RUSSELL CLAY GEORGE
Reproductive Ecology of the American Oystercatcher (*Haematopus palliatus*) in Georgia
(Under the Direction of SARA H. SCHWEITZER)

This study was initiated in 1999 with the objective of providing the first detailed breeding data for American Oystercatchers nesting at numerous sites and habitats along the Georgia coast. Surveys for oystercatcher clutches and mated pairs were conducted at three sites in 2000 and 2001, and measures of reproductive success and productivity were calculated. The effects of recreation on oystercatcher breeding were monitored at the same sites in 2001. Reproductive success was low and variable, but consistent with previous studies. Common causes of clutch failure were predation and flooding during storms. Reproductive success was slightly lower at marsh habitats than at beaches and sand spits, due to increased rates of flooding at marsh habitats. Recreation appeared to affect reproductive success negatively by influencing nesting habitat selection: more pairs nested in marsh habitats at sites where beaches were highly disturbed. Management should continue to address the need for undisturbed beach and sand spit habitat.

INDEX WORDS: American Oystercatcher, *Haematopus palliatus*, Georgia, Breeding, Reproductive success, Productivity, Shorebirds, Recreation, Human disturbance, GIS

REPRODUCTIVE ECOLOGY OF THE AMERICAN OYSTERCATCHER (*HAEMATOPUS PALLIATUS*) IN GEORGIA

by

RUSSELL CLAY GEORGE

B.A., The University of North Carolina at Chapel Hill, 1997

A Thesis Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree

MASTER OF SCIENCE

ATHENS, GEORGIA

2002

REPRODUCTIVE ECOLOGY OF THE AMERICAN OYSTERCATCHER

(*HAEMATOPUS PALLIATUS*) IN GEORGIA

by

RUSSELL CLAY GEORGE

Approved:

Major Professor: Sara H. Schweitzer

Committee: Robert Cooper
Cecil A. Jennings

Electronic Version Approved:

Gordhan L. Patel
Dean of the Graduate School
University of Georgia
August 2002

ACKNOWLEDGMENTS

I would first like to thank my advisor, Sara Schweitzer, for arranging such a wonderful project and for taking a chance on a then under-experienced graduate student to initiate it. This project has been the opportunity of a lifetime, and for that opportunity, I am truly grateful. Secondly, but no less importantly, I would like to thank Brad Winn for his endless patience, instruction, and assistance in the field. His dedication to Georgia's shorebirds was instrumental to the success of this project and is hopefully reflected in the following pages. But most of all, I would like to thank my wonderful wife, Jennifer, for her undying support over the last three years.

Numerous people provided invaluable help, both in Athens and at the coast. Thanks to my committee members, Robert Cooper and Cecil Jennings for their many comments. Thanks also to Chris Fonnesbeck for statistics help and Karen Paine, Jeanne Epstein, and Trip Lowe for GIS help. I appreciate the help of those who assisted in various other ways including, Angie Cone, Andrew Walde, Phil Hale, Mark Dodd, Adam Mackinnon, Barb Zoodsma, Tyler Gault, Eric Kellon, Royce Hayes, Terry Norton, Deb Beirrero, Kelly and Jeff Spratt, and Andre and Laura Nel.

I am especially grateful to those involved in funding this project, including Mike Harris at the Georgia Department of Natural Resources, Nongame and Endangered Wildlife Section, Arnett Mace at the D. B. Warnell School of Forest Resources, and the Georgia Ornithological Society. Thanks also to the Nature Conservancy, Altamaha Bioreserve and the Georgia Department of Natural Resources, Game Management Division for assistance with housing.

