2018

Behavior of Stiff-Tailed Diving Ducks and West Indian Whistling Ducks in Laguna Cartagena National Wildlife Refuge, Puerto Rico

Nick S. Goodman

Follow this and additional works at: <https://researchrepository.wvu.edu/etd>

Recommended Citation

Goodman, Nick S., "Behavior of Stiff-Tailed Diving Ducks and West Indian Whistling Ducks in Laguna Cartagena National Wildlife Refuge, Puerto Rico" (2018). *Graduate Theses, Dissertations, and Problem Reports*. 5695.

<https://researchrepository.wvu.edu/etd/5695>

This Thesis is protected by copyright and/or related rights. It has been brought to you by the The Research Repository @ WVU with permission from the rights-holder(s). You are free to use this Thesis in any way that is permitted by the copyright and related rights legislation that applies to your use. For other uses you must obtain permission from the rights-holder(s) directly, unless additional rights are indicated by a Creative Commons license in the record and/ or on the work itself. This Thesis has been accepted for inclusion in WVU Graduate Theses, Dissertations, and Problem Reports collection by an authorized administrator of The Research Repository @ WVU. For more information, please contact researchrepository@mail.wvu.edu.

Behavior of Stiff-Tailed Diving Ducks and West Indian Whistling Ducks in Laguna Cartagena National Wildlife Refuge, Puerto Rico

Nickolas S. Goodman

Thesis submitted to the Davis College of Agriculture, Natural Resources and
Design at West Virginia University

in partial fulfillment of the requirements for the degree of

Master of Science in
Wildlife and Fisheries Resources

James T. Anderson, Ph.D., Chair
George T. Merovich, Jr., Ph.D.
Jack C. Eitnien, M.S.

School of Natural Resources

Morgantown, West Virginia
2018

Keywords: Masked Duck, Niche Partitioning, Northern Ruddy Duck, Puerto Rico, Stiff-Tailed Ducks, Time-Activity Budgets, Waterfowl Behavior, West Indian Ruddy Duck, West Indian Whistling Ducks.

Copyright 2018 Nickolas S. Goodman

ABSTRACT

Behavior of Stiff-Tailed Diving Ducks and West Indian Whistling Ducks in Laguna Cartagena National Wildlife Refuge, Puerto Rico

Nickolas S. Goodman

Masked ducks (*Nomonyx dominicus*), migratory northern ruddy ducks (*Oxyura jamaicensis jamaicensis*), non-migratory West Indian ruddy ducks (*Oxyura j. jamaicensis Gmelin*), and West Indian whistling-ducks (*Dendrocygna arborea*) are all duck taxa that have declining populations in Puerto Rico. Masked ducks are listed as endangered in Puerto Rico and are a species of concern in the Caribbean while West Indian whistling ducks are considered an “at-risk” species listed as vulnerable. All 4 taxa of duck have areas of their life history where information is lacking including behavioral information. I studied the 4 taxa of duck at Laguna Cartagena National Wildlife Refuge from January–April 2015 and 2016. I quantified diurnal and nocturnal time activity-budgets of masked ducks ($n = 142$), West Indian ruddy ducks ($n = 3,765$), and Northern ruddy ducks ($n = 1,401$) and also collected dive and inter-dive times on masked ducks ($n = 60$), West Indian ruddy ducks ($n = 445$), and northern ruddy ducks ($n = 70$). Behaviors varied among taxa, between sexes, and between diurnal and nocturnal sampling periods ($P < 0.01$). Resting and sleeping were common behaviors observed during the day and night, but all three taxa fed more at night with more time spent feeding by West Indian ruddy ducks (Day, $\bar{x} = 12.3\%$ SE = 0.85, Night, $\bar{x} = 19.8\%$ SE = 0.68) than the northern ruddy ducks (Day, $\bar{x} = 4.4\%$ SE = 0.75, Night, $\bar{x} = 6.3\%$ SE = 1.9), but northern ruddy ducks were observed to have a longer dive time (22.9 ± 0.75 seconds) than West Indian ruddy ducks (18.8 ± 0.02 seconds). Northern ruddy ducks and West Indian ruddy ducks time-activity budgets varied with 7 of 8 behavioral categories during the day and 5 of 8 behavioral categories at night differing. Ecological differences such as body size or migration of northern ruddy ducks may account for the differences in behavior when compared to non-migratory West Indian ruddy ducks.

I calculated average flock size and total numbers, and provide updated numbers on West Indian whistling ducks in Puerto Rico. Previous estimates of West Indian whistling ducks in Puerto Rico were about 100 individuals, but when I conducted ten 8-hour night observations at Laguna Cartagena National Wildlife Refuge between 19 January 2016 and 8 April 2016, I found an average of 131.9 (SE=4.5) with a high count of 153 individuals. The West Indian whistling ducks used the lagoon at night arriving from the West 2–67 minutes after sunset with an average flock size of 4.65 (SE=0.6). They departed to the West before sunrise and are likely roosting during the day in the mangroves of Refugio de Aves de Boquerón. My counts indicate that the population of West Indian Whistling-Ducks in Puerto Rico is larger than previously estimated. To keep the ducks year round, it is suggested not to drain the entire lagoon at the same time so they have a place to feed.

ACKNOWLEDGMENTS

Thanks to the West Virginia University (WVU) Natural History Museum for providing funding for this project. I also thank WVU Department of Biology and the WVU School of Natural Resources for financial support. Thanks to the U.S. Fish and Wildlife service for logistical support and access to Laguna Cartagena National Wildlife Refuge. I thank Dr. Anderson for his patience, support, and advice. I thank Jack Eitnienar for help in setting up the project and for insight into working in Puerto Rico. I thank my committee members, Dr. Anderson, Dr. Merovich, and Jack Eitnienar for their reviews and comments. I thank the Morel family, Oscar Diaz, Gisella Burgos, and Phyllis Montalvo for help while in Puerto Rico. Thanks to everyone that assisted me in the field or in the lab, including Lori Petruski, Carlos H Sierra, and Donna Hartman. I thank my family, friends, fellow graduate students, and Dave from the craft center for their support, encouragement, and stress relief. I also thank Aldo Leopold, Frances Hamerstrom, Charles Darwin, Edward O. Wilson, Joelle Buffa, and Clyde Morris for inspiring me.

TABLE OF CONTENTS

ABSTRACT.....	ii
ACKNOWLEDGEMENTS.....	iii
TABLE OF CONTENTS.....	iv
CHAPTER 1: LIST OF FIGURES.....	vi
CHAPTER 2: LIST OF TABLES.....	vii
CHAPTER 2: LIST OF FIGURES.....	viii
CHAPTER 3: LIST OF TABLES.....	ix
CHAPTER 3: LIST OF FIGURES.....	x
CHAPTER 4: LIST OF TABLES.....	xi
CHAPTER 4: LIST OF FIGURES.....	xii
LIST OF APPENDICES.....	xiii
 CHAPTER 1.....	 1
Introduction to the behavior of Stiff-Tailed Diving Ducks and West Indian Whistling-Ducks.....	1
Introduction	2
<i>Background (Masked Duck)</i>	2
<i>Background (Northern and West Indian Ruddy Ducks)</i>	6
<i>Background (Masked Duck and Ruddy Duck)</i>	8
<i>Background (West Indian Whistling-Duck)</i>	10
Justification	11
Objectives	12
Study Sites	14
Thesis Format	15
Literature Cited	16
 CHAPTER 2.....	 25
Diurnal and Nocturnal Dive Durations and Inter-Dive Intervals of Stiff-Tailed Ducks in Puerto Rico.....	25
Abstract	26
Introduction	27
Methods	27
<i>Study Area</i>	27
<i>Data Collection and Analysis</i>	28
Results	29
Discussion	31
Acknowledgments	33
Literature Cited	34
 CHAPTER 3.....	 42

Time-Activity Budgets of Stiff-tailed Ducks in Laguna Cartagena National Wildlife Refuge, Puerto Rico.....	43
Abstract	44
Introduction	45
<i>Study Area</i>	46
Methods	47
<i>Time-activity Budgets</i>	47
<i>Macroinvertebrates and Seeds</i>	49
<i>Statistical Analysis</i>	49
Results	50
<i>Diurnal Time-Activity Budgets</i>	51
<i>Nocturnal Time-Activity Budgets</i>	51
<i>Macroinvertebrates and Seeds</i>	52
Discussion	53
<i>Feeding Behavior</i>	54
<i>Ruddy Duck Taxa Comparison</i>	55
Management Implications	56
Acknowledgments	57
Literature Cited	58
 CHAPTER 4.....	68
Flock Size of West Indian Whistling-Ducks (<i>Dendrocygna arborea</i>) in Puerto Rico.....	68
Abstract	69
Introduction	70
<i>Study Area</i>	70
Observations and Results	71
Discussion	72
Acknowledgments	72
Literature Cited	73
 APPENDICES.....	76

CHAPTER 1: LIST OF FIGURES

Figure 1. Location of Laguna Cartagena National Wildlife Refuge in Puerto Rico and its observation tower.....	22
Figure 2. Observation tower on Laguna Cartagena National Wildlife Refuge.....	23
Figure 3. View from the observation tower on Laguna Cartagena National Wildlife Refuge.....	24

CHAPTER 2: LIST OF TABLES

Table 1. Average dive times (D), average inter-dive times (IT), and sample size (N) of West Indian Ruddy Ducks (WI), Northern Ruddy Ducks (NR), and Masked Duck (MA) in Laguna Cartagena National Wildlife Refuge, Puerto Rico, 2015–2016.....	37
--	----

CHAPTER 2: LIST OF FIGURES

Figure 1. Map of Puerto Rico, showing the location of Laguna Cartagena National Wildlife Refuge.....	39
Figure 2. Dive durations of Masked Ducks, Northern Ruddy Ducks, and West Indian Ruddy Ducks in Laguna Cartagena National Wildlife Refuge, Puerto Rico, 2015-2016....	40
Figure 3. Inter-dive intervals of Masked Ducks, Northern Ruddy Ducks, and West Indian Ruddy Ducks in Laguna Cartagena National Wildlife Refuge, Puerto Rico, 2015-2016.....	41

CHAPTER 3: LIST OF TABLES

Table 1. Summary of diurnal time-activity budgets of West Indian ruddy ducks (male N = 1,153, female N = 908), Northern ruddy ducks (male N = 561, female N = 614), and masked ducks (male N = 3, female N = 49) in Laguna Cartagena National Wildlife Refuge, Puerto Rico, 2015–2016.....	64
Table 2. Summary of nocturnal time-activity budgets of West Indian ruddy ducks (male N = 961, female N = 773), Northern ruddy ducks (male N = 121, female N = 105), and masked ducks (male N = 48, female N = 42) in Laguna Cartagena National Wildlife Refuge, Puerto Rico, 2015–2016.....	65
Table 3. Simpson’s diversity, abundance (No./m ²), and familial richness of macroinvertebrates and seed abundance (No./ m ²) and percentage per sample for 5 locations in Laguna Cartagena National Wildlife Refuge, Puerto Rico, 2015–2016.....	66

CHAPTER 3: LIST OF FIGURES

Figure 1. Map of Puerto Rico, showing the study site location of Laguna Cartagena National Wildlife Refuge.....	67
---	----

CHAPTER 4: LIST OF TABLES

Table 1. Observations of West Indian Whistling-Ducks in Laguna Cartagena NWR, Puerto Rico.....	74
--	----

CHAPTER 4: LIST OF FIGURES

Figure 1. Map of Laguna Cartagena NWR and Refugio de Aves de Boquerón in Puerto Rico.....	75
---	----

LIST OF APPENDICES

Appendix A. Time-Activity Budget Figures.....	76
Appendix B. Statistical Test Results.....	78
Appendix C. Macroinvertebrate and Seed Data.....	80

CHAPTER 1

Introduction to the behavior of Stiff-Tailed Diving Ducks and West Indian Whistling-Ducks

Nickolas S. Goodman¹

¹ School of Natural Resources, Wildlife and Fisheries Resources Program, West Virginia University, PO Box 6125, Percival Hall, Morgantown, WV 26506

Introduction

Masked ducks (*Nomonyx dominicus*), migratory northern ruddy ducks (*Oxyura jamaicensis jamaicensis*), and non-migratory West Indian ruddy ducks are all stiff-tailed duck taxa found in Puerto Rico. West Indian whistling-ducks (*Dendrocygna arborea*) are an “at-risk” species of tree duck endemic to the West Indies and are also found in Puerto Rico. Masked ducks are considered “endangered” in Puerto Rico and are a “species of concern” in the Caribbean (Baldassarre 2014). All taxa occur on the Laguna Cartagena National Wildlife Refuge (NWR) in Lajas, Puerto Rico and all have decreasing population trends (IUCN 2016). There has been little behavioral research on these species. This information is needed to better manage and conserve their habitat.

Background (Masked Duck)

Masked ducks are small, secretive ducks with little known about them compared to other stiff-tailed ducks (Johnsgard and Carbonell 1996). They inhabit small lakes and ponds covered with thick emergent and floating vegetation and they range from eastern South America north into the southern United States, in areas such as Texas and Florida (Eitniear and Colon-Lopez 2005, Johnsgard and Carbonell 1996, Lockwood 1997, Todd 1996). What little ecological information there is on the species varies throughout its range.

Masked ducks have a long breeding season that varies depending on its geographical location. Eitniear (1999) suggests that nests are found from October until August in Texas, June until October in the West Indies, and April to September in Venezuela (Eitniear and Colon-López 2005), while breeding occurs in November in Argentina (Holland 1892). There is little information on the nest site other than it is formed close to water (Johnsgard and Carbonell 1996). The nest is shaped like a deep cup that has a roof over it resembling a basketball

(Johnsgard 1975). The information on incubation is uncertain and needs more study. A nest typically contains 4–8 eggs, but the number of eggs varies widely with the geographic range. In Cuba, nests of 8–18 eggs have been found (Bond 1961). This is thought to be done by more than 1 female and is an act called “egg-dumping” (Johnsgard and Carbonell 1996). Egg dumping occurs in Argentina, Cuba, and elsewhere, where there are high densities of masked ducks. As many as 27 eggs were found in a single nest (Johnsgard 1975, Todd 1996). Clutch size varies across its range with typical clutch size being 6 eggs in Texas, 8 eggs in Mexico, 10 in Argentina, and 8–18 in Cuba (Johnsgard and Carbonell 1996).

Masked ducks are considered a resident throughout their range, but wanders widely (Eitnienar 2014). It is occasionally recorded outside of its resident range in the U.S. and some have been observed in Vermont, Massachusetts, Wisconsin, and Maryland (Bent 1925). This indicates occasional long-distance movements. There is currently no information on whether some individuals exhibit regular migratory movements within resident range (Eitnienar 1999). Masked ducks are described as “somewhat nomadic” in Mexico and N. Central America depending on water fluctuation levels (Howell and Webb 1995). Future studies are currently being planned to determine the seasonal home range and habitat use for masked ducks (by age and sex) (Rylander and Eitnienar 2014 Not Published).

With masked ducks varying so much over their range, an accurate population estimate is hard to determine. From September to March in 1992–1993, Anderson et al. (1998) counted 47 masked ducks in Texas while doing surveys of 652 random 64.7-ha quarter sections. Mean densities of masked ducks were used to determine a total maximum of 3,817 birds within suitable habitat along the Texas Coast. This estimate makes the global estimate of 10,000 made by Callaghan and Green (1993) highly unlikely because the Texas coast is only a small portion

of the masked ducks' range. The secretive nature of the masked duck may lead to false population estimates and may give off a false impression of its rarity (Madge and Burn 1988, Lockwood 1997). It is considered a common species in the rice-growing portions of northeastern Venezuela and Argentina where Todd (1996) observed a single marsh containing 80–100 birds. The largest known flock of masked ducks to date was observed at the Laguna Cartagena National Wildlife Refuge in Puerto Rico with over 140 different masked ducks being seen at one time, producing an estimate of more than 300 individuals (Eitnienar and Morel 2012). Additional high counts of masked ducks include 80 in Guadeloupe (Eitnienar and Colon-Lopez 2005) and 100 in El Salvador (Ibara and Rivera 1998).

