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Breeding biology of the Bahama Parrot (*Amazona leucocephala bahamensis*)

Gnam, Rosemarie Sophie, Ph.D.

City University of New York, 1991

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BREEDING BIOLOGY OF THE BAHAMA PARROT

(Amazona leucocephala bahamensis)

by

Rosemarie S. Gnam

A dissertation submitted to the Graduate Faculty in Biology in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York.

1991

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APRIL 1, 1991
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Abstract

BREEDING BIOLOGY OF THE BAHAMA PARROT

by

Rosemarie Gnam

Advisers: Dr. Lester Short & Dr. Robert Rockwell

Although the Bahama Parrot (Amazona leucocephala bahamensis) was once abundant and ranged throughout the Bahamas archipelago, it is endangered now and survives only on two islands- Abaco and Great Inagua. Bahama Parrots on Abaco nest in limestone solution cavities beneath the ground, a habit unique among New World psittacines. Between 1985 - 1988, I located and monitored 76 parrot nests in two nesting areas on southern Abaco. Eggs were laid in late May and early June and hatched asynchronously, 26-28 days after the female began incubation. While the female incubated the eggs, the male visited the nest on average four times per day to feed her. After the first week post- hatching, the female left the nest to forage with the male. Parents returned to their nests four to six times per day to feed the nestlings. Chicks fledged asynchronously in late August and early September,56-58 days after hatching. I evaluated reproductive investment and loss in this population using a fitness components model which corresponded to stages of the reproductive cycle. On average, a pair produced 3.6 eggs and fledged only 0.8 young. While losses accrued throughout the cycle, they were highest during the hatching and post-hatching stages. Partial hatching failure and total brood failure were the primary sources of loss at these stages. These components did not change significantly over the four years of this study. Causes of nest failure were (in ascending order of importance): poaching of chicks, flooding of nest cavities, abandoned eggs, chick deaths, and predation by snakes, rats, land crabs, and feral cats. I observed parrots feeding upon 18 plant species in the nesting area. Major staples in their diet were seeds extracted from unripe cones of Caribbean pine, and fruits of wild guava and poisonwood. Between 1986 and 1989, three population counts were made to estimate the size of the parrot population on Abaco. Current population estimates range from a well-defined minimum of 860-1142 parrots (actual birds counted) to a less well-defined maximum of 1300 parrots. Present threats to this population include nest predation by feral cats, poaching and unprotected habitat.

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promptly, efficiently and with some 'field advice'.

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Bill Konstant, the Executive Director of Wildlife

Preservation Trust International and board member, Robert Rattner, were always willing to offer assistance and guidance during this study. A special note of thanks to Dr. Donald Bruning from the New York Zoological Society who introduced me to the Bahama Parrot and helped me experience the realities of conservation biology. Dr. Noel Snyder made his field notes from his previous study of the Bahama Parrot available and always offered his needed expertise and support. Ron Johnson, Curator of Birds at the Miami Metro Zoo and his wife, Cindy, helped with travel arrangements, hospitality and advice on captive breeding.

I am especially grateful to my doctoral committee members - Dr. Lester Short for his never ending faith in my abilities, Dr. Robert Rockwell for his statistical advice and sense of humor, Dr. James Wiley for sharing his expertise in parrot biology with a novice, and Drs. Peter Chabora and Carol Simon for their help.

Lastly, I thank my family and friends for their encouragement and support during the six years of this study. I dedicate this dissertation to my parents, Martha and Gus Gnam who raised this field biologist with lots of love.

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General Introduction

The parrot genus *Amazona* is confined to the neotropical region, ranging from Mexico to Argentina (Forshaw 1989). Of the 28 extant species, nine are endemic to the West Indies. Six of these species, including two subspecies, are considered to be endangered or threatened (King 1977). The Cuban Parrot (*Amazona leucocephala*) is a polytypic species with five recognized subspecies: *leucocephala* (Cuba), *palmarum* (Western Cuba and Isla de la Juventud), *caymanensis* (Grand Cayman), *hesterna* (Cayman Brac) and *bahamensis* (Bahamas) (Bond 1956).

Historically, the Bahama Parrot (*Amazona leucocephala bahamensis*) was recorded from Abaco, New Providence, San Salvador, Long Island, Crooked Island, Acklins and Great Inagua (Forshaw 1989). Fossil remains of Bahama Parrots have been excavated from New Providence and Crooked Island (Olson and Hilgartner 1982). The records for San Salvador and Long Island are based on observations which Christopher Columbus recorded in his log (Dunn and Kelley 1989), although the precise Bahamian islands visited by Columbus on his first voyage are often disputed (Judge 1986). The Acklin's population was described by early ornithologists (Todd and Worthington 1911), but it had become extinct by the early 1940's (Bond 1956).

Today, this subspecies is regarded as endangered and survives only on the islands of Abaco and Great Inagua, at the northern and southern limits of its former range (Figure 1). The Abaco population is the northernmost breeding population of any species in the genus Amazona (Snyder et al. 1982). In recent years, this population has declined as a result of habitat destruction, logging activities, development, Hurricane Betsy in 1965 and hunting pressures (Attrill 1981, Snyder et al. 1982).

The plumage of the Bahama Parrot is mainly green with black edging on its feathers. It has a white forehead and forecrown and a rose-red throat (Forshaw 1989). The primary coverts, primaries and secondaries are blue. The Bahama Parrot is distinguished from other subspecies of A. leucocephala by an extremely restricted or entirely absent venous-red abdominal patch, its slightly larger size (34 cm) and by having its white forecrown extend more posteriorly and below the eyes to its upper cheeks (Figure 2). Sexual dimorphism is lacking.

Although Christopher Columbus was the first European to see the Bahama Parrot, it was not until 1866 that Bryant (1866) officially described the taxonomic race of bahamensis. Cory (1880) visited Great Inagua and briefly reported on the nesting and feeding habits of the parrot. Until Snyder et al's (1982) study of the Bahama Parrot, information on the biology of this parrot was fragmentary and anecdotal. They made three trips to Abaco between 1976 -

1977 to census the population and observe the parrot's nesting and feeding habits. Population estimates of the parrot population on Abaco ranged from a minimum of 450 birds to a loosely defined maximum of 800 birds (Snyder et al 1982).

Abaco, the second largest island in the Bahamas archipelago, is composed of two islands, Great and Little Abaco, now linked by a land bridge (Figure 3). It lies 242 km east of Fort Lauderdale, Florida and 121 km north of New Providence. Most of its 7000+ residents live in Marsh Harbour and on small offshore cays. The interior of Abaco is largely uninhabited. Like the rest of the Bahamas, Abaco is relatively flat and composed of limestone (Sealey 1985). The island's climate is subtropical and fairly dry; annual rainfall averages 162.3 cm at Green Turtle Cay (Henry 1974). There is rain all year, but rainfall is heaviest (90 cm) from May through September (Henry 1974).

The Abaco population of the Bahama Parrot is found in the mixed broadleaf coppice (native, evergreen hardwood) and Caribbean pine (Pinus caribaea) areas of southern Abaco (Snyder et al. 1982). Henry (1974) described the vegetation of this pine forest and differentiated it into two types: (1) Site Quality II (Type 12) and Site Quality I (Type 13). Type 12 is pine woodland on rocky land with a high water-table characterized by poor pine growth and a variety of palm species, whereas, Type 13 is woodland on ridged rocky land which has a lower water-table than Type 12. Its vegetation is dominated by Pinus caribaea with a variable shrub understory that is influenced by canopy density and fire. Bahama Parrots inhabit both types of pine forest (Snyder et al. 1982).

Although there are no apparent morphological differences between the Great Inagua and Abaco populations, parrots on Abaco nest almost exclusively in natural, limestone solution cavities in the ground, in contrast to the tree-cavity nesting habits of parrots on Inagua (Snyder et al. 1982). Many of these ground cavities or "holes" have internal ledges or rocky overhangs to protect and conceal the eggs within them. In a freshwater swamp region (Site Quality II) along the west side of southern Abaco, parrots are reported to nest in Pond Top Palm (Sabal palmetto) hollows (Carraway and Carraway 1979). This mode of nesting is rare and was never observed in my study.

The subterranean nesting habit of the Abaco population is unique among other New World psittacids. Hole-nesting in vertical cliffs is exhibited by other New World psittacids which include the Hyacinth Macaw (Anodorhynchus hyacinthinus), Glaucous Macaw (Anodorhynchus glaucus), Military Macaw (Ara militaris), Green-winged Macaw (Ara chloroptera), Red-fronted Macaw (Ara rubrogenys), Red-fronted Conure (Aratinga wagleri), Brown-throated Conure (Aratinga pertinax), Maroon-fronted Parrot (Rhynchopsitta *pachyrhyncha terrisi*), Slender-billed Conure (*Enicognathus leptorhynchus*), and Rufous-fronted Parakeet (*Bolborhynchus ferrugineifnous*) (Forshaw 1989). The Patagonian Conure (*Cyanoliseus patagonus*), Sierra Parakeet (*Bolborhynchus aymara*), Andean Parakeet (*Bolborhynchus orbygnesius*), and Mountain Parakeet (*Bolborhynchus aurifrons*) excavate nesting holes in bank burrows (Forshaw 1989). Most *Amazona* species nest in tree hollows, as do all other subspecies of *Amazon leucocephala* (King et al. 1979). Observations of nesting in limestone cavities within cliffs/hills have been reported for the Puerto Rican Parrot (*Amazona vittata*; historically, Snyder et al. 1987), Yellow-shouldered Amazon (*Amazona barbadensis*; Rooth 1968), Blue-fronted Amazon (*Amazona aestiva*; Forshaw 1989) and Hispaniolan Parrot (*Amazona ventralis*; Snyder et al. 1987); although tree-cavity nesting is the usual mode among these species. The Inagua population of *Amazona leucocephala bahamensis* nests in tree cavities (Snyder et al. 1982).

During May of 1977, Snyder et al. (1982) collected data in the early breeding cycle of the Bahama Parrot on Abaco. In comparison to other West Indian Amazons, egg-laying in the Abaco population of the Bahama Parrot is late and occurs in May (Snyder et al. 1982). Bahama Parrots are monogamous and both sexes care for the altricial young. Clutch size ranges from 2 to 5 eggs. In captivity, the incubation period averaged 28 days (Noegel 1977). Hatching is asynchronous.

Young fledge eight weeks after hatching and associate with their parents in post-breeding flocks (Snyder et al. 1982).

My research was designed to further investigate the breeding biology of the Abaco population of the Bahama Parrot. I chose to study this population because its unusual subterranean nesting habit suggested that this "nesting-shift" and correlated adaptations might yield insight into the ecological characteristics which influence the evolution of life history traits in this species and in other *Amazona*. This study provides a framework for the comparison of breeding biology among West Indian taxa of *Amazona*. Recent field studies have been undertaken with other subspecies of *leucocephala* (Bradley 1986; Gonzalez, pers. comm.), the Hispaniolan Parrot (Snyder et al. 1987) and the endangered Puerto Rican Parrot (Snyder et al. 1987). All of these species nest in tree cavities. Bond (1963) postulated on the derivations of the West Indian *Amazona* and concluded that these species evolved from the ancestor of the White-fronted Amazon (*Amazona albifrons*) and thus, are closely interrelated.

My research on the breeding biology of the Bahama Parrot on Abaco focused on: (1) population size and stability, (2) reproductive productivity and success, (3) nesting behavior and (4) feeding ecology. In view of its endangered status, the overall objective of my research has been to develop a comprehensive biological understanding of this population upon which an effective conservation program can be based. This objective could be achieved if the four focal points mentioned above were properly addressed.

Materials and Methods (Study Design)

Since 1985, my field assistants, Susan Berman, Linda de Lay, Ian Lothian, Erin Shanahan, Kirsten Silvius, Bill Strausberger, Jr. and Lori Willimont and I have located and monitored 76 parrot nests in two nesting areas of southern Abaco (Latitude 26^{0} N, Longitude 78^{0} W). These study areas were located within the pine-coppice areas south of the settlement of Crossing Rock. Henry (1974) described the vegetation and recent history of this forest area. We conducted field research from 3 May to 12 September 1985, 9 May to 13 September 1986, 7 May to 19 September 1987, and 25 May to 20 September 1988; during which periods the parrots were breeding. In addition, I made three additional trips to Abaco to estimate the population size - 21 to 29 January 1986, 5 to 28 January 1988 and 5 to 31 January 1989.

The specific methodologies which I followed to collect data on population numbers, reproductive success, nesting behavior and feeding ecology are presented in the respective chapters on these topics. Generally, I collected data in the field pertaining to stages of the nesting cycle: pre-egglaying, egg-laying, incubation, hatching and rearing of chicks and fledging. The estimates of population size were made during the non-breeding season when parrots are gregarious and aggregate in large roosting flocks.

We constructed five PVC (polyvinylchloride plumbing pipe) blinds to observe nesting pairs in the study area. Parrots were not individually marked during the course of my research. Leg-bands are of little use in marking parrots because their tarsi are short and their legs are rarely seen clearly. Rowley and Saunders (1980) developed a wing-tag marking technique for their studies of Australian Cockatoos. However, I chose not to use this technique because the risks associated with patagial (wing) tags could not justify their use on an endangered species, especially one that is ground nesting. Saunders (1988) observed increased mortality of patagial tagged Carnaby's Cockatoos (Calyptorhynchus funereus latirostris) which resulted from increased predation by Wedge-tailed Eagles (Aquila audax). Bahama Parrots on Abaco suffer from predation by Red-tailed Hawks (Buteo jamaicensis) (pers. observation). Therefore, one could expect some increased mortality associated with the use of patagial tags with Bahama Parrots.

Statistical Analyses were done using SAS (SAS Institute 1985) and BMDP (Dixon 1985) software packages on the City University of New York's IBM mainframe system.

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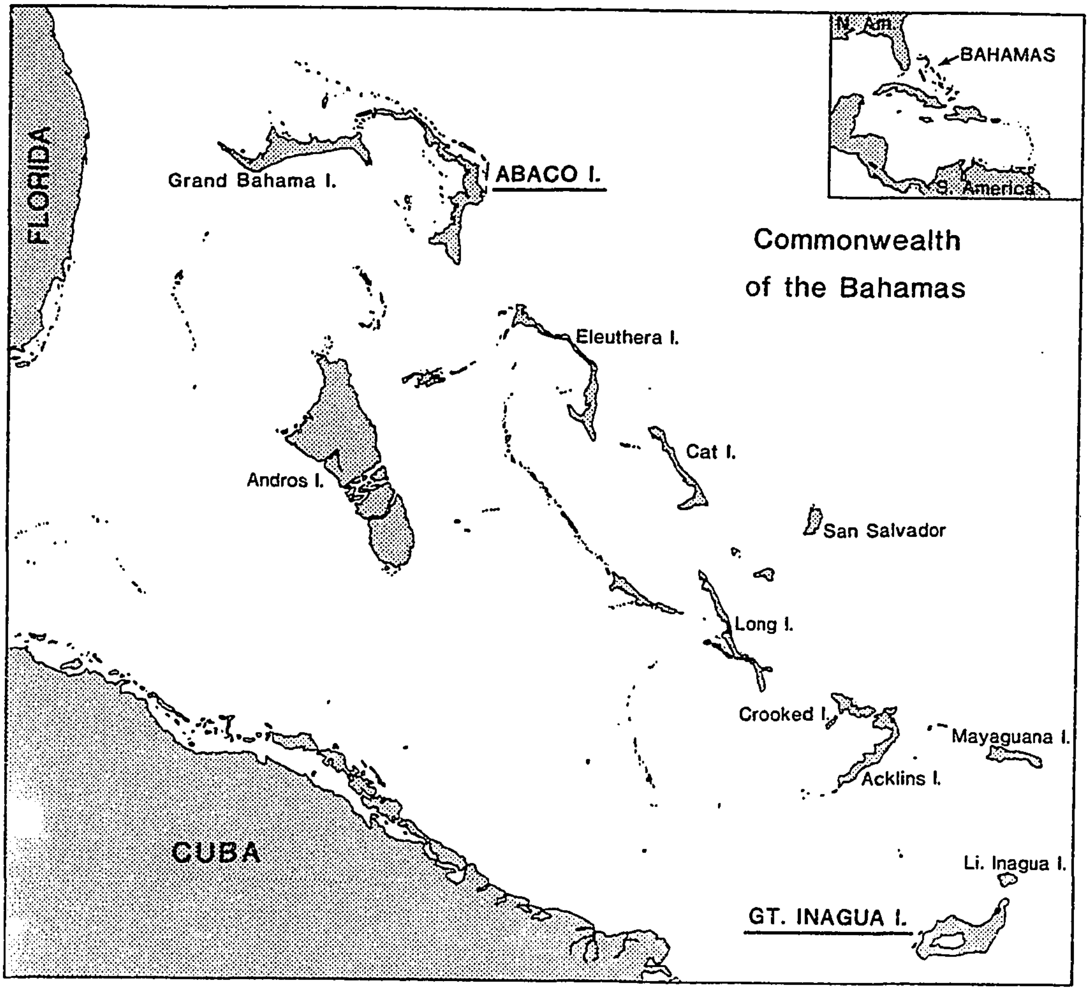

Figure 1. The Bahama Parrot (Amazona leucocephala bahamensis) survives on the islands of Abaco and Great Inagua. The map shown is a courtesy of Stephen Nash and Wildlife Preservation Trust International.

