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BIRDS CONSUMED BY THE INVASIVE BURMESE PYTHON (*PYTHON MOLURUS BIVITTATUS*) IN EVERGLADES NATIONAL PARK, FLORIDA, USA

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ABSTRACT.—We identified 25 species of birds representing nine avian Orders from remains in digestive tracts of 85 Burmese pythons (*Python molurus bivittatus*) collected in Everglades National Park, Florida, USA, from 2003 to 2008. Four species of birds identified in this study are of special concern in Florida and a fifth, the Wood Stork (*Mycteria americana*), is listed as federally endangered. This represents the first detailed analysis of the avian component of the diet of the introduced Burmese python, now established in Everglades National Park, Florida and highlights the potential for considerable negative impact of this invasive species on native bird populations. Received 9 June 2010. Accepted 27 September 2010.

The Burmese python (*Python molurus bivittatus*) is now well established in Everglades National Park (ENP), Florida (Snow 2006, Snow et al. 2007c). These snakes, often considered a subspecies of the Indian python (*P. molurus*), can grow to 6 m and weigh 90 kg (Ernst and Zug 1996). The Burmese python was first recorded in the Everglades in 1979 and has since frequently been observed or collected in canals, along main park roads, and even in remote mangrove (red mangrove, *Rhizophora mangle*; black mangrove, *Avicennia germinans*; white mangrove, *Laguncularia racemosa*; buttonwood, *Conocarpus erecta*) backcountry areas (Snow et al. 2007a). Large specimens of this snake were reported in ENP in the 1980s (Meshaka et al. 2000) but have only been documented as breeding in the United States since 2006 (Snow et al. 2007b). The Burmese python has spread throughout ENP over the past two decades and has also been recorded in the Florida Keys and elsewhere in Florida.

Typical food items consumed by the closely related Indian python (*P. molurus molurus*) include mammals, amphibians, lizards, snakes, birds, and fish (Ernst and Zug 1996). Researchers are just now beginning to investigate the dietary habits of the Burmese python in ENP to help identify the impact of this invasive species on the

native fauna (Snow et al. 2007a). Mammal species recorded as prey by the Burmese python in ENP include rodents and carnivores (Snow et al. 2007a), and as reported by Greene et al. (2007), the endangered Key Largo woodrat (*Neotoma floridana smalli*).

We identified birds consumed by Burmese pythons in ENP from 2003 to 2008 using a combination of feather identification techniques and morphological comparisons of osteological fragments. Many of the same samples examined were used to identify mammalian prey (Snow et al. 2007a). Continued documentation of the prey species of this invasive snake will add to our knowledge of the diet of the Burmese python in ENP, and alert conservation agencies, park officials, and the pet trade of the potential devastation this species can cause to native bird populations that did not evolve with this type of predator.

METHODS

Eighty-five of 343 Burmese pythons (25%) collected within Everglades National Park locations (Fig. 1) during 2003–2008 were found to have bird remains in the intestinal tracts. Standard mass (g) and measurements (cm) of total length and snout-vent length were available for most of the pythons examined.

Intestinal tracts or gut contents of individual Burmese pythons were sent to the Feather Identification Laboratory, National Museum of Natural History, Smithsonian Institution, in Washington, D.C. for bird species identification. Identification of species of birds from fragmentary feathers has frequently been applied to ecological studies of prey remains (Day 1966, Gilbert and Nancekivell 1982, Griffin 1982, Ward