There is little information on the masked ducks' diet. It is thought that their primary food source is plant material such as seeds, stems, leaves, and roots (Eitnienar 2014). Stomachs of 3 Cuban specimens contained seeds from smartweed (*Polygonum* spp.), dodder (*Cuscuta* spp.), *Fimbristylis* spp., and sawgrass (*Cladium* spp.), along with parts of water lily (*Castalia* spp.) (Cottam 1939, Johnsgard and Carbonell 1996, Weller 1968). Adults and young may feed on macroinvertebrates during the breeding season, but there are little data to support this claim (Cottam 1939). The shape of the masked ducks' bill suggests that it is better adapted to eating seeds compared to the bill of the ruddy ducks and other *Oxyura* ducks (Johnsgard and Carbonell 1996, Eitnienar and Rylander 2008).

The information on the behavior of masked ducks is lacking. According to Todd (1996), this species is more agile than other stiff-tailed ducks and he observed it resting and preening on a log for over 6 hours. The masked duck is a strong swimmer that usually dives into thick vegetation rather than using flight to avoid predation (Johnsgard and Carbonell 1996). When it does fly, it flies close to the water with strong wing beats and drops into thick vegetation,

disappearing (Todd 1996). There are no known behavioral interactions between masked ducks and other species, and masked ducks are less likely to form flocks than other species (Eitnienar 2014). When flocks are observed, they are usually fairly small with an average of about 7 birds in Texas (Anderson 1999) and less than 20 elsewhere (Palmer 1976).

The social and sexual behavior of the masked duck is also lacking in information. There has yet to be any evidence of masked ducks being territorial, but there is such a lack of data on the species that they could be territorial and it just hasn't yet been observed or recorded (Johnsgard and Carbonell 1996). They are acknowledged as a monogamous species with temporary pair bonds that are broken before hatching occurs, but there are limited observations to support this (Johnsgard 1975, Johnsgard and Carbonell 1996). Since the masked duck is such a little studied and secretive duck, there is little reliable information on the courtship behavior. Some observers have reported the masked ducks courtship to be similar to the ruddy ducks with a bubbling sequence occurring, but that is questionable and more reliable observations are needed (Johnsgard and Carbonell 1996, Eitnienar 2014).

Risks to the masked duck populations include predation, brood parasitism, and hunting. Crested caracaras (*Caracara plancus*) are the main predators of adult masked ducks, while rats (*Rattus* spp.) depredate eggs in masked duck nests (Johnsgard 1975, Raffaele et al. 1998). Brood parasitism has been observed in Argentina, where the black-headed duck (*Heteronetta atricapilla*) lays its eggs in the masked duck nest (Weller 1968). Hunting is frequently cited as a major cause of mortality (Raffaele et al. 1998). Masked ducks are hunted in Texas with a daily bag limit of 6 ducks (Lockwood 1997) and they are likely hunted throughout their range (Eitnienar 2014). The masked duck has a large geographic range and a large global population

size, so even though the population trend is decreasing, it has an IUCN red list conservation status of Least Concern (BirdLife International 2012).

Background (Northern and West Indian Ruddy Duck)

Ruddy ducks are stiff-tailed ducks that have been extensively studied compared to masked ducks, but their taxonomy is still unresolved (Baldassarre 2014). There are three commonly acknowledged subspecies of ruddy ducks, but some acknowledge more subspecies: the first being the most abundant, the northern Ruddy duck (*O. j. jamaicensis*), which is found in North America, Central America, and the Caribbean; the second is the Andean ruddy duck (*O. j. andina*), which is found in the high Andes of Columbia; and the third subspecies is the Peruvian ruddy duck (*O. j. ferruginea*), which is found in the highland lakes and marshes in the Andes Mountains of Peru and Chile as well as the lowlands of Chile and Argentina (Baldassarre 2014) into the neotropics (Johnsgard and Carbonell 1996). There is also a non-migratory ruddy duck found in Puerto Rico known as the West Indian ruddy duck (*Oxyura j. jamaicensis Gmelin*) (Danforth 1926, Phillips 1922–26, Palmer 1976, Molinares 1981).

The non-migratory West Indian ruddy duck is closely related to the northern ruddy duck (Bellrose 1978). Danforth (1926) first described the West Indian ruddy duck as a new species with it having a shorter tail and wings along with a longer tarsus compared to the northern ruddy duck. This difference is only visible when the ducks are in hand, but the male of the West Indian ruddy duck can be recognized from male northern ruddy ducks by looking at their cheeks (Danforth 1926, Molinares 1981). The male West Indian ruddy duck has black mixed in with the white on their cheek (Danforth 1926, Molinares 1981), while the male northern ruddy duck always have white cheeks (Johnsgard 1978). The females of the northern and West Indian ruddy

ducks are only distinguishable from each other in the hand by taking careful measurements.

There has been no research comparing the behavior of these 2 taxa of stiff-tailed ducks.

There is little information on the diet of the South American ruddy duck sub-species (*O. j. ferruginea* and *O. j. andina*). Only two Peruvian ruddy ducks' stomachs have been examined and contained mostly mollusks (50%), and amphipods (47%), with small quantities of plant debris and seeds (Johnsgard and Carbonell 1996). The North American ruddy ducks' diet has been much more comprehensively studied and the majority (72.4 %) of the stomach contents were of plant origin, with vegetative pieces and seeds of pondweed (*Potamogeton* sp.), bulrush (*Scirpus* sp.), and widgeongrass (*Ruppia* sp.), along with some algae (*Chara* sp.), making up the greatest portion (Cottam 1939). The majority of the animal remains were midge larvae (Chironomidae) and horsefly larvae (Tabanidae) (Cottam 1939).

Diurnal time budgets completed on feral ruddy ducks in Great Britain found that they spend about 70% of the day resting and sleeping, with only about 7% of the day feeding (Hughes 1990). Hughes (1990) also found that males, females, and juveniles did not differ significantly in their behavior. This study was done during the nonbreeding season (January and February) so that is probably why the females time budget did not differ from the males. Daily energy expenditure of ruddy ducks do not match up with only 7% of the day spent feeding, so Hughes (1990) suggests that ruddy ducks feed more nocturnally.

Diurnal activity budgets were calculated by Tome (1991) on female ruddy ducks breeding in Manitoba. Pre-laying, laying, and incubating activities were observed. Foraging comprised 66.3% of the time during pre-laying and 54.4% of the time during laying (Tome 1991). Once incubation began, resting went from 11% of the time to 73.5% of the time, with foraging taking up 76.4% of the time when the female was rearing from incubation (Tome

1991). The reason why foraging rates are so high for female ruddy ducks during reproduction is because they have such a high daily cost of egg production scaled against basal metabolic rate (BMR) (280% of BMR) (Alisauskas and Ankney 1994). That is one of the highest recorded percent of BMR in waterfowl (Alisauskas and Ankney 1994). The Tome (1991) study only focused on diurnal behavior; however, if it included nocturnal behavior, the foraging rate may have been an even higher percent of the female ducks' time.

Bergan et al. (1989) completed diurnal and nocturnal time-activity budgets on diving ducks wintering in South Carolina. Their diurnal results for ruddy ducks were that they fed more and slept less during the late day sampling period (14:30 hr.–sun set). Ruddy ducks slept 27.6% of the time during the late day sampling, 49.5% during midday (10:30–14:30 hr.), and 44.6% during early day (sunrise–10:30 hr.). Nocturnal results showed that ruddy ducks fed more at night than during the day (Bergan et al. 1989). The increased time spent feeding was also complemented by increased time performing locomotion and decreased time resting and sleeping. When ruddy ducks did rest at night, it was done more during the late night period (11.3%), compared to midnight (5.3%), and early night (4.8%). The results of this study showed that nocturnal behavior differs from diurnal behavior which shows the importance of considering an entire 24 hour day when making management decisions about waterfowl habitat (Bergan et al. 1989). The Bergan et al. (1989) study was done in a different region than the West Indies and was done during the winter, so the results could be different in Puerto Rico.

Background (Masked and Ruddy Duck)

Currently the masked and ruddy ducks belong to different genera, but there once was a debate whether the masked duck should be in the genus *Oxyura* with many other stiff-tailed ducks, like ruddy ducks, or its own monotypic genus, *Nomonyx*. The masked duck was first

proposed to split off of *Oxyura* in 1895 by Salvadori based on characteristics of the differing morphology and behavior traits (Eitnienar and Rylander 2008). In a phylogenetic analysis of the order Anseriformes (which contains stiff-tailed ducks) using morphological characters, Livezey (1986) determined that the masked duck is a sister group to the highly derived *Oxyura-Biziura* clade. Livezey (1986) determined this by looking at the morphological trait of the speculum on the stiff-tailed ducks and noticed that the speculum is absent in *Oxyura* and *Biziura*, whereas it is retained in *Nomonyx*. Some fairly recent authors (Carboneras 1992, Johnsgard and Carbonell 1996) suggested merging *Nomonyx* into *Oxyura* based on the distinct courtship display shared by the males in each genus. The males in both genera perform rapid thumping of their bills on inflated throat sacs (Eitnienar 2014). Eitnienar and Rylander (2008) compared the mandibular structure of the ruddy duck (*Oxyura*) and the masked duck (*Nomonyx*) using 12 different characteristics and found that the ruddy duck had a longer and broader bill than the masked duck. This shows that masked ducks have morphological similarities and differences with *Oxyura* and more comparison needs to be conducted.

A genetic study done by Gonzalez et al. (2009) used DNA sequence data from 2 mitochondrial genes to establish phylogenetic relationships on 121 species of Anseriformes. They found that in their phylogeny, the relationships among the stiff-tailed ducks as a monophyletic group agree with the morphology-based study of Livezey (1995). McCracken and Sorenson (2005) also conducted a study to determine the genetic tree of stiff-tailed ducks. They found that a monophyly of all *Nomonyx-Oxyura* species was strongly supported by their control region data with bootstrap values ranging from 97–100% (McCracken and Sorenson 2005). Analysis of the control region and combined data sets showed that *Nomonyx* is substantially diverged from *Oxyura*, and that they should have separate genera (McCracken and Sorenson

2005). Although the genetic data suggests that they should be in separate genera, the morphological and behavior data are not so clear. A comparison of habitat use, behavioral patterns, and niche partitioning could provide strong evidence in settling this argument.

Background (West Indian Whistling-Ducks)

West Indian whistling ducks, which are currently listed as vulnerable by the International Union for Conservation of Nature are a tree duck species endemic to the West Indies (BirdLife International 2017). Their range was once over 1,900 km², but has declined over the past century and has been extirpated from Haiti and other islands (Collar et al. 1992, Staus 1998, Staus and Sorenson 1997, Raffaele et al. 1998). Hunting, habitat degradation, and predation by introduced mammals like the Indian mongoose (*Herpestes auropunctatus*) have all increased the decline of the West Indian whistling ducks' population (Staus 1998, BirdLife International 2013).

Population estimates vary for the West Indian whistling ducks with the current estimates being; at least 1,500 WIWD for the Bahamas and the Turks and Caicos Islands, an estimated 14,000 in Cuba, 800–1,200 in the Cayman Islands, 500 in Jamaica, six populations in the Dominican Republic (Ottenwalder 1997), 500 in Antigua, 50 in Barbuda, and a reported 100 in Puerto Rico (PR) (Sorenson et al. 2004, Birdlife International 2013) with a count of 116 individuals at Laguna Cartagena (PR) (Schaffner and Sánchez-Colón 2011).

Research conducted on West Indian whistling ducks suggests they utilize a wide variety of habitats but, prefer ponds and mangroves with the mangroves being used mainly during the day for roosting and the ponds used for feeding at night (Staus 1998). They are a highly gregarious species that are known to feed on corn at provisioning stations and exhibit distinct patterns of habitat use (Staus 1998). Many aspects of life-history data are unknown for the West Indian whistling ducks including average flock sizes.

Justification

Masked ducks, northern ruddy ducks, West Indian ruddy ducks, and West Indian whistling ducks all provide many ecological and economic services. All duck taxa have a unique ecological niche to which they contribute to a distinctive assemblage of waterbirds and native biodiversity (Anderson and DuBowy 1996). Masked ducks and West Indian whistling ducks indirectly contribute to the economy by bringing in money from outside sources through ecotourism. Avid birders often travel hundreds of miles for the opportunity to see this species and many people travel to tropical locations to view all of the exotic biodiversity, including masked ducks and West Indian whistling ducks. More information on masked ducks and West Indian whistling ducks is drastically needed if we want to ensure the opportunity of viewing these secretive ducks to future generations.

Masked ducks are one of the least studied species in North America so any information gained on the species will most likely be new and valuable. Eitniear (1999 and 2014) as well as Johnsgard and Carbonell (1996) completed a review on the masked duck and found that there are many places where there is little or no information on this species, especially life history.

Northern ruddy ducks are a much more studied species, but most of the research has occurred in North America and there has been little study done on them in the Caribbean and South America. For example, there is no information on ruddy ducks feeding in South America and the Caribbean (Johnsgard and Carbonell 1996). Brown and Collier (2004) have reported that northern ruddy ducks are expanding their range by moving into the Lesser Antilles (south east of Puerto Rico) and are nesting there. Masked ducks are also found in the Lesser Antilles, so as ruddy ducks continue to expand, it is important to know their habitat, niche, and food source needs, and if they overlap with the masked duck.

The West Indian ruddy duck is also a little studied duck. What little research that has been done on them found that their recruitment is low (Molinares 1981). Information needs to be gathered to determine the extent interactions between migratory northern ruddy ducks and West Indian ruddy ducks. Also basic life-history data are unknown for many aspects of West Indian whistling duck ecology.

Activity budgets have proven valuable by increasing our understanding of habitat use and niche partitioning among species (Titman 1981, Rave and Baldassarre 1989). This information is important to have to better manage an area for all species. Non-breeding habitats especially have an important function in maintaining waterfowl populations by providing protection and food resources for both adults and young (Fredrickson 1980, Fredrickson and Heitmeyer 1988).

Activity budgets also provide vital information on species behavior, allowing for better understanding, management, and conservation of a species.

Objectives

The objectives of this study are to:

1. Compare dive and inter-dive times among masked duck, West Indian ruddy duck, and northern ruddy duck by sex and time of day.
2. Quantify diurnal and nocturnal time activity-budgets of masked duck, West Indian ruddy duck, and northern ruddy duck and to compare time activity-budgets among taxa, between sexes, and between sampling times.
3. Compare the habitat use and niche partitioning of masked ducks, northern ruddy ducks, and West Indian ruddy ducks by using macroinvertebrate and seed abundance and diversity.

4. Report on average flock size and provide updated numbers on West Indian whistling ducks in Puerto Rico.

I predict masked and both ruddy duck taxa will have low daytime feeding behavior with most of the time being spent resting and sleeping. I think ruddy ducks will feed more during the day compared to masked ducks because masked ducks are a more secretive species. Most of the feeding for both species will likely take place at night with some taking place at dusk and dawn.

When comparing the sexes within each species, I think that the females will forage more than the males and the males will rest/sleep more than the females. Females in these 3 taxa of stiff-tailed ducks lay one of the biggest eggs relative to its body size in the entire avian world. The females will probably need to feed more often and rest/sleep less to provide the nutrients necessary to do this. Since the males invest little to no energy in rearing offspring, it is thought that they need less food to survive and thus will spend less time foraging.

Habitat use will likely differ somewhat in the 3 taxa with masked ducks being located in heavy vegetation for cover and northern and West Indian ruddy ducks being located in open water. With the ruddy ducks taxa feeding more heavily on macroinvertebrates compared to masked ducks, I think that they will feed in an area that has more macroinvertebrate abundance and diversity than the area where masked ducks feed. Masked ducks have not been shown to feed on macroinvertebrates, so I think they will feed in an area with heavy vegetation cover and high amount of seeds and less macroinvertebrates. The masked duck could possibly feed in the thick vegetation, while the ruddy ducks taxa feed in the open water. I do not think that ruddy ducks taxa and masked ducks will feed in the same area to avoid interspecific competition.