Figure 2. Bahama Parrot (Amazona leucocephala bahamensis) at its nest site, Abaco Island, Bahamas.

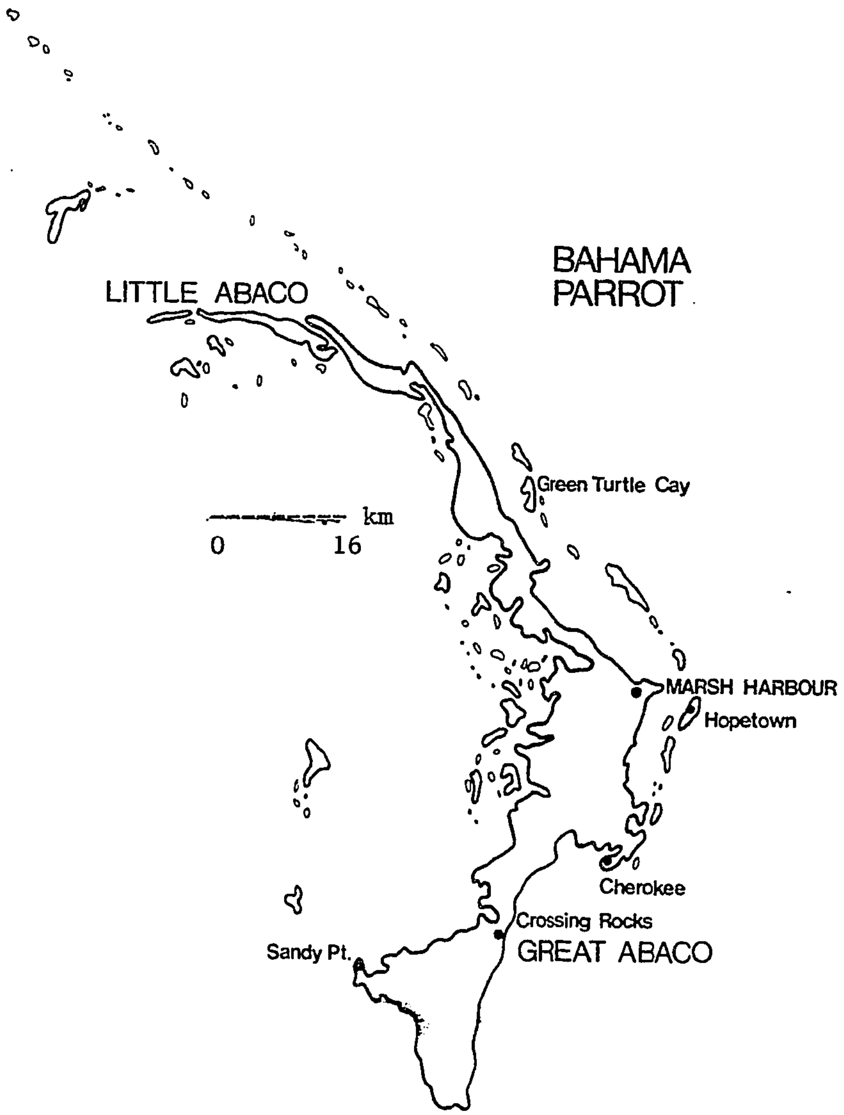

Figure 3. Great and Little Abaco Island, Bahamas.

Chapter 1.

Population estimates for the Bahama Parrot on Abaco Island, Bahamas.

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Abstract - As part of a long-term study of the biology of the endangered Bahama Parrot on Abaco,population counts were done during the nonbreeding season to estimate the relative size of this population and assess its relative stability. Since 1986, we have conducted three population counts. The only previous census of the Abaco population was done in 1976 and the then total population was estimated to be between a minimum of 450 parrots and a loosely defined maximum of 650 to 800 parrots. Since parrots on Abaco roosted communally at night and dispersed from/to roosts in flocks, survey counts were made at roosts and along flight paths to roosts. In 1989, we counted a minimum of 830 to a maximum of 1082 parrots on southern Abaco. Present threats to this population include: nest predation by feral cats, poaching and unprotected habitat.

The Cuban Amazon (*Amazona leucocephala*) is a polytypic species with five recognized subspecies: *leucocephala* (Cuba), *palmarum* (Western Cuba and Isla de la Juventud), *caymanensis* (Grand Cayman), *hesterna* (Cayman Brac), and *bahamensis* (Bahamas) (Bond 1956). Historically, the Bahama Parrot (*A.l.bahamensis*) was recorded from Abaco, New Providence, San Salvador, Long Island, Crooked Island, Acklins, and Great Inagua (Bond 1956). Today, this subspecies is regarded as rare (King 1977) and is restricted to two islands, Abaco and Great Inagua.

The Abaco population of the Bahama Parrot is the northernmost native breeding population of any species of the genus *Amazona* (Snyder et al. 1982). This population is centered in the mixed broadleaf coppice (thickets of native evergreen hardwoods) and pine (*Pinus caribaea*) areas of southern Abaco. In recent years, the Abaco population has declined as a result of habitat destruction from logging activities and hurricanes, and from hunting pressures (Attrill 1981; Snyder et al. 1982).

Unlike the Bahama Parrots on Great Inagua, which nest in tree cavities, parrots on Abaco nest in natural limestone solution cavities in the ground. The subterranean nesting habit of the Abaco population is unique among the 138 species of New World parrots (Forshaw 1989; King et al. 1979; Snyder et al. 1982).

In 1986 we began a long-term study of the biology of the Bahama Parrot on Abaco. The overall objective of the project has been to develop a sound biological understanding of this subspecies upon which an effective conservation program can be based.

Since 1986, we have conducted three population counts during the nonbreeding season to estimate the size of the population and its relative stability. The only previous survey of the Abaco population of the Bahama Parrot was done in 1976 by Snyder et al.(1982). They estimated the total population to be between a minimum of 450 birds and a loosely defined maximum of 650 to 800 birds.

METHODS

Our three population estimates were based on fieldwork between 21 and 29 January 1986, 5 and 28 January 1988 and 5 and 31 January 1989. Rosemarie Gnam also made a trip to Abaco in January 1987 but a population survey was impossible because of widespread forest fires on southern Abaco. Our methodology followed that of Snyder et al. (1982) in which they derived population estimates from roost counts, so that past and present counts would be comparable. Local residents assisted with some counts. Our most comprehensive population count was made in 1989 aided by the field participation of a crew of Operation Raleigh volunteers.

Since parrots on Abaco roosted communally at night and moved to and from roosts in flocks, survey counts were made at roosts and along flight paths to roosts. Parrots roosted along the inner edge of the coppice bordering on pine forests and in inland "coppice islands," which occur in pine yards where coppice vegetation replaces pine as a result of succession and poor pine regeneration after past logging activities. We conducted surveys in the region south of Crossing Rock to Hole in the Wall lighthouse (Fig. 1).

We divided southern Abaco into five zones for survey counts (Fig. 1). These zones are centers of parrot activity and their boundaries are loosely defined. Local hunters commonly divide southern Abaco into the parrot area north of road 14 which is an old logging road (Zone A), and the area south of road 14 (Zone B). Both Zones A and B contain parrot nesting areas and have large tracts of pine with coppice borders. Gnam (unpublished) has noted a difference in the vocalizations between breeding pairs in Zone A and B. Zone C is commonly referred to as the "Cocoplum" Area and is characterized by a vegetative understory adapted to freshwater swamp conditions. Besides pine, Zone C has a high density of Pond Top Palms (Sabal palmetto) and Cocoplum (Chrysobalanus icaco). Zone D contains sparse pine yards and has large tracts of dense coppice scrub. The small xeric scrub area around Hole in the Wall comprises Zone E.

Observers were positioned along the old logging roads which divide the island into a grid system and were positioned at about 1.6 km (1 mi.) intervals because flying and vocalizing parrots are detectable up to approximately

0.8 km (Snyder et al. 1982). At each station, observers recorded the number of parrots seen or heard, the direction of their flight and the time of their detection. It is generally difficult to count parrots in groups larger than 10-15 individuals because they mill around in a confusing fashion and birds often repeatedly enter or leave roosts (Snyder et al. 1987). Therefore, observers counted a minimum (subtracted any birds possibly seen more than once) to a maximum (all birds counted) number of parrots in a flock or at a roost. On successive days we progressively surveyed the entire pine-coppice interface of southern Abaco. In addition, inland areas of parrot activity and possible inland roost locations were assessed by vehicle surveys in the early morning and late evening. Areas where parrots were seen or heard were later worked with ground observers.

In those areas where the terrain and paucity of roads made counts difficult, we cut foot paths for better access or made observations from treetops. The area between Alexandria and Hole in the Wall lighthouse was impenetrable because of dense coppice scrub. Here, rough population counts were made by counting the numbers of vocalizing birds.

Counts were conducted from first light to 0830 hours and from 1600 hours until dark. These hours corresponded with peak travel periods from/to roosts and activity within roosts. Duplicate sightings of parrots by different observers were eliminated by comparing flight directions and times between adjacent stations. When one roost was observed from different directions, the total count was the sum of the counts for each direction. Whenever possible, roosts with counts greater than 50 were resurveyed during the population counts and an average count derived. Stations were resurveyed when poor weather conditions, such as heavy rains, resulted in reduced visibility and flock movements.

RESULTS

From counts that were made at the same stations (N=20) used by Snyder et al. (1982) in 1976, we made an initial estimate of 304 to 398 birds for southern Abaco in 1986 (Table 1). Snyder et al. (1982) counted 240 - 276 birds at these stations (Table 1). However, this estimate assumed that very few birds roost inland (centrally) and that a census of only the pine-coppice interface border adequately estimated population size. Because of our discovery of a substantial inland roost in Zone A in 1986 (Table 1) and observations of roosting behavior in the breeding season, we expanded our methodology in 1988 to include inland roost surveys. As a result of this change, we counted a minimum of 1089 birds to a maximum of 1317 birds in 1988 (Table 1). In 1989, these same stations were surveyed and population estimates ranged from 830 to 1082 birds (Table 1).

Bahama Parrot populations were largely concentrated in Zones A and B, with small populations elsewhere (Table 1).

Parrot nesting areas are located in both these areas (Gnam 1988). From observations, we determined that inland roosts in Zone A are likely to be occupied in succeeding years.

Local hunters have often reported seeing a flock of 300+ parrots in Zone B between ridges in the area. In 1988, we spent considerable time in this area and counted a large roosting flock of 250 - 300 birds (Table 1). This flock did not use the same roost nightly but moved the roost within a prescribed inland area of about 8 km ^{2}. In 1989, we located a flock of 152 - 222 birds, 4.5 km south of the 1988 station.

Between January, 1988 and January, 1989, the parrot population in Zone A declined by 224 - 251 birds (Table 1). Unlike the decline of parrots in Zone D, which may have represented our failure to locate the roost in this impenetrable scrub or movement of the birds into Zone B, we believe the decline in Zone A to be a true loss. Despite increased observers, repeated counts in the area, and attempts to locate new parrot roosts in the western area of Zone A, we were unable to find additional birds in this region.

Most Bahama Parrots are restricted to southern Abaco where we conducted our surveys. However, we received reports of a few Bahama Parrots living in and north of Marsh Harbour (Fig. 1). These may have been largely escaped pet psittacines of various species. There have been a few reliable sightings of a flock in the central portion of the island between Crossing Rock and Bahama Palm Shores (Fig. 1). We made an effort to locate this flock, but with no success. From reports given to us by local residents (C. Boyles and G. Chambers pers. comm.), we estimated this population to number from 30 to 60 birds. Thus, we estimate the total Bahama Parrot population on Abaco in the late 1980's to have ranged from a well-defined minimum of 860 - 1142 individuals (actual birds counted) to a less well-defined maximum of about 1300 individuals. We derive this maximum by taking the number of birds counted and adjusting this number for the possible existence of a flock in Zone D.

How closely this estimate of population size approached the true population size is dependent upon how completely we located the parrot roosts of southern Abaco. Our efforts were thorough enough that we doubt if we missed any major concentrations of parrots. In any case, we are quite confident that at least 860 parrots existed in the wild on Abaco during the 1980's.

DISCUSSION

Because we did not monitor all stations simultaneously during our counts, it is possible that some error in counts may have been produced by birds moving between roosts in successive days. However, replicate counts at given roosts have given quite consistent results, so we doubt such movements were normally taking place.

Since the initial census of Snyder et al. (1982), actual counts of the Bahama Parrot population on southern Abaco increased from a minimum of 325 birds in 1976 to an absolute minimum of 830 birds in 1989. However, the large number of parrots that we found roosting inland were not assessed by Snyder et al. (1982). To arrive at long-term trends we should only compare areas censused in both time periods. Although parrot roosting behavior may have changed between 1976 and 1986, our 1986 counts of the pine-coppice border interface stations covered by Snyder et al. (1982) yielded 256 - 338 parrots, which was very similar to their count of 240 - 276 parrots. For the same stations in 1988 and 1989 total counts were 364 to 380 and 252 to 292. These comparisons suggest: (1) an increase of the population from 1976 to 1988, (2) a decrease from 1988 to 1989, and (3) a relative stability overall for the 14-year period.

Parrot numbers in Zone A declined dramatically from 1988 to 1989, which may reflect, in part, the poor nesting season that parrots experienced in 1988. In 1988, Bahama Parrots on Abaco exhibited the lowest reproductive rate observed in four years of study, with only 29% of nests fledging young. The number of young fledged per egg-laying pair was 0.60 and per successful pair was 2.0 (Gnam 1990). The cause of this poor reproductive performance was increased nest predation by feral cats, which was responsible for 45% of all nest failures (Gnam, 1990).

The introduction of cats to islands has resulted in the eradication of many bird species in the Galapagos (Cruz and Cruz 1987), Marion Island (Van Aarde 1984) and New Zealand (Veitch 1985). Because of their ground-nesting habit, incubating Bahama Parrots are extremely vulnerable to predation by feral cats. In 1988, the nesting female was killed in 50% and injured in 14% of the 14 known attacks (Gnam, 1990). Nest predation by feral cats thus affects the Bahama Parrot population in two ways, poor recruitment as a result of low nesting success and loss of breeding adult females, which can affect the future reproductive potential of the population. Some means of reducing the impacts of feral cats is urgently needed for southern Abaco.