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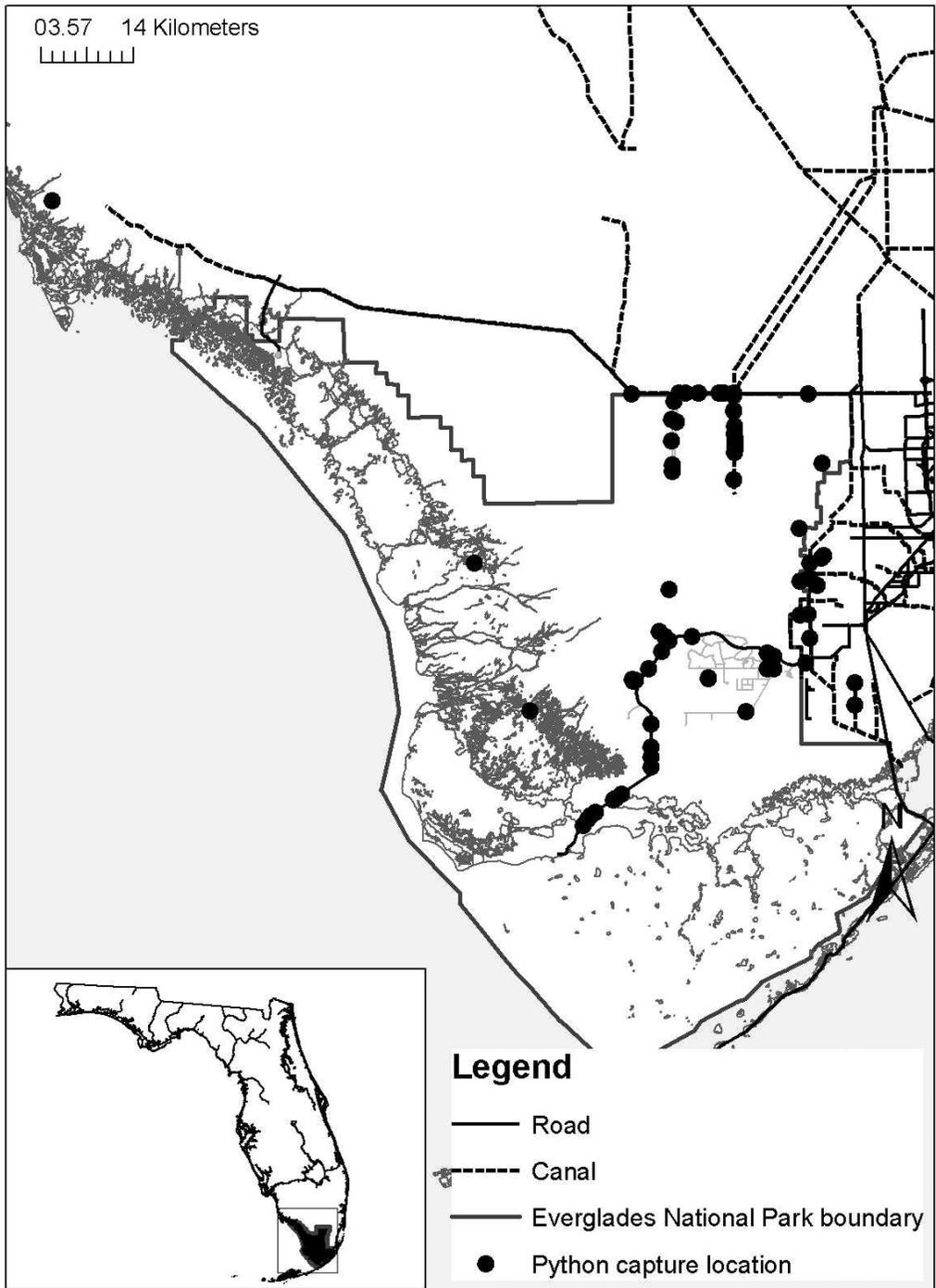


FIG. 1. Everglades National Park, Florida and surrounding area showing collection sites of Burmese pythons examined in this study (Map by M. R. Rochford).

TABLE 1. Size and mass ($\bar{x} \pm$ SD) of Burmese pythons that were feeding on birds and collected in Everglades National Park, Florida, USA (2003–2008). Range data for all measurements are estimated to the nearest decimal point.

	<i>n</i>	Total length (cm)	<i>n</i>	Snout-vent length (cm)	<i>n</i>	Mass (g)
Male	37	231.8 \pm 52.6; range 91–325	37	202.1 \pm 45.7; range 80–286	36	6,415 \pm 3,524; range 990–17,054
Female	44	276.0 \pm 72.4; range 114–475	44	243.7 \pm 65.2; range 99–424	42	12,158 \pm 11,778; range 490–56,690
Totals	81	255.8 \pm 67.4; range 91–475	81	224.7 \pm 60.5; range 80–424	78	9,508 \pm 9,371; range 490–56,690

and Laybourne 1985) when ample material is available. Python gut samples were first sorted and cleaned following methods used by Sabo and Laybourne (1994) for dry pellets. Many of these samples were wet or frozen and often odoriferous. Thus, we worked in a fume hood to sort and conduct initial cleaning. Species identification methods used depended on the type, quality, and quantity of material, and on the extent of digestion of each sample. Large items of whole feathers, feather fragments, or partial bones were subsampled and cleaned separately. This reduced the amount of time in the cleaning process and left some material with the original sample for future analysis of other food items.