I hypothesize that the flock size of West Indian whistling ducks will vary substantially. I predict their numbers will be slightly higher than what was previously predicted for Puerto Rico.

Study Area

The study was conducted on the 422 ha Laguna Cartagena NWR in Lajas, Puerto Rico (Figure 1). In 1989, the U.S. Fish and Wildlife Service (USFWS) obtained 313 ha of wetland and associated uplands from the Puerto Rico Land Administration, and later in 1996, an additional 109 ha of uplands were added (Laguna Cartagena National Wildlife Refuge). Laguna Cartagena is managed by the Caribbean island NWR complex whose headquarters are in Cabo Rojo, Puerto Rico, 11 km northwest of the refuge. The community of Maguayo, Lajas, Puerto Rico borders the refuge to the east and is about 2 km from the center of the wetland complex. The majority remainder of the NWR is bordered by farmland. The lagoon is located at 18°01'N, 67°06'W.

The lagoon is about 80 ha and is a remainder of what was once a large open expanse of water (Laguna Cartagena National Wildlife Refuge). About half of the lagoon is open water with some emergent vegetation and the other half is native cattail (*Typha domingensis*). It is the only natural freshwater lagoon in Puerto Rico and it is classified as a freshwater marsh (Deliz-Quiñones 2005). It is an important freshwater habitat for migrating waterfowl and aquatic birds with historically about half of the breeding birds in Puerto Rico being observed in the area. However, due to agricultural practices where there is an excess of nitrogen, phosphorus, and potassium run off into the lagoon, up to 90 percent of the lagoon is covered with vegetation. Recently the USFWS has been managing to create open water by scraping the vegetation (mainly cattails) during the dry season.

The lagoon vegetation is mainly water hyacinth (*Eichhornia crassipes*), cattail, sedge (*Cyperus* sp.), and water lettuce (*Pistia stratiotes*). Throughout the 1950s water hyacinth was introduced to control water levels in the lagoon and the cattail was planted to provide cover for waterfowl (Díaz-Soltero 1990).

An in-depth study of water quality using macroinvertebrates on Laguna Cartagena was completed in 2005 by Deliz-Quiñones (2005). She found a total of 67 different insect species and 33 families in the lagoon (Deliz-Quiñones 2005). The abundance and diversity of the insects was directly related to dissolved oxygen (DO) concentration.

The mean annual air temperature on Laguna Cartagena is 25° C with a max around 38° C and a min around 10° C, while the mean annual precipitation is 97 cm (Deliz-Quiñones 2005). Showers happen throughout the year, but heavy rainfall peaks from September to November, and in May (Deliz-Quiñones 2005, Díaz-Soltero 1990). An observation tower (Figure 2) is constructed on the south central side of the lagoon and it has a good view of the entire wetland (Figure 3).

Thesis Format

This thesis is written in four chapters. Chapter 1 is this chapter which is the introduction. Chapter 2 entitled “Diurnal and Nocturnal Dive Durations and Inter-Dive Intervals of Stiff-Tailed Ducks in Puerto Rico” covers comparing dive and inter-dive times among masked ducks, West Indian ruddy ducks, and northern ruddy ducks by sex and time of day. Chapter 3 entitled “Time-Activity Budgets of Stiff-tailed Ducks in Laguna Cartagena National Wildlife Refuge, Puerto Rico” covers quantifying diurnal and nocturnal time activity-budgets of masked duck, West Indian ruddy duck, and northern ruddy duck and comparing time activity-budgets among taxa, between sexes, and between sampling times. It also covers comparing habitat use and niche partitioning of masked ducks, northern ruddy ducks, and West Indian ruddy ducks by using macroinvertebrate and seed abundance and diversity. Chapter 4 entitled “Flock Size of West Indian Whistling-Ducks (*Dendrocygna arborea*) in Puerto Rico” covers average flock size and provides updated numbers on West Indian whistling ducks in Puerto Rico.

LITERATURE CITED

- Alisauskas, R. T., and C. D. Ankney. 1994. Costs and rates of egg formation in ruddy ducks. *Condor* 96: 11–18.
- Anderson, J. T., and P. J. DuBow. 1996. The importance of coastal Texas wetlands for wintering and migrating waterbirds. *Wetland Journal* 8: 10–13.
- Anderson, T. J. 1999. Habitat use by masked ducks along the Gulf Coast of Texas. *Wilson Bulletin* 111:119–121.
- Anderson, T. J., G. T. Muehl, and T. C. Tacha. 1998. Distribution and abundance of waterbirds in coastal Texas. *Bird Populations* 4: 1–15.
- Baldassarre, G. 2014. Ducks, geese, and swans of North America. Johns Hopkins University Press, Baltimore. Revised and updated edition, Volume 2: 983–1013.
- Bellrose, F. C. 1978. Ducks, geese, and swans of North America. Stackpole Books, Harrisburg, Pennsylvania.
- Bergan, J. F., L. M. Smith, J. J. Mayer. 1989. Time-activity budgets of diving ducks wintering in South Carolina. *Journal of Wildlife Management* 53: 769–776.
- Bent, A. C. 1925. Life histories of North American wild fowl. U.S. National Museum, Bulletin 130: 1–316.
- BirdLife International 2012. *Nomonyx dominicus*. The IUCN Red List of Threatened Species. Version 2014.2. www.iucnredlist.org
- BirdLife International. 2013. *Dendrocygna arborea*. The IUCN Red List of Threatened Species 2013. <http://dx.doi.org/10.2305/IUCN.UK.2013-2.RLTS.T22679770A48132607.en>
- BirdLife International. 2017. IUCN Red List for birds 2017. <http://datazone.birdlife.org/species/factsheet/22679770>

- Bond, J. 1961. Sixth supplement to the checklist of the birds of the West Indies. Academy of Natural Science, Philadelphia, Pennsylvania.
- Brown, A. C. and N. Collier. 2004. A new breeding population of *Oxyura jamaicensis* (ruddy duck) on St. Martin, Lesser Antilles. Caribbean Journal of Science 40: 259–263.
- Callaghan, D. A. and A. J. Green. 1993. Wildfowl at risk. Wildfowl 44: 149–169.
- Carboneras, C. 1992. Family Anatidae (ducks, geese and swans). Pp. 536–628 in del Hoyo, J., A. Elliot, and J. Sargatal, eds. Handbook of the Birds of the World, Volume 1. Lynx Edicions, Barcelona.
- Collar, N. J., L. P. Gonzaga, N. Krabbe, A. Madrono Nieto, L. G. Naranjo, T. A. Parker III, and D. C. Wege. 1992. Threatened birds of the Americas. The ICBP / IUCN red data book. 3rd ed., pt. 2. International Council for Bird Preservation, Cambridge, United Kingdom.
- Cottam, C. 1939. Food habits of North American diving ducks. U.S. Department of Agriculture Technical Bulletin 643:46–53.
- Danforth, S. T. 1926. An ecological study of Cartagena Lagoon, Puerto Rico, with special references to birds. Journal Department of Agriculture 10: 1–136.
- Deliz-Quñones, K. Y. 2005. Water quality assessment of a tropical freshwater marsh using aquatic insects. M.S. Project Research in the Department of Biology University of Puerto Rico.
- Díaz-Soltero, H. 1990. Laguna Cartagena National Wildlife Refuge restoration, development and management plan. University of Puerto Rico-Mayagüez, Master Thesis, 411.
- Eitnienar, J. C. 1999. Masked duck (*Nomonyx dominicus*). In the birds of North America, no. 393 (A. Poole and F. Gill, Editors). The Birds of North America, Inc., Philadelphia, Pennsylvania.

- Eitnienar, J. C. 2014. Masked duck (*Nomonyx dominicus*). Neotropical Birds Online (T.S. Schulenberg, Editor). Ithaca: Cornell Lab of Ornithology.
- Eitnienar, J. C. and K. Rylander. 2008. A comparison of mandibular structure in ruddy and masked ducks (*Oxyura jamaicensis* and *Nomonyx dominicus*). Texas Journal of Science 60: 215–220.
- Eitnienar, J. C., and S. Colon-López. 2005. Recent observations of masked duck (*Nomonyx dominicus*) in the Caribbean. Caribbean Journal of Science 41: 861–864.
- Eitnienar, J. C. and M. Morel. 2012. A large concentration of masked ducks (*Nomonyx dominicus*) in Puerto Rico. Journal of Caribbean Ornithology 25: 92–94.
- Fredrickson, L. H. 1980. Management of lowland hardwood wetlands for wildlife: problems and potential. Transactions of the North American Wildlife and Natural Resources Conference 45: 376–389.
- Fredrickson, L. H. and M. E. Heitmeyer. 1988. Waterfowl use of forested wetlands of the southern United States: an overview. Pages 307–323 in M. W. Weller, ed. Waterfowl in winter. University of Minnesota Press, Minneapolis, Minnesota.
- Gonzalez, J., H. Duttman, and M. Wink. 2009. Phylogenetic relationships based on two mitochondrial genes and hybridization patterns in Anatidae. Journal of Zoology 279: 310–318.
- Holland, A. H. 1892. Short notes on the birds of Estancia Espartilla, Argentine Republic. Ibis 4: 193–214.
- Howell, S. G. N. and S. Webb. 1995. A guide to the birds of Mexico and Northern Central America. Oxford University Press, New York, New York.

- Hughes, B. 1990. The ecology and behavior of the North American ruddy duck (*Oxyura jamaicensis*) in Great Britain and its interaction with native waterbirds: a progress report. *Wildfowl* 41: 133–138.
- Ibarra, R. P. and R. M. Rivera. 1998. Observaciones de aves en el complejo el jocotal, El Salvador durante 1997. *Mesoamericana* 3: 11–12.
- IUCN. 2016. Red List of Threatened Species. Version 2016–3. <www.iucnredlist.org>. Accessed on 17 March 2017.
- Johnsgard, P. A. 1975. *Waterfowl of North America*. University of Nebraska Press, Lincoln, Nebraska.
- Johnsgard, P. A. 1978. *Ducks, geese, and swans of the world*. University of Nebraska Press, Lincoln, Nebraska.
- Johnsgard, P. A. and M. Carbonell. 1996. *Ruddy ducks and other stiff-tails*. University of Oklahoma Press, Norman, Oklahoma.
- Livezey, B. C. 1986. A phylogenetic analysis of recent Anseriform genera using morphological characters. *Auk* 103: 737–754.
- Livezey, B. C. 1995. Phylogeny and comparative ecology of stiff-tailed ducks (Anatidae: Oxyurini). *Wilson Bulletin* 107: 214–234.
- Lockwood, M. W. 1997. A closer look: masked duck. *Birding* 5: 386–390.
- Madge, S., and H. Burn. 1988. *Waterfowl: An identification guide to the ducks, geese and swans of the world*. Houghton Mifflin Company, Boston, Massachusetts. 298.
- McCracken, K. G. and M. D. Sorenson. 2005. Is homoplasy or lineage sorting the source of incongruent mtDNA and nuclear gene trees in stiff-tailed ducks (*Nomonyx-Oxyura*)? *Systematic Biology* 54: 35–55.

- Molinares A. 1981. Reproduction and morphology of the West Indian ruddy duck in Puerto Rico. M.S. Thesis. Oklahoma State University, Norman, Oklahoma.
- Ottenwalder, J. A. 1997. Situación actual y conservación de la Yaguaza Antillana (*Dendrocygna arborea*) en la República Dominicana. Pitirre 10: 2–10.
- Palmer, R. S. 1976. Handbook of North American birds. Volume 3 (2). Yale University Press, New Haven, Connecticut.
- Phillips, J. C. 1922–26. A natural history of the ducks. 4 volumes. Houghton Mifflin, Boston, Massachusetts.
- Raffaele, H., J. Wiley, O. Garrido, A. Keith, and J. Raffaele. 1998. A guide to the birds of the West Indies. Princeton University Press, Princeton, New Jersey.
- Rave, D. P. and G. A. Baldassarre. 1989. Activity budgets of green-winged teal wintering in wetlands of Louisiana. Journal Wildlife Management 53: 753–759.
- Rylander, M. K. and J. C. Eitniear. 2014. Masked Duck Ecology and Behavior (A Proposal). N.P.
- Schaffner, F. C., and Y. M. Sánchez-Colón. 2011. Population trends in West Indian whistling-ducks and other *Dendrocygna* at Laguna Cartagena, Puerto Rico. Abstract (No. 53, p 77) and presentation, Society for the Conservation and Study of Caribbean Birds, 18th Regional Meeting, July 21-25, 2011, Freeport, Grand Bahama.
- Sorenson, L. G., P. E. Bradley, and A. H. Sutton. 2004. The West Indian whistling-duck and wetlands conservation project: a model for species and wetlands conservation and education. Journal of Caribbean Ornithology 17: 72–80.
- Staus, N. L. 1998. Behaviour and natural history of the West Indian whistling-duck *Dendrocygna arborea* on Long Island, Bahamas. Wildfowl 49: 194–206.

- Staus, N. L., and L. G. Sorenson. 1997. West Indian whistling-duck (WIWD) workshop summary and draft action plan, prepared for the West Indian Whistling-Duck Working Group of the Society of Caribbean Ornithology. Unpublished report, Society of Caribbean Ornithology.
- Titman, R. D. 1981. A time-activity budget for breeding mallards (*Anas platyrhynchos*) in Manitoba. Canadian Field-Naturalist 95: 266–271.
- Todd, F. S. 1996. Natural History of Waterfowl. Ibis Publication Company, Vista, CA.
- Tome, M. W. 1991. Diurnal activity budget of female ruddy ducks breeding in Manitoba. Wilson Bulletin 103: 183-189.
- Weller, M. W. 1968. The breeding biology of the parasitic black-headed duck. Living Bird 7: 169–207.

Figure 1: Location of Laguna Cartagena National Wildlife Refuge in Puerto Rico and its observation tower.

Figure 2: Observation tower on Laguna Cartagena National Wildlife Refuge, Puerto Rico.

Figure 3: View from the observation tower on Laguna Cartagena National Wildlife Refuge, Puerto Rico.

CHAPTER 2

Nickolas S. Goodman, Graduate Research Assistant
Division of Forestry and Natural Resources
West Virginia University

PO Box 6125
Morgantown, WV 26506
Phone: 330-987-1418
E-mail: nsgoodman@mix.wvu.edu

Diurnal and Nocturnal Dive Durations and Inter-Dive Intervals of Stiff-Tailed Ducks in Puerto Rico

NICKOLAS S. GOODMAN^{1,*}, JACK C. EITNIEAR² AND JAMES T. ANDERSON¹

¹School of Natural Resources, West Virginia University, P.O. Box 6125, Morgantown, West
Virginia, 26506, USA

²Center for the Study of Tropical Birds, Inc., 218 Conway Drive, San Antonio, Texas, 78209,
USA

*Corresponding author; E-mail: nsgoodman@mix.wvu.edu

Written in the style of: Waterbirds

Goodman, N. S., J. C. Eitnietar, and J. T. Anderson. 2017. Diurnal and nocturnal dive durations
and inter-dive intervals of stiff-tailed ducks in Puerto Rico. *Waterbirds* 30:396–402.

Abstract.—Research comparing dive durations and inter-dive intervals of stiff-tailed diving ducks, which is important for understanding differences in species ecology, is lacking for the non-migratory Masked Duck (*Nomonyx dominicus*) and West Indian Ruddy Duck (*Oxyura jamaicensis jamaicensis*), and the migratory Northern Ruddy Duck (*Oxyura jamaicensis jamaicensis*). Although the Northern Ruddy Duck and West Indian Ruddy Duck are considered the same species, we treated them separately to evaluate possible ecological differences. All three were observed at the same time in the same place in Laguna Cartagena National Wildlife Refuge, Puerto Rico. Dive durations and inter-dive intervals were recorded for Masked Duck ($n = 60$), Northern Ruddy Duck ($n = 70$), and West Indian Ruddy Duck ($n = 445$) from 1 January through 30 April 2015 and 2016. The Northern Ruddy Duck had a longer mean ($\pm$ SE) dive duration (22.9 ± 0.75 sec) than the West Indian Ruddy Duck (18.8 ± 0.02 sec). Northern Ruddy Ducks likely had longer dive times because of their larger body size and migratory behavior.