Parrots in Zone A may also have declined because of other unknown reasons, such as increased mortality in the nonbreeding season and dispersion of birds from this zone into other zones. Annual adult mortality is presently unknown. Future radiotelemetry studies are planned to examine postfledging survivorship and flock movements.

With the exception of a small parrot flock in central Abaco, the Bahama Parrot population of the late 1980's was restricted to southern Abaco(an area of 275 km^2) and numbered 830 to 1082 birds. Although the Bahama Parrot population on Great Inagua is assumed to be larger than that of Abaco, reliable data are lacking (Snyder et al. 1982).

Population estimates for other subspecies of the Cuban Parrot are higher. The nominate form, A.l.leucocephala, numbers about 5000 birds (H. Gonzalez pers. comm.) and A.l.caymanensis numbered 1351 birds in 1985 (Bradley 1986). However, this estimate was made before Hurricane Gilbert struck in 1988 and present numbers may be lower. The subspecies A.l.hesterna on Cayman Brac remains the most critically endangered subspecies. Bradley (1986) estimated the wild population in 1985 to be only 39 birds.

Although the Bahamian Department of Lands and Surveys (Forestry Section) has proposed the creation of a 6880-ha parrot reserve as part of a larger 27,519-ha forest reserve for southern Abaco (J. Hook pers.comm.), legislative approval has not yet been achieved, and the habitat of the Bahama Parrot on Abaco presently remains unprotected. Unless a long-term conservation management plan for this parrot is implemented soon, the future survival of this parrot is questionable (Gnam 1990). The Puerto Rican Parrot (Amazona vittata) population numbered 200 birds in 1953, but without conservation measures precipitously declined to 24 birds in 1968 when a recovery plan was initiated at considerable expense (Snyder et al. 1987). Conservation measures for Bahama Parrots that begin now would likely yield better results and be more cost effective. Too often, conservation efforts begin only when populations have declined to such low levels that they may no longer be genetically or ecologically viable (Soule 1987).

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Table 1. Minimum-maximum Bahama Parrot (*Amazona leucocephala bahamensis*) population counts from Abaco Island, Bahamas.

Area	1976[1]	1986	1988	1989
Southern Abaco	325-375[E]			
Zone A				
Coppice-Pine Margin	66-81	168-209	132-139	92
Inland	NS	48-60	413-542	239-338
Zone B				
Coppice-Pine Margin	97-103	16-31	46	95-125
Inland	1	NS	312-395	314-427
Zone C	63-75	43-69	60+	65-75
Zone D	14-16	29	126-135	0
Zone E	NS	NS	NS	25
Central Abaco	100[E]	0	0	30-60[2]
Marsh Harbour/ North Abaco		0	0	0
Total	450-800[E]	304-398	1089-1317	860-1142

1 Snyder et al. (1982), Snyder (pers.comm.)

2 Chambers (pers. comm.)

E Estimated Count

NS Area not surveyed

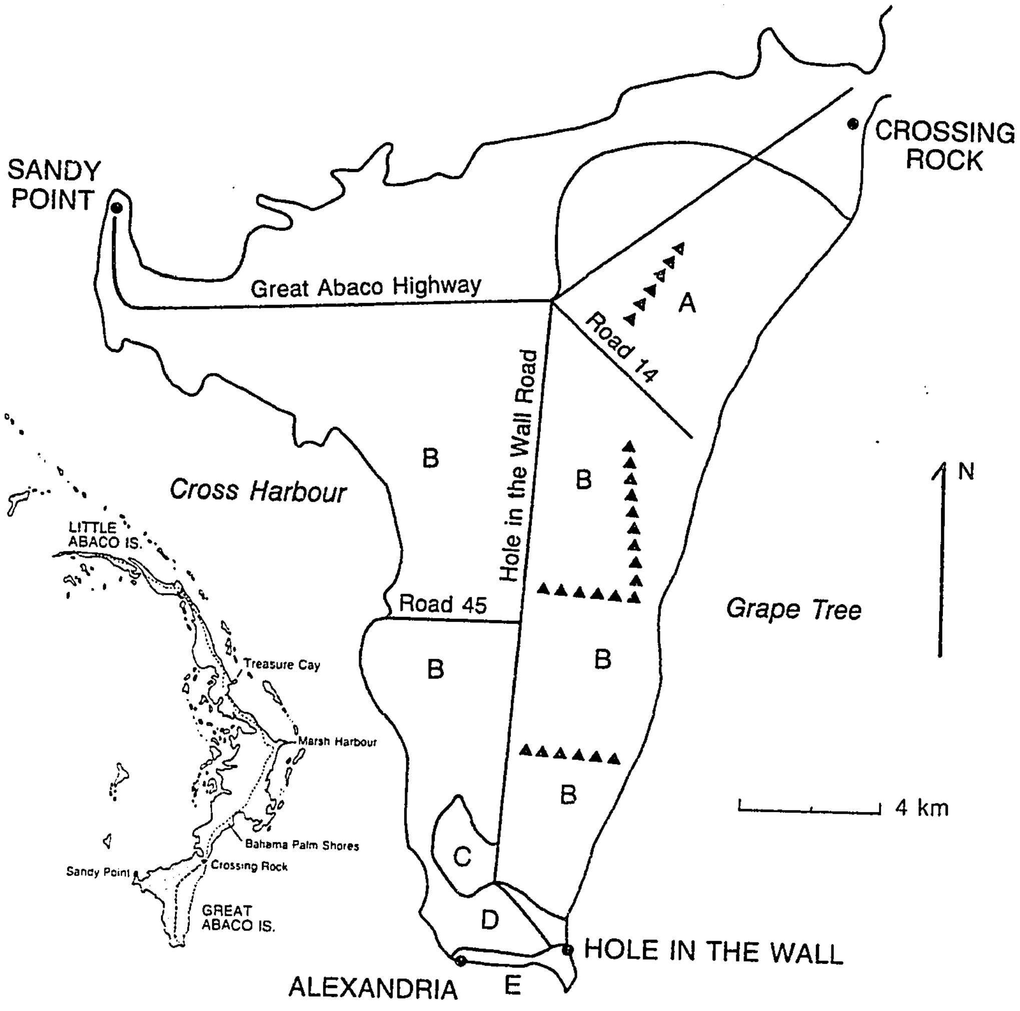

Figure 1. Areas of southern Abaco Island, Bahamas that were surveyed for Bahama Parrots (Amazona leucocephala bahamensis). Limestone ridges which can reach a maximum elevation of 37 m are indicated by triangles.

Chapter 2

Reproductive potential and output of the Bahama Parrot (*Amazona leucocephala bahamensis*)

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Abstract.

We evaluated reproductive investment and loss in the endangered Bahama Parrot (Amazona leucocephala bahamensis) using a fitness components model that corresponds to stages of the reproductive cycle of this species. On average, a pair produced 3.6 eggs and fledged only 0.8 young. This is a 77% loss on their initial investment. While losses accrued throughout the cycle, they were highest during the hatching and post-hatching stages. Partial hatching failure and total brood failure, respectively, were the primary sources of loss at these stages. These components did not change significantly over the four years of the study. Total nesting failure changed significantly over time and exacerbated losses during the incubation stage in two of the four years of the study. The implementation of a conservation management plan for this species, which would reduce total nest and brood failures is urgently needed.

Introduction

Although parrots are commonly kept in captivity and many wild parrot populations are harvested annually for the pet trade (Dixon 1986), very little is known of their reproductive rates in the wild. Often, data are anecdotal, fragmentary and based on the observations of one or two nesting pairs (Forshaw 1989). With the notable exception of studies on Australian parrots (Rowley 1980; Wyndham 1981; Saunders 1982, 1986; Smith & Saunders 1986), the Kakapo (*Strigops habroptilus*; Merton, Morris & Kepler 1984) and the Puerto Rican Parrot (*Amazona vittata*; Snyder, King & Kepler 1987), few studies have comprehensive details on fecundity within a population over several nesting years. These few, long-term studies of nesting success demonstrate the K-oriented (Pianka 1970) reproductive strategies of parrots; e.g., delayed maturity, small clutches, high parental investment and fledge few offspring.

The Bahama Parrot (*Amazona leucocephala bahamensis*) is one of six endangered species of *Amazona* found in the West Indies (King 1977). Although the parrot was once abundant and widespread throughout the Bahamas, it has declined as a result of habitat destruction and hunting (Attrill 1981). It is now restricted to only two islands in its formerly extensive range - Great Abaco and Great Inagua (Snyder, King & Kepler 1982). Unlike the Bahama Parrot population on Inagua and other Caribbean *Amazona*, all of which nest in tree cavities, parrots on Abaco nest exclusively in limestone-solution cavities in the ground. Although rock-cavity nesting in cliffs occurs in species of several groups of parrots (Forshaw 1989) and the Patagonian Conure (Cyanoliseus patagonus) nests in river bank cavities, the subterranean nesting habit of the Abaco population on relatively flat terrain is unique among New World Parrots. Snyder, King & Kepler (1982) observed the nesting behavior of this population in the pre-egglaying and egglaying stages but were unable to measure reproductive success.

A necessary step in the development of a biologically sound and effective conservation plan for an endangered species is to quantify reproductive success, ascertain whether it is declining and identify the causes for any such decline. Reproductive success is a product of a set of co-adapted traits expressed at stages of the reproductive cycle and subsequent recruitment into the breeding population, which for some birds extends from nest initiation through fledging (see Stearns 1976). Since there may be tradeoffs among traits, a more complete picture of reproductive success can be obtained by examining an individual's performance at these various reproductive stages (see Rockwell 1989). In this fashion, for example, Martin, Hannon & Rockwell (1989) were able to demonstrate that equal overall reproductive output of two populations of Willow Ptarmigian (Lagopus lagopus) resulted from tradeoffs between initial clutch size and total nest failure. The population with a higher initial investment also suffered higher loss.

Analyses of this type have never been attempted for parrots. In this paper, we examined reproductive fitness of the endangered Bahama Parrot population on Abaco, using a compartmental life history model modified from Rockwell, Findlay & Cooke (1987). Bahama Parrots are monogamous, territorial and remain together throughout the nesting cycle to produce a single brood. Eggs are laid in late May and early June and fledge in late August (approximately 7-8 weeks post-hatching). In this study, our objectives were to : (1) quantify the components of fitness corresponding to stages of the reproductive cycle; (2) establish which stages suffer the highest loss; (3) evaluate whether these components or overall production change with time; (4) relate these stages and temporal variation to the parrot's ecology; (5) estimate the expected reproductive success for each breeding season and over several breeding seasons; and (6) make recommendations as to how these results could be used in establishing a species management plan.

Study Area and Methods

We studied Bahama Parrots on southern Abaco, 64 km south of Marsh Harbour (latitude 26^0 , longitude 78^0), from 1985 to 1988. In 1988, the population ranged from a well-defined minimum of 860 to 1142 parrots to a less well-defined maximum of 1300 parrots. It was restricted to the Caribbean pine (Pinus caribaea) and mixed broadleaf coppice (native, evergreen hardwood) areas of southern Abaco.

We collected nesting data from early May to early September as part of a larger investigation into the breeding biology of this species. Nests were found by daily searches into two study localities, which were designated as Nest Areas 'A' and 'B'. We found nests by following individuals or pairs in these areas during pre-egglaying and incubation, and by searching around known parrot nests for nests of neighboring pairs. Since 1985, we located 76 nests but not all of these nests were active in a given year. Clutch size was recorded and most nests were checked at least once a week until fledging or the nest failed.

We used a general compartmental model modified from Rockwell, Findlay & Cooke (1987) to estimate the components of fecundity and survival in the Bahama Parrot. The model allowed us to examine losses at successive stages in the reproductive cycle. The fecundity components of fitness span the period from egglaying to the fledgling of chicks (Table 1). The state variables, total clutch laid (TCL), clutch size at hatch (CSH), parrots at hatch (PHN) and brood size at fledgling (BSF), correspond to the major stages of the Bahama Parrot reproductive cycle. They are connected by a set of transition probabilities, egg survival (P1), hatching success (P2) and fledgling success (P3) (Table 1). Although values of less than one for the transition probabilities indicate partial loss between stages of the reproductive cycle, they do so only for individuals that hatch or fledge at least one chick, not for individuals that fail to produce any chicks. To account for total losses, we define four additional probabilities for those individuals that fail to lay (TLF), incubate to term (TNF), hatch (THF) or fledge any chicks (TBF) (Table 1). We considered only fecundity components of fitness in the analyses presented here.

The state variables (TCL,CSH,PHN AND BSF) correspond to sequential stages of the reproductive cycle that are marked by critical events (e.g., hatching; fledgling) and each imposes an upper limit on the succeeding one. Thus, one might argue that only TCL and the transition probabilities need be evaluated. However, our sampling scheme does not ensure that all variables and transitions are collected for all females. Hence, the estimates for each are based on different subsamples of the population. To maximize our chances of detecting differences among years, we evaluate each state variable separately, using the largest available sample for each.

To examine whether the fecundity components varied over the years of the study, we subjected the components - TCL, P1, CSH, P2, PHN, P3 and BSF to one-factor analyses of variance (ANOVA) and the remaining components - TLF, TNF, THF and TBF to multidimensional contingency analysis (MCDA).

Analysis of variance was performed with SAS (1985) and multidimensional contingency analysis was performed with procedure P4F from BMDP (Dixon,1985). The test statistic reported here for MDCA is G^2, the log-ratio chi-square. We excluded six nests from the above statistical analyses because they were found late in the reproductive cycle (chick stage) or on the periphery of nest area 'A', which buffered them from feral cat predation. We assumed that these nests had a higher probability of success and their inclusion into the above analyses would bias any results.

Results

The fecundity components of the Abaco population of the Bahama Parrot are defined for specific stages of their reproductive cycle (Figure 1). The reproductive output of individuals flows through the system from pre-egglaying through egglaying and hatching to fledging. The global means of the state variables (TCL, CSH, PHN, BSF) and transition probabilities (both partial and total) are pooled over the four years of the study and provide a general view of reproductive success in the species (Figure 1). Losses accrued throughout the reproductive cycle. From an average, initial clutch of 3.55 eggs that did not fail totally at some stage, a nesting pair of Bahama Parrots fledged an average of 1.79 chicks.

The annual means for the fecundity components were calculated (Table 2). We examined the data for annual variation in these components with Analysis of Variance (state variables and partial loss transition probabilities). Year effects were not significant for any of the state variables (TCL, CSH, PHN, BSF) or partial loss transition probabilities (P1, P2, P3) implying that these components have not changed over the cause of this study (Table 3). In sharp contrast, we found significant heterogeneity over years for total laying failure (TLF) and total nesting failure (TNF) (Table 4).

The overall significant heterogeneity in these variables was examined for homogeneous subsets following procedures outlined in Rockwell, Findlay & Cooke (1987). The overall yearly heterogeneity in total failure of a female to lay (TLF) can be broken down into two homogeneous subsets: 1985 with high TLF (29%) and the years 1986, 1987 and 1988 with none. In 1985, four nests failed before the female laid her first egg because of flooding or injury to the female, whereafter she abandoned the nest. The overall yearly heterogeneity in total nest failure (TNF) can be split into two homogeneous but significantly different subsets : 1985 and 1988 which have higher TNF than 1986 and 1987 (Table 2).

Proximate causes of total failure for each reproductive stage are desertion, flooding, predation, chick deaths and human disturbance (Table 5). Although total brood failure (TBF) ranged from 14 to 64 %, it did not vary among years, whereas total nest failure (TNF) significantly varied (Table

4). The causes of total nest failure were distributed uniformly in 1985 (Table 5). In marked contrast, the significantly higher TNF in 1988 was caused solely by feral cat predation (Table 5). During incubation, nests may be more susceptible to nest predation by cats because more nests can be found at this stage - reinforcing what may be a 'learned' behavior by cats and the male parrot's behavior of perching near a nest and calling to the female, so that she exits the nest to be fed, may attract attention to the nest. We used these clues to locate parrot nests and, in a similar fashion, we have observed feral cats to stalk calling males. In 1988, the incubating female was killed in 50% and injured in 14% of the known cat attacks (n=14). Nest predation by feral cats continued in 1989 (Gnam 1990) and the only nests that fledged young in area 'A' were those surrounded by protective fencing.