TABLE OF CONTENTS

Page

ACKNOWLEDGMENTS iv

CHAPTER

1 INTRODUCTION 1

Life History 2

Status and Conservation 6

Study Overview 7

Literature Cited 8

2 REPRODUCTIVE SUCCESS OF AMERICAN OYSTERCATCHERS IN GEORGIA 13

Abstract 14

Introduction 15

Methods 16

Results 19

Discussion 23

Acknowledgments 28

Literature Cited 29

3 REPRODUCTIVE SUCCESS OF AMERICAN OYSTERCATCHERS AT MANAGED SITES IN GEORGIA 32

Abstract 33

Introduction 34

Methods 35

Results 38

Discussion 42

Acknowledgments 45

Literature Cited 45

4 THE EFFECTS OF HUMAN RECREATION ON AMERICAN OYSTERCATCHER REPRODUCTIVE SUCCESS AND NESTING HABITAT SELECTION IN GEORGIA 50

Abstract 51

Introduction 52

Methods 53

Results 58

Discussion 64

Acknowledgments 66

Literature Cited 67

5 CONCLUSIONS 70

Future Research Needs 73

Management Suggestions 74

Literature Cited 76

APPENDIX

A PARAMETERS OF AMERICAN OYSTERCATCHER CLUTCHES AT THREE SITES IN COASTAL GEORGIA, MARCH-JULY, 2000 AND 2001 78

CHAPTER 1

INTRODUCTION

In the first scientific survey of the Georgia coast, Johnson and Hillestad (1974) predicted that the future of Georgia's coastal islands "no doubt will be based upon either their value for intensive residential and recreational development or their ecological and aesthetic values as relatively natural areas." Twenty-seven years later, these often conflicting values continue to divide lawmakers, developers, residents, and others on the issues surrounding Georgia's coastal resources. With only 160 linear km of coastline, Georgia has more undisturbed coastline than any other state on the Atlantic Seaboard. Two-thirds of Georgia's barrier islands are parks, refuges, or preserves, and Georgia's 150,000 ha of coastal marshes constitute about one-third of the remaining salt marsh on the Atlantic Coast (Georgia Coastal Management Program 1997). However, the population of coastal Georgia is growing by approximately 20% per decade (Georgia Coastal Management Program 1997). When coupled with a growing tourism industry that generated an estimated $1.4 billion in 1993 alone (Georgia Coastal Management Program 1997), the conflict among population growth, economics, and conservation is intensifying.

One component of the ecosystem that may be especially vulnerable to human impacts is Georgia's population of nesting shorebirds (family Charadriiformes). Each spring, the shorebird nesting season peaks with the onset of coastal recreational activities (i. e., fishing, boating, sunbathing). Although most of Georgia's barrier islands are inaccessible by car, nearly 25,000 boats were registered along the coast in 1997 and 40 marinas and 36 public boat ramps serviced the area (Georgia Coastal Management Program 1997). The resulting increase in recreation and its potential to affect nesting shorebirds negatively led the Georgia Department of Natural

Resources (DNR) to establish recreation restrictions at certain important shorebird nesting sites. This action generated considerable concern from commercial fishing and recreational interests because, historically, all of Georgia's beachfront has been open to public recreational use.

The purpose of this project was to examine the reproductive success, status, and effects of recreational disturbance on one of Georgia's resident shorebird species—the American Oystercatcher (*Haematopus palliatus*). The American Oystercatcher was an ideal specimen for such a study because it is easily identified, it nests on open beaches and estuarine habitats throughout coastal Georgia, it is intolerant of human disturbance, and little is known about the Georgia population (Rappole 1981; Nol and Humphrey 1994; Winn 2000). Furthermore, the American Oystercatcher is a state-listed rare species (Ozier *et al*. 1999) and a species of high concern in the recently completed U.S. Shorebird Conservation Plan (Brown *et al.* 2001). Conservation of American Oystercatcher nesting habitat could also benefit other state-listed, beach nesting species, including the Least Tern (*Sterna antillarum*), Gull-billed Tern (*S. nilotica*), and Wilson's Plover (*Charadrius wilsonia*; Ozier *et al*. 1999). Previous shorebird studies conducted along the Georgia Coast have suggested that human disturbance may affect reproductive success of American Oystercatchers and other shorebird species negatively (Rappole 1981; Corbat 1990; Plauny *unpublished data*). However, in each of these studies, either quantifiable data regarding human disturbance were noticeably missing or sample sizes were too small to draw meaningful conclusions. The study reported herein was the first in Georgia to focus explicitly on the reproductive ecology of the American Oystercatcher.