Received 1 March 2017, accepted 9 August 2017.

Key words.—dive durations, inter-dive intervals, Masked Duck, niche partitioning, *Nomonyx dominicus*, Northern Ruddy Duck, *Oxyura jamaicensis jamaicensis*, Puerto Rico, stiff-tailed ducks, West Indian Ruddy Duck.

Running Head: STIFF-TAILED DUCK DIVE DURATIONS

The Masked Duck (*Nomonyx dominicus*), and Northern Ruddy Duck (*Oxyura jamaicensis jamaicensis*), as well as the West Indian Ruddy Duck (currently recognized as being the same species as the Northern Ruddy Duck), are stiff-tailed ducks commonly found in Puerto Rico. Although the non-migratory West Indian Ruddy Duck is not formally recognized as a separate species from the Northern Ruddy Duck, herein we treat them as such to see if they have ecological differences aside from the migratory vs. non-migratory behavioral differences. Masked Ducks are considered endangered in Puerto Rico and are a species of concern in the Caribbean (Eitniear and Colon 2005; Baldassarre 2014). All three occupy the Laguna Cartagena National Wildlife Refuge (NWR) in Lajas, Puerto Rico.

Niche partitioning among different species of ducks often causes large distances to exist among species while foraging (Cody 1968; Willard 1977; White and James 1978; Ishtiaq *et al.* 2010). As a result, simultaneously recording interspecific behavior of several members of a taxonomic family is seldom conducted. There has been no research comparing dive durations and inter-dive intervals of these closely related species, which is important for understanding differences in species ecology. Our objective was to compare dive durations and inter-dive intervals among Masked Duck, West Indian Ruddy Duck, and Northern Ruddy Duck (hereafter, ducks) by sex and time of day.

METHODS

Study Area

This study was conducted on the 422-ha Laguna Cartagena NWR in Lajas, Puerto Rico (18° 00' 40.1" N, 67° 06' 10.1" W; Fig. 1). The lagoon covers 80 ha and is all that remains of a once larger lagoon (U.S. Fish and Wildlife Service 2011). Cattail (*Typha domingensis*) covers

about half of the lagoon with the remainder being open water with small patches of sedges (*Cyperus* spp.) and floating vascular plants: water lettuce (*Pistia stratiotes*) and water hyacinth (*Eichhornia crassipes*) (Sánchez-Colón 2012). When full, the water depth ranges from 0 to 200 cm. The lagoon is one of the few natural freshwater lagoons in Puerto Rico (Deliz-Quíñones 2005). Historically, about half of the breeding bird species in Puerto Rico were observed in the area, and it is an important stopover point for migrating waterfowl (U.S. Fish and Wildlife Service 2011).

Data Collection and Analysis

We recorded dive durations and inter-dive intervals (Osterrieder *et al.* 2014) for the three types of ducks to the nearest sec using a stopwatch from 1 January through 30 April 2015 and 2016 during a behavioral observation study. We collected dive durations and inter-dive intervals opportunistically when the ducks were feeding for multiple dives. Dive durations were classified as the time spent underwater while feeding and inter-dive intervals were the pause between dives when the ducks remained stationary before their next dive. We conducted diurnal observations from an 8-m high elevated platform using a Barska 20-60x60 mm spotting scope and Nikon Monarch 12x42 binoculars. We obtained nocturnal observations from a dike in the middle of the lagoon using the same equipment with the addition of an Exelis night enforcer PVS-14 monocular night vision device attached to the spotting scope. To observe the three types of ducks, we randomly selected an individual and recorded its dive duration and inter-dive interval for a 5-min observation period along with its sex. We averaged dive durations and inter-dive intervals of the selected duck to a tenth of a sec, and only dive durations and inter-dive intervals for ducks with multiple dives during the 5-min observation period were used. We began observations at one side of the lagoon and moved to the other side to avoid sampling the same

individual repeatedly in a short amount of time. Sampling various locations likely reduced our incidence of recording the same individual multiple times during a day; however, it is likely that we recorded behavior on some of the same individuals multiple times (pseudoreplication) during a month. Nonetheless, we treat each sample independently due to our efforts to avoid repeated sampling (Osterrieder *et al.* 2014). We observed ducks from a distance between 25 and 200 m. We recorded water depth to the nearest centimeter twice a month (January through April 2015 and 2016) in the locations where the three different types of ducks were diving.

We used 3-way analysis of variance (ANOVA) to compare dive durations and inter-dive intervals (dependent variables) among duck types, sex, and time of day (nocturnal, diurnal), the 3-way interaction, and all 2-way interactions (independent variables). We also tested months individually and as a part of interactions for dive durations and inter-dive intervals. We considered all tests to be significant if $P < 0.05$ and analyzed data using the statistical package R with packages ‘car’ and ‘ggplot2’ (R Development Core Team 2016). We tested significant mean effects using Tukey’s multiple comparison test. We used an ANOVA to compare water depth (dependent variable) among duck types (independent variables). We tested ANOVA assumptions and found that data were normally distributed for dive durations ($W = 0.99$, $P = 0.62$), inter-dive intervals ($W = 0.99$, $P = 0.54$), and water depth ($W = 0.99$, $P = 0.26$) using the Shapiro-Wilk’s test for normality and that variances were equal for dive durations ($F_{2, 575} = 0.21$, $P = 0.65$), inter-dive intervals ($F_{2, 575} = 0.71$, $P = 0.40$), and water depth ($F_{2, 132} = 6.08$, $P = 0.30$) based on Levene’s test.

RESULTS

We recorded dive duration and inter-dive intervals for Masked Duck ($n = 60$), Northern Ruddy Duck ($n = 70$), and West Indian Ruddy Duck ($n = 445$) (Table 1). There were no significant 2- or 3-way interactions for inter-dive intervals ($F_{2, 564} \geq 0.17$, $P \geq 0.12$). Because there was a significant 2- and 3-way interaction for dive duration ($F_{2, 564} \geq 9.03$, $P \leq 0.03$), we analyzed dive duration data among the three ducks for each sex and time period combination (i.e., diurnal males, diurnal females, nocturnal males, nocturnal females). Dive duration ($F_{2, 575} = 27.08$, $P < 0.01$) and inter-dive intervals ($F_{2, 575} = 3.2$, $P = 0.04$) varied among the three ducks (Figs. 2 and 3). Inter-dive intervals for Northern Ruddy Duck were 1.4 sec (18.7%) longer than Masked Duck inter-dive intervals ($P = 0.04$). Although not significant, inter-dive intervals for West Indian Ruddy Duck were 0.6 sec (18.5%) longer than Masked Duck ($P = 0.45$) and 0.8 sec (10.3%) shorter than Northern Ruddy Duck ($P = 0.10$) inter-dive intervals. Inter-dive intervals had no significant difference between day and night ($P = 0.09$) and there was no significant difference between male and female inter-dive intervals ($P = 0.10$) (Table 1).

Dive durations of males during the day differed ($F_{1, 164} = 4.36$, $P = 0.04$) between West Indian Ruddy Duck and Northern Ruddy Duck ($P = 0.04$) with Northern Ruddy Ducks diving an average of 1.8 sec (8.3%) longer, but there were no other differences between any other duck types (Table 1). Dive durations of males at night differed ($F_{2, 114} = 24.28$, $P < 0.01$) with West Indian Ruddy Duck having an average dive interval 7.9 sec (34.7%) shorter than the Northern Ruddy Duck ($P < 0.01$) and 5.5 sec (25.5%) shorter than Masked Duck ($P < 0.01$), but there was no significant difference between Northern Ruddy Duck and Masked Duck ($P = 0.53$). Dive intervals of females during the day differed ($F_{2, 141} = 18.07$, $P < 0.01$) with Northern Ruddy Duck diving 4.9 sec (23.2%) longer than West Indian Ruddy Duck ($P < 0.01$) and 8.7 sec (45.2%) longer than Masked Duck ($P = 0.01$). Female West Indian Ruddy Duck dove 3.8 sec

(22.6%) longer than Masked Duck ($P < 0.01$). Dive intervals of females feeding during the night differed ($F_{2, 145} = 6.0$, $P < 0.01$) between West Indian Ruddy Duck and Masked Duck ($P < 0.01$) with Masked Duck diving 3.5 sec (19.0%) longer, but there were no other differences between any other duck types. Month did not have a significant effect on dive duration ($F_{3, 564} \leq 4.02$, $P \geq 0.28$) or inter-dive intervals ($F_{3, 564} \leq 0.43$, $P \geq 0.72$).

Water depth varied by duck type ($F_{2, 132} = 20.7$, $P < 0.01$) and the average water level where each species was diving was: Northern Ruddy Duck (21.5 cm, SE = 1.1), West Indian Ruddy Duck (29.7 cm, SE = 1.2), and Masked Duck (21.9 cm, SE = 0.8). West Indian Ruddy Duck dived at a water level 7.8 cm (30.2%) deeper than Masked Duck ($P < 0.01$) and 8.2 cm (32.0%) deeper than Northern Ruddy Duck ($P < 0.01$), but there was no significant difference in water levels where Masked Duck and Northern Ruddy Duck dove ($P = 0.97$).

DISCUSSION

Many factors may be responsible for the differences we observed in dive durations and inter-dive intervals among duck types including variation in body size, water depth, foraging method, dietary prey abundance, habitat, and energetic needs due to migratory vs. non-migratory behavior. Although we cannot definitively determine the causes of these differences, it is likely that all the factors have at least some influence on dive and inter-dive times, although migratory behavior and body size appear to be most relevant. Northern Ruddy Ducks had longer dive durations and inter-dive intervals than West Indian Ruddy Ducks, possibly due to the migration distances of the Northern Ruddy Duck and the need for more food intake during this time than the non-migratory West Indian Ruddy Duck (Botton *et al.* 1994; Restani *et al.* 2000). Migratory birds like the Northern Ruddy Duck are known to accumulate more food storage prior to

migration and at intermittent stops (Lindström 2003). However, these longer dive durations cannot be attributed to water depth, because the West Indian Ruddy Duck occurred in deeper water, but dived for a shorter period than the Northern Ruddy Duck. Another possible explanation could be that the West Indian Ruddy Duck (wing length: $\bar{X} = 131.8$ cm) is smaller than the Northern Ruddy Duck (wing length: $\bar{X} = 144.5$ cm) (Molinares 1981). Body size influences dive duration and inter-dive intervals with larger animals (including ducks) having longer dive durations and inter-dive intervals (Beauchamp 1992; Boyd and Croxall 1996; Mori 2002; Osterrieder *et al.* 2014).

The Masked Duck's average dive duration (21.2 sec) falls between those for the Northern Ruddy Duck and West Indian Ruddy Duck. Both types of Ruddy Ducks differ from Masked Ducks in terms of morphology, habitat use, and foraging methods (Eitniear and Rylander 2008). Masked Ducks feed on plant material (Eitniear 2014) and generally surface one or two body lengths from where they dived (Jenni 1969); whereas both types of Ruddy Ducks forage along the bottom for both plants and aquatic macroinvertebrates, with aquatic macroinvertebrates being targeted when available (Cottam 1939). Our observations support this with Masked Ducks surfacing where they dived and sometimes having vegetation in their bill and both types of Ruddy Ducks not surfacing where they dived. These distinct feeding behaviors are reinforced by their locations in the wetland with the Masked Duck occupying emergent and aquatic-bed vegetation and both types of Ruddy Ducks occupying open water.

No previous study has compared dive durations of these three types of ducks on the same body of water. Jenni (1969) recorded average dive durations of 21 sec ($n = 16$; Range = 11-26) and inter-dive intervals of 11.5 sec ($n = 12$; Range = 8-15) for Masked Ducks in Costa Rica. Additionally, Hughes (1992) documented average dive durations of 27 sec ($n = 172$; SD ± 0.4)

and inter-dive intervals of 11 sec ($n = 184$; $SD \pm 0.3$) for Northern Ruddy Duck in Great Britain. Although recorded under different conditions, dive duration data for Masked Ducks in Costa Rica were similar to what we recorded in Puerto Rico, but inter-dive intervals were higher than what we recorded (Jenni 1969; Jenni and Gambs 1974); dive durations and inter-dive intervals for Northern Ruddy Ducks in Great Britain were higher than our observations (Hughes 1992).

ACKNOWLEDGMENTS

We thank the U.S. Fish and Wildlife Service for logistical support and access to Laguna Cartagena NWR. We also thank Dr. George Merovich and an anonymous reviewer for their comments and Dr. Christopher Rota for statistical support. Funding was provided by the West Virginia University Natural History Museum. All applicable ethical guidelines for the use of birds in research have been followed, including those presented in the Ornithological Council's "Guidelines to the Use of Wild Birds in Research". This is scientific article number 3326 of the West Virginia Agricultural and Forestry Experiment Station, Morgantown.

LITERATURE CITED

- Baldassarre, G. 2014. Ducks, geese, and swans of North America. Revised and updated edition. Johns Hopkins University Press, Baltimore, Maryland.
- Beauchamp, G. 1992. Diving behavior in Surf Scoters and Barrow's Goldeneyes. *Auk* 109: 819-827.
- Botton, M. L., R. E. Loveland and T. R. Jacobsen. 1994. Site selection by migratory shorebirds in Delaware Bay, and its relationship to beach characteristics and abundance of horseshoe crab (*Limulus polyphemus*) eggs. *Auk* 111: 605-616.
- Boyd, I. L. and J. P. Croxall. 1996. Dive durations in pinnipeds and seabirds. *Canadian Journal of Zoology* 74: 1696-1705.
- Cody, M. L. 1968. On the methods of resource division in grassland bird communities. *American Naturalist* 102: 107-147.
- Cottam, C. 1939. Food habits of North American diving ducks. U.S. Department of Agriculture Technical Bulletin 643: 46-53.
- Deliz-Quinones, K. Y. 2005. Water quality assessment of a tropical freshwater marsh using aquatic insects. M.S. Thesis, University of Puerto Rico, San Juan.
- Eitnienar, J. C. 2014. Masked Duck (*Nomonyx dominicus*). In *Neotropical Birds Online* (T. S. Schulenberg, Eds.). Cornell Lab of Ornithology, Ithaca, New York.
<https://neotropical.birds.cornell.edu/Species-Account/nb/species/masduc/overview>,
accessed 06 September 2016.
- Eitnienar, J. C. and S. C. Colon. 2005. Recent observations of Masked Duck (*Nomonyx dominicus*) in the Caribbean. *Caribbean Journal of Science* 41: 861-864.

- Eitnienar, J. C. and K. Rylander. 2008. A comparison of mandibular structure in ruddy and masked ducks (*Oxyura jamaicensis* and *Nomonyx dominicus*). *Texas Journal of Science* 60: 215-220.
- Hughes, B. 1992. The ecology and behavior of the ruddy duck (*Oxyura jamaicensis jamaicensis*) in Great Britain. Ph.D. Dissertation, University of Bristol, Bristol, U.K.
- Ishtiaq, F., S. Javed, M. Coulter and A. Rahmani. 2010. Resource partitioning in three sympatric species of storks in Keoladeo National Park, India. *Waterbirds* 33: 41-49.
- Jenni, D. A. 1969. Diving times of the Least Grebe and Masked Duck. *Auk* 86: 355-356.
- Jenni, D. A. and R. D. Gambs. 1974. Diving times of grebes and Masked Ducks. *Auk* 91: 415-417.
- Lindström Å. 2003. Fuel deposition rates in migrating birds: causes, constraints and consequences. Pages 307-320 *in* Avian Migration (P. Berthold, E. Gwinner and E. Sonnenschein, Eds.). Springer, Berlin, Germany.
- Molinares A. 1981. Reproduction and morphology of the West Indian Ruddy Duck in Puerto Rico. M.S. Thesis, Oklahoma State University, Norman.
- Mori, Y. 2002. Optimal diving behavior for foraging in relation to body size. *Journal of Evolutionary Biology* 15: 269-276.
- Osterrieder, S. K., M. A. Weston, R. W. Robinson and P. J. Guay. 2014. Sex-specific dive characteristics in a sexually size dimorphic duck. *Wildfowl* 64: 126-131.
- R Development Core Team. 2016. R: a language and environment for statistical computing v. 3.1.3. R Foundation for Statistical Computing, Vienna, Austria. <http://www.R-project.org/>, accessed 6 September 2016.