The expected annual reproductive output of a female that began laying eggs can be obtained by combining the mean initial clutch size (TCL) with the estimates of the transition probabilities (Table 2). Formally, this expected reproductive success is :

$$ERS = TCL * (1-TNF) * P1 * (1-THF) * P2 * (1-TBF) * P3.$$

Expected reproductive success (ERS) is essentially a female's return on her initial investment allowing for both the probability of total failure and the extent of partial loss. We have calculated the ERS for each year and also provide a pooled estimate for general reference (Figure 2). We depict how the initial investment (reproductive potential) depreciates over the reproductive cycle by plotting the expectations at each stage (e.g., the expectation of clutch size at hatch [E(CSH)] is TCL * (1-TNF) *P1) (Figure 2).

Measured over the entire cycle, the average depreciation in reproductive potential is 77%, ranging from a 60% loss in 1985 to a 90% loss in 1988. The general pattern (Figure 2, 'pooled') is that, although depreciation of ERS occurs throughout the reproductive cycle, it is greater during hatching (49% loss) and post-hatching (46% loss) than during incubation (17% loss). Hatching depreciation stems largely from partial hatching loss (P2), whereas post-hatching depreciation stems mainly from total brood failure (TBF). The major impact of these two components did not change significantly over the duration of this study (Table 3). The exception to this general pattern is related to the temporally varying fitness component, total nest failure (TNF). The differential impact of TNF is obvious in the incubation depreciation (TCL→ E(CSH)) depicted for 1985 and 1988 versus 1986 and 1987 (Figure 2).

Discussion

In a given nesting year, Bahama Parrots lay 2 -5 eggs and can expect an average return of 23% (0.8 chicks) on their initial investment of 3.55 eggs. Assuming the population has an equal sex ratio, half of these chicks will be female and annual female production to the fledging stage is thus, 0.4 chicks. Compared to other subspecies of leucocephala and other Greater Antillean Amazona, it is clear that Bahama Parrots produce fewer young per nesting attempt (Table 6).

Although intraspecific and interspecific differences can be found in habitat and ecology, mean initial clutch size among these Caribbean Amazona is similar (Table 6). Taxonomic affinities can help explain this finding (Stearns 1976), but body size may also play a contributing role. The Galah (Cacatua roseicapilla), which weighs 315 gm. and is placed in a different family than Amazona lays a mean clutch of 3.6 eggs (Smith & Saunders 1986). Its reproductive investment is identical to the slightly smaller Bahama Parrot ,yet, taxonomically, they are distantly related. Saunders, Smith & Campbell (1984) found that within the Psittaciformes, the larger the species the smaller the clutch size. In the larger Lesser Antillean Amazona, A.imperialis and A.guildingii, clutches of two appear to be the predominant pattern (Gregoire 1980; Nichols 1980).

Although the Greater Antillean Amazona lay similar-sized clutches, they vary in the number of young fledged and overall nesting success (Table 6). As a general rule, tropical hole-nesting birds have success rates that exceed

60%, possibly because hole-nesting affords better protection from predation (Skutch 1976). The tree- cavity nesting Puerto Rican Parrot, Hispaniolan Parrot (A. ventralis; Snyder, Wiley & Kepler 1987) and White-tailed Black Cockatoo (Calyptorhynchus funereus latirostris; Saunders 1986) fit this pattern but the subterranean - nesting Bahama Parrot population on Abaco is well below this reproductive rate (Table 6). It is unknown when this subterranean nest shift occurred, but it has exposed the parrots on Abaco to different selection pressures and increased risks of nest loss from predation and flooding. Because of their ground-nesting habit, parrots on Abaco are vulnerable to nest predation by introduced mammalian predators (Gnam 1990). Since the Caribbean islands where the parrot evolved were devoid of mammalian predators until recent times, they lack the appropriate anti-predator behavioral and ecological responses seen in continental species. Similar effects of species naive to mammal predators have been observed in other ground-nesting, island species, such as the Kakapo (Merton, Morris & Atkinson 1984); the Bermuda Petrel (Pterodrama cahow; Wingate 1977) and Red-crowned Parakeets (Cyanoramphus n.novaezelandiae; Taylor 1985).

Nesting success in the dry tropics for open-nesting species is 50% whereas, the overall nesting success in the tropics for open-nesting species ranges from 24 - 50% (Skutch 1985). The greatest cause of nesting failures in the tropics is predation and open-nesting species are at greater risk (Skutch 1985). With a nesting success of 42%, Bahama Parrots are comparable with open-nesting species in the dry tropics.

Assuming the years of this study are representative, the lack of annual variation in most fecundity components (i.e., total clutch laid, number of chicks hatched and fledged), partial clutch and brood loss is noteworthy. Clutch and brood size often vary as a proximate response to changes in food availability (Lack 1968). However, islands have long been considered stable environments characterized by constant climates and predictable food resources (Cody 1971). Birds breeding in such environments typically exhibit reduced clutch size (consistent with K-selection) and little annual variability (Crowell & Rothstein 1981). This pattern, shown here for the Bahama Parrot (small clutch of only 3.6 eggs with no significant variation in clutch size) was also reported in the Puerto Rican Parrot (Snyder, Wiley & Kepler 1987).

Since the Inagua population of the Bahama Parrot nests in tree cavities, the shift to subterranean nesting is most likely recent for the Abaco population. It is unclear whether new pressures associated with this shift will ultimately result in an evolutionarily altered clutch size. It should also be noted that the current population size is well below carrying capacity. An attendant temporary reduction in competition could result in at least a short term increase in the clutch size. Continued monitoring of this population is needed to clarify these points.

Attrition of eggs and chicks accrued throughout the reproductive cycle, but a major loss occurred during hatching. Hatching success (averaging 56%) did not vary significantly among years. In a survey of hatching failure in 30 tropical species, Skutch (1985) found that 6% of the eggs incubated failed to hatch. Ricklefs (1969) observed an 8.1% hatching failure in 6 species from temperate North America. The high hatching failure (44%) of the Bahama Parrot may be abnormal among birds. In a study of five Australian parrot species, Smith & Saunders (1986) found low hatching failure (0-25%) in four species and only the Red-tailed Black Cockatoo (Cacatua magnificus), with a hatching failure of 35% is comparable to the Bahama Parrot. In a study of five nests of A.l.leucocephala in the Zapata Swamp, Cuba, De la Pozas and Gonzalez (1984) reported that 50% of the eggs did not hatch. The Puerto Rican Parrot has 16% hatching failure (Snyder, Wiley & Kepler 1987).

Eggs fail to hatch because of infertility, embryonic deaths or chick death during hatching (O'Connor 1984). In the Bahama Parrot, all of these factors may be responsible for hatching failure. However, we suspect that embryonic mortality, rather than infertility, plays the larger role. In 1988, all eggs that we examined were fertile. Snyder, Wiley & Kepler (1987) have found fertility rates of 90-100% in wild Puerto Rican and Hispaniolan Parrot eggs.

Mechanisms for embryonic mortality, (environmental contaminates and possible nest microclimate changes from the subterranean-cavity nest shift), may be responsible for the high hatching failure in the Bahama Parrot and need investigation. The effects of asynchronous hatching should also be considered. Since incubation in the Bahama Parrot begins with the laying of the first egg, hatching is asynchronous. Bancroft (1985) proposed that the degree of partial losses within broods is directly correlated with hatching asynchrony. Embryonic mortality of later laid eggs can result when female Bahama Parrots leave the nest to forage after the first or second chick hatches and the remaining eggs cool. Females or siblings can accidentally push these later laid eggs aside (Gnam, pers. obs.). Slagsvold (1982) observed that hatching failure in the Fieldfare (Turdus pilaris) increased when hatching was asynchronous.

Lack (1954) proposed that asynchronous hatching was a mechanism whereby brood size could be adjusted to the availability of food (brood-reduction hypothesis). Clark & Wilson (1981) argued that asynchronous hatching was a mechanism to reduce the risks of total nest failure from predation (brood-survival hypothesis). Brood reduction has been well documented in cockatoos (Saunders 1982; Smith &

Saunders 1986) and in these species, it was related to food availability, not nest predation. Asynchronous hatching in the Bahama Parrot may well be a mechanism to adjust brood size to food availability. They may regulate the size of their brood by hatching success, rather than by the partial brood loss of chicks from starvation, as observed in cockatoos. During our four-year study, partial brood loss (1-P3 [Fledging success]) ranged from 0 to 12%.

Total nest Failure (TNF) explained much of the variance in expected reproductive success between years. In this population, TNF results from environmental factors such as, heavy rains and introduced predators that are unpredictable, vary annually in their intensity and function as "biological catastrophes" (sensu, Shaffer 1987). Catastrophes impose a severe drain on an already 'stressed' reproductive system (small clutch, high hatching failure) of the Bahama Parrot and can occur at any stage in the reproductive cycle, causing total reproductive failure. These catastrophes are not likely to be pressures against which adaptations could have evolved in the past by parrots.

If Bahama Parrots renested and subsequently fledged young, they could compensate for high total nest failure. It is not known if any pairs do renest, but we suspect this is not the case. Our suspicion stems from our observations that we have never observed an unsuccessful pair to renest in their nest or any nearby cavity in their territory and the high synchrony of egglaying and fledgling in the population. In four years, we have never found a nest in the egg stage while other nests were in the chick stage.

The selection pressures of a stable environment that result in the Bahama Parrot being K-oriented in its life history characteristics put the species at risk in a rapidly changing environment. In recent times, the habitat of the Bahama Parrot has changed because of logging activities and human disturbances, such as fire and introduced predators.

To develop a biologically effective conservation plan and to maximize reproductive success in this endangered parrot, one must consider the fecundity components, their variability and the mechanisms which affect them. For the Bahama Parrot, it would be difficult to develop a management strategy which improves hatching success (P2) because this component may be intrinsic to the reproductive strategy of the species and dependent upon food availability in stable habitats. It is more realistic (and cost effective) to develop a management plan which reduces total nest and total brood failures and guards against their catastrophic effects. Nest cavities could be improved so that they drain more readily when it rains. A feral cat control program for southern Abaco could reduce the loss of breeding females from the population and increase recruitment as a result of higher nesting success.

Continued monitoring of reproductive success in this population is clearly needed. In addition, studies of post-fledging survivorship and adult mortality are necessary to complete the analysis of population viability. The Bahama Parrot population on Abaco is under stress; its reproductive success is low and its size numbers less than 1300 birds. Conservation measures to protect the parrot's remaining habitat and manage its population numbers need to be implemented now while numbers are sufficiently large to maintain biological viability.

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Table 1. Fecundity components of fitness for Bahama Parrots (*Amazona leucocephala bahamensis*).

Component	Description
State Variables:	
Total clutch laid (TCL)	Total number of eggs laid in the nest.
Clutch size at hatch (CSH)	Number of eggs in the nest when hatching begins or 26 days of incubation have elapsed.
Parrots at hatch (PHN)	Number of chicks present in the nest after hatching.
Brood size at fledging (BSF)	Number of chicks that fledge.
Transition Probabilities:	
Egg survival (P1=CSH/TCL)	Proportion of total clutch laid still present at hatch.
Hatching success (P2=PHN/CSH)	Proportion of surviving eggs that hatch.
Fledging success (P3=BSF/PHN)	Proportion of chicks that fledge.
Total laying failure (TLF)	Proportion of females that failed to lay a clutch. Failure is evidenced by a female that roosted in the nest prior to egglaying but failed to lay any eggs because of flooding, injury or predation (of the female).
Total nest failure (TNF)	Proportion of nests that failed prior to hatch. A nest failed totally if all of the eggs were preyed upon or abandoned prior to any of them hatching.
Total hatch failure (THF)	Proportion of nests that failed to have any eggs incubated to full term hatch.
Total brood failure (TBF)	Proportion of broods that failed totally. A brood failed totally if none of the hatchlings fledged.

Table 2. Annual nesting success and productivity of the Bahama Parrot (*Amazona leucocephala bahamensis*) on Abaco Island, Bahamas, 1985-1988.

	1985			1986			1987			1988		
Fitness component	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Total laying failure (TLF)	0.29	0.12	14	0.00	0.00	24	0.00	0.00	31	0.00	0.00	26
Total clutch laid (TCL)	2.86	0.14	7	3.60	0.13	15	3.63	0.17	19	3.73	0.30	15
Total nest failure (TNF)	0.30	0.15	10	0.00	0.00	22	0.03	0.03	30	0.44	0.10	23
Egg survival (P1)	1.00	0.00	5	0.98	0.02	15	0.99	0.01	18	1.00	0.00	8
Clutch size at hatch (CSH)	3.00	0.00	5	3.53	0.13	15	3.56	0.17	18	3.63	0.26	8
Total hatch failure (THF)	0.00	0.00	7	0.09	0.06	22	0.10	0.06	29	0.15	0.10	13
Hatching success (P2)	0.67	0.11	5	0.50	0.08	13	0.54	0.04	14	0.67	0.12	6
Parrot chicks at hatch (PHN)	1.86	0.26	7	1.81	0.25	16	1.72	0.14	25	2.44	0.38	9
Total brood failure (TBF)	0.14	0.13	7	0.50	0.11	20	0.31	0.09	26	0.64	0.15	11
Fledging success (P3)	1.00	0.00	6	0.93	0.05	10	0.91	0.04	18	0.88	0.07	4
Brood size at fledging (BSF)	2.00	0.26	6	2.00	0.30	10	1.50	0.12	18	2.25	0.48	4

Standard errors (SE) for TFL, TNF, THF and TBF were estimated with standard equations for binomial equations.

Table 3. Analyses of variance of fecundity components of Bahama Parrots (*Amazona leucocephala bahamensis*) on Abaco Island, Bahamas, 1985-1988. The analyses examine the effect of year on the state variables (TCL, CSH, PHN, BSF) and the transition probabilities (P1, P2, P3). The latter were angularly transformed before analysis.

Component	Source	df	Mean Square	F	p
Total clutch laid (TCL)	Year	3	1.34	2.06	0.12
	error	52	0.65		
Egg success (P1)	Year	3	<0.01	0.28	0.84
	error	42	0.01		
Clutch size at hatch (CSH)	Year	3	0.48	1.26	0.30
	error	42	0.38		
Hatching success (P2)	Year	3	0.11	1.10	0.36
	error	34	0.10		
Parrots at hatch (PHN)	Year	3	1.19	1.64	0.19
	error	53	0.73		
Fledging success (P3)	Year	3	0.06	0.81	0.50
	error	34	0.07		
Brood size at fledging (BSF)	Year	3	1.02	2.01	0.13
	error	34	0.51		

Table 4. Multidimensional Contingency Analyses (MCDA) of yearly differences in total reproductive failure components of Bahama Parrots (Amazona leucocephala bahamensis) on Abaco Island, Bahamas, 1985-1988.

Source	df	Log-Ratio Chi-Square			
		Total laying failure (TLF)	Total nest failure (TNF)	Total hatch failure (THF)	Total brood failure (TBF)
Years	3	16.42^{**}	23.58^{**}	1.86	6.48

** $p < 0.01$

Table 5. Causes of total reproductive failure of Bahama Parrot (*Amazona leucocephala bahamensis*) nests on Abaco Island, Bahamas. TNF, THF and TBF are total nest failure, total hatch failure, and total brood failure respectively.