Microscope slides were made from downy feather barbules in gut samples following Dove et al. (2005) for fragmentary evidence. The feather identification technique involved examining the variation in the microscopic characters of the plumulaceous (downy) barbs and comparison of whole feathers or large pieces of feathers to museum study skins stored in the Division of Birds, National Museum of Natural History. Microscopic identifications were primarily used to identify the material to taxonomic Order or Family (i.e., Rallidae, Anatidae) of each sample, and then in combination with other feather fragments, osteological material, geographic location, and circumstantial evidence associated with the sample to corroborate species identifications. We counted samples that contained more than one species of bird (e.g., sample #128; Anatidae and Anhingidae) accordingly but were unable to ascertain if more than one individual of the same species was consumed in heavily digested samples. We used measurements of ≥ 260 cm TL for females and ≥ 200 cm TL for males provided by Reed and Rodda (2009), to ascertain if pythons were mature.

RESULTS

Gender, length, and mass were available for most pythons examined. The ratio of males to

females was nearly equal (37 males, 44 females). Males were smaller than females in both mass and body measurements (Table 1). Sixty-eight of the 85 Burmese pythons in this study were ascertained to be mature based on measurements. Burmese pythons were collected throughout ENP during every month of the year with most being collected in December and January.

We identified 25 species of birds representing nine avian Orders from the 85 Burmese pythons (Table 2). Eighty-nine individual birds were recorded including 54 that were identified to species level, one identified to Order, 18 identified to Family, and 16 that were identified only as Aves (bird), due to lack of diagnostic feather material.

Gruiformes (rails and allies) were the most numerous bird prey of Burmese pythons and represented eight species and 32 individuals (36% of birds consumed). Ciconiiformes (herons and bitterns) were also common in the samples (18%) and included six of the 13 species occurring in Florida. Pied-billed Grebe (*Podilymbus podiceps*), White Ibis (*Eudocimus albus*), and Limpkin (*Aramus guarauna*) were the species most commonly identified, each occurring in seven different python samples. The most interesting prey item encountered was a Magnificent Frigatebird (*Fregata magnificens*; sample #744) collected ~50 km from a known roosting area for frigatebirds (R. W. Snow, pers. obs.). Domestic Chicken (*Gallus gallus domesticus*) was found in two separate samples and Domestic Duck (*Anas platyrhynchos domesticus*) in one sample collected near agricultural areas that abut the park. Four species identified, Little Blue Heron (*Egretta caerulea*), Snowy Egret (*E. thula*), White Ibis, and Limpkin are considered species of special concern by the Florida Fish and Wildlife Conservation Commission (Gruber 2010) and a fifth, the Wood Stork (*Mycteria americana*), is listed as federally endangered (Federal Register: 27 September 2006, Volume 71, Number 187). We found no evidence of eggs or chicks in any of the python samples examined.

TABLE 2. Eighty-nine individual birds representing nine avian Orders and 25 species consumed by Burmese pythons in Everglades National Park, Florida, USA. Birds were identified in 25% of the 343 pythons collected during 2003–2008. Python field numbers shown in **bold** indicate multiple bird species consumed by one snake. Numbers in parentheses = % of Order in diet rounded to nearest decimal point.