- Restani, M., A. R. Harmata and E. M. Madden. 2000. Numerical and functional responses of migrant Bald Eagles exploiting a seasonally concentrated food source. *Condor* 102: 561-568.
- Sánchez-Colón, Y. 2012. Effect of water level fluctuations and rainfall on phosphorus release and binding at a tropical freshwater wetland (Laguna Cartagena, Puerto Rico). M.S. Thesis, Universidad del Turabo, Gurabo, Puerto Rico.
- U.S. Fish and Wildlife Service. 2011. Comprehensive conservation plan, Laguna Cartagena National Wildlife Refuge, Lajas, Puerto Rico. Unpublished report, U.S. Department of the Interior, Fish and Wildlife Service, Southeast Region, Atlanta, Georgia.
<https://www.fws.gov/southeast/planning/PDFdocuments/LagunaFinalCCPs/WebVersionLagunaCartagenaCCPEnglish.pdf>, accessed 16 September 2016.
- White, D. H. and D. James. 1978. Differential use of fresh water environments by wintering waterfowl of coastal Texas. *Wilson Bulletin* 90: 99-111.
- Willard, D. E. 1977. The feeding ecology and behavior of five species of herons in southeastern New Jersey. *Condor* 79: 462-470.

1 **Table 1. Average dive durations (D), average inter-dive intervals (Int), and sample size (n) of Masked Ducks, Northern Ruddy**
2 **Ducks, and West Indian Ruddy Ducks in Laguna Cartagena National Wildlife Refuge, Puerto Rico, 2015-2016.** ^a = $P < 0.05$ for
3 Masked Duck–Northern Ruddy Duck, ^b = $P < 0.05$ for Masked Duck–West Indian Ruddy Duck, and ^c = $P < 0.05$ for West Indian
4 Ruddy Duck–Northern Ruddy Duck.

Category	Masked Duck			Northern Ruddy Duck			West Indian Ruddy Duck		
	<i>n</i>	D ± SE	Int ± SE	<i>n</i>	D ± SE	Int ± SE	<i>n</i>	D ± SE	Int ± SE
Sex									
Male	31	24.3 ± 0.6	7.1 ± 0.4	37	23.1 ± 1.0	7.8 ± 0.2	215	20.1 ± 0.3	7.7 ± 0.2
Female	29	18.0 ± 1.2	6.5 ± 0.4	33	22.6 ± 1.2	8.7 ± 0.6	230	17.7 ± 0.3	7.0 ± 0.2
Time									
Day	11	14.4 ± 1.5	5.6 ± 0.5	60	22.9 ± 0.8	8.1 ± 0.3	214	19.9 ± 0.3	7.0 ± 0.2
Night	49	22.7 ± 0.7	7.1 ± 0.3	10	22.4 ± 2.1	9.2 ± 0.8	231	17.8 ± 0.3	7.7 ± 0.2
Time*Sex									
Male/Day	0	NA	NA	33	22.7 ± 1.1 ^c	7.6 ± 0.2	133	20.9 ± 0.4 ^c	7.4 ± 0.3
Male/Night	31	24.3 ± 0.6 ^b	7.1 ± 0.4	4	26.7 ± 1.8 ^c	9.3 ± 0.5	82	18.8 ± 2.1 ^{b,c}	8.1 ± 0.4
Female/Day	11	14.9 ± 1.5 ^{a,b}	5.7 ± 0.5	27	23.6 ± 1.2 ^{a,c}	8.7 ± 0.7	106	18.7 ± 0.4 ^{b,c}	6.6 ± 0.2
Female/Night	18	20.2 ± 1.6 ^b	7.1 ± 0.5	6	18.2 ± 2.5	8.6 ± 1.3	124	16.7 ± 0.3 ^b	7.4 ± 0.3
Overall	60	21.2 ± 0.8	6.8 ± 0.3 ^a	70	22.9 ± 0.8	8.2 ± 0.3 ^a	445	18.8 ± 0.0	7.4 ± 0.2

Figure Captions

Figure 1. Map of Puerto Rico showing the location of Laguna Cartagena National Wildlife Refuge (NWR).

Figure 2. Dive durations of Masked Ducks, Northern Ruddy Ducks, and West Indian Ruddy Ducks in Laguna Cartagena National Wildlife Refuge, Puerto Rico, 2015-2016.

Figure 3. Inter-dive intervals of Masked Ducks, Northern Ruddy Ducks, and West Indian Ruddy Ducks in Laguna Cartagena National Wildlife Refuge, Puerto Rico, 2015-2016.

Figure 1.

Figure 2.

Figure 3

CHAPTER 3

Time-Activity Budgets of Stiff-tailed Ducks in Laguna Cartagena National Wildlife Refuge, Puerto Rico

NICKOLAS S. GOODMAN¹, JACK C. EITNIEAR², AND JAMES T. ANDERSON¹

1 School of Natural Resources, West Virginia University, P.O. Box 6125, Morgantown, WV
26506, USA

2 Center for the Study of Tropical Birds, Incorporated, 218 Conway Drive, San Antonio, Texas,
USA

Written in the style of: The Journal of Wildlife Management

22 Feb. 2018
Nickolas S. Goodman, Graduate Research Assistant
School of Natural Resources
West Virginia University
PO Box 6125
Morgantown, WV 26506
nsgoodman@mix.wvu.edu

RH: Goodman et al. • TA Budgets of Stiff-Tailed Ducks

Time-Activity Budgets of Stiff-Tailed ducks in Laguna Cartagena National Wildlife Refuge

NICKOLAS S. GOODMAN, *School of Natural Resources, West Virginia University, P.O. Box 6125, Morgantown, WV 26506, USA*

JACK C. EITNIEAR, *Center for the study of Tropical Birds, Incorporated, 218 Conway Drive, San Antonio, Texas, USA*

JAMES T. ANDERSON, *School of Natural Resources, West Virginia University, P.O. Box 6125, Morgantown, WV 26506, USA*

The Journal of Wildlife Management

ABSTRACT Habitat loss and degradation have contributed to declining populations of stiff-tailed ducks including the migratory northern ruddy duck (*Oxyura jamaicensis jamaicensis*), and non-migratory masked duck (*Nomonyx dominicus*) and West Indian ruddy duck (*Oxyura j. jamaicensis Gmelin*), and studies collecting time-activity budgets on waterfowl can provide important insight into habitat use, behavior, and niche partitioning. Even though the northern ruddy duck and West Indian ruddy duck are recognized as the same species, we treated them separately to appraise possible ecological differences. We recorded 24-hour time-activity budgets on masked ducks ($n = 142$), northern ruddy ducks ($n = 1,401$), and West Indian ruddy ducks ($n = 3,765$) on the Laguna Cartagena National Wildlife Refuge in Lajas, Puerto Rico from January through April 2015 and 2016. Behaviors varied among taxa, between sexes, and between diurnal and nocturnal sampling periods ($P < 0.01$). Resting and sleeping were common behaviors observed during the day and night, but all 3 taxa fed more at night with the West Indian ruddy duck spending more time feeding (Day, $\bar{x} = 12.3\%$ SE = 0.85, Night, $\bar{x} = 19.8\%$ SE = 0.68) than the northern ruddy duck (Day, $\bar{x} = 4.4\%$ SE = 0.75, Night, $\bar{x} = 6.3\%$ SE = 1.9). Northern ruddy duck and West Indian ruddy duck time-activity budgets varied with 7 of 8 behavioral categories during the day and 5 of 8 behavioral categories at night differing. Ecological differences such as body size and migration of northern ruddy ducks may account for the differences in behavior when compared to non-migratory West Indian ruddy ducks.

KEY WORDS Laguna Cartagena National Wildlife Refuge, masked duck, northern ruddy duck, niche partitioning, Puerto Rico, stiff-tailed ducks, time-activity budgets, waterfowl behavior, West Indian ruddy duck, wintering waterfowl.

Masked ducks (*Nomonyx dominicus*), northern ruddy ducks (*Oxyura jamaicensis jamaicensis*), and West Indian ruddy ducks (currently recognized as being the same species as the northern ruddy duck) are stiff-tailed duck taxa that are found on the Laguna Cartagena National Wildlife Refuge (NWR) in Lajas, Puerto Rico. All 3 taxa have decreasing population trends (IUCN 2016) and hunting of them has been forbidden in Puerto Rico since the mid-1970s (Molinares 1981). Masked ducks are considered endangered in Puerto Rico and are a species of concern in the Caribbean (Baldassarre 2014). The migratory northern ruddy duck is closely related to the non-migratory West Indian ruddy duck (Bellrose 1978). The West Indian ruddy duck was first described as a new species by Danforth (1926); it has a shorter tail and wings along with a longer tarsus compared to the northern ruddy duck. Although these differences are only visible with careful measurements when the ducks are in hand, the 2 taxa can be separated at a distance by looking at the male's cheeks (Danforth 1926, Molinares 1981). Male West Indian ruddy duck has black and white on their cheeks (Danforth 1926, Molinares 1981), whereas the male northern ruddy duck only has white cheeks (Johnsgard 1978). Females of the 2 taxa are only distinguishable from each other in hand by taking measurements of the tail, wings, and tarsus, but they flock with their own taxa (Molinares 1981) so they can be distinguished by looking at the males around them. Currently these 2 taxa are not formally recognized as separate species; however, we treat them as such to see if they have ecological differences aside from being migratory versus non-migratory.

Habitat loss and degradation are thought to have contributed to the declines of these duck taxa and many others (Baldassarre and Bolen 1994). Studies collecting time-activity budgets on waterfowl have provided important insight into habitat use (Poulton et al. 2002, Michot et al. 2006, Crook et al. 2009), foraging impacts (Tatu et al. 2007), and niche partitioning (Titman

1981, Rave and Baldassarre 1989). Because of niche partitioning among taxa of ducks, large distances often exist between similar taxa (Cody 1968, Willard 1977, White and James 1978, Ishtiaq 2010), which makes simultaneously recording interspecific behavior of several members of a taxonomic family difficult. Because of this, there has been no research comparing time-activity budgets of these 3 taxa. Also, there have been no time-activity budgets collected on the masked duck or West Indian ruddy duck and none collected for the northern ruddy duck in Puerto Rico.

Simultaneously collecting time-activity budgets on these 3 closely related taxa will: (1) show how they interact with each other, (2) provide insight into how they spend their time, (3) allow for speculation of dietary and energy needs, and (4) acquire new information to be used for management of the waterfowl and Laguna Cartagena (Adams et al. 2000, Crook et al. 2009). Our objectives were to compare: (1) diurnal and nocturnal time-activity budgets of masked duck, West Indian ruddy duck, and northern ruddy duck between sexes and sampling times and (2) macroinvertebrate and seed abundance and diversity among feeding sites.

STUDY AREA

The study area was the 422 ha Laguna Cartagena NWR in Lajas, Puerto Rico (18° 00' 40.1" N, 67° 06' 10.1" W; Fig. 1). Our observations occurred on the 80-ha lagoon, which is all that remains of a once larger lagoon (USFWS 2011). About 50% of the lagoon was dominated by cattail (*Typha domingensis*) with the remainder being open water with small patches of sedges (*Cyperus* spp.) and floating vascular plants (water lettuce [*Pistia stratiotes*] and water hyacinth [*Eichhornia crassipes*]) (Sánchez-Colón 2012, 2015). When full, the water depth ranged from 0 to 200 cm (Goodman et al. 2018), but the lagoon is occasionally drained during the dry season to

perform cattail control. There is a dike that goes about halfway across the lagoon like a peninsula, but the lagoon is one continuous cell. Historically, about half of the breeding species in Puerto Rico were observed in the area and it was an important stopover point for migrating waterfowl (USFWS 2011). An 8-m tall wooden observation tower on the south-central side of the lagoon provides a good view of the entire lagoon. The mean annual air temperature on Laguna Cartagena NWR was 25° C with a max around 38° C and a min around 10° C, while the mean annual precipitation was 97 cm (Deliz-Quiñones 2005).

METHODS

Time-Activity Budgets

We recorded 24-hour behavioral observations for time-activity budgets on masked ducks, northern ruddy ducks, and West Indian ruddy ducks using focal animal observations (Altmann 1974) from January through April 2015 and 2016. Our observations began at one side of the lagoon and moved to the other side to avoid sampling the same individual repeatedly in a short amount of time. We randomly selected individuals of each sex by moving a spotting scope across the lagoon and the bird closest to the center of the scope was the one we observed (Bergan et al. 1989, Poulton et al. 2002, Crook et al. 2009). Sampling various locations within the lagoon likely reduced our frequency of recording the same individual multiple times during a sampling period; however, it is probable that we recorded behavior on some of the same individuals multiple times (pseudoreplication) during a month (Goodman et al. 2017). We still treat each sample independently because of our efforts to avoid repeated sampling (Osterrieder et al. 2014). We observed each individual for 5 consecutive minutes while recording a specific behavioral activity every 10 seconds. We used a stop watch to ensure the sampling time was accurate. After the 5

minutes, we observed another individual of the opposite sex. Masked ducks were less common and more secretive than either ruddy duck taxa, so once a masked duck was spotted, we began a 5-minute observation right away. Ducks that were disturbed during the observation were not used as the focal individual since they show atypical behavior (Bergan et al. 1989). When a disturbance occurred (usually by dogs or horses), we stopped observations in the disturbed area and waited at least 15 minutes from when it ended to resume observations in that area.

We classified behavioral activity of masked, northern ruddy, and West Indian ruddy ducks into 1 of 8 categories. We recorded: (1) aggression (any behavior by an individual that caused displacement of a second individual), (2) feeding (diving or feeding on the surface), (3) inter-dive loaf (the pause between dives when the duck remained stationary before its next dive), (4) resting (stationary with neck retracted either partially or fully, but bill not tucked under wing), (5) locomotion (swimming or flying), (6) courtship (pair bond displays, copulation, or head-pumping), (7) comfort movement (preening, stretching, or bathing), and (8) sleeping (bill tucked under wing) (Hohman 1984, Bergan et al. 1989, Poulton et al. 2002, Crook et al. 2009).

Sampling occurred equally throughout 6 time periods, 3 diurnal (early (sunrise–1030), midday (1031–1430), and late (1431–sunset)) and 3 nocturnal (early night (sunset–2230), midnight (2231–0230), and late night (0231–sunrise)) (Bergan et al. 1989). We conducted diurnal observations from the observation tower using a Barska® 20–60 x 60 mm spotting scope and Nikon Monarch® 12 x 42 binoculars. We conducted nocturnal observations from a dike in the middle of the lagoon and used the same equipment with the addition of an Exelis night enforcer PVS-14® monocular night vision device attached to the spotting scope. We observed ducks from a distance between 25 and 200 m.

Macroinvertebrates and Seeds

We sampled macroinvertebrates and seed abundance twice (1 diurnal and 1 nocturnal [to account for temporal activity patterns]) each month (January–April) in 5 different areas within the lagoon: 1 area where masked ducks typically fed, 1 area where Northern ruddy ducks fed, 1 area where West Indian ruddy duck fed, and 2 random locations within the lagoon (Poulton et al. 2002). We collected 5 soil core samples and 2 sweep net samples at each of the 5 sites (Anderson et al. 2013). We collected soil core samples with a polyvinyl chloride (PVC) soil corer producing a core with a diameter of 51 mm and depth of 20 cm. We strained cores with a 500-micrometer standard testing sieve to find the macroinvertebrates and seeds which were then counted and placed into vials containing 70% isopropanol (Hyvönen and Nummi 2000, Poulton et al. 2002). We completed sweep net samples by performing 10 m transects at each sampling area using a 50-cm wide D-frame sweep net which was placed on top of the substrate (Turner and Trexler 1997). We then counted macroinvertebrates and seeds and placed them into vials containing 70% isopropanol for storage until all collected benthic macroinvertebrates were identified to family level (Merritt et al. 2008) using microscopes as necessary. We did not identify seeds to species, but aggregated them across all species to calculate total abundance.