Cause of failure	Number of nests that failed								
	1985			1986-1987			1988		
	TNF	THF	TBF	TNF	THF	TBF	TNF	THF	TBF
Eggs deserted[a]	1	0	0	0	5	0	0	2	0
Flooding	1	0	0	0	0	1	0	0	1
Feral cat predation	0	0	0	1	0	3	9	0	5
Unknown predation[b]	1	0	1	0	0	4	1	0	1
Human disturbance	0	0	0	0	0	2	0	0	0
Chick death - unknown cause	0	0	0	0	0	2	0	0	0
Unknown[c]	0	0	0	0	0	6	0	0	1

a Only complete clutches are included here. Nest desertion is an imprecise term for a variety of ultimate causes of failure, including such things as non-hatching eggs and flooding. Often, the nest was found abandoned and the proximate cause of abandonment could not be determined.

b We could not determine if the nest had been depredated by rats, snakes, or land crabs. Cats could be ruled out.

c Cause of failure was undetermined.

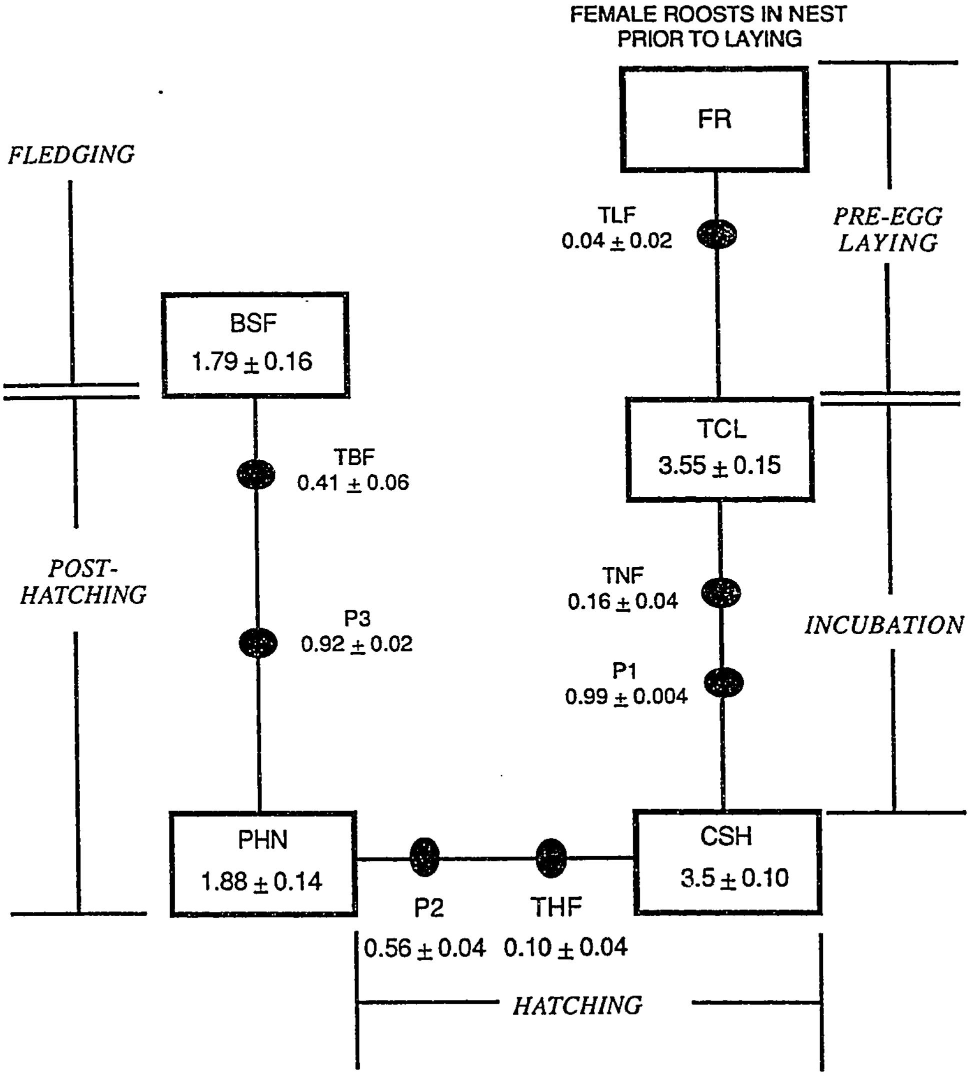
Table 6. Comparison of reproductive success among Caribbean *Amazona* species.

Amazona species	Body mass (gm)	Mean clutch size (Range)	Number of young per egglaying pair	% egg-laying pairs successful	Source
A. leucocephala bahamensis	260-301	3.6 (2 - 6)	0.80	42	this study
A. l. caymanensis	292-300 [a]	3.2 (2 - 5)	1.80	70	Bradley, 1986
A. l. hesterna	-------	------------	1.25	--	Bradley, 1986
A. l. leucocephala	245-319 [b]	3.0 (3 - 4)	----	--	Berovides Alvarez, 1986
A. ventralis	223-332 [c]	2.8 (? - ?)	2.50	82	Snyder et al, 1987
A. vittata	200-250 [c]	3.0 (3 - 4)	1.80	69	Snyder et al, 1987

[a] R. Noegel, pers. comm.

[b] R. Johnson, pers. comm.

[c] J. Wiley, pers. comm.



The standard errors of TFL, TNF, THF, TBF are estimated with equations for binomial distributions. Standard errors of the remaining components are estimated fron one-way analyses of variance of the effects of years on the fecundity variable. The estimate is formed as:

$$SE=\{MS_B/(df_T+1)\}^{1/2}$$

where MS_B is the Mean Square between years and df_T is the total degrees of freedom.

Figure 1. Fecundity components and their relation to the reproductive cycle of the Bahama Parrot (Amazona leucocephala bahamensis) on Abaco Island, Bahamas, 1985-1988. Mean values for each component are shown with their standard errors. Deatails on the components are given in Table 1.

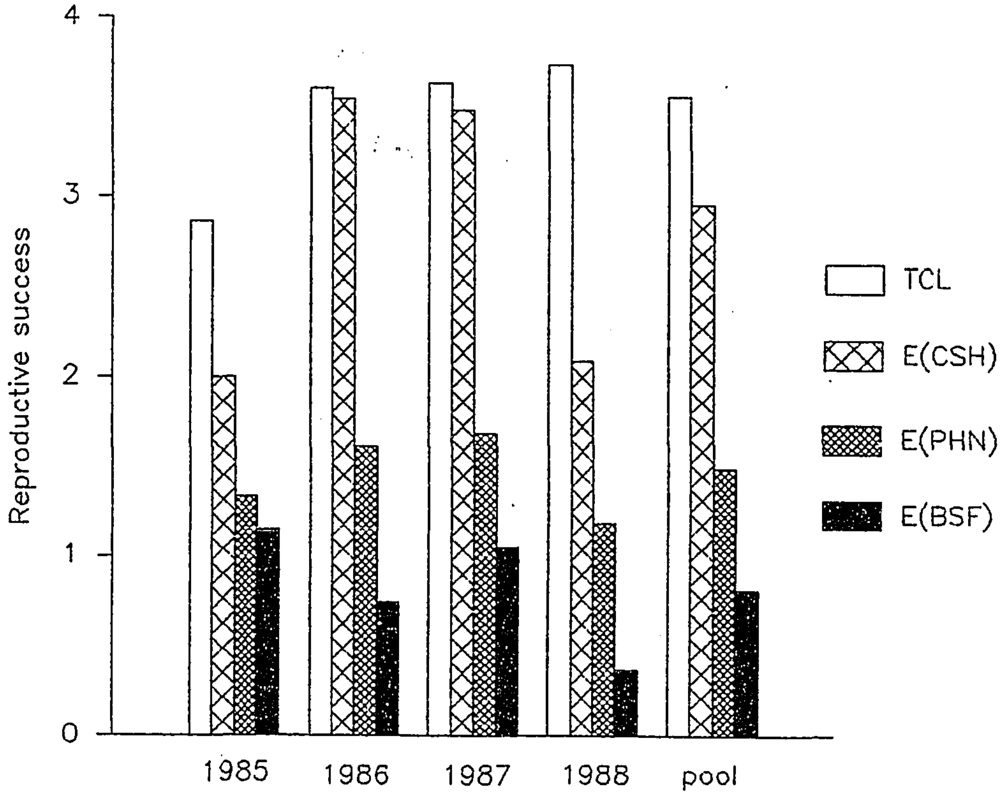


Figure 2. The depreciation of a female Bahama Parrot's (Amazona leucocephala bahamensis) expected reproductive (ERS) from total clutch laid (TCL), clutch size at Hatch (CSH), parrots at hatch (PHN) and brood size at fledging (BSF) on Abaco Island, Bahamas, 1985-1988.

Chapter 3

Nesting Behavior of the Bahama Parrot (*Amazona leucocephala bahamensis*) on Abaco Island, Bahamas.

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ABSTRACT

NESTING BEHAVIOR OF THE BAHAMA PARROT (*Amazona leucocephala bahamensis*) ON ABACO ISLAND, BAHAMAS.

Although the Bahama Parrot was once abundant and ranged throughout the Bahamas archipelago, it is endangered now and survives only on two islands- Abaco and Great Inagua. Bahama Parrots on Abaco nest in limestone solution cavities beneath the ground, a habit unique among New World psittacines. Between 1985 - 1988, I located and monitored 76 parrot nests in two nesting areas on southern Abaco. Eggs were laid in late May and early June and hatched asynchronously, 26-28 days after the female began incubation. While the female incubated the eggs, the male visited the nest on average four times per day to feed her. After the first week post-hatching, the female left the nest to forage with the male. Parents returned to their nests four to six times per day to feed the nestlings. Chicks fledged asynchronously in late August and early September,56-58 days after hatching. Bahama Parrots exhibited low reproductive success; successfully nesting pairs fledged a mean of 1.79 ± 0.16 chicks per nesting effort.

Introduction

The Cuban Parrot (*Amazona leucocephala*) is a polytypic species with five recognized subspecies: *leucocephala* (Cuba), *palmarum* (Western Cuba and Isla de la Juventud), *caymanensis* (Grand Cayman), *hesterna* (Cayman Brac) and *bahamensis* (Bahamas) (Bond 1956). Although the Bahama Parrot was probably present on all major islands in the Bahama archipelago, historically it was recorded from Abaco, New Providence, San Salvador, Long Island, Crooked Island, Acklins and Great Inagua. Today, this species is listed as endangered and persists only on the islands of Abaco and Great Inagua. In recent years, the Abaco population has declined as a result of habitat destruction, logging activities, development, Hurricane Betsy in 1965, and hunting pressures (Attrill 1981; Snyder et al. 1982).

Bahama Parrots were studied by Snyder et al. (1982), who estimated the Abaco population to number less than 1000 birds. Current population estimates range from 860 to 1300 parrots. Unlike the Inagua population and other subspecies of *leucocephala* which nest in tree cavities, parrots on Abaco nest in limestone-solution cavities beneath the ground, a habit unique among New World parrots (Forshaw 1989).

The Abaco population of the Bahama Parrot is found in Caribbean pine (*Pinus caribaea*) and mixed broadleaf coppice (native, evergreen hardwood) areas of southern Abaco.

As part of a larger investigation into the breeding biology of bahamensis, I studied the nesting behavior of the Abaco population. With the notable exception of studies on the Puerto Rican Parrot (Amazona vittata; Snyder et al. 1987), the Kakapo (Strigops habroptilus; Merton et al. 1984) and Australian psittacines (Rowley,1980; Wyndham,1981; Saunders 1982), data on the nesting behavior of parrots in the wild are often anecdotal, fragmentary and based on the observations of one or two nesting pairs. The objectives of my study were to (1) investigate the behavior of the Bahama Parrot throughout the stages of its nesting cycle, (2) determine the pattern of parental care, and (3) compare its nesting behavior with other Caribbean Amazona.

STUDY AREA AND METHODS

I studied Bahama Parrots in an area 64 km south of Marsh Harbour (Latitude 26° N, longitude 78° W), Abaco Island, from early May to September each year, 1985 through 1988. Since 1985, I located 76 nests but not all of these nests were active in a given year. Clutch size was recorded in all active nests and nests were checked at least once a week until chicks fledged or the nest failed. Observation blinds were placed 10-15 m from the nests of five pairs and the behavior of these pairs was recorded from sunrise to sunset (a 14-15 hour period). These nesting pairs were observed at least once a week from egg-laying until chicks fledged or the nest failed.

Due to risks associated with tagging parrots (Saunders 1988),I did not try to capture and tag individuals, but instead recognized them by the usually considerable differences in their plumage markings and other physical characteristics. These physical differences were consistent through a season and from year to year. Initially, the five nesting pairs to be observed were selected randomly from a pool of active parrot nests but in succeeding years, pairs which returned to the same nest cavity were given observational preference over newly found nests.

The external and internal dimensions of nest cavities were measured to the nearest 0.5 cm. Nest depth was measured from the lip of the nest to the floor of the nest cavity.

I used the SAS (1985) software package on an IBM mainframe system (at the City University of New York) for statistical analyses.

Data were pooled over the four years of study and provide a general view of nesting behavior in this unique population. Unless otherwise specified, mean values with their standard errors are reported.

RESULTS

Bahama Parrots on Abaco are monogamous and seasonally defend their nest site. Mates remain together throughout the nesting cycle to produce a single brood.

Nest Site Characteristics

Although Carraway and Carraway (1979) reported a Bahama Parrot nest on Abaco in the hollow of a Pond Top Palm (Sabal palmetto) and I searched for nests in this area, all of the nests which I located were in limestone-solution cavities beneath the ground, the normal pattern for this population. Nest cavity entrances measured on average 18.3 ± 0.9 (S.E.) cm vertically and 19.8 ± 1.0 cm horizontally. Nest cavities were more spacious internally and on average measured 39.9 ± 2.4 cm by 27.9 ± 1.1 cm. The mean nest depth (N=70) was 125.1 ± 6.6 cm ; 74.3 percent of these nests ranged from 51 - 150 cm in depth (Figure 1). Nine percent of the nests had two entrance cavities and 74% (N=52) of the nest cavities had internal ledges or rocky overhangs within them to protect and conceal the eggs.

Incubation

Clutches of 2 - 6 eggs (Mean 3.6 ± 0.2) were laid in late May or early June. The frequency of 2-egg nests was 4, 3-egg nests was 19, 4-egg nests was 31, 5-egg nests was 2 and 6-egg nests was 1. Egg-laying was asynchronous and eggs were generally laid at two day intervals. Eggs were incubated exclusively by the female. Most females began incubation with the laying of the first egg. Incubation may have been irregular until the clutch was completed. The incubation period was 26 - 28 days. Incubating females never left their nests except to be fed by their mates. There was no relationship (polynomial regression, $p>0.05$) between the time that a female spent off the nest and the stage of incubation (Figure 2). Females spent an average of 62.1 ± 3.9 minutes per day off the nest.

Males spent little time in the nest area except when feeding their mates. When males arrived in the nest area, they perched in a nearby pine or shrub and called to their mates. Females exited the nest on average 11.5 ± 1.4 minutes after the male arrived to feed them. Females recognized and responded to the calls of their own mates and never left their nests when neighboring males called. During incubation the male on average fed the female four times per day with food transfers (N=170) lasting an average of 16.0 ± 0.9 minutes for the various pairs. Most feedings occurred in the morning and late evening. Generally, males fed the female in nearby pines in the nest area. A female was fed in the nest only if she remained in the nest after repeated, unsuccessful male visits and calling. During egg-laying, copulation often followed food transfers. Copulatory behavior followed the pattern described for other Amazona species (Skeate 1984; Snyder et al. 1987). The male perched beside the female with one foot and rested his other foot on his mate's back while she swayed her tail back and forth horizontally against his tail, making cloacal contact.

Pairs gave loud, territorial high-squawk calls when they returned to the nest. Females then immediately entered the nest and resumed incubation. Males flew off to forage and roost, often accompanied by neighboring males. Males did not roost in the nest or nest area in the evening. They roosted communally in large flocks (50-60 parrots). Two roost sites were located 300 m and 1000 m from the main nesting area.

