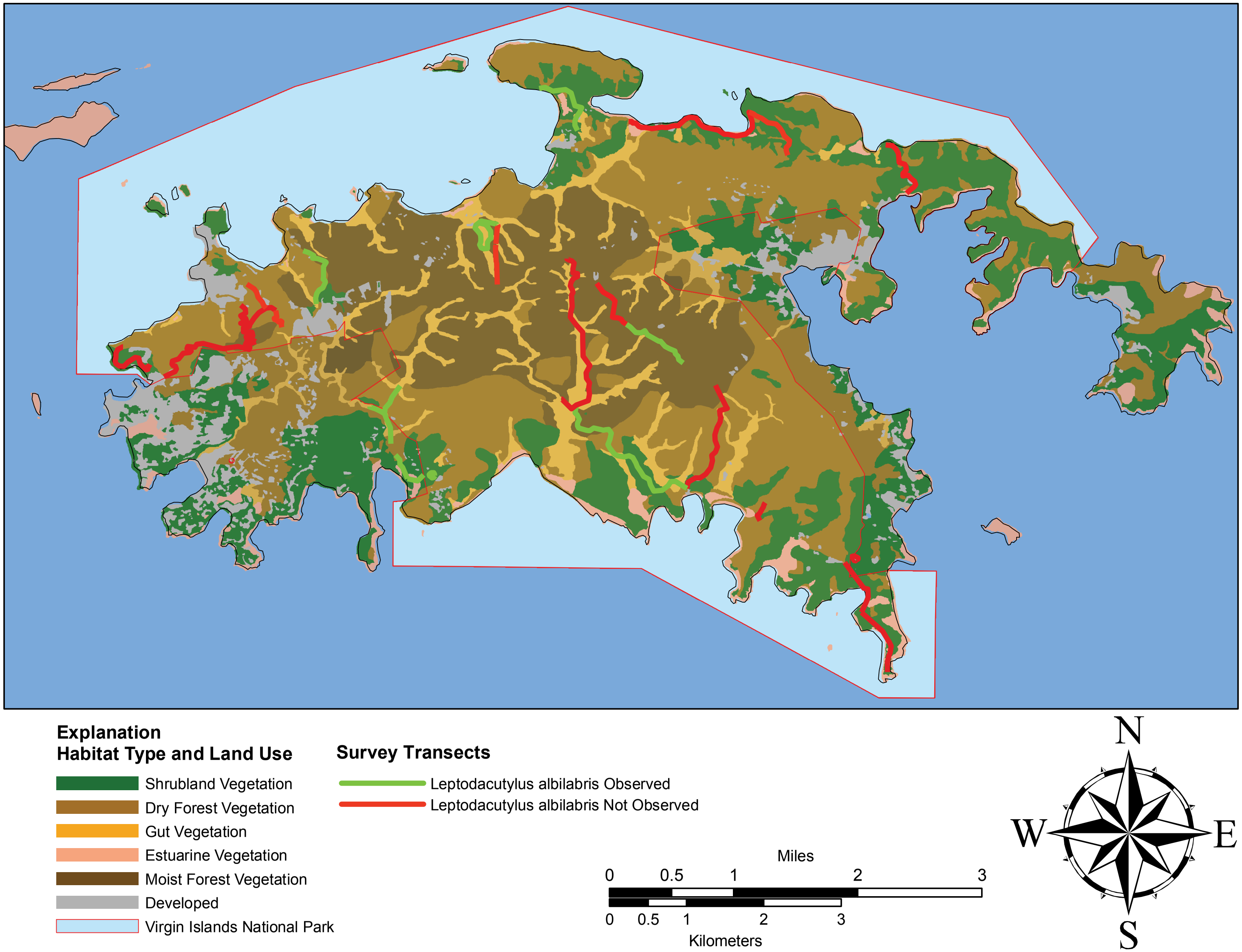

Figure 12. Locations of survey transects within VINP where *L. albilabris* were observed.