Statistical Analyses

We calculated percent time allocated to each of the 8 activities for each observation by dividing the time spent doing an activity by the total time of the observation (300 seconds) (Hohman 1984, Crook et al. 2009). We used multivariate analysis of variance (MANOVA) to compare behavioral activities (dependent variables) among taxa, sex, and time of day (nocturnal, diurnal), the 3-way interaction, and all 2-way interactions (independent variables). We considered all tests to be significant at $P < 0.05$. Following a significant MANOVA (Wilks' λ),

we used analysis of variance (ANOVA) to test the effects of independent variables on time-activity budgets, and if significant, we used a Tukey's multiple comparison test to separate means. Normality of residuals was tested using the Shapiro-Wilk statistic and found to be normally distributed ($W = 0.999$, $P = 0.36$), while Bartlett's test showed variances were equal ($K\text{-squared} = 4.737$, $P = 0.094$). We used Bartlett's test because the sample sizes were unequal (Milliken and Johnson 1992).

We used Simpson's diversity index (Simpson 1949) to calculate the familial diversity of macroinvertebrates at each site, for each month, for both sampling times (diurnal and nocturnal), for both sampling methods (soil core and sweep net) and ANOVA to compare macroinvertebrate and seed abundance (no./m²; dependent variables) among sites, among months, and between time of day, the 3-way interaction, and all 2-way interactions (independent variables). We tested ANOVA assumptions and found that data were normally distributed for macroinvertebrates ($W = 0.968$, $P = 0.427$), and seeds ($W = 0.948$, $P = 0.120$) using the Shapiro-Wilk test for normality and that variances were equal for macroinvertebrates ($F_{2, 33} = 0.001$, $P = 0.971$) and seeds ($F_{2, 33} = 0.831$, $P = 0.369$) based on Leven's test.

RESULTS

We recorded 142 behavioral observations for masked duck, 1,401 for northern ruddy duck, and 3,795 for West Indian ruddy duck (Table 1). Behaviors varied among taxa (Wilks' $\lambda = 0.90$, $P < 0.01$), between sexes (Wilks' $\lambda = 0.95$, $P < 0.01$), and between sampling times (Wilks' $\lambda = 0.81$, $P < 0.01$). We analyzed behavioral data among taxa by sex separately for diurnal and nocturnal periods because the 3-way (Wilks' $\lambda = 0.99$, $P < 0.01$) and all 2-way (Wilks' $\lambda \geq 0.96$,

$P < 0.01$) interactions were significant. However, because we also were interested in differences between sexes for each taxon, we compared behaviors between sexes for each taxon.

Diurnal Time-Activity Budgets

West Indian ruddy ducks spent significantly more time in courtship (17.6–100%), sleep (6.6–100%), and aggression (100%), and less time in resting (11.3–51.7%) and locomotion (53.6–77.4%) than northern ruddy duck and masked duck ($F_{2, 3,282} \geq 7.55$, $P < 0.01$) (Table 1). Northern ruddy ducks spent less time performing inter-dive loaf (61.5–77.6%) than West Indian ruddy ducks and masked ducks ($F_{2, 3,282} = 47.02$, $P = 0.02$). West Indian ruddy ducks spent more time feeding (47.5–76.5%) than northern ruddy ducks ($F_{2, 3,282} = 41.25$, $P < 0.01$). Masked ducks spent less time engaged in comfort movements (24.2–84%) than West Indian and northern ruddy ducks ($F_{2, 3,282} = 3.53$, $P = 0.03$). Female West Indian ruddy ducks spent more time feeding (30.3%) ($F_{1, 3,282} = 6.27$, $P < 0.01$) and in inter-dive loaf (25%) than males ($F_{1, 3,282} = 3.77$, $P = 0.02$), but males spent more time in courtship (82.4%) than females ($F_{1, 3,282} = 29.19$, $P < 0.01$) (Table 1). Masked ducks behaved similarly between sexes and northern ruddy ducks had 1 difference with females resting 46.9% more than males ($F_{1, 3,282} = 5.41$, $P = 0.02$) (Table 1).

Nocturnal Time-Activity Budgets

All 3 taxa spent more time at night feeding (19.8–65.4%) than during the day ($F_{2, 5,326} = 53.44$, $P < 0.01$). Masked ducks spent the most percentage of their time feeding (29.5–41%) and in inter-dive loaf (13.4–16.9%), followed by West Indian ruddy ducks (feeding 12.6–27%, inter-dive loaf 5.4–12.1%), then northern ruddy ducks (feeding 4.6–15.2%, inter-dive loaf 2.0–6.3%) (Table 2). Females from each taxon spent more time feeding (28.1–69.7%) and inter-dive loafing (20.7–65.4%) than males ($F_{1, 2,044} \geq 101.89$, $P < 0.01$). Male West Indian ruddy ducks spent more time in courtship (94.6%) than females ($F_{1, 2,044} = 185.76$, $P < 0.01$) and male West Indian

ruddy ducks courted 100% more than northern ruddy ducks and masked ducks ($F_{2, 2,044} = 24.05$, $P < 0.01$). Male West Indian ruddy ducks spent more time being aggressive (100%) ($F_{1, 2,044} = 6.84$, $P < 0.01$) than females, but there were no differences in time spent performing aggression or comfort movements among taxa. The aggression was always intraspecific usually towards other males performing courtship behaviors.

Male masked ducks at night spent the most time in locomotion (29.5%) and the least time resting (15.7%) and sleeping (0%) (Table 2). Male masked ducks spent more time in locomotion (43.5%) ($F_{1, 2,044} = 8.25$, $P < 0.01$) than females (Table 2). West Indian ruddy ducks rested (19.8–61.5%) more than northern ruddy ducks and masked ducks ($F_{2, 2,044} = 20.20$, $P < 0.01$). Northern ruddy ducks spent more time sleeping (89.5–100%) than West Indian ruddy ducks and masked ducks ($F_{2, 2,044} = 186.60$, $P < 0.01$). Male West Indian ruddy slept 40.3% more than the females ($F_{1, 2,044} = 5.00$, $P = 0.03$).

Macroinvertebrates and Seeds

There were no 3-way or 2-way interactions for macroinvertebrates ($F_{2, 9} \leq 1.93$, $P \geq 0.20$) or seeds ($F_{2, 9} \leq 1.78$, $P \geq 0.25$) sampled with soil cores (Table 3). Macroinvertebrate diversity, familial richness, and abundance were similar among sampling sites ($F_{2, 9} \leq 0.14$, $P \geq 0.9$), and between sampling times (diurnal vs. nocturnal) ($F_{2, 9} \leq 5.08$, $P \geq 0.06$); months also were similar ($F_{2, 9} \leq 2.41$, $P \geq 0.07$). Seed abundance was similar between sampling times ($F_{2, 9} = 2.19$, $P = 0.23$), months ($F_{2, 9} = 1.19$, $P = 0.08$), and sites ($F_{2, 9} = 0.40$, $P = 0.59$). Although not significant, the site where masked ducks fed had the highest density of seeds from soil core samples (494 /m²: SE = 15.44) (Table 3).

There were no 3-way or 2-way interactions for macroinvertebrates ($F_{2, 9} \leq 1.37$, $P \geq 0.32$) or seeds ($F_{2, 9} \leq 1.33$, $P \geq 0.33$) sampled with D-nets. Macroinvertebrate diversity, familial

richness, and abundance along with seed abundance was similar between sampling times ($F_{2,9} \leq 0.60$, $P \geq 0.46$), among months ($F_{2,9} \leq 1.90$, $P \geq 0.25$), and among sites ($F_{2,9} \leq 3.25$, $P \geq 0.06$). Northern ruddy ducks fed in the site with the highest total familial richness (12) of macroinvertebrates. The only statistically significant difference for the macroinvertebrates (abundance and familial richness) and seeds (abundance) was between sampling methods with the soil core method having significantly ($F_{2,9} \leq 13.16$, $P \leq 0.01$) more macroinvertebrates and seeds than the D-net method in every site (Table 3).

DISCUSSION

Overview

Northern ruddy ducks, West Indian ruddy ducks, and masked ducks all occurred at different locations within the lagoon and no interspecific aggression was observed. No intraspecific aggression was observed for masked ducks, but some was observed for both ruddy duck taxa with West Indian ruddy ducks showing this behavior more than northern ruddy ducks. This is probably because West Indian ruddy ducks were breeding during the study. They breed at any time of the year in Puerto Rico with increased breeding occurring after a rainy season (Molinares 1981). The breeding behavior of West Indian ruddy ducks is supported when we compare the time spent performing courtship behaviors. West Indian ruddy ducks spent much more time (3.1%) in courtship than the other 2 taxa (0.1% for northern ruddy ducks and 0.0% for masked ducks). The increased time spent performing courtship and aggression by West Indian ruddy ducks could also influence other behaviors such as feeding and inter-dive loaf since courtship and aggression are high energy expenditure behaviors (Wooley and Owen 1978). Male West Indian ruddy ducks spent more time performing high energy behaviors like courtship and

aggression than females, but females spend extensive amounts of energy producing eggs that are amongst the largest of any waterfowl proportional to body size (Lack 1968, Tome 1991).

Feeding Behavior

All 3 taxa of stiff-tailed ducks fed more at night which has previously been reported in other studies (Bergan et al. 1989). Masked ducks spent more time feeding than the 2 taxa of ruddy ducks which can be explained by masked ducks differing from ruddy duck taxa in terms of morphology, habitat use, and foraging methods (Eitniear and Rylander 2008). Masked duck's bill is built for it to feed on plant material (Eitniear 2014) and they generally surface 1 or 2 body lengths from where they dived (Jenni 1969) indicating they seldom forage for moving aquatic invertebrates. Both ruddy duck taxa forage along the bottom for both plants and aquatic macroinvertebrates, with aquatic macroinvertebrates being targeted when available (Cottam 1939) as they would be year-round in Puerto Rico (Deliz-Quiñones 2005). Observations taken during a dive and inter-dive time study support this, with masked ducks surfacing where they dived and sometimes having vegetation in their beak and ruddy duck taxa not surfacing where they dived (Goodman et al. 2017). These distinct feeding behaviors also were supported by observations of the different taxa being in different parts of the lagoon. Masked ducks were observed occupying emergent vegetation, while the ruddy duck taxa were occupying open water. Masked ducks were observed far less than both ruddy duck taxa with only 3 males observed diurnally. The masked ducks were not only less numerous than the ruddy ducks, but were also harder to find since they were hidden in thick vegetation.

Time-activity budgets have not been previously collected or reported on masked ducks and West Indian ruddy ducks, but they have been on northern ruddy ducks. In South Carolina, ruddy ducks fed more at night than the day, but spent more time feeding at night (~35%) (Bergan

et al. 1989) compared to our observations of West Indian ruddy duck (~20%) and northern ruddy duck (~7%). Hughes (1990) completed diurnal time activity budgets on ruddy ducks in Great Britain and found that they spent about 70% of their time resting and sleeping, which is higher than our diurnal observations of both West Indian ruddy ducks (~60%) and northern ruddy ducks (~52%). The differences between our study and both Bergan et al. (1989) and Hughes (1990) are possibly due to the studies occurring in different regions of the world where the ruddy ducks have different accessibility to nutritious or abundant food sources. Hughes (1992) also conducted a study on dive durations and inter-dive intervals for northern Ruddy Ducks in Great Britain and his results were higher than the results of a study conducted in Puerto Rico (Goodman et al. 2017). We suspect that food resources were not limiting at the time of our study and that the 3 taxa were not at carrying capacity on the study area. However, this needs to be further studied in the future and diet selection needs to be examined.

Ruddy Duck Taxa Comparison

Although both ruddy duck taxa occupied open water, they were never observed interacting in the same location. Overall, 7 of the 8 behavioral categories during the day and 5 of the 8 behavioral categories at night were significantly different. These differences could stem from migration because northern ruddy ducks migrate and West Indian ruddy ducks do not. Migration is known to change the behavior of species with food intake being more important (Restani et al. 2000, Lindström 2003, Arzel et al. 2006). This was not observed in time spent feeding or inter-dive loaf in northern ruddy ducks, but they did have longer dive and inter-dive times (Goodman et al. 2017). Another possibility to describe the difference in feeding habits is body size. West Indian ruddy ducks have a smaller body size than northern ruddy ducks and body size influences dive and inter-dive times with larger animals having longer dive and inter-

dive times (Beauchamp 1992, Boyd and Croxall 1996, Mori 2002, Osterrieder et al. 2014).

Waterfowl feeding on food sources that are low water, high energy foods spend less time feeding than other waterfowl consuming high water, low energy foods (Paulus 1983). It is possible that northern ruddy ducks are feeding in an area with higher quality food and need less time feeding to get the nutrition and energy they require. Northern ruddy ducks primarily feed in the eastern side of the lagoon which has the highest total familial richness (12), but is close to a village and is frequently disturbed by people, dogs, and horses. Because northern ruddy ducks migrate, they may risk being disturbed for the increased food quality (Lima and Dill 1990).

MANAGEMENT IMPLICATIONS

Our study demonstrated that Laguna Cartagena provided the necessary resources for all major activities of the 3 stiff-tailed taxa. Laguna Cartagena NWR should strive to maintain and increase production of abundant invertebrates and native seeds through moist soil management (Anderson and Smith 1999, 2000). The lagoon should never be completely drained in case some waterfowl are breeding at that time of the year. Instead, we recommend extending the dike to go across the entire lagoon with a water control structure in the middle. That way water can be kept in part of the lagoon and it will allow for easier water level drawdowns for moist soil management and cattail control. Controlling the water level can also increase emergent vegetation and floating vascular plants that masked ducks use as shelter and foraging habitat. Also disturbances should be kept to a minimum. Dogs and horses frequently walk through the lagoon disturbing the waterfowl and possibly trampling their nests (J.C. Eitniear, Center for the Study of Tropical Birds, unpublished report). We recommend banning horses on the refuge and

enforcing the dog-free area. If these management strategies are implemented, we believe that the refuge can be improved for all waterfowl including the endangered masked duck.

ACKNOWLEDGMENTS

We thank the U.S. Fish and Wildlife service for access to Laguna Cartagena NWR and for logistical support. We also thank Mike Morel and Dr. Fred Schaffner for support in Puerto Rico and Dr. George Merovich for review of this manuscript. Funding was provided by the West Virginia University Natural History Museum. J. T. Anderson was supported by the National Science Foundation under Cooperative Agreement OIA-1458952 and by the USDA National Institute of Food and Agriculture, McIntire Stennis project WVA00117 during manuscript preparation. This is manuscript number xxxx of the West Virginia Agricultural and Forestry Experiment Station, Morgantown.