Nestling Period

Eggs hatched asynchronously in late June and early July. The pattern of female care remained unchanged from that which was seen during incubation until about a week after hatching (Figure 3). At this time females started to forage with the males, spending more time off the nest but returning to feed and brood the chicks. There was no apparent relationship between brood size and the amount of time the female spent off the nest (ANOVA, $p = 0.63$) (Figure 1). As the chicks grew older, the time that the female spent off the nest increased until she foraged consistently with her mate during the day and returned to the nest only to feed the chicks (Figure 3). By the fourth week post-hatching, most females no longer roosted in the nest; at this stage, the chicks' body feathers had erupted from the shafts, particularly on the back, wings and thighs.

Males continued to feed the females directly the first week post-hatching and rarely entered the nest to feed the chicks (Table 1). As females decreased daytime brooding of the chicks, males gradually increasingly entered the nest and fed the chicks directly (Table 1). In contrast to the female's barely observable, secretive entry into a nest, the male's initial entries were awkward and took longer. Males lingered on the nest lip, obviously uneasy at entering.

Once females no longer roosted in the nest, males and females returned together to the nest four to six times per day to feed their chicks. Males and females showed no differences (ANOVA, p=0.53) in the amount of time that they spent in the nest after the female ceased overnight roosting (Figure 4). Visit time decreased for both males and females at the same rate(ANOVA p= 0.44) as fledging approached (Figure 4).

Fledging

Chicks fledged asynchronously (usually 24-48 hours apart) in late August and early September, 56-60 days after hatching. Several days before fledging, chicks began to appear at the nest lip when their parents were in the nest area. The chicks' initial appearances were brief (less than two minutes) but gradually, more of the chick's body protruded from the nest cavity until the chick fledged. As fledging approached(eight weeks post-hatching), parents spent little time inside the nest and despite the chicks' vigorous begging, feedings were brief (Figure 4, Table 1). From a tree or a shrub within 3 m of a nest, parents called to the chicks, apparently coaxing them from the nest. I observed nine fledgings; 67% occurred in the morning and always when the parents were present. Upon fledging, chicks flew considerable distances (> 300 m) accompanied by their parents; chicks had left the nest area by sunset. All fledging flights observed were silent and, except for begging during food transfers, the young and their parents remained virtually silent in the days following fledging.

Nesting Success

An extensive analysis of nesting success data is presented in Gnam (1991), but a brief review of these results follows here. During the years 1985-1988, the mean clutch size at hatching was 3.5 ± 0.1 but the mean number of parrot chicks hatched per nest was 1.88 ± 0.1. Forty-six percent of all egg-laying pairs fledged young. Successful pairs which hatched at least one chick, fledged a mean of 1.79 ± 0.16 chicks. Causes of nest failure were (in descending order of importance): predation by feral cats (Felis catus), land crabs (Cardisoma guanhumi), snakes, and rats (Rattus rattus); chick deaths from unknown causes; abandoned eggs; flooding of nest cavities; and human disturbance (poaching of chicks).

DISCUSSION

The general pattern of nesting behavior in Bahama Parrots follows that seen in other species of Amazona (Snyder et al. 1987; Silva 1989). Some exceptions to this pattern are noteworthy and likely related to this species' ecology. Although egg-laying in most Caribbean Amazona species occurs in late winter or early spring (Feb. - Mar.)

(Snyder et al. 1987), the Abaco population of the Bahama Parrot lays its eggs in late spring. Its late breeding season coincides with the peak abundance and availability of its food sources during nesting. Caribbean pine produces immature(unripe) pine cones during June through August and poisonwood (Metopium toxiferum) and wild guava (Tetrazygia bicolor) fruit at this time. These food items accounted for 74% of the observed diet during the nesting period.

Although the incubation pattern of Puerto Rican and Bahama Parrot females is similar (females spend less than 100 minutes per day off the nest to be fed by their mates), the female patterns differ once nestlings appear (Snyder et al. 1987). During the fourth week post-hatching, female Bahama Parrots no longer roost in the nest in the evening, unlike female Puerto Rican Parrots which roost in the nest until chicks fledge. White-tailed Black Cockatoo (Calyptorhynchus funereus) females cease roosting in the nest about 2-3 weeks before chicks fledge (Saunders 1982). In the Bahama Parrot, roosting in the nest with chicks may be related to the feather and thermoregulatory development of the chicks, rather than to nest defense from predation. Abaco has been devoid of mammalian predators until the relatively recent introduction of cats and rats by man. On at least two occasions, I observed a female who had ceased overnight nest roosting return to her nest and brood chicks during a heavy rainfall.

In the Puerto Rican Parrot, females with larger sized broods reach a plateau of time off the nest earlier in the nestling period than do females with small broods (Snyder et al. 1987). Brood size seems not to affect the time that female Bahama Parrots spend off the nest. My sample size may be too small to detect differences; alternatively, presently unknown ecological factors may be responsible. Subterranean nesting may provide a more stable thermal environment, so that females with even small-sized broods can safely leave chicks. Food sources may be limiting, patchily distributed and/or require considerable handling time and therefore, regardless of brood size, females must forage after the first week post-hatching to feed themselves and their chick(s).

The parental care pattern of Bahama Parrots in which females are responsible for the incubation of eggs and brooding of nestlings and both sexes feed the nestlings, is similar to that seen in large psittacines, such as the Puerto Rican Parrot (Snyder et al. 1987) and White-tailed Black Cockatoo (Saunders 1982). Although male and female Bahama Parrots visited the nest together to feed the chicks and spent comparable amounts of time in the nest, they may still differ in their interactions with the nestlings. We could not observe behavior within a nest. In large broods, parents may feed the chicks differentially as do parakeets (Arrowood & Flint in press).

Despite considerable parental care and time expenditure, Bahama Parrots fledge few offspring and reproductive success is low when compared with other Caribbean Amazona species (Gnam 1991). Eighty-two percent of all egg-laying Hispaniolan Parrots (Amazona ventralis) fledge 2.5 chicks while 69% of all egg-laying Puerto Rican Parrots fledge 1.8 chicks (Snyder et al. 1987). Various factors affect the reproductive potential and output of this island species); but its ground-nesting habit has put the species at risk from nest predation by introduced mammals. Nesting behavior patterns which were selected for in stable environments may be disadvantageous in a rapidly changing environment.

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Table 1. Nest attendance by male Bahama Parrots (*Amazona leucocephala bahamensis*) on Abaco Island, Bahamas, 1985-1988.

Nestling period	Males	Daily nest visits		Total time spent in nest (minutes per day)	
(week)*	(N)	Mean	SE	Mean	SE
1	15	0.5	0.2	5.4	2.6
2	20	1.5	0.4	16.7	4.7
3	14	2.6	0.5	20.4	4.9
4	14	4.1	0.2	29.0	3.2
5	12	4.9	0.3	32.3	4.1
6	11	5.5	0.6	28.9	4.2
7	10	4.2	0.6	19.1	4.1
8	10	3.6	0.5	12.4	2.8
9	3	1.7	0.7	4.3	1.9

* Day first chick hatched counted as day 1.

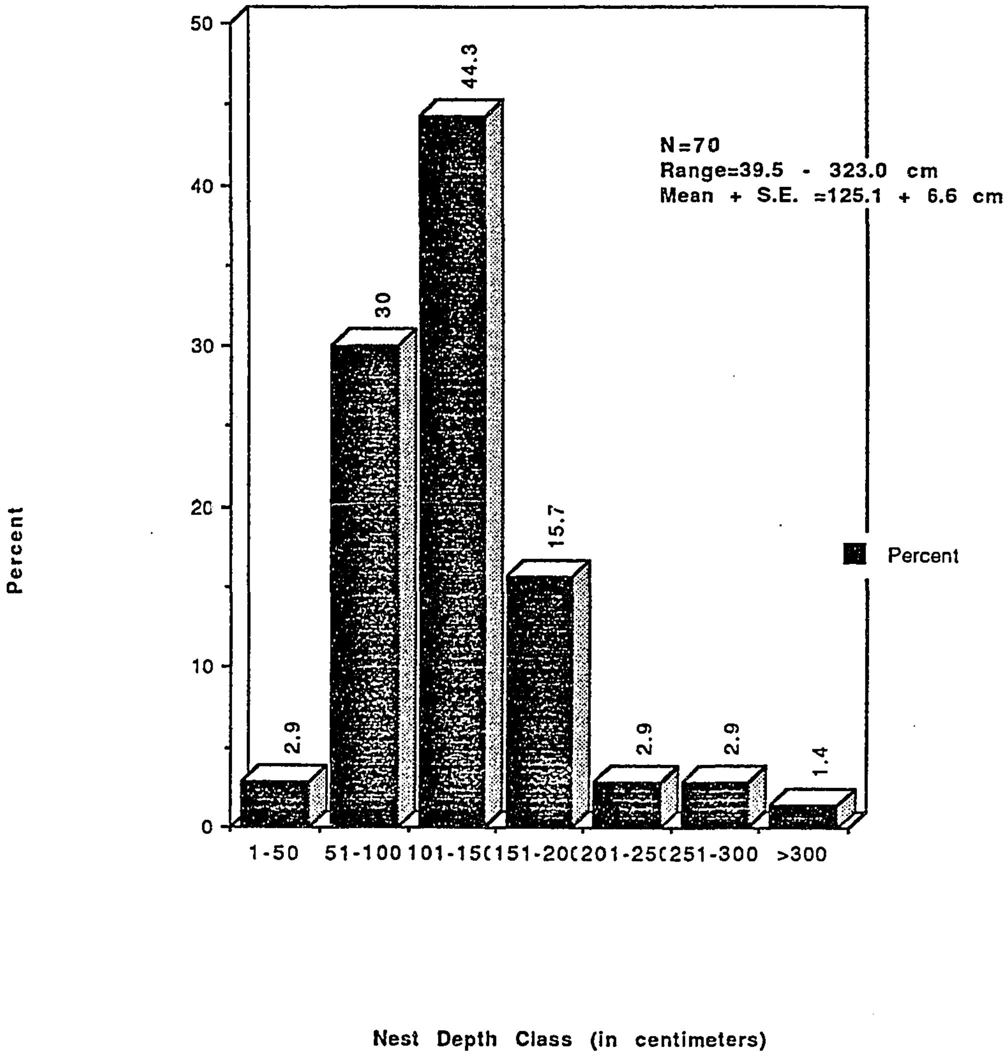

Figure 1. Distribution of Bahama Parrot (Amazona leucocephala bahamensis) nest depth classes in subterranean solution holes on Abaco Island, Bahamas, 1985-1988.

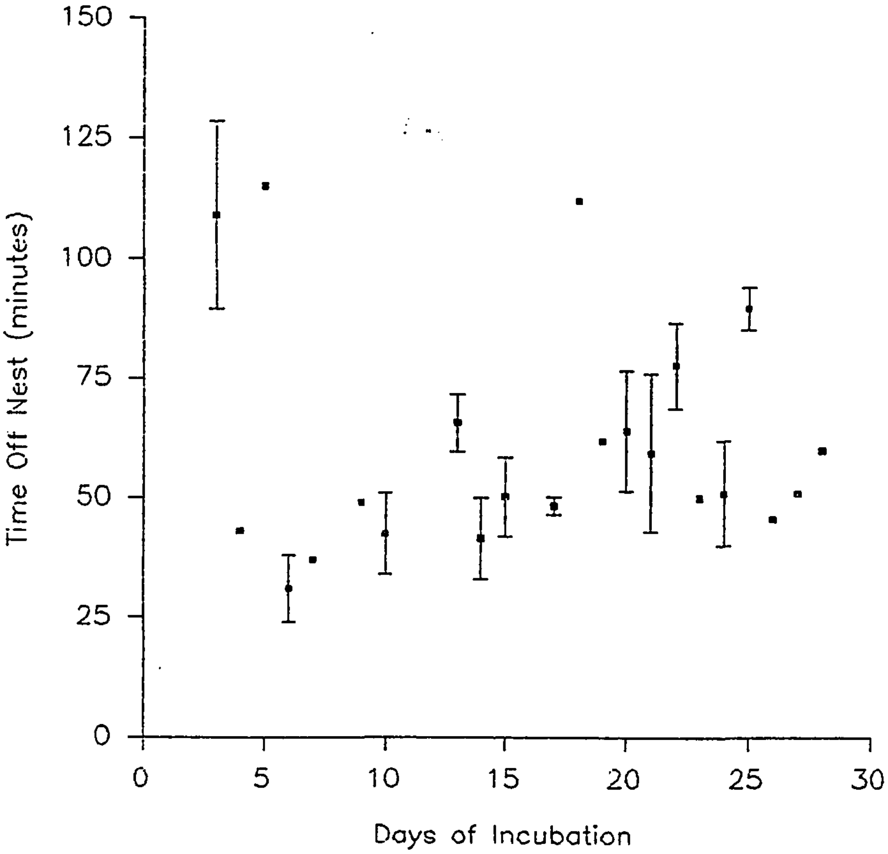

Figure 2. Time spent off the nest during incubation by female Bahama Parrots (Amazona leucocephala bahamensis) on Abaco Island, Bahamas, 1985-1988. Values shown are for one nest unless a mean (solid square) with its standard error (vertical bar) is shown and for these nests, sample sizes (N) were 3,2,2,3,2,4,3,3,2,3,2,2,2.

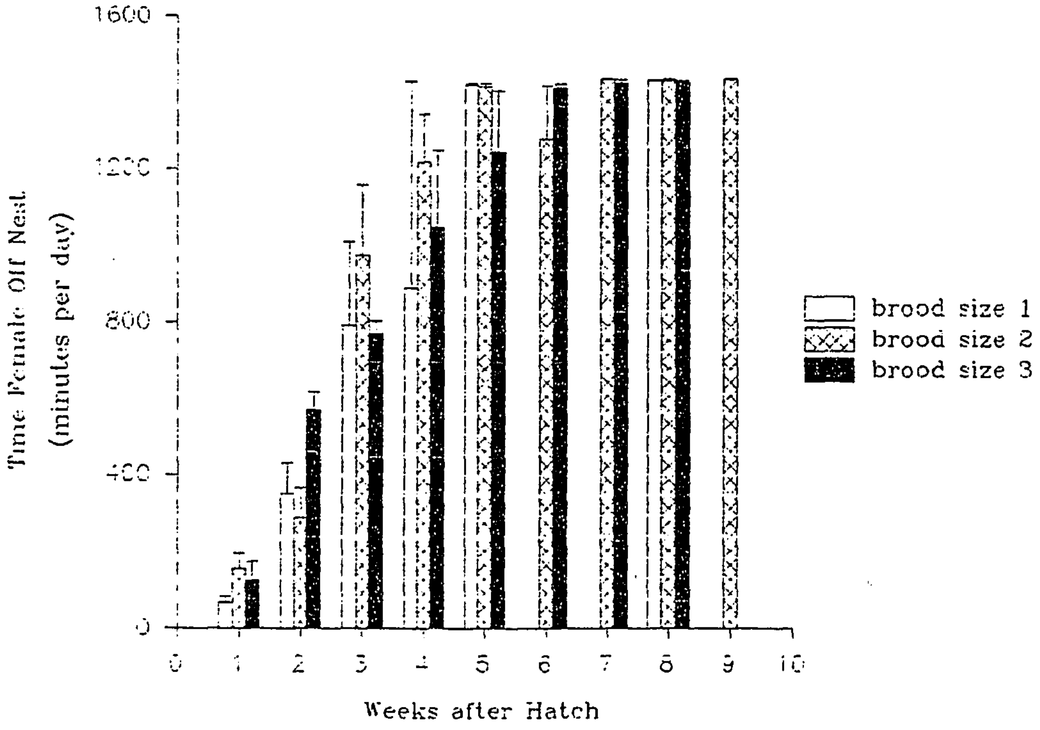

Figure 3. Time spent off the nest as a function of brood size for female Bahama Parrots (Amazona leucocephala bahamensis)on Abaco Island, Bahamas, 1985-1988. Values shown are means with their standard errors. Sample sizes (N) for brood size one were 4, 8,4,2,4,1; for brood size two : 6,8,5,7,2,5,5,3,3, and for brood size three : 5,4,4, 4,4,4,4,4.