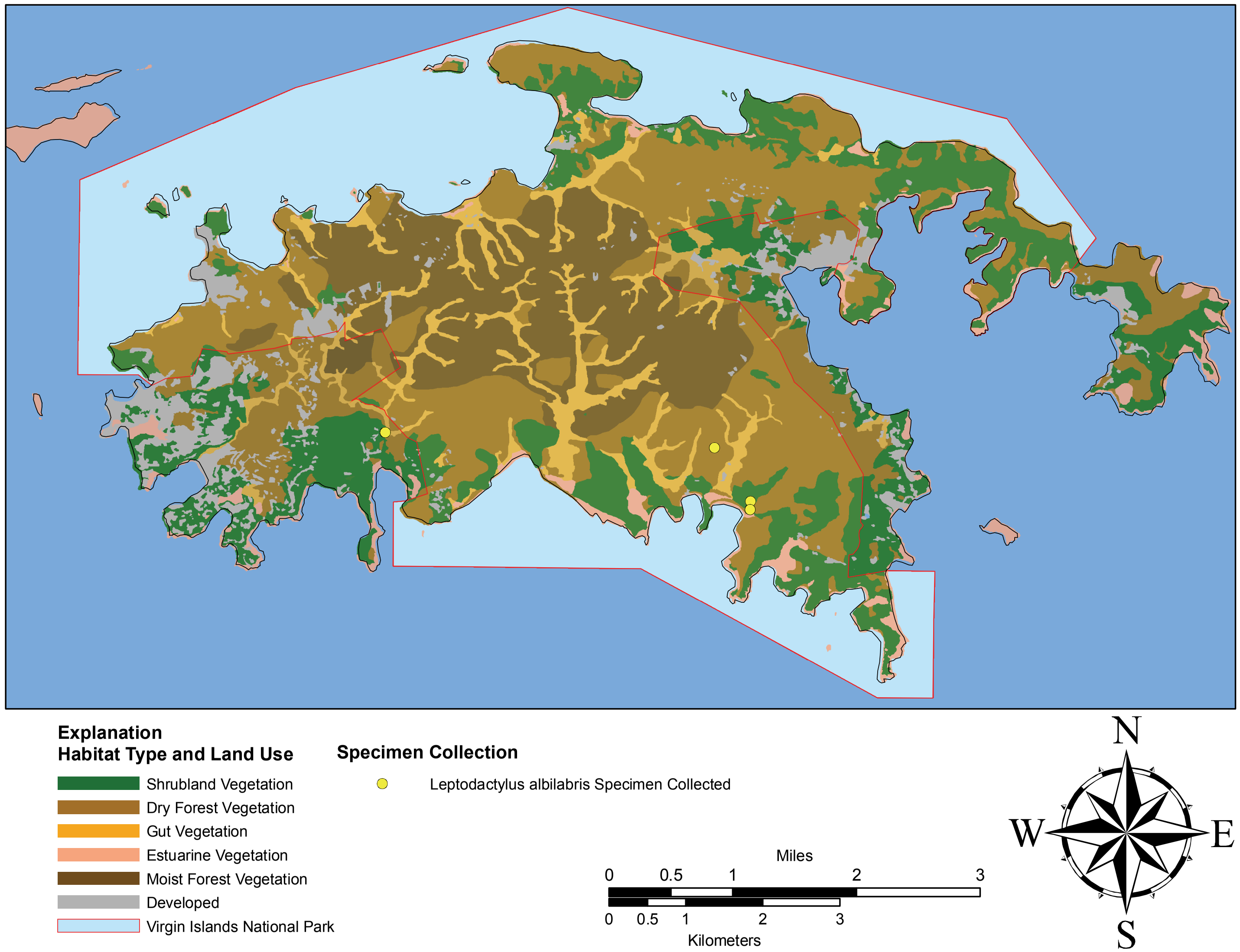

Figure 13. Locations where voucher specimens of *L. albilabris* were collected.
*Note: Multiple individuals may have been collected from the points shown in Figure 13.