LIFE HISTORY

The American Oystercatcher is a relatively large, conspicuous, black, brown, and white shorebird attaining a length of 40-44 cm and a weight of 400-700 g (Nol and Humphrey 1994). Its most distinguishing characteristic is its long, tapered, bright orange bill which it uses to pry open bivalves (class Bivalvia) and probe for marine invertebrates. The American Oystercatcher is one of as many as eleven species of oystercatchers found throughout the world and the only oystercatcher native to the Atlantic coast of North America (Nol and Humphrey 1994). American Oystercatchers breed locally along the Atlantic coast from Nova Scotia, south to Florida, along the Gulf and Carribean coasts, locally throughout the Greater and Lesser Antilles, and along the Atlantic coast of South America from Venezuela, southward to central Argentina. A western race also breeds locally along the Pacific coast from Baja California, southward to Costa Rica and Chile (Nol and Humphrey 1994; American Ornithologists Union 1998; Davis 1999). Although little is known about the migratory habits of the northern Atlantic sub-population, breeding birds from the Mid-Atlantic and New England coasts are believed to travel south for the winter, congregating in flocks along with resident birds from the Southeastern coast. Once spring approaches, northern birds presumably disperse northward while Southeastern birds remain to breed (Tomkins 1954; Nol and Humphrey 1994).

Oystercatchers' diets consist predominately of bivalves and other large marine invertebrates (Bent 1929; Tomkins 1947; Johnsgard 1981; Nol 1989). Individuals forage within a variety of coastal micro-habitats, including oyster beds, beaches, and tidal flats. In addition to bivalves, prey items may include: marine worms (order Polychaeta), Mole Crabs (*Emerita talpoida*), limpets (*Aemaeu* spp.), jellyfish (class Scyphozoa), sea urchins (*Strongylocentratus* spp.), starfish (*Asteria* spp.), and numerous species of crabs (order Decapoda; Bent 1929;Tomkins 1947; Post and Raynor 1964; Siegel-Causey 1991; Nol and Humphrey 1994). Most food habits studies have depended on visual observations of foraging birds (Tomkins 1947; Post and Raynor 1964; Cadman 1980; Nol 1989; Tuckwell and Nol 1997*a*, *b*) and early reports of stomach contents from gunshot birds (Bent 1929; Tomkins 1947). A study of ten birds collected in Argentina found that stomach contents consisted primarily of marine worms (69%), aquatic worms (Lumbriculidae; 13%), and crabs (*Eurypodius latreilli*; 11%; Siegel-Causey 1991). The wide assortment of prey items taken and habitats utilized by American Oystercatchers seem to repudiate early theories that the species' distribution is limited by their dependency on oysters (*Crassostrea virginica*; Tomkins 1947). To date, no studies have found a convincing link between food supply and reproductive performance in American Oystercatchers (Nol 1989).

Like other Charadriiformes, the American Oystercatcher is long-lived. Re-sightings of banded individuals confirm that birds routinely exceed ten years of age (Nol and Humphrey 1994) and some individuals probably survive 20-40 years like the closely related European Oystercatcher (*Haematopus ostralegus*; Ens *et al*. 1996; Davis 1999). Breeding is delayed until the third or fourth year (Nol and Humphrey 1994). Oystercatchers are generally monogamous and a pair bond may last for multiple seasons (Nol 1985). Once the winter flocks disband, breeding pairs disperse to their breeding grounds where they defend a nesting territory from other oystercatchers. Competition for high quality sites can be intense, resulting in aggressive intraspecific interactions. If nesting territories lack sufficient foraging resources, pairs may also defend separate foraging territories up to 300 m away (Cadman 1979; Nol 1985). Conversely, oystercatchers often nest peaceably within tern (*Sterna* spp.) and Black Skimmer (*Rhynchops niger*) colonies (Nol and Humphrey 1994). Highly sought nesting habitats are open, undisturbed, sand or shell substrates, well above high tide with little to moderate vegetation, such as those found on beaches, sand spits, and large oyster-shell rakes (Bent 1929; Tomkins 1954; Post and Raynor 1964; Rappole 1981; Shields and Parnell 1990). Clutch initiation occurs in March in southern locations and as late as June more northward (Nol *et al*. 1984; Nol and Humphrey 1994; *this study*). The nest consists of a shallow scrape on sand or shells, occasionally lined with surrounding shells, wrack, and other debris. Clutch size ranges from one to three eggs; four eggs occur rarely (Nol and Humphrey 1994). Communal nesting has been documented in Texas