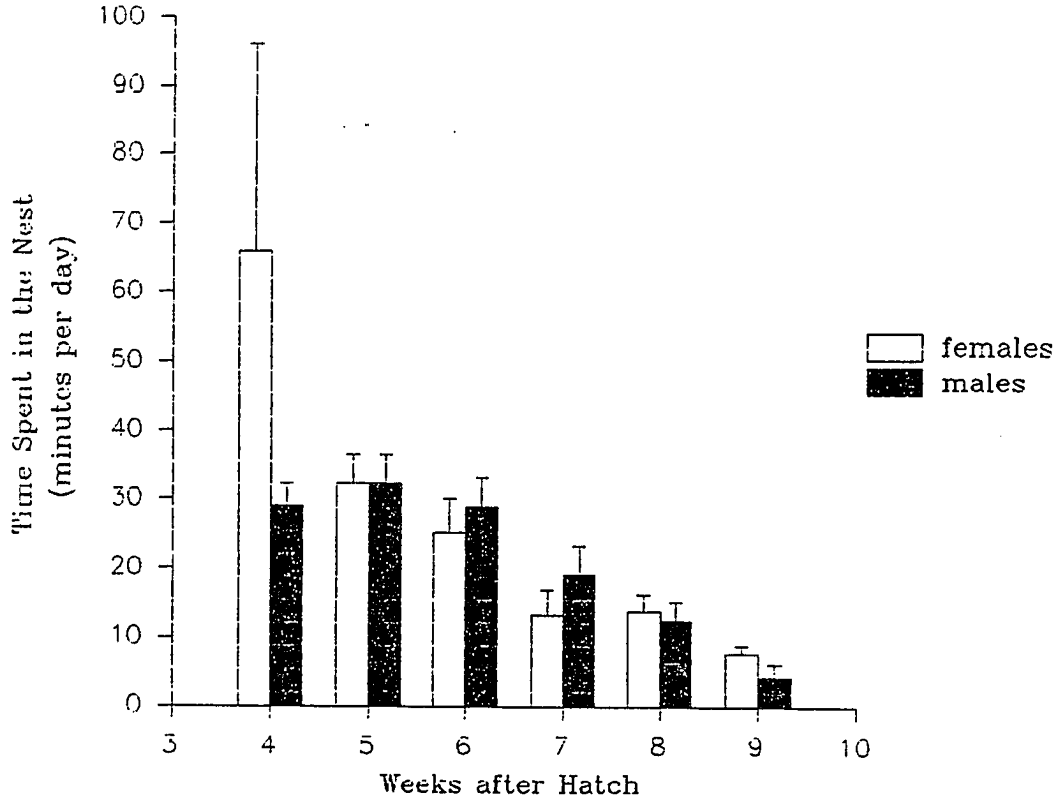

Figure 4. Total time spent in the nest by male and Bahama Parrots (Amazona leucocephala bahamensis) on Abaco Island, Bahamas, 1985-1988. Values shown are means with their standard errors. Sample Sizes (N) for males and females were 14, 12, 11, 10, 10, 3.

Chapter 4.

Diet, foraging behavior, and nutrition of the Bahama Parrot (Amazona leucocephala bahamensis)

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Although the 28 extant species of Amazona are probably the most well-known of all New World parrots, very little is known of their feeding habits in the wild. Forshaw (1989) reports that they feed on a variety of fruits, seeds, nuts, berries, flowers and leaf buds. Often, diet data for Amazon Parrots are anecdotal, fragmentary and based on the incidental observations of a few feeding pairs or flock. Higgins (1979) observed a flock of 8-10 Mealy Parrots (Amazona farinosa) to feed on the seeds of Brosimum utile in Costa Rica over a two-day period. With the notable exception of the studies on the Puerto Rican Parrot (Amazona vittata; Rodriguez-Vidal 1959, Snyder et al. 1987), few studies have examined the diets of Amazona in a comprehensive and quantitative manner. As part of a larger study into the breeding biology of the endangered Bahama Parrot (Amazona leucocephala bahamensis) on Abaco Island, we collected data on its feeding ecology.

Although the Bahama Parrot was once widespread throughout the Bahamas archipelago, today it persists on only two islands - Abaco and Great Inagua (Gnam 1990a). The Abaco population of the Bahama Parrot differs in its feeding habits from the Inagua population. Since Caribbean pine is absent from Inagua, parrots there feed heavily on the seeds, fruits and flowers of the dry, scrubland coppice species such as joewood (Jacquinia berterii), wild tamarind

(Lysiloma latisiliquum) and buttonwood (Conocarpus erectus) (Gnam, 1990b).

Bahama Parrots are found in the Caribbean pine (Pinus caribaea) and mixed broadleaf coppice (native, evergreen hardwood) areas of southern Abaco (Gnam 1990a). Pairs are monogamous, territorial, subterranean nesters and produce a single brood. Unlike other Caribbean Amazona which breed in late winter and early spring, the breeding season of the Abaco population is late (May through early September. Snyder et al. (1982) suggested that its delayed breeding season may be related to the availability and abundance of its food sources.

The objectives of our study were to: (1) determine the Bahama Parrot's diet in the breeding season, (2) relate their diet to the distribution and availability of food resources in their habitat, (3) examine the nutritional composition of their diet, and (4) make recommendations as to how these results could be used in establishing a conservation management plan for this population.

Study Area and Methods

We studied Bahama Parrots on southern Abaco, 64 km south of Marsh Harbour (latitude 26 °N longitude 78 °W), from 1985 to 1988. In 1988, the population ranged from a well-defined minimum of 860 to 1142 parrots to a less well-defined maximum of 1300 parrots. We collected feeding data from early May to early September.

We recorded the feeding behavior of parrots in two study areas, which were designated as Nest Areas 'A' and 'B' (see Chapter 1). Parrots were observed from blinds placed at nests and by walking through the nest areas during daily nest visits. During the breeding season, parrots commonly feed in pairs or in small flocks (6-20 parrots). We followed the methodology of Snyder et al. (1987) and each feeding encounter was scored as one observation, irrespective of the number of parrots involved or the length of time that they fed. Thus, we assumed that the observed frequency of feeding on a particular food item was equivalent to the proportion of an individual's time spent feeding on that item. Since we suspected that the single observation of a large flock feeding on a given food item overrated the dependence of parrots upon that item, feeding observations were not weighted by the number of parrots feeding.

Henry (1974) described the vegetation of the pine forests of Abaco and we collected samples of all plants in our study areas for later identification. Plant nomenclature and fruiting season data were taken from Correll and Correll (1982). We followed the techniques of James and Shugart (1970) to determine the abundance of shrubs in our study areas by surveying the vegetation at 12 nests where observation blinds had been placed. Shireen Chambers, Forestry Officer on Abaco, provided data on the density of Caribbean pine on southern Abaco. We collected, for nutritional analysis, 5 g (dry weight) samples of all parrot food items. Nutritional composition assays were done by the Nutritional Biochemistry Laboratory at the Peabody Museum, Harvard University.

We used the SAS (1985) software package at the City University of New York's IBM mainframe system for statistical analyses. We excluded from analyses the feeding observations which I collected in Nest Area 'B' because sample size (N = 34) was too small to reach any conclusions on the parrots' feeding behavior in that area. All analyses are based on the feeding data which was collected in Nest Area 'A' where a total of 686 feeding observations were recorded.

Results

Bahama Parrots fed on 18 plant species in their nest area. Caribbean pine, wild guava (Tetrazygia bicolor) and poisonwood (Metopium toxiferum) accounted for 76% of all our feeding records (Table 1). We regularly observed parrots feeding on these three food sources before they entered their nests to feed their chicks. Parrots selected a green, unopened pine cone with their bill, then held it in their raised foot and removed the seeds from beneath the cone scales. They discarded the scales and, unless disturbed, dropped the cone when only the spine remained. With the exception of bay-rush (Zamia pumila), fruit was swallowed whole and often, parrots snipped off a cluster of fruit and held it in their foot as they ate the fruits. The left foot was used to hold food in 76% of our observations. Bahama Parrots fed on small-sized food resources (Table 1) and handling times per fruit were less than 60 seconds and per pine cone averaged 7.8 minutes.

The nesting habitat was in Caribbean pine forest (Table 2) with a shrub understory of 31 species and herbaceous growth dominated by Bahamian holly (_Xylosma_ _buxifolium_) and common ernodea (_Ernodea_ _littoralis_). Bahama Parrots did not feed on fruiting shrubs randomly in the nest area (Table 3) (likelihood ratio chi square = 468.10, df =19, $p < 0.001$). Sixty-nine percent of the feeding observations on fruits comes from the five most abundant shrub species in the nest area (Table 3).

The nutrient composition of 16 Bahama Parrot food items was determined (Table 4) which accounted for 99.6% of our feeding records. We assumed that our feeding records reflected the proportion of a given food item in a Bahama Parrot's diet (Table 1) and calculated the nutrient composition of a 100 g sample of a Bahama Parrot's diet during the breeding season (Table 5). Seeds provided major dietary protein and lipid sources in the diet, whereas flowers and fruits contributed primarily carbohydrates (Table 4; Table 5). Caribbean pine seeds were a major staple in the Bahama Parrot's diet and provided the parrots with 91% of the protein and lipids in their total diet. The fruits of wild guava, poisonwood and pigeonberry (Duranta repans) accounted for 70% of the total fruit consumption and provided 60% of the carbohydrates in their diet.

Discussion

Like other parrot biologists before us (Snyder et al. 1987), we probably have had some bias in the collection of our feeding data. If parrots spend any considerable time foraging and feeding in the coppice edge of southern Abaco which has a different floristic species structure than the Caribbean pine forest habitat, then our results will have underestimated these species and overestimated the importance of Caribbean pine forests where parrots nest and the food sources contained within them. However, we rarely observed parrots in the coppice during the breeding season and we feel our observations accurately reflect the parrot's habitat utilization. Radio-tracking of fledgings in 1989 showed that both parents and their fledglings gradually moved over a two week period from the pine forest to the coppice; coppice vegetation thus, becomes more important following the breeding season.

During the breeding season, Bahama Parrots on Abaco are primarily granivorous and frugivorous. Although parrots feed on a variety of fruits, flowers and seeds in the breeding season, they depend heavily on the seeds of Caribbean pine, and the fruits of poisonwood, wild guava and pigeonberry. Caribbean pine cones ripen in early August and shed their seeds 2-3 weeks after turning brown (mature) (Lamb 1973). The timing of the parrot's breeding season coincides with the maximum availability of maturing, unripe (green) cones which are consumed by parrots. Glossy Black Cockatoos (Calyptorhynchus lathami) feed only on seeds from closed cones of Allocasuarina species and raise their young on this diet (Clout 1989). Like Caribbean pine seeds, Allocasuarina cotyledons are high in protein (27%). The absolute dependence of Bahama Parrots on Caribbean pine and other fruiting shrubs requires further study, including detailed fruiting phenologies of these food items.

Bahama Parrots showed a left foot preference in handling their food as do other species of Amazona (Friedmann and Davis 1938; Snyder et al. 1987).

During the time that Bahama Parrots were raising chicks, their diet contained 22% protein. In laboratory studies of Cockatiel (Nymphicus hollandicus) chicks, optimal growth was obtained when chicks were fed a diet of 20% protein (Grau and Roudybush 1985; Roudybush and Grau 1986). Cockatiels fed a diet containing 10% protein suffered high mortality and those fed 35% protein had depressed growth. The similarity of protein content between wild and captive diets most likely reflects true physiological needs of growing psittacines; but it is the first documentation of dietary nutrient composition in free-ranging parrots.

It is beyond the scope of this study to comment in depth on the role Bahama Parrots play in the dispersal of seeds in their habitat. However, some general comments are possible. Parrots have frequently been regarded as seed predators rather than seed-dispersing frugivores (Snow 1981). Nonetheless, parrots on Abaco may possibly act as dispersing agents for poisonwood and wild guava because fruits are ingested whole with seeds excreted later. Studies of digestibility/germination of seeds utilizing captive Bahama Parrots are warranted to prove or disprove this theory. Negron Ortiz and Breckon (1989) observed that rodents play a role in the dispersal of seeds of the cycad, _Zamia pumila_, on Puerto Rico. We have observed parrots on Abaco gnawing on _Zamia_ fruit, eating only the fleshy pericarp and dropping the intact seed away from the parent plant.

The reliance of the Abaco population of Bahama Parrots on Caribbean pine seed during the breeding season makes the preservation of the Caribbean pine forest habitat critical for this population. Clearance of this forest for agriculture and development would cause food shortages and stress this small population even further (Gnam 1990a). Based on nutrient composition data in Table 4, it is unlikely that the other food items in its diet could adequately meet its protein requirements. Currently, parrot conservation on Abaco depends upon preserving large tracts of Caribbean pine, and/or implementing appropriate fire-management and lumbering regimes to minimize the loss of cone-producing stands and allow for their regeneration. Study of the Abaco population's feeding habits throughout the non-breeding season and dietary nutrient composition of its maintenance diet would also prove informative and useful.

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Table 1. Foods of Bahama Parrots (*Amazona leucocephala bahamensis*) during the breeding season, Abaco Island, Bahamas, 1985-1988.

					Observation	
Common name	Scientific name	Plant type	Structure eaten	Size *	Frequency	Percent
Caribbean pine	*Pinus caribaea*	Tree	Seed	5-8 mm	302	44.02
			Shoot		20	2.92
Wild guava	*Tetrazygia bicolor*	Shrub	Fruit	8-10 mm	106	15.45
			Flower	5-10 mm	3	0.44
Poisonwood	*Metopium toxiferum*	Shrub	Fruit	1-1.5 cm	90	13.12
Pigeonberry	*Duranta repans*	Shrub	Fruit	7-11 mm	36	5.25
Beef-bush	*Tabebuia bahamensis*	Shrub	Flower	3-5 cm	16	2.33
			Seed	--	14	2.04
			Leaf	--	1	0.15
Woe-vine	*Cassytha filiformis*	Vine	Stem		19	2.77
Bastard stopper	*Petitia domingensis*	Shrub	Fruit	4-6 mm	18	2.62
Prickly green-brier	*Smilax havensis*	Vine	Fruit	4-6 mm	11	1.60
Bay-rush	*Zamia pumila*	Cycad	Fruit/ pericarp	15-20 mm	10	1.46
Pond top palm	*Sabal palmetto*	Tree/ shrub	Fruit	6-12 mm	10	1.46
Butler bough	*Exothea paniculata*	Shrub	Fruit	1-1.5 cm	9	1.31
Krug's holly	*Ilex krugiana*	Shrub	Fruit	4 mm	7	1.02
Myrsine	*Myrsine floridana*	Shrub	Fruit	4 mm	4	0.58
Short-leaved wild fig	*Ficus citrifolia*	Shrub	Fruit	8-18 mm	3	0.44
Cinnecord	*Acacia choriophylla*	Shrub	Seed	8 mm	2	0.29
Gum elemi	*Bursera simaruba*	Tree/ shrub	Fruit	1-1.5 cm	2	0.29
Bahamian holly	*Xylosma buxifolium*	Herb	Fruit	4-6 mm	2	0.29
Common ernodea	*Ernodea littoralis*	Herb	Fruit	5 mm	1	0.15
				Total	686	100

* Measurements taken from Correll (1982) *Flora of the Bahama Archipelago*.

Table 2. Characteristics of the Caribbean pine (Pinus caribeea) forest where Bahama Parrots nested, Abaco Island, Bahamas. Data were supplied by the Forestry Section, Dept. of Lands and Surveys, Abaco.