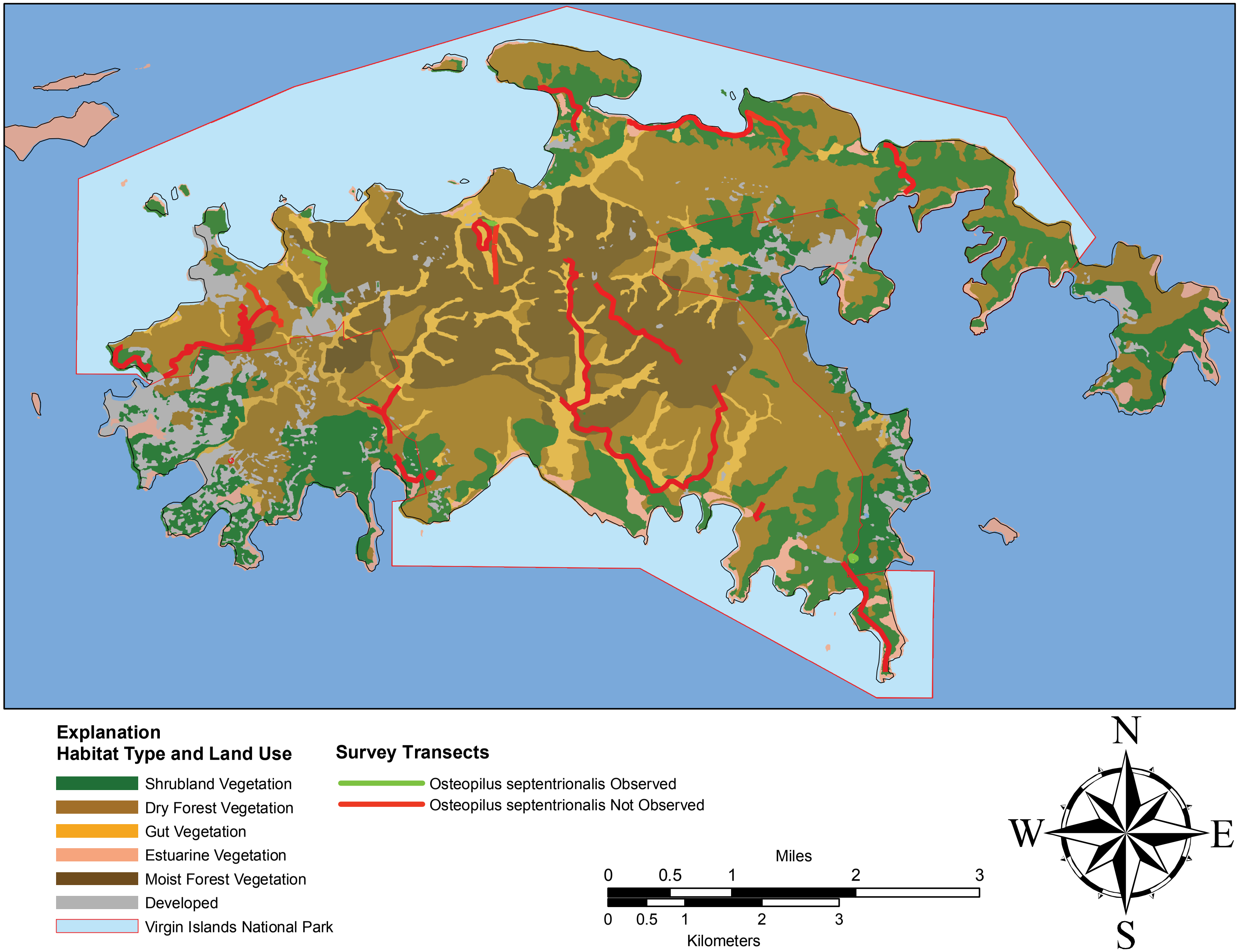

Figure 14. Locations of survey transects within VINP where *O. septentrionalis* were observed.