LITERATURE CITED

- Adams, P. A., G. J. Robertson, and I. L. Jones. 2000. Time-activity budgets of harlequin ducks molting in the Gannet Islands, Labrador. *Condor* 102:703–708.
- Altmann, J. 1974. Observational study of behavior: sampling methods. *Behavior* 49:227–267.
- Anderson, J. T., and L. M. Smith. 1999. Carrying capacity and diet use of managed playa wetlands by nonbreeding waterbirds. *Wildlife Society Bulletin* 27:281–291.
- Anderson, J. T., and L. M. Smith. 2000. Invertebrate response to moist-soil management of playa wetlands. *Ecological Applications* 10:550–558.
- Anderson, J. T., F. L. Zilli, L. Montalto, M. R. Marchese, M. McKinney, and Y.-L. Park. 2013. Sampling and processing aquatic and terrestrial invertebrates in wetlands. Pages 142–195 in J. T. Anderson, and C. A. Davis, Eds. *Wetland Techniques. Volume 2: Organisms*. Springer, New York, New York, USA.
- Arzel, C., J. Elmberg, and M. Guillemain. 2006. Ecology of spring-migrating Anatidae: a review. *Journal of Ornithology* 147:167–184.
- Baldassarre, G. 2014. Ducks, geese, and swans of North America. Revised and updated edition. Johns Hopkins University Press, Baltimore, Maryland, USA.
- Baldassarre, G. A., and E. G. Bolen. 1994. Waterfowl ecology and management. John Wiley & Sons, New York, New York, USA.
- Beauchamp, G. 1992. Diving behavior in surf scoters and Barrow's goldeneyes. *Auk* 109:819–827.

- Bellrose, F. C. 1978. Ducks, geese, and swans of North America. Stackpole Books, Harrisburg, Pennsylvania, USA.
- Bergan, J. F., L. M. Smith, and J. J. Mayer. 1989. Time-activity budgets of diving ducks wintering in South Carolina. *Journal of Wildlife Management* 53:769–776.
- Boyd, I. L., and J. P. Croxall. 1996. Dive durations in pinnipeds and seabirds. *Canadian Journal of Zoology* 74:1696–1705.
- Cody, M. L. 1968. On the methods of resource division in grassland bird communities. *American Naturalist* 102:107–147.
- Cottam, C. 1939. Food habits of North American diving ducks. U.S. Department of Agriculture Technical Bulletin 643:46–53.
- Crook, S. L., W. C. Conway, C. D. Mason, and K. J. Kraai. 2009. Winter time-activity budgets of diving ducks on eastern Texas reservoirs. *Waterbirds* 32:548–558.
- Danforth, S. T. 1926. An ecological study of Cartagena Lagoon, Puerto Rico, with special references to birds. *Journal of the Department of Agriculture* 10:1–136.
- Deliz-Quiñones, K. Y. 2005. Water quality assessment of a tropical freshwater marsh using aquatic insects. Thesis, University of Puerto Rico, Mayaguez, Puerto Rico.
- Eitnienar, J. C. 2014. Masked duck (*Nomonyx dominicus*). Neotropical birds online (T.S. Schulenberg, Eds.). Cornell Lab of Ornithology, Ithaca, New York, USA.
- Eitnienar, J. C. and K. Rylander. 2008. A comparison of mandibular structure in ruddy and masked ducks (*Oxyura jamaicensis* and *Nomonyx dominicus*). *Texas Journal of Science* 60:215–220.

- Goodman, N. S., J. C. Eitnienar, and J. T. Anderson. 2018. Flock size of West Indian whistling-ducks (*Dendrocygna arborea*) in Puerto Rico. *Journal of Caribbean Ornithology* 30: in press.
- Goodman, N. S., J. C. Eitnienar, and J. T. Anderson. 2017. Diurnal and nocturnal dive durations and inter-dive intervals of stiff-tailed ducks in Puerto Rico. *Waterbirds* 30:396–402.
- Hohman, W. L. 1984. Diurnal time-activity budgets for ring-necked ducks wintering in central Florida. *Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies* 38:158–164.
- Hughes, B. 1990. The ecology and behavior of the North American ruddy duck (*Oxyura jamaicensis*) in Great Britain and its interaction with native waterbirds: a progress report. *Wildfowl* 41:133–138.
- Hughes, B. 1992. The ecology and behavior of the ruddy duck (*Oxyura jamaicensis jamaicensis*) in Great Britain. Ph.D. Dissertation, University of Bristol, Bristol, U.K.
- Hyvönen, T. and P. Nummi. 2000. Activity traps and the corer: complementary methods for sampling aquatic invertebrates. *Hydrobiologia* 432:121–125.
- Ishtiaq, F., S. Javed, M. Coulter, and A. Rahmani. 2010. Resource partitioning in three sympatric species of storks in Keoladeo National Park, India. *Waterbirds* 33:41–49.
- IUCN. 2016. Red list of threatened species. Version 2016–3. <www.iucnredlist.org>. Accessed on 17 March 2017.
- Jenni, D. A. 1969. Diving times of the least grebe and masked duck. *Auk* 86: 355-356.
- Johnsgard, P. A. 1978. Ducks, geese, and swans of the world. University of Nebraska Press, Lincoln, Nebraska, USA.

- Lack, D. 1968. Ecological adaptations for breeding in birds. Chapman and Hall, London, England.
- Lima, S. L., and L. M. Dill. 1990. Behavioral decisions made under the risk of predation: a review and prospectus. *Canadian Journal of Zoology* 68:619–640.
- Lindström Å. 2003. Fuel deposition rates in migrating birds: causes, constraints and consequences. Pages 307–320 *in* Avian Migration (P. Berthold, E. Gwinner, and E. Sonnenschein, Eds.). Springer, Berlin, Germany.
- Merritt, R. W., K. W. Cummins, and M. B. Berg. 2008. An introduction to the aquatic insects of North America. Fourth edition. Kendall/ Hunt Publishing, Dubuque, Iowa, USA.
- Michot, T. C., M. C. Woodin, S. E. Adair, and E. B. Moser. 2006. Diurnal time-activity budgets of redheads (*Aythya americana*) wintering in seagrass beds and coastal ponds in Louisiana and Texas. *Hydrobiologia* 567:113–128.
- Milliken, G. A., and D. E. Johnson. 1992. One-way treatment structure in a completely randomized design structure with heterogeneous errors. *Analysis of Messy Data Volume 1: Designed Experiments*. Van Nostrand Reinhold, New York, New York, USA.
- Molinares, A. 1981. Reproduction and morphology of the West Indian ruddy duck in Puerto Rico. Thesis, Oklahoma State University, Stillwater, Oklahoma, USA.
- Mori, Y. 2002. Optimal diving behavior for foraging in relation to body size. *Journal of Evolutionary Biology* 15:269–276.
- Osterrieder, S. K., M. A. Weston, R. W. Robinson, and P. J. Guay. 2014. Sex-specific dive characteristics in a sexually size dimorphic duck. *Wildfowl* 64:126–131.

- Paulus, S. L. 1983. Dominance relations, resource use and pairing chronology of gadwalls in winter. *Auk* 100:947–952.
- Poulton, V. K., J. R. Loworn, and J. Y. Takekawa. 2002. Clam density and scaup feeding behavior in San Pablo Bay, California. *Condor* 104:518–527.
- Rave, D. P., and G. A. Baldassarre. 1989. Activity budgets of green-winged teal wintering in wetlands of Louisiana. *Journal of Wildlife Management* 48:838–845.
- Restani, M., A. R. Harmata, and E. M. Madden. 2000. Numerical and functional responses of migrant bald eagles exploiting a seasonally concentrated food source. *Condor* 102:561–568.
- Sánchez-Colón, Y. 2012. Effect of water level fluctuations and rainfall on phosphorus release and binding at a tropical freshwater wetland (Laguna Cartagena, PR). Thesis, Universidad del Turabo, Gurabo, Puerto Rico.
- Sánchez-Colón, Y. M. 2015. Identifying nonpoint sources of phosphorus (P) and nitrogen (N) pollution and dynamics, internal eutrophication and anoxia variability at a tropical freshwater wetland (Laguna Cartagena, Puerto Rico). Dissertation, Universidad del Turabo, Gurabo, Puerto Rico.
- Simpson, E. H. 1949. Measurement of diversity. *Nature* 163:688–688.
- Tatu, K. S., J. T. Anderson, L. J. Hindman, and G. Seidel. 2007. Mute swans' impact on submerged aquatic vegetation in Chesapeake Bay. *Journal of Wildlife Management* 71:1431–1439.
- Titman, R. D. 1981. A time-activity budget for breeding mallards (*Anas platyrhynchos*) in Manitoba. *Canadian Field–Naturalist* 95:266–271.

- Tome, M. W. 1991. Diurnal activity budget of female ruddy ducks breeding in Manitoba. *Wilson Bulletin* 103:183–189.
- Turner, A. M., and J. C. Trexler. 1997. Sampling aquatic invertebrates from marshes: evaluating the options. *Journal of North America Benthological Society* 16:694–709.
- U.S. Fish and Wildlife Service [USFWS]. 2011. Comprehensive Conservation Plan Laguna Cartagena National Wildlife Refuge Lajas, Puerto Rico. U.S. Department of the Interior, Fish and Wildlife Service, Southeast Region. <https://www.fws.gov/southeast/planning/PDFdocuments/LagunaFinalCCPs/WebVersionLagunaCartagenaCCPEnglish.pdf>. Accessed 16 September 2016.
- White, D. H., and D. James. 1978. Differential use of fresh water environments by wintering waterfowl of coastal Texas. *Wilson Bulletin* 90:99–111.
- Willard, D. E. 1977. The feeding ecology and behavior of five species of herons in south-eastern New Jersey. *Condor* 79:462–470.
- Wooley J. B., J R., and R. B. Owen, JR. 1978. Energy costs of activity and daily energy expenditure in the black duck. *Journal of Wildlife Management* 42:739–745.

Associate Editor:

Table 1. Average percent time spent in each behavior category for diurnal time-activity budgets of West Indian ruddy ducks (male N = 1,153, female N = 908), northern ruddy ducks (male N = 561, female N = 614), and masked ducks (male N = 3, female N = 49) in Laguna Cartagena National Wildlife Refuge, Puerto Rico, 2015–2016.

Sex Behavior	Northern Ruddy Duck		West Indian Ruddy Duck		Masked Duck	
	$\bar{x}^a$	SE	$\bar{x}^a$	SE	$\bar{x}^a$	SE
Male						
Aggression	0.0 Ba	0.0	0.1 Aa	0.0	0.0 Ba	0.0
Feeding	5.3 Ba	0.8	10.1 Ab	0.7	5.7 ABa	5.7
Inter-dive Loaf	1.5 Ba	0.3	3.9 Ab	0.3	6.7 Aa	3.7
Resting	24.7 Bb	1.7	21.9 Ca	1.0	41.0 Aa	29.5
Locomotion	18.4 Aa	1.5	8.3 Ba	0.6	36.7 Aa	23.3
Courtship	0.3 Ba	0.2	1.7 Ab	0.3	0.0 Ba	0.0
Comfort Movement	13.2 Aa	1.3	14.7 Aa	0.9	10.0 Ba	10.0
Sleep	36.7 Ba	2.0	39.3 Aa	1.4	0.0 Ba	0.0
Female						
Aggression	0.0 Aa	0.0	0.1 Ba	0.0	0.0 Aa	0.0
Feeding	3.4 Ba	0.7	14.5 Aa	1.0	11.3 ABa	3.4
Inter-dive Loaf	0.9 Ba	0.2	5.2 Aa	0.4	4.8 Aa	1.5
Resting	31.5 Ba	1.7	21.3 Ca	1.2	42.5 Aa	6.7
Locomotion	19.8 Aa	1.5	7.8 Ba	0.7	16.8 Aa	4.7
Courtship	0.0 Ba	0.0	0.3 Aa	0.1	0.0 Ba	0.0
Comfort Movement	15.0 Aa	1.3	12.8 Aa	0.9	2.4 Ba	1.2
Sleep	29.3 Ba	1.8	38.2 Aa	1.6	22.2 Ba	6.0

^a Means followed by the same upper case letter, are not significantly different among taxa ($P > 0.05$). Means followed by the same lower case letter are not significantly different between sexes ($P > 0.05$).

Table 2. Average percent time spent in each behavior category for nocturnal time-activity budgets of West Indian ruddy ducks (male N = 961, female N = 773), northern ruddy ducks (male N = 121, female N = 105), and masked ducks (male N = 48, female N = 42) in Laguna Cartagena National Wildlife Refuge, Puerto Rico, 2015–2016.

Sex Behavior	Northern Ruddy Duck		West Indian Ruddy Duck		Masked Duck	
	$\bar{x}^a$	SE	$\bar{x}^a$	SE	$\bar{x}^a$	SE
Male						
Aggression	0.1 Aa	0.1	0.1 Ab	0.0	0.0 Aa	0.0
Feeding	4.6 Cb	1.6	12.6 Bb	0.8	29.5 Ab	4.8
Inter-dive Loaf	2.0 Cb	0.7	5.4 Bb	1.3	13.4 Ab	2.2
Resting	26.1 Aa	3.8	40.8 Ba	1.3	15.7 Aa	4.8
Locomotion	21.9 ABa	3.5	21.9 Ba	0.9	37.7 Ab	6.6
Courtship	0.0 Aa	0.0	9.5 Bb	0.6	0.0 Aa	0.0
Comfort Movement	1.4 Aa	1.0	2.9 Aa	0.4	3.7 Ab	2.5
Sleep	43.8 Aa	4.5	6.7 Bb	0.8	0.0 Ca	0.0
Female						
Aggression	0.0 Aa	0.0	0.0 Aa	0.0	0.0 Aa	0.0
Feeding	15.2 Ca	0.5	27.0 Ba	1.1	41.0 Aa	5.3
Inter-dive Loaf	6.3 Ca	0.2	12.1 Ba	0.6	16.9 Aa	2.3
Resting	29.6 Aa	0.6	36.9 Ba	1.5	20.7 Aa	6.1
Locomotion	25.3 ABa	4.0	17.6 Ba	1.0	21.3 Aa	5.8
Courtship	0.0 Aa	0.0	0.5 Ba	0.2	0.0 Aa	0.0
Comfort Movement	0.7 Aa	0.4	2.3 Aa	0.4	0.0 Aa	0.0
Sleep	38.1 Aa	4.8	4.0 Ba	0.7	0.0 Ca	0.0

^a Means followed by the same upper case letter, are not significantly different among taxa

($P > 0.05$). Means followed by the same lower case letter are not significantly different between sexes ($P > 0.05$).

Table 3. Simpson's diversity(Averaged by site and sampling methods across all months and years), abundance (No./m²), familial richness(No./Sample), and total numbers of families of macroinvertebrates, and seed abundance (No./ m²) for 5 locations in Laguna Cartagena National Wildlife Refuge, Puerto Rico, 2015–2016.

Sampling Method	Macroinvertebrates							Seeds	
	Simpson's Diversity		Abundance		Familial Richness			Abundance	
	$\bar{x}$	SE	$\bar{x}^a$	SE	Total	$\bar{x}^a$	SE	$\bar{x}^a$	SE
Northern ruddy duck									
Sweep Net	0.50	0.07	3.64	0.75	12	3.88	0.72	0.14	0.05
Soil Core	0.77	0.09	679.2	209.15	4	0.79	0.24	441.48	32.16
West Indian ruddy duck									
Sweep Net	0.32	0.07	2.45	0.36	8	3.38	0.24	0.07	0.04
Soil Core	0.47	0.04	554.35	274.05	3	1.5	0.19	359.58	40.4
Masked duck									
Sweep Net	0.42	0.09	4.77	1.08	10	4.63	0.85	0.25	0.04
Soil Core	0.02	0.04	833.56	323.41	1	0.71	0.18	493.96	15.44
Random No. 1									
Sweep Net	0.35	0.11	1.42	0.42	5	2.25	0.52	0.16	0.04
Soil Core	0.86	0.03	597.99	267.71	3	0.88	0.24	265.77	54.25
Random No. 2									
Sweep Net	0.32	0.05	2.98	0.77	8	3.88	0.55	0.17	0.05
Soil Core	0.45	0.02	707.5	368.67	3	1.25	0.32	254.7	61.78

^a Mean abundance was significantly ($P < 0.05$) different between sampling methods in each site but not significant ($P > 0.05$)

between sites.

Figure 1. Map of Puerto Rico, showing the study site location of Laguna Cartagena National Wildlife Refuge.

CHAPTER 4

Flock Size of West Indian Whistling-Ducks (*Dendrocygna arborea*) in Puerto Rico.