(Chapman 1982), New York (Lauro *et al*. 1992; Zarudsky 1985), Massachusetts, and Maryland (Nol and Humphrey 1994), resulting in as many as six eggs. Such interactions usually occur between three or four individuals, and apparently result from high breeding densities in combination with nesting habitat scarcity (Lauro *et al*. 1992). Incubation lasts 24-27 days and is performed by both sexes (Baicich and Harrison 1997). If successful, pairs only nest once per season. If unsuccessful, second and third re-nesting attempts may continue into July (Nol *et al*. 1984; *this study*). Hatchlings are precocial, in the sense that they are fully downed and mobile at hatching. However, chicks are almost completely dependent on adults for food during the 35-day hatchling period and the first month of the fledgling period (Nol and Humphrey 1994).

Annual fecundity in American Oystercatchers is relatively low and erratic, with pairs producing as few as one hatchling every four years (Nol 1989; Davis *et al*. 2001). Loss of eggs and chicks commonly results from predation by Raccoon (*Procyon lotor*), Feral Cats (*felis domesticus*), Mink (*Mustela vison*), Red Fox (*Vulpes vulpes),* gulls (*Larus* spp.), and crows (*Corvus* spp.), or from flooding during storms and high spring tides (Baker and Cadman 1980; Nol 1989; Corbat 1990; Nol and Humphrey 1994; Davis *et al*. 2001). Human disturbance may further reduce reproductive success (Nol and Humphrey 1994; Toland 1999; Davis *et al*. 2001; *this study*). Adult oystercatchers flush quickly from nests when disturbed by humans, making eggs and chicks vulnerable to avian predators and domestic pets, and overheating on hot sand (Rappole 1981; Toland 1999). Death of chicks has also been caused by vehicles when driving is allowed on beaches (Davis *et al*. 2001). Numerous studies have documented an increase in nesting on isolated sand spits, dredge spoil islands, marsh islands, and other atypical sites (Frohling 1965; Cadman 1979; McNair 1988; Lauro and Burger 1989; Shields and Parnell 1990; Toland 1992). Use of such sites for nesting has occurred presumably in response to increased disturbance of beach habitats by humans, but whether this trend is lowering reproductive success in American Oystercatchers is unclear. While Lauro and Burger (1989) found that marsh nesting in Virginia resulted in reduced reproductive success (due to higher instances of nest flooding in marsh habitats), Toland (1992) found that reproductive success was higher on dredge spoil islands in Florida. Regardless, both authors hypothesized that the use of atypical nesting habitat was related to a reduction in the availability of traditional habitats as a consequence of increased human disturbance.

STATUS AND CONSERVATION

Oystercatcher populations in North America reached their lowest levels toward the end of the 19th century because of unrestricted egg collecting and market hunting (Bent 1929). By this time, oystercatchers had been extirpated from the northern half of their range and were scarce throughout the remainder of their range, including Georgia (Erichsen 1921). With the passage of the Migratory Bird Treaty Act in 1918, direct human impacts were reduced considerably and oystercatchers began to reclaim much of their former range. By the 1930s, American Oystercatchers were once again common along the Virginia portion of the Delmarva Peninsula. Viable populations soon followed in the Carolinas and Georgia. Re-expansion into New York occurred by 1957 (Post and Raynor 1964), Massachusetts by 1969 (Finch 1970; Humphrey 1990), and most recently into Nova Scotia in 1997 (Davis 1999). Nonetheless, the total U.S. breeding population has been estimated to be as low as 1,600 to 3,000 pairs (Davis *et al*. 2001).