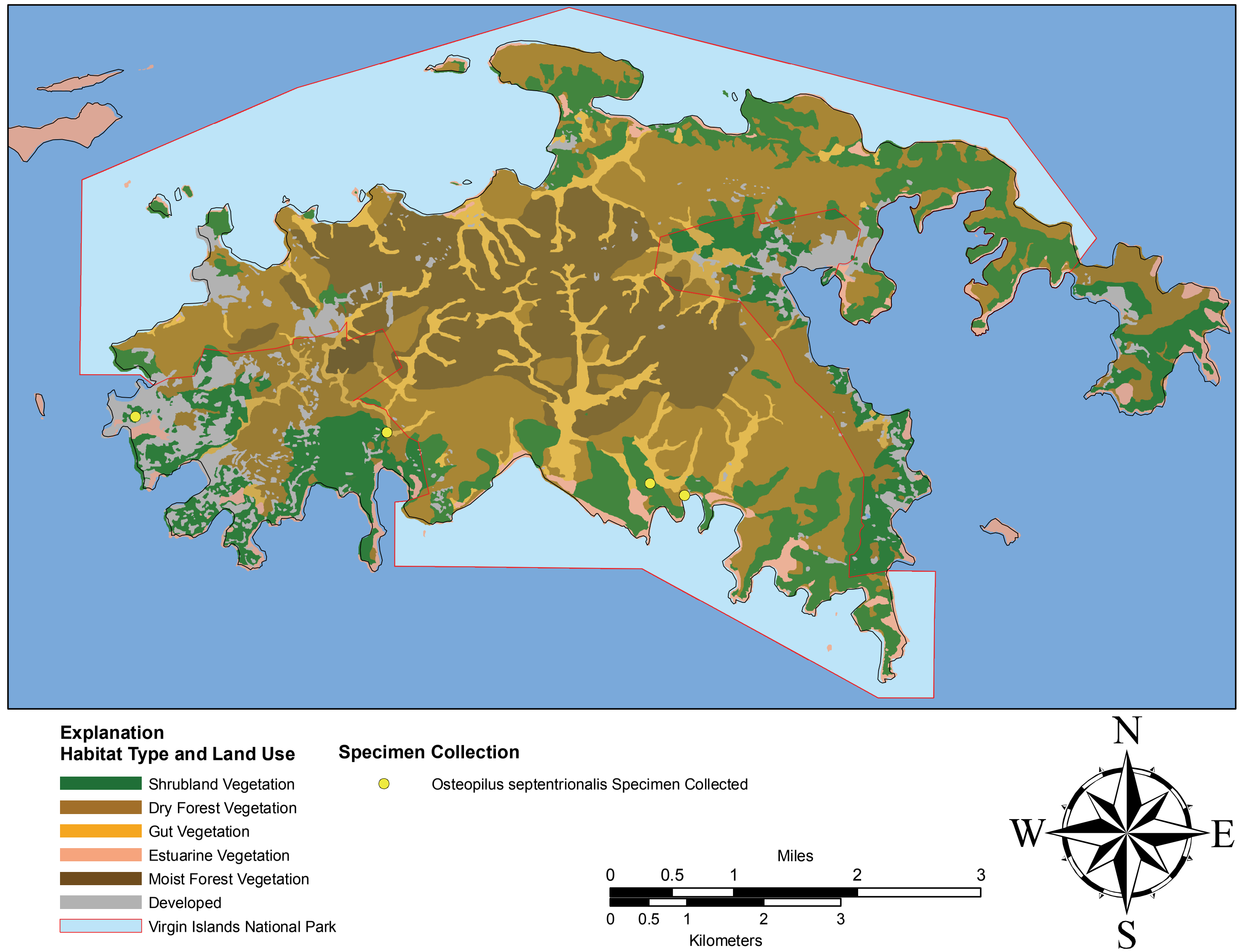

Figure 15. Locations where voucher specimens of *O. septentrionalis* were collected.
*Note: Multiple individuals may have been collected from the points shown in Figure15.