NICKOLAS S. GOODMAN¹, JACK C. EITNIEAR², AND JAMES T. ANDERSON¹

¹School of Natural Resources, West Virginia University, P.O. Box 6125, Morgantown, WV
26506, USA

²Center for the Study of Tropical Birds, Incorporated, 218 Conway Drive, San Antonio, Texas,
USA

Written in the style of: Journal of Caribbean Ornithology (accepted)

Abstract.— West Indian Whistling-Ducks (*Dendrocygna arborea*) are endemic to the West Indies and have been declining in recent decades. While a scientifically accurate census has yet to be taken, it is estimated that there are about 100 individuals on the island of Puerto Rico. We conducted ten 8-hour night observations at Laguna Cartagena National Wildlife Refuge between 19 January 2016 and 8 April 2016, resulting in an average of 131.9 (SE=4.5) with a high count of 153. West Indian Whistling-Ducks used the lagoon at night with the average arriving flock size being 4.65 (SE=0.6). The ducks approached from the West 2–67 minutes after sunset and departed to the West before sunrise. It is likely that the West Indian Whistling-Ducks are spending their days roosting in the mangroves of Refugio de Aves de Boquerón and their nights feeding at Laguna Cartagena National Wildlife Refuge. Our counts indicate that the population of West Indian Whistling-Ducks in Puerto Rico is larger than previously estimated.

Key words.— *Dendrocygna arborea*, flock size, population, Puerto Rico, West Indian Whistling-Duck

West Indian Whistling-Ducks (*Dendrocygna arborea*) are an “at-risk” species endemic to the West Indies. They rely on freshwater, brackish, and marine wetlands for feeding and roosting (Sorenson *et al.* 2004). The range of the West Indian Whistling-Duck (WIWD) was historically over 1,900 km², but it has undergone strong declines in recent decades and has been extirpated from several islands (Collar *et al.* 1992, Staus 1998, Staus and Sorenson 1997, Raffaele *et al.* 1998). The WIWD is listed as vulnerable by the International Union for Conservation of Nature because of its small and severely fragmented range. Threats limiting the population include hunting, habitat degradation, and the introduction of predators (BirdLife International 2013). Resident populations of at least 1,500 WIWD have been reported for the Bahamas and the Turks and Caicos Islands, an estimated 14,000 in Cuba, 800–1,200 in the Cayman Islands, 500 in Jamaica, six populations in the Dominican Republic (Ottenwalder 1997), 500 in Antigua, 50 in Barbuda, and a reported 100 in Puerto Rico (Sorenson *et al.* 2004, Birdlife International 2013). However, maximum total counts of up to 116 individuals at Laguna Cartagena were reported for 2010 by Schaffner and Sánchez-Colón (2011). Basic life-history data are unknown for many aspects of WIWD ecology including no previous data on their flock sizes. In this paper we report on average flock size and provide updated numbers on WIWD in Puerto Rico.

STUDY AREA

This study was conducted on the 422 ha Laguna Cartagena National Wildlife Refuge (NWR) in Lajas, Puerto Rico (18°01'N, 67°06'W; Fig. 1). The 80 ha lagoon is a remainder of what was once a large open expanse of water (U.S. Fish and Wildlife Service 2011). About half of the lagoon is covered by cattail (*Typha domingensis*). The remainder of the lagoon is open water with small patches of sedges (*Cyperus* spp.) and floating vascular plants (water lettuce

[*Pistia stratiotes*] and water hyacinth [*Eichhornia crassipes*]) (Sánchez-Colón 2012, 2015).

Water depth ranges from 0 to about 200 cm. It is one of Puerto Rico's few freshwater lagoons and is classified as a freshwater marsh (Deliz-Quiñones 2005). It is an important freshwater habitat for migrating waterfowl and aquatic birds with historically about half of the species of breeding birds in Puerto Rico being observed in the area.

OBSERVATIONS AND RESULTS

Beginning on 19 January 2016 and continuing through 8 April 2016, ten 8-hour nights were spent observing the WIWD at Laguna Cartagena NWR. WIWD would fly in from the West after sunset and depart to the West before sunrise. The total number of WIWD was counted from an 8 m-tall observation platform using an Exelis night enforcer PVS-14® monocular night vision device. WIWD were counted as they flew into the lagoon and landed on the water to feed. The largest count of WIWD was 153 and the lowest count was 106 with the average total number of WIWD being 131.9 (SE=4.5) (Table 1). Average flock size of WIWD was 4.65 (SE=0.6) with a range of 1 to 23 birds (Table 1). The average largest flock each evening was 15 (SE=2.28), while the average smallest flock was 1 (SE=0) (Table 1). The average arrival time of the first bird was 19:14 Atlantic Standard Time (SE = 0.002). The first birds arrived 2 to 67 minutes (mean = 32.14; SE = 9.03) after sunset. The observed WIWD arrived from the West and departed to the West presumably where they came from. It is likely that they are roosting in the mangroves of Refugio de Aves de Boquerón which is almost directly West of Laguna Cartagena NWR (Fig. 1).

DISCUSSION

We provide the first reports of flock size in WIWD. The flock size in WIWD varied from 23 to 1 with the average being 4.65 (SE=0.6). This wide range with a low average is because there were many small flocks (68% had <5 birds) and few large flocks. Perhaps with WIWD moving from a commonly used day roosting site to the same night feeding area, they do not need to form large flocks to locate the sites.

The total number of WIWD in Puerto Rico based on previously published data was estimated to be 100 (Sorenson 2004), but our counts indicate that there are more than 150 in just one location in southwestern Puerto Rico. The population of WIWD is larger in Puerto Rico than previously thought. Estimating numbers of WIWD is difficult because they are more active at night and are typically roosting in mangroves during the day (Staus 1998). However, counting them at night when they arrive at the feeding site improves the accuracy of the counts.

Laguna Cartagena NWR is likely used as the main feeding site for the WIWD. To keep the WIWD year round, it is suggested not to drain the entire lagoon at the same time so they have a place to feed.

ACKNOWLEDGMENTS

We thank the U.S. Fish and Wildlife service for logistical support and access to Laguna Cartagena NWR. We also thank Dr. Fred Schaffner for comments on earlier versions of this manuscript and Lori Petruski for assistance with some of the WIWD observations. Research on the WIWD was funded by West Virginia University Natural History Museum. This is manuscript number 3296 of the West Virginia University Agriculture and Forestry Experiment Station.

LITERATURE CITED

- BirdLife International. 2013. *Dendrocygna arborea*. The IUCN Red List of Threatened Species 2013. <http://dx.doi.org/10.2305/IUCN.UK.2013-2.RLTS.T22679770A48132607.en> Downloaded on 13 May 2016.
- Collar, N. J., L. P. Gonzaga, N. Krabbe, A. Madrono Nieto, L. G. Naranjo, T. A. Parker III, and D. C. Wege. 1992. Threatened birds of the Americas. The ICBP / IUCN red data book. 3rd edn., pt. 2. International Council for Bird Preservation, Cambridge, UK.
- Deliz-Quiñones, K.Y. 2005. Water quality assessment of a tropical freshwater marsh using aquatic insects. Master's Thesis, University of Puerto Rico, Ponce, Puerto Rico.
- Ottenwalder, J. A. 1997. Situación actual y conservación de la Yaguaza Antillana (*Dendrocygna arborea*) en la República Dominicana. Pitirre 10: 2–10.
- Raffaele, H., J. W. Wiley, O. Garrido, A. Keith, and J. Raffaele. 1998. A guide to the birds of the West Indies. Princeton University Press, Princeton, NJ.
- Sánchez-Colón, Y. M. 2012. Effect of water level fluctuations and rainfall on phosphorus release and binding at a tropical freshwater wetland (Laguna Cartagena, PR). Master's Thesis, Universidad del Turabo, Gurabo, Puerto Rico.
- Sánchez-Colón, Y. M. 2015. Identifying nonpoint sources of phosphorus (P) and nitrogen (N) pollution and dynamics, internal eutrophication and anoxia variability at a tropical freshwater wetland (Laguna Cartagena, Puerto Rico). PhD Dissertation, Universidad del Turabo, Gurabo, Puerto Rico.
- Schaffner, F. C., and Y. M. Sánchez-Colón. 2011. Population trends in West Indian Whistling Ducks and other *Dendrocygna* at Laguna Cartagena, Puerto Rico. Abstract (No. 53, p 77) and presentation, Society for the Conservation and Study of Caribbean Birds, 18th Regional Meeting, July 21-25, 2011, Freeport, Grand Bahama.
- Sorenson, L. G., P.E. Bradley, and A.H. Sutton. 2004. The West Indian Whistling-duck and wetlands conservation project: a model for species and wetlands conservation and education. Journal of Caribbean Ornithology 17(Special issue): 72–80.
- Staus, N. L. 1998. Behaviour and natural history of the West Indian Whistling-Duck *Dendrocygna arborea* on Long Island, Bahamas. Wildfowl 49: 194–206.
- Staus, N. L., and L. G. Sorenson. 1997. West Indian Whistling-Duck (WIWD) workshop summary and draft action plan, prepared for the West Indian Whistling-Duck Working Group of the Society of Caribbean Ornithology. Unpublished report, Society of Caribbean Ornithology.
- U.S. Fish and Wildlife Service. 2011. Comprehensive Conservation Plan Laguna Cartagena National Wildlife Refuge Lajas, Puerto Rico. U.S. Department of the Interior Fish and Wildlife Service Southeast Region Atlanta, Georgia. pp 1-186.

Table 1. Observations of West Indian Whistling-Ducks in Laguna Cartagena NWR, Puerto Rico.

Date	Sunset (AST)	Arrival Time of First Flock	Total # of WIWD	Mean Flock Size (SE)	Flock Range
19 January 2016	19:04		124		
20 January 2016	19:04		153		
22 January 2016	19:04		138		
24 January 2016	19:03	19:05	141		
25 January 2016	19:03	19:13	137		
29 February 2016	18:48	19:10	145	6.9 (1.37)	1–23
10 March 2016	18:41	19:05	106	4.6 (0.9)	1–17
19 March 2016	18:34	19:25	119	3.1 (0.41)	1–11
29 March 2016	18:26	19:15	118	4.4 (0.67)	1–13
8 April 2016	18:18	19:25	137	4.25 (0.63)	1–11
Mean	18:48	19:14	131.8	4.65 (0.6)	1–15

Figure 1. Map of Laguna Cartagena NWR and Refugio de Aves de Boquerón in Puerto Rico.

APPENDIX A. TIME-ACTIVITY BUDGET FIGURES

Figure A. Diurnal time-activity budgets of 3 stiff-tailed diving duck taxa on Laguna Cartagena National Wildlife Refuge. Sample size are shown at the bottom of the bar graph and sex effects are illustrated. Means followed by the same upper case letter, are not significantly different among taxa ($P > 0.05$). Means followed by the same lower case letter are not significantly different between sexes ($P > 0.05$).

Figure B. Nocturnal time-activity budgets of 3 stiff-tailed diving duck taxa on Laguna Cartagena National Wildlife Refuge. Sample size are shown at the bottom of the bar graph and sex effects are illustrated. Means followed by the same upper case letter, are not significantly different among taxa ($P > 0.05$). Means followed by the same lower case letter are not significantly different between sexes ($P > 0.05$).

APPENDIX B. STATISTICAL TEST RESULTS

Table 1. Multivariate analysis of variance for time-activity budgets showing 2-way and 3-way interactions.

	Numerator Df	Denominator Df	Wilks	F-value	P-value
Species	2	5336	0.902	35.32	< 0.001
Sex	1	5337	0.953	32.47	< 0.001
Time	1	5337	0.814	151.92	< 0.001
Species:Sex	2	5336	0.973	8.82	< 0.001
Species:Time	2	5336	0.955	15.31	< 0.001
Sex:Time	1	5336	0.969	21.16	< 0.001
Species:Sex:Time	2	5336	0.993	2.29	0.002

Table 2. Analysis of variance for macroinvertebrates from soil samples.

	Numerator Df	Denominator Df	F-value	P-value
Site	4	137	0.14	0.94
Time	1	137	5.08	0.06
Month	3	137	4.42	0.29
Site:Time	4	137	1.85	0.20
Site:Month	12	127	0.83	0.62
Time:Month	2	137	1.93	0.20
Site:Time:Month	8	137	1.38	0.32

Table 3. Analysis of variance for seeds from soil samples.

	Numerator Df	Denominator Df	F-value	P-value
Site	4	137	2.19	0.53
Time	1	137	2.19	0.23
Month	3	137	1.19	0.08
Site:Time	4	137	1.09	0.30
Site:Month	12	127	1.01	0.39
Time:Month	2	137	1.78	0.25
Site:Time:Month	8	137	0.03	0.64

Table 4. Analysis of variance for macroinvertebrates from D-net samples.

	Numerator Df	Denominator Df	F-value	P-value
Site	4	72	0.06	.80
Time	1	72	1.44	0.23
Month	3	72	0.47	0.69
Site:Time	4	72	0.74	0.39
Site:Month	12	72	1.30	0.38
Time:Month	2	72	0.92	0.77
Site:Time:Month	8	72	1.37	0.32

Table 3. Analysis of variance for seeds from D-net samples.

	Numerator Df	Denominator Df	F-value	P-value
Site	4	72	3.25	0.06
Time	1	72	0.02	0.88
Month	3	72	1.9	0.25
Site:Time	4	72	0.7	0.78
Site:Month	12	72	0.79	0.37
Time:Month	2	72	1.33	0.33
Site:Time:Month	8	72	1.23	0.34

APPENDIX C. MACROINVERTEBRATE AND SEED DATA

Crude protein (% protein) and gross energy values (Kcal/g) are from the following literature:

¹Anderson, J. T. and L. M. Smith. 1998. Protein and energy production in playas: implications for migratory bird management. *Wetlands* 18:437–446.

²Cummins, K. W. and J. C. Wuycheck. 1971. Caloric equivalents for investigations in ecological energetics. International Association of Theoretical and Applied Limnology Communication Number 18.

³Davis, C. A. 1996. Ecology of spring and fall migrant shorebirds in the playa lakes region of Texas. Dissertation, Texas Tech University, Lubbock, TX, USA.

⁴Driver, E. A. 1981. Caloric values of pond invertebrates eaten by ducks. *Freshwater Biology* 11:579–581.

⁵Driver, E. A., L. G. Sugden, and R. J. Kovach. 1974. Caloric, chemical, and physical values of potential duck foods. *Freshwater Biology* 4:281–292.

⁶Haukos, D. A. and L. M. Smith. 1995. Chemical composition of seeds from plants in playa wetlands. *Wildlife Society Bulletin* 23:514–519.

Table 1. Total number of macroinvertebrates for each family found at each sampling site.

Site	Unknown	Protoneridae	Leptoceridae	Lestidae	Chloroperlidae	Veliidae	Haliplidae	Phryganeidae	Seeds
Northern ruddy duck	9	1	1	0	0	2	0	1	32
West Indian ruddy duck	2	2	0	0	0	0	0	0	27
Masked Duck	17	5	0	0	0	4	1	0	12
Random N0.1	4	0	0	1	1	0	0	0	19
Random N0.2	4	0	0	1	1	0	0	0	16
% Protein			56.64 ²	54.5 ³					~10 ⁶
Kcal/g			4.6 ²	5.6 ³					~4.5 ⁶

Site	Chironomidae	Snail	Coenagrionidae	Notonectidae	Aeshnidae	Tipulidae	Libellulidae	Corixidae	Pleidae	Corduliidae
Northern ruddy duck	141	3	18	6	0	1	4	1	0	5
West Indian ruddy duck	66	20	20	0	1	0	25	0	1	3
Masked Duck	195	0	40	2	0	0	11	6	0	2
Random N0.1	78	10	15	10	0	0	26	1	0	4
Random N0.2	78	10	15	10	0	0	26	1	0	4
% Protein	51.5 ¹		67.4 ³	60.2 ¹	63.9 ⁵	43.8 ⁴	64.6 ¹	59.5 ¹		
Kcal/g	3.9 ¹		4.8 ³	4.1 ¹	4.4 ⁵	5.4 ⁴	5.1 ¹	5.3 ¹		