Despite their continued northward expansion, concern exists regarding the stability and trajectory of the southeastern breeding population. Recent studies indicate that breeding numbers may be declining in the species' traditional stronghold of Virginia and the Carolinas (Davis *et al*. 2001). For this reason, the American Oystercatcher has been listed as a species of extremely high priority in the U.S. Shorebird Conservation Plan, Southeastern Coastal Plain–Carribean Regional Shorebird Plan (Hunter 2001). The American Oystercatcher remains a state-listed rare species in

Georgia (Ozier *et al*. 1999), with an estimated state-wide breeding population of about 100 pairs (Winn 2000). Oystercatchers are also a state-listed threatened species in Florida (Below 1996) and a species of special concern in Alabama (Holliman 1986). Low numbers in Florida are attributed to human population increases in coastal areas, especially along the Atlantic coast (Below 1996; Toland 1999). The reason for low numbers in Georgia and elsewhere remain largely unclear.

Rappole (1981) was the first to survey the Georgia breeding population of American Oystercatchers and estimated its number at 70 pairs. By targeting predominately barrier islands and surveying areas only once, his estimate may have been low. Nonetheless, Rappole believed that reproductive success was low and that Georgia should be capable of sustaining two to three times its then current breeding population. After concluding that reproductive success was being suppressed by excessive predation and human disturbance, he offered numerous management suggestions, including posting signs around breeding sites, erecting predator-excluding fencing, controlling predators directly, enhancing breeding sites (burning vegetation, dumping new spoil), and coordinating efforts among state officials and local landowners (Rappole 1981). Corbat (1990) supported most of Rappole's suggestions and urged that recreational activities be restricted at certain frequently disturbed nesting sites. Georgia DNR subsequently has followed many of these recommendations, such as prescribed burning and posting signs at some nesting sites, limiting recreational access at certain state-owned breeding islands, and also conducting annual winter and summer shorebird surveys. Additionally, Georgia DNR is in the process of formulating a comprehensive state-wide shorebird conservation plan (B. Winn *pers. comm.*).

STUDY OVERVIEW

This study had three overall objectives, which are addressed in the following three chapters. The first objective was to gather accurate baseline data regarding the reproductive ecology of American Oystercatchers in Georgia. To accomplish this, surveys for pairs and nests were conducted from March to July, of 2000 and 2001, within three study sites with the highest densities of nesting oystercatchers in the state (Winn 2000). In doing so, estimates of reproductive success and overall production were obtained for oystercatchers nesting in a variety of coastal habitats. Possible causes of nest and chick failure were also identified. The second objective was to identify factors affecting reproductive success of oystercatchers at Georgia DNR-managed shorebird breeding sanctuaries. Each of three study sites contained at least one such site. The third and final objective was to assess the effects of human recreation on breeding oystercatchers in Georgia. To accomplish this, the effects of recreation on breeding distribution were analyzed spatially with the use of Geographical Information System (GIS) software. A project summary, possible management implications, and further research suggestions follow in the fifth and final chapter.

LITERATURE CITED

American Ornithologists Union. 1998. Check-list of North American birds, Seventh edition. The American Ornithologists' Union, Washington, D.C.

Baicich, P. J., and C. J. O. Harrison. 1997. A guide to the nests, eggs and nestlings of North American birds. Second edition. Academic Press, London.

Baker, A. J., and M. Cadman. 1980. Breeding schedule, clutch size and egg size of American Oystercatchers (*Haematopus palliatus*) in Virginia. Wader Study Group Bulletin 32: 33.

Below, T. H. 1996. American Oystercatcher. Pages 230-235 *in* Rare and endangered biota of Florida, volume 5, birds (J. A. Rodgers, Jr., H. W. Kale, and H. T. Smith, Eds.). University of Florida, Gainesville, FL.