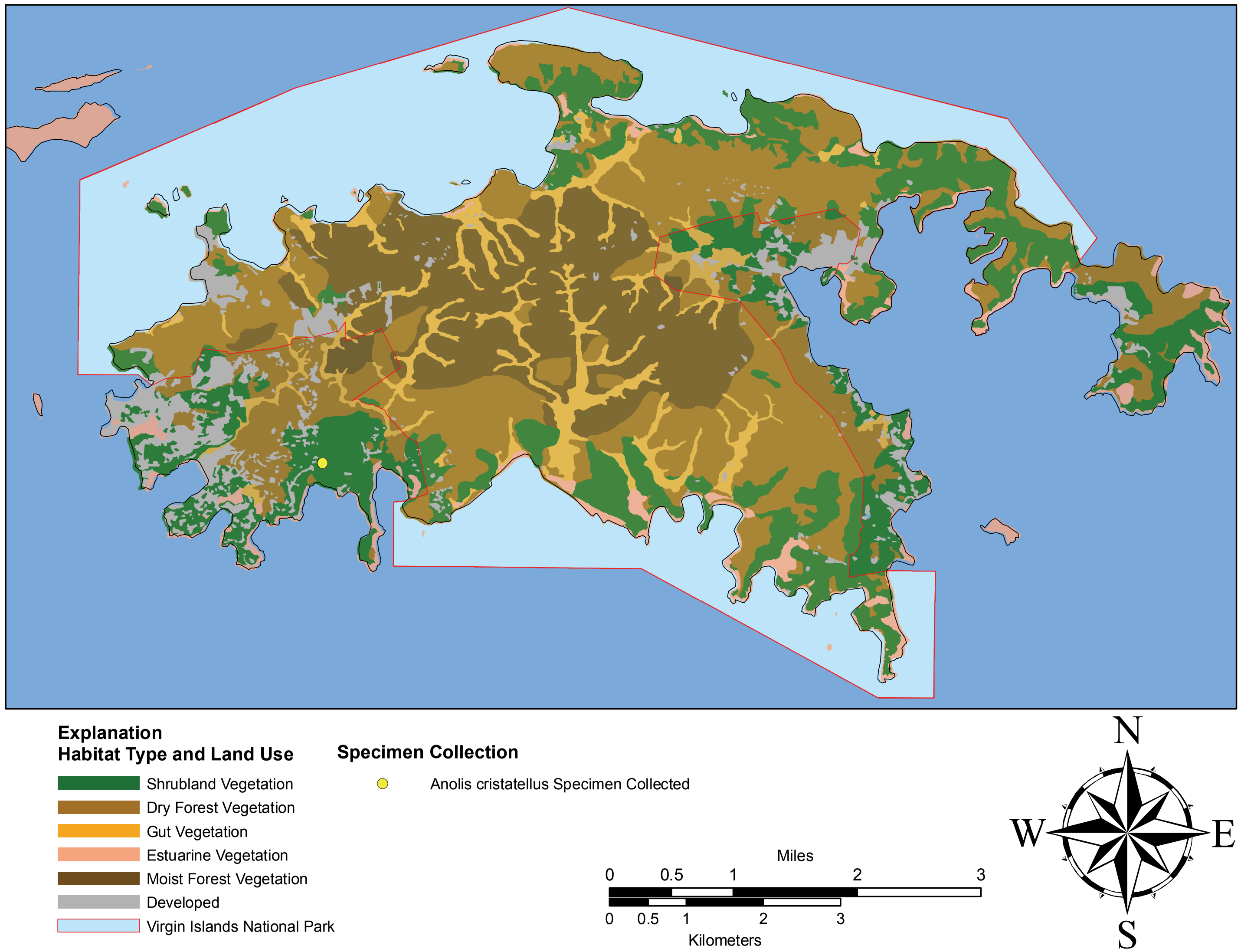

Figure 16. Location where voucher specimens of *A. cristatellus* were collected.
*Note: Multiple individuals may have been collected from the point shown in Figure 16.