	Mean *			
Species	Dominant Tree Height (m)	D. B. H. (cm)	Estimated Age (years)	Trees per acre (.4 hectare)
Caribbean pine	9	15	15	104

* All measurements were averaged by Forestry and 16 points were sampled randomly within a 500 acre block.

Table 3. Fruits taken by Bahama Parrot (*Amazona leucocephala bahamensis*) in relation to the abundance of fruiting shrubs available during the breeding season, Abaco Island, Bahamas, 1985-1988. Plant nomenclature and fruiting availability (chronology) taken from Correll and Correll (1982).

Shrub species Common name	Scientific name	Number of [a] shrubs/.48 ha	Number of parrot feeding records
Poisonwood	*Metopium toxiferum*	428	90
Bahama sagebrush	*Lantana demutata*	262	0
Beef bush	*Tabebuia bahamensis*	231	31
Old man	*Guettarda krugii*	133	0
Wild guava	*Tetrazygia bicolor*	87	109
Krug's holly	*Ilex krugiana*	87	7
Wild mulberry	*Morinda royoc*	81	0
Pigeonberry	*Duranta repans*	59	36
Wild tea	*Myrica cerifera*	47	0
Cinnecord	*Acacia choriophylla*	38	2
Naked-wood	*Thouinia discolor*	36	0
Bastard stopper	*Petitia domingensis*	35	18
Pond top palm	*Sabal palmetto*	30	10
Myrsine	*Myrsine floridana*	21	4
Buttonwood	*Conocarpus erectus*	19	0
Rare species [b]		19	5
White stopper	*Eugenia axillaris*	17	0
Bay-rush	*Zamia pumila*	12	10
Strong-back	*Bourreria ovata*	8	0
Butler bough	*Exothea paniculata*	0	9

[a] Based on 0.1 acre (0.04 hectare) samples at 12 nests (James and Shugart, 1970).

[b] Includes these shrubs where the chi-square expected deviation was < 5. Gum limbo and Short-leaved fig were included among the rare species.

Table 4. Nutrient composition of major foods of the Bahama Parrot (Amazona leucocephala bahamensis) during the breeding season, Abaco Island, Bahamas.

Food	Nutrient (% of dry weight)				
	% Moisture[a]	Protein[b]	TNC[c]	Lipid	Fiber
Fruits					
Wild guava	76	5.9	56.4	1.0	25.0
Poisonwood	68	7.7	16.7	13.0	51.0
Pigeonberry	77	7.0	22.8	3.0	46.0
Bastard stopper	75	6.1	43.7	3.0	27.0
Prickly green-brier	79	13.7	31.3	12.5	39.8
Bay-rush (pericarp)	33	6.4	28.6	30.0	22.0
Pond top palm	60	14.5	7.3	2.0	57.0
Butler bough	56	5.9	44.2	0	15.0
Krug's holly	71	11.5	35.0	5.4	59.0
Myrsine	42	7.0	12.3	22.0	47.0
Short-leaved wild fig	69	7.4	26.7	3.0	40.0
Gum elemi	74	5.9	4.2	3.0	53.0
Seeds					
Caribbean pine	8.5	27.4	1.6	26.0	37.0
Cinnecord	61.0	21.6	6.6	11.5	26.3
Beef-bush	76.0	9.6	22.8	6.0	30.7
Flower					
Beef-bush	86.0	9.1	25.7	2.0	31.0
Stem					
Woe-vine	70.0	11.8	5.2	2.1	45.6

[a] Determined in this study.

[b] Ninhydrin protein percentage.

[c] Total non-structural carbohydrates.

Table 5. Nutrient composition of a 100g sample of a Bahama Parrot's (Amazona leucocephala bahamensis) diet in the breeding season, Abaco Island, Bahamas.

Food	Wet Weight[a] (gm)	Dry Weight (gm)	% Moisture	Nutrient (% of dry weight)				
				Protein[b]	TNC[c]	Lipid	Fiber	Ash
Fruits	45.1	13.24	70.6	7.4	32.3	8.3	38.1	13.9
Seeds	49.28	43.56	11.6	27.2	1.9	25.7	36.9	8.3
Flowers	2.33	0.33	85.8	9.1	25.7	2.0	31.0	33.3
Stems	2.80	0.84	70.0	11.8	5.2	2.1	45.6	35.0
Total:	99.51	57.97	41.7	22.4	9.0	21.3	37.3	10.1

[a] Determined from the % of feeding observations (Table 1)

[b] Ninhydrin protein percentage.

[c] Total non-structural carbohydrates.

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Conclusion

Conservation of the Bahama Parrot

Rosemarie S. Gnam

The parrot genus Amazona is confined to the neotropical region, from Mexico to Argentina. Of the 27 extant species, nine are endemic to the West Indies and five of these species and two subspecies are considered to be endangered or threatened (King 1977). The Cuban Parrot (Amazona leucocephala) is a polytypic species with five recognized subspecies: leucocephala (Cuba), palmarum (western Cuba and Isla de la Juventud), caymanensis (Grand Cayman), hesterna (Cayman Brac), and bahamensis (Bahamas) (Bond 1956).

Historically, the Bahama Parrot (A. l. bahamensis) was recorded from Abaco, New Providence, San Salvador, Long Island, Crooked Island, Acklins, and Great Inagua, although it probably was present on all major islands in the Bahama archipelago. Today, this subspecies is regarded as endangered and persists only on the islands of Abaco and Great Inagua, at the northern and southern ends of its former range. The Abaco population of any species in the genus Amazona (Snyder et al. 1982). In recent years this population has declined as a result of habitat destruction, logging activities, development, Hurricane Betsy in 1965, and hunting pressures (Attrill 1981; Snyder et al. 1982).

Early studies on the biology of the Bahama Parrot and its conservation status were done by Snyder et al. (1982). They estimated the then Bahama Parrot population on Abaco to be less than 1000 parrots and recommended further study of its biology and monitoring of the population. Since 1985, I have been studying the breeding biology of this subspecies and its current status in the wild. Although my research efforts have largely concentrated on the Abaco population, I made two brief trips to Inagua in 1989. The overall objective of this project has been to develop a sound biological understanding of this parrot upon which an effective conservation program can be based.

Biology

The Abaco population of the Bahama Parrot is found in the caribbean pine (Pinus caribaea) and mixed broadleaf coppice (native, evergreen hardwood) areas of southern Abaco. Current population estimates range from a well-defined minimum of 860-1142 parrots (actual birds counted) to a less well-defined maximum of 1300 parrots.

Unlike the Inagua population and other subspecies of leucocephala, which nest in tree cavities, Bahama Parrots on Abaco nest in limestone-solution cavities beneath the ground. Although nesting in limestone holes in vertical cliffs is a relatively common habit in psittacids (Forshaw 1989) and Patagonian Conures (Cyanoliseus patagonus) excavate nest cavities in dirt banks, the Abaco population of the Bahama Parrot is the only New World parrot that nests in subterranean rock cavities. In the 70 nests which we found nest depth ranged from 39.5 to 323 cm and the mean nest depth was 124.2 ± 55.4 (s.d.) cm. Many of these nests have internal ledges or rocky overhangs to protect and conceal the eggs within.

A clutch of 2-4 eggs is laid in late May and early June. Eggs hatch asynchronously, approximately 26-28 days after the female begins incubation. During the years 1985-1987, the mean clutch size at hatching was 3.47 but the mean number of parrot chicks hatched per nest was 1.74. Forty-six percent of the eggs that were present in a clutch at hatching failed to hatch.

In contrast to other species of Caribbean parrots, Bahama Parrots on Abaco exhibit a low rate of reproductive success with less than 50 percent of egg-laying pairs fledging young (Table 1). Causes of nest failure in the Bahama Parrot are (in ascending order of importance): human disturbance (poaching of chicks); flooding of nest cavities during heavy rains; abandoned eggs; chick deaths from unknown causes; and predation by snakes, land crabs (Cardisoma guanhumi), rats (Rattus rattus) and feral cats (Felis catus).

Because of their ground-nesting habit, Bahama Parrots are extremely vulnerable to predation by feral cats. In 1988, Bahama Parrots on Abaco exhibited the lowest reproductive rate that I have observed in four years of study (Table 1), with only 29% of nests fledging young. The cause of this poor reproductive performance was increased nest predation by feral cats. Feral cat predation was responsible for failure at 14 nests (45%) and the nesting female was injured in two (14%) and killed in seven (50%) of the 14 known attacks. Prior to 1988, I had observed only four definite instances of nest predation by feral cats. The high level of cat predation continued in 1989, when 39% of the nests in one nesting area failed because of feral cat predation and only 42% of all nests fledged young. The reasons for this high level of cat predation remain unclear; but I believe learning of this predatory behavior by cats is involved.

Nest predation by feral cats thus affects the Bahama Parrot population in two ways: poor recruitment into the population as a result of low nesting success, and loss of breeding adult females, which can affect the future reproductive potential of the population.

Throughout the nesting cycle, Bahama Parrots feed opportunistically on fruits of native shrubs. I observed parrots feeding on at least 15 plant species (Gnam 1988). Staples in their diet are seeds extracted from unripe cones of Caribbean pine and the fruits of poisonwood (*Metopium toxiferum*), pigeon berry (*Duranta repens*), wild guava (*Tetrazygia bicolor*), and gumbo-limbo (*Bursera simaruba*).

Conservation Status

Although Snyder et al. (1982) visited Great Inagua in 1979 and I made two exploratory trips there in 1989, too little is known of the Bahama Parrot's biology and population numbers on Inagua to provide an adequate understanding of their present status and conservation needs. However, much of the habitat of the island is protected in a National Park which is administered by the Bahamas National Trust, a non-government organization.

Despite comparable Bahama Parrot population estimates for Abaco between 1976 and 1989, the present population is under stress. Major threats to the Abaco population include: unprotected habitat, which is subject to increasing developmental pressures from agriculture and tourism; nest predation by feral cats; illegal poaching of parrots for the pet trade; and catastrophes such as hurricanes.

Using the data from my research to date, the Forestry Section of the Bahamian Department of Lands and Surveys proposed the creation of a 6880-hectare (17,000-acre) parrot reserve as part of a larger 21,854-hectare (54,000-acre) forest reserve for southern Abaco. The forest reserve would be logged on a rotational and selective scheme. However, this management plan would take into consideration the parrot's needs for sufficient stands of pine in which to feed and roost. Since the Bahama Parrot is not dependent on old-aged Caribbean pines for nest cavities, it can coexist with a logging effort that does not clear cut large tracts of forest and allows for regeneration. Legislative approval is still pending for this proposal. Recently, the Department of Agriculture in the Ministry of Trade and Industry requested a loan from the Inter-American Development Bank to develop agriculture on southern Abaco. Such development would jeopardize the parrot reserve proposal, and if implemented, would surely accelerate the loss of parrot habitat.

Given their subterranean nesting habits, Bahama Parrots on Abaco will continue to be vulnerable to nest predation by feral cats. An investigation of the feral cat population and a long-term cat control program are urgently needed.

The Bahama Parrot is protected by the Wild Birds Protection Act of the Bahamas and by international legislation such as CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) and the U.S. Endangered Species Act. While most residents of Abaco are aware of these laws and respect them, illegal poaching of parrots could rapidly decimate the population. In 1987, poachers raided four of our study nests and six Bahama Parrot chicks were taken. We recovered three of these. The illegal capture of parrots for trade has been a major factor in the decline of other Caribbean amazons, such as the Puerto Rican Parrot (Amazona vittata) (Snyder et al. 1987), the St. Vincent Parrot (A. guildingi) and the Imperial Parrot (A. imperialis) (Paul Butler, pers. comm.). The creation and management of a well-protected and patrolled parrot reserve could help thwart illicit poaching of parrots.

I have worked on a Bahama Parrot conservation awareness program for Abaco with Jill Weech of the Forestry Section, who in 1989 started an environmental education program in the primary schools of Abaco. In these grassroots efforts, we give public lectures, show an educational video on the parrot, and distribute educational pamphlets. The Abaco Chapter of the Bahamas National Trust has assisted us in this and other conservation efforts.

Since the extant Bahama Parrot population on Abaco is small and localized, it is highly vulnerable to extinction from catastrophes (Ewens et al. 1987). When the population was larger and more widespread on Abaco, parrot populations could survive the stress of hurricanes because devastated areas could be repopulated from surviving refugia.

Previous workers recommended re-establishing the Bahama Parrot on other Bahamian islands to increase its probability of surviving catastrophes (Attrill 1981; Snyder et al. 1982). Although captive-raised individuals are commonly used in reintroduction and restocking programs, a better alternative exists with the Bahama Parrot - the translocation of wild-caught individuals. There are compelling reasons for favoring this approach. Captive breeding programs are very expensive, time consuming and labor intensive. Judging from other such programs, such as the Puerto Rican Parrot (Snyder et al. 1987), it may take years to establish a self-sustaining population which is capable of supplying significant numbers of birds for release. Also, they often distract resources and funding from the real problems which face the species in the wild and may not be easily be solvable (Imboden 1987). The Bahamas National Trust initiated a captive breeding program for the Inagua population in 1977, but the program has had very limited success and only four parrots still survive in captivity (Low 1989).

In addition, captive-raised parrots are at best much less likely than wild-caught parrots to survive in release efforts because of behavioral problems (Snyder et al. 1989). Finally, the existing wild populations of Bahama Parrots are clearly large enough to safely donate the few dozen parrots that should be required in relocation efforts, and such efforts can be made at comparatively small expense. The Forestry Section has recommended that Andros, which is the largest island in the Bahamas, be considered as a release site for the relocation of Bahama Parrots from Abaco. In 1989, I visited Andros; preliminary habitat surveys showed that a relocation there could have merit and be feasible.

Recommendations

A multi-faceted approach is necessary if progress is to be made in addressing the threats to the Bahama Parrot and implementing its recovery:

1. The Forestry Section and the Department of Agriculture should formally commit themselves to the conservation and recovery of both extant Bahama Parrot populations in the wild. Since the Forestry Section manages the Crown Lands (parrot habitat) and the Department of Agriculture is responsible for conservation and the enforcement of wildlife laws, a cooperative effort between these agencies will be required to insure the long-term stability of parrot populations.

2. The proposed parrot reserve and forest reserve on Abaco should be established immediately.

3. The above agencies should seek long-term solutions to the feral cat problem on Abaco. If possible, technical and operational assistance from the Pest Control Division of the U.S. Department of Agriculture should be requested.

4. A recovery team should be formed to offer recommendations to the responsible government agencies in the Bahamas. This team could be set up under the sponsorship of ICBP and should include a number of biologists with expertise in the field study of parrots as well as government representatives from the Bahamas and a

representative from the Bahamas National Trust.

5. Research efforts on Abaco should be continued and expanded. Other aspects of the ecology of Abaco, such as the role of fire in the Caribbean pine and coppice ecosystem, need to be addressed.

6. A comprehensive study of the Inagua population, including census efforts, should be initiated.

7. Environmental education efforts by the government and the Bahamas National Trust should be expanded to a national level.

8. Translocation efforts to establish new populations on other Bahamian islands should be initiated.

Unless a long-term conservation management plan for this parrot is implemented now, the survival of the Bahama Parrot is questionable. Too often, conservation efforts begin only when populations have declined to such low levels that they may no longer be genetically or ecologically viable (Soule 1987).

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Table 1. Productivity of the Bahama Parrot (Amazona leucocephala bahamensis) on Abaco Island, Bahamas, 1985-1988.

Year	No. of egg-laying pairs	No. of successful pairs	% egg-laying pairs successful	No. of young fledged	No. of young/egg laying pairs	No. of young/successful pairs
1985	10	6	60	12	1.20	2.00
1986	25	11	44	21	0.84	1.90
1987	32	19	59	28	0.88	1.47
1988	31	9	29	18	0.60	2.00
All	Total	Total	Average	Total	Average	Average
	98	45	46	79	0.81	1.76

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