Order	Species	Number of individual birds	Python field number
Podicipediformes (9)	Pied-billed Grebe (<i>Podilymbus podiceps</i>)	7	104,124,202,339,364,740,846
	Podicipedidae (unidentified species)	1	504
Pelecaniformes (3)	Magnificent Frigatebird (<i>Fregata magnificens</i>)	1	744
	Anhinga (<i>Anhinga anhinga</i>)	2	128,844
Ciconiiformes (18)	Great Blue Heron (<i>Ardea herodias</i>)	1	547
	Great Egret (<i>A. alba</i>)	1	491
	Snowy Egret (<i>Egretta thula</i>)	1	484
	Little Blue Heron (<i>E. caerulea</i>)	1	327
	White Ibis (<i>Eudocimus albus</i>)	7	113,168,492,580,760,887,918
	Wood Stork (<i>Mycteria americana</i>)	1	539
	Ardeidae (unidentified species)	2	503,552
	Threskiornithidae (unidentified species)	2	177,804
Anseriformes (7)	Northern Pintail (<i>Anas acuta</i>)	1	1141
	Blue-winged Teal (<i>A. discors</i>)	1	310
	Domestic Duck (<i>A. platyrhynchos domesticus</i>)	1	731
	Anatidae (unidentified species)	3	128,513,870
Galliformes (2)	Domestic Chicken (<i>Gallus gallus domesticus</i>)	2	653,731
Gruiformes (36)	Purple Gallinule (<i>Porphyrio martinica</i>)	2	509,1158
	Common Moorhen (<i>Gallinula chloropus</i>)	1	451
	American Coot (<i>Fulica americana</i>)	3	325,546,553
	Clapper Rail (<i>Rallus longirostris</i>)	2	379,781
	King Rail (<i>R. elegans</i>)	4	242,362,437,478
	Virginia Rail (<i>R. limicola</i>)	1	163
	Sora (<i>Porzana carolina</i>)	2	500,535
	Limpkin (<i>Aramus guaranauna</i>)	7	129,363,373,460,507,514,551
	Rallidae (unidentified species)	10	120,196,316,341,369,512,549, 567,568,754
	Charadriiformes (1)	Whimbrel (<i>Numenius phaeopus</i>)	1
Columbiformes (1)	Columbidae (species unidentified)	1	653
Passeriformes (5)	House Wren (<i>Troglodytes aedon</i>)	1	77
	Red-winged Blackbird (<i>Agelaius phoeniceus</i>)	1	85
	Eastern Meadowlark (<i>Sturnella magna</i>)	1	603
	Passerine (unidentified species)	1	494
AVES (18)	Aves (unidentified species)	16	283,374,469,508,510,515,519, 528,538,555,561,563,727, 756,854,871
Totals		89	85

DISCUSSION

Identification of prey remains from fragmentary evidence is vital to help document the diets of invasive predators. Our analysis demonstrates that even if the dietary material was heavily digested and in poor condition, we were able to provide species-level identifications for many of the samples. Most species-level identifications were based on the presence of whole feathers or large fragments of feathers and bone which allowed exact morphological comparison. This allows high confidence in the species-level identifica-

tions, and microscopic analysis allowed us to obtain Family-level identification of gut samples that did not contain sufficient macroscopic material for whole feather/bone comparison. Seventeen of the samples noted as heavily digested contained large portions of avian feet, partial bills and skulls that assisted greatly with species identifications; these anatomical parts apparently are the last to be processed within the pythons' digestive system.

The Rallidae (rails and allies) was the group most heavily consumed by Burmese pythons in ENP. The threat of this unfamiliar predator to rails

and other birds is eminent. The seven species of rails identified occupy habitats in ENP that are familiar to the Burmese python and include both freshwater and brackish marshes, riverbanks, mud flats, and areas of dense vegetation. Rails have been particularly vulnerable throughout history to extinction on islands, mainly from introduced predators. The extinction of the Guam Rail (*Gallirallus owstoni*) was the first documented case of a snake (brown tree snake, *Boiga irregularis*) being implicated as an agent of extinction (Taylor 1996). Limpkin were recorded in nearly 8% of the samples analyzed. This species typically nests in Florida from February through June, roosts in trees or shrubs at night, and forages nocturnally year-round (Bryan 1996) making it particularly vulnerable to predation by the Burmese python. This python in ENP is noted as being nocturnal during June–August and mainly diurnal in October–April (R. W. Snow, pers. obs.), the closely related Indian python is active both day and night (Zug and Ernst 2004).

The dietary habits of invasive pythons are broad and represent a threat to the native fauna of the diverse habitats that it is capable of inhabiting. Ground-dwelling birds such as rails and egrets are particularly threatened because not only are they susceptible to predation of eggs and young by resident carnivores and birds, but the adult age cohort has a newly established effective predator. The high reproductive rate, longevity, ability to consume large prey (Rodda et al. 2009), and consumption of avian species by pythons, is cause for serious conservation, educational, and eradication measures. This predator is particularly hazardous to native bird populations in North America because birds have not evolved in conjunction with a large predator that has both diurnal and nocturnal feeding habits and is capable of consuming large and small prey items. Despite continuing discussions over the potential northward spread of these pythons by Rodda et al. (2009) and Pyron et al. (2008), Federal species recovery plans should seriously consider and address this novel threat in future plans.

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