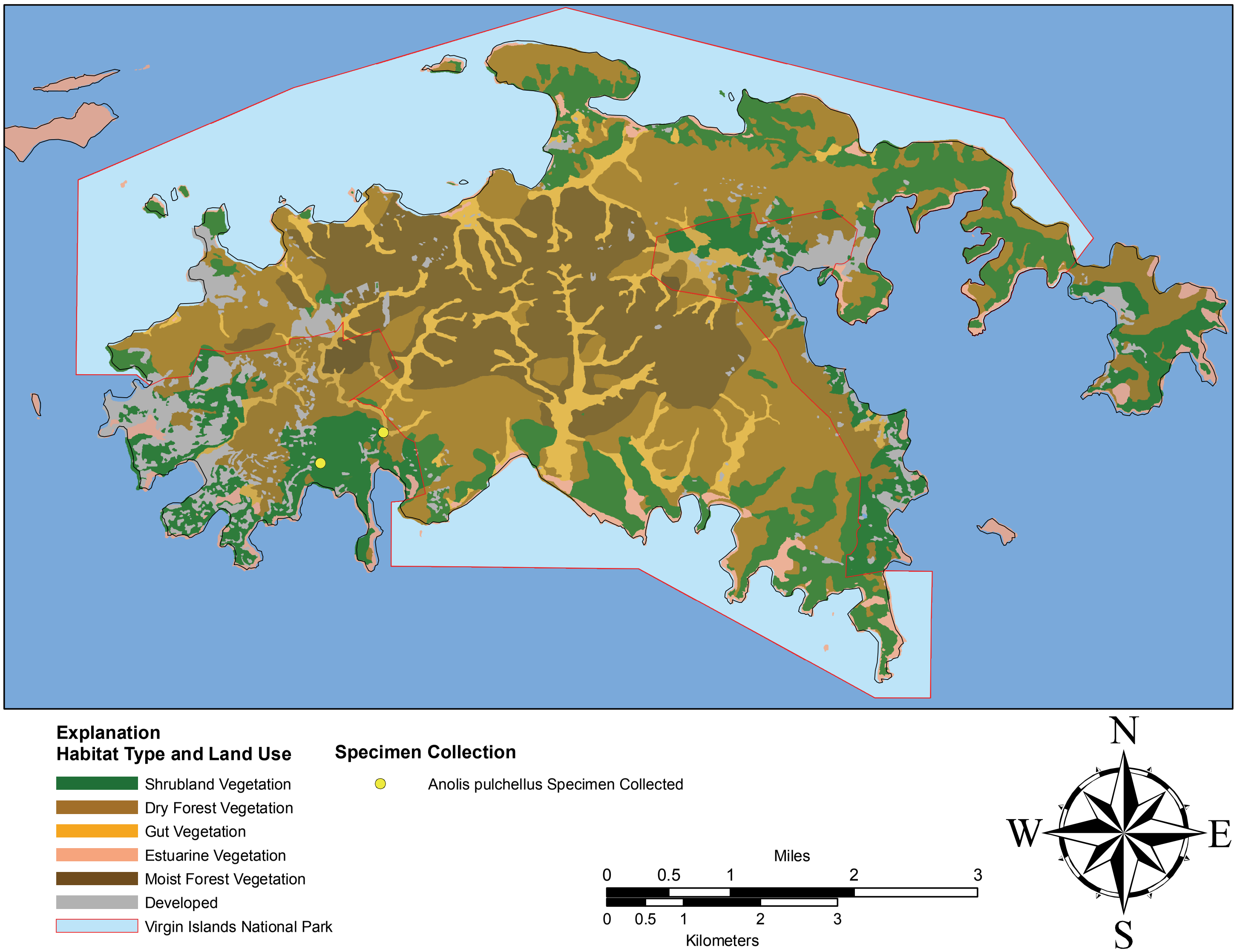

Figure 17. Locations where voucher specimens of *A. pulchellus* were collected.
*Note: Multiple individuals may have been collected from the points shown in Figure 17.

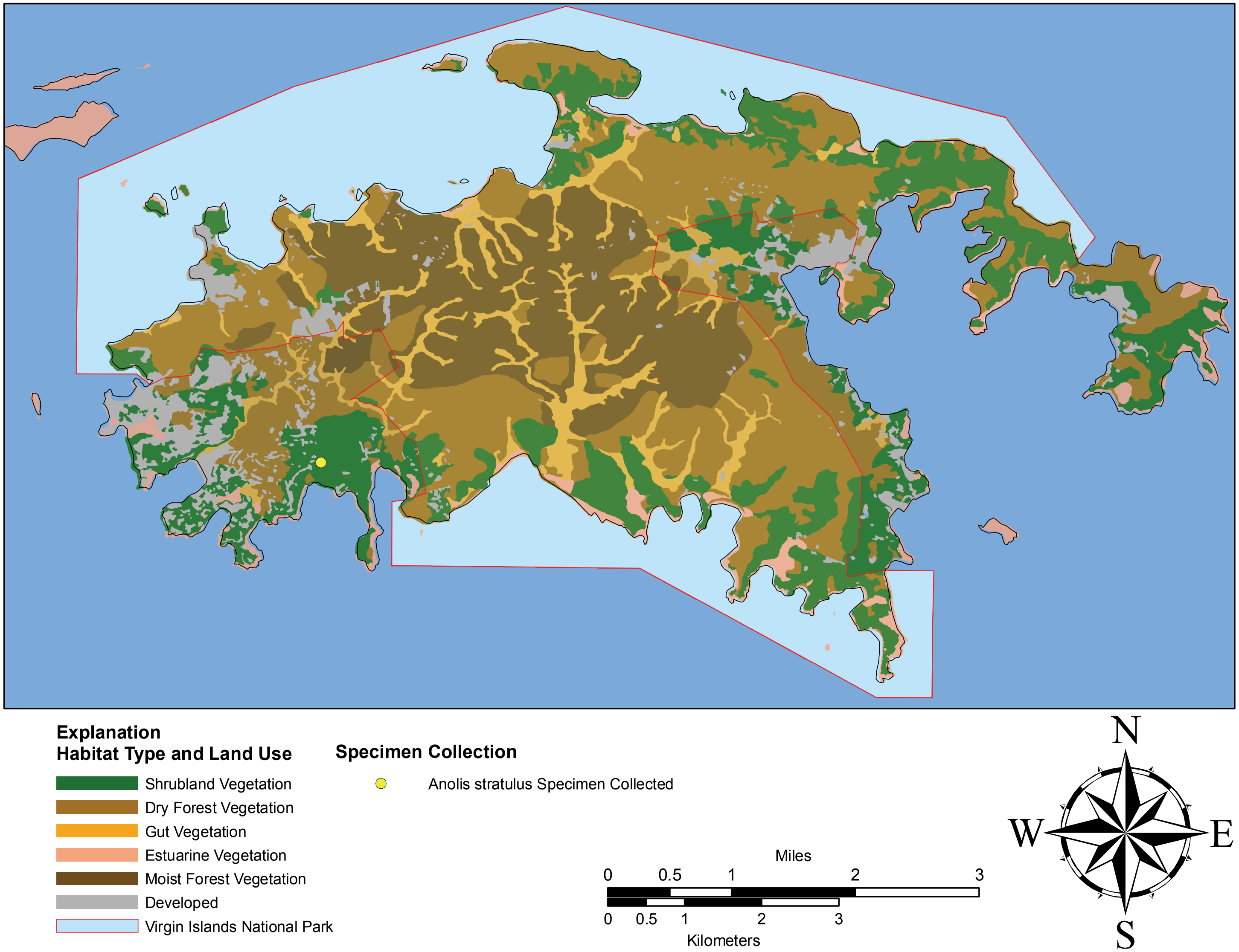

Figure 18. Location where voucher specimens of *A. stratulus* were collected.
*Note: Multiple individuals may have been collected from the point shown in Figure 18.

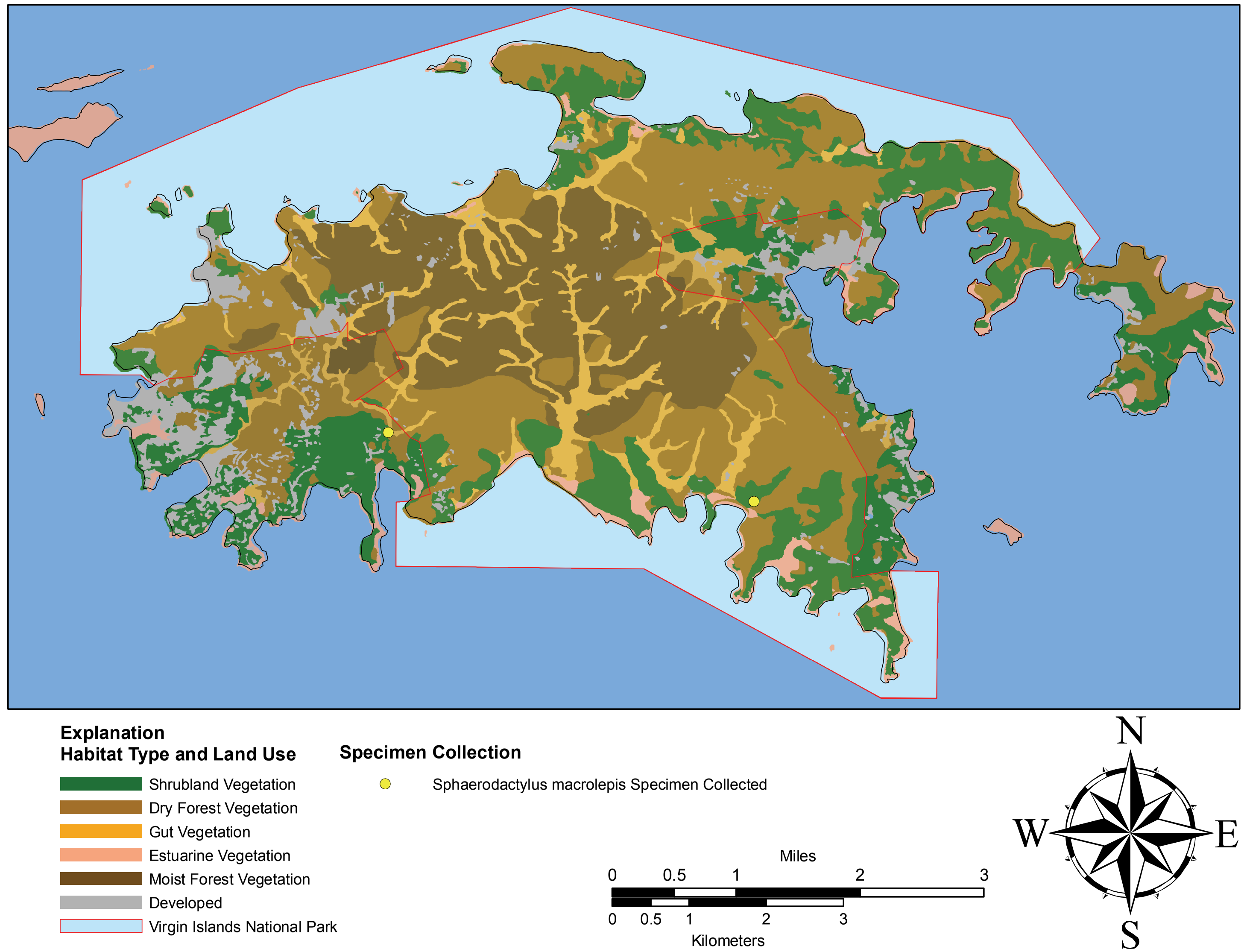

Figure 19. Locations where voucher specimens of *S. macrolepsis* were collected.
*Note: Multiple individuals may have been collected from the points shown in Figure 19.

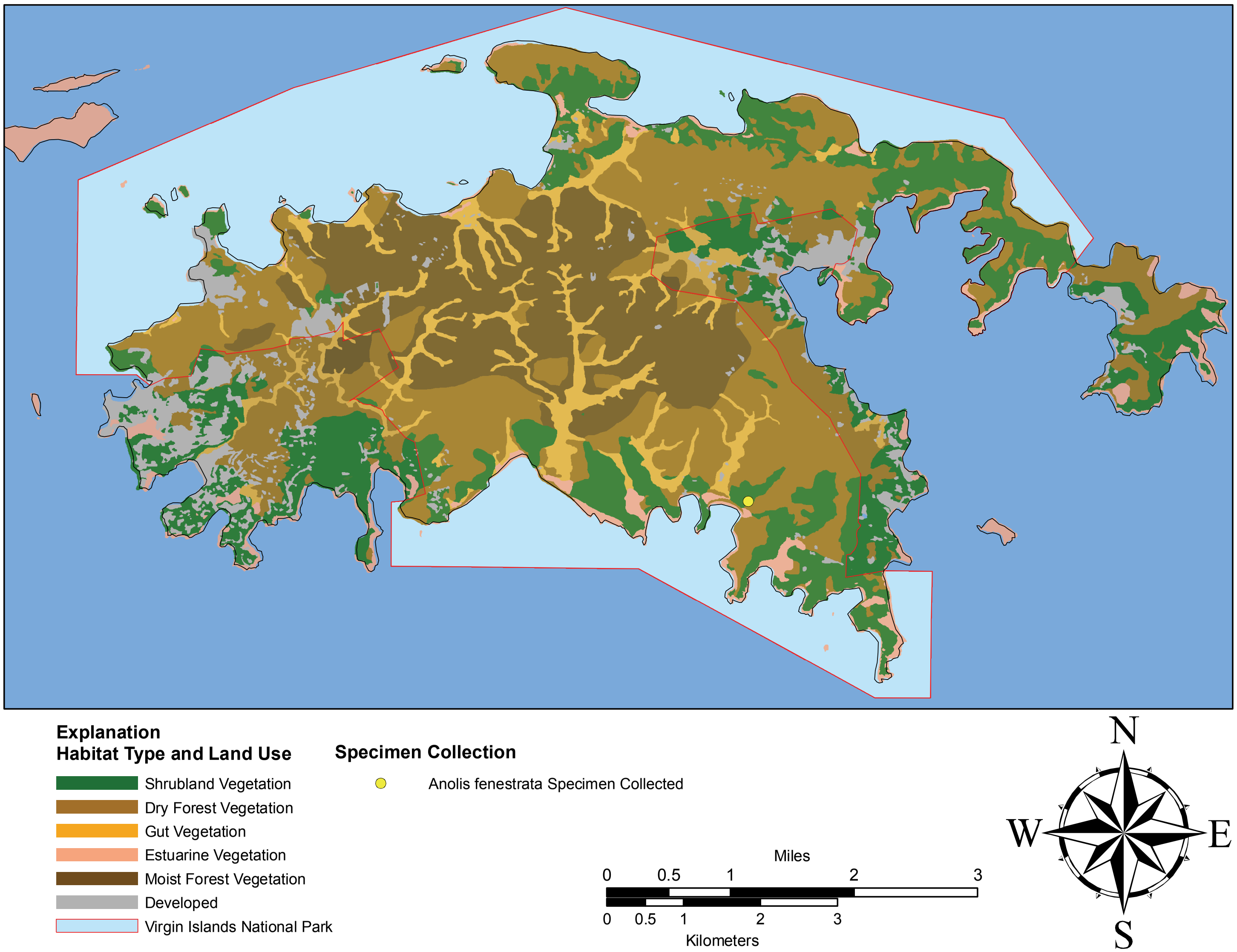

Figure 20. Location where voucher specimens of *A. fenestrata* were collected.
*Note: Multiple individuals may have been collected from the point shown in Figure 20