Bent, A. C. 1929. Life histories of North American shore birds. Part 2. U.S. National Museum Bulletin, Number 146. Washington, D.C.

Brown, S., C. Hickey, B. Harrington, and R. Gill, editors. 2001. The U.S. shorebird conservation plan, second edition. Manomet Center for Conservation Sciences, Manomet, MA.

Cadman, M. 1979. Territorial behavior in American Oystercatchers (*Haematopus palliatus*). Wader Study Group 27: 40-41.

_____. 1980. Age-related foraging efficiency of the American Oystercatcher (*Haematopus palliatus*). Thesis, University of Toronto, Toronto, ON.

Corbat, C. A. 1990. Nesting ecology of selected beach-nesting birds in Georgia. Dissertation, University of Georgia, Athens, GA.

Davis, M. B. 1999. Reproductive success, status, and viability of the American Oystercatcher (*Haematopus palliatus*). Thesis, North Carolina State University, Raleigh, NC.

_____, T. R. Simons, M. J. Groom, J. L. Weaver, and J. R. Cordes. 2001. The breeding status of the American Oystercatcher on the east coast of North America and breeding success in North Carolina. Waterbirds 24: 195-202.

Ens, B. J., K. B. Briggs, U. N. Safriel, and C. J. Smit. 1996. Life history decisions during the breeding season. Pages 186-218 *in* The oystercatcher, from individuals to populations (J. D. Goss-Custard, Ed.). Oxford University Press, New York, NY.

Erichsen, W. J. 1921. Notes on the habits of the breeding water birds of Chatham County, Georgia. Wilson Bulletin 33: 82.

Finch, D. W. 1970. The nesting season: June 1, 1970-August 15, 1970, Northeastern Maritime region. American Birds 24: 662.

Frohling, R. C. 1965. American Oystercatcher and black Skimmer nesting on salt marsh. Wilson Bulletin 77: 193-194.

Georgia Coastal Management Program. 1997. Combined coastal management program and final environmental impact statement for the state of Georgia. U.S. Department of Commerce, Office of Ocean and Coastal Resource Management, National Oceanic and Atmospheric Administration. Silver Spring, MD.

Holliman, D. C. American Oystercatcher. Pages 91-93 *in* Vertebrate Animals of Alabama in Need of Special Attention. R. H. Mount, editor. Alabama Agricultural Experiment Station, Auburn University, Auburn, Alabama, USA.

Humphrey, R. C. 1990. Status and range expansion of the American Oystercatcher on the Atlantic coast. Transactions of the Northeast Section of the Wildlife Society 47: 54-61.

Hunter, W. C. 2000. U.S. shorebird conservation plan: southeastern coastal plain—Carribean regional shorebird plan. U.S. Fish and Wildlife Service. Atlanta, GA.

Johnsgard, P. A. 1981. The plovers, sandpipers and snipes of the world. University of Nebraska, Lincoln, NE.

Johnson, A. S., H. O. Hillestad, S. F. Shanholtzer, and G. F. Shanholtzer. 1974. An ecological survey of the coastal region of Georgia. National Park Service scientific monograph series, Number 3. Washington, D.C.

Lauro, B., and J. Burger. 1989. Nest-site selection of American Oystercatcher (*Haematopus palliatus*) in salt marshes. Auk 106: 185-192.

_____, E. Nol, and M. Vicari. 1992. Nesting density and communal breeding in the American Oystercatcher. Condor 94: 286-289.

McNair, D. 1988. Atypical nest-site in the American Oystercatcher in South Carolina. Chat 52: 11-12.

Nol, E. 1985. Sex roles in the American Oystercatcher. Behaviour 95: 232-260.

_____. 1989. Food supply and reproductive performance of the American Oystercatcher in Virginia. Condor 91: 429-435.

_____, A. J. Baker, and M. D. Cadman. 1984. Clutch initiation dates, clutch size and egg size of the American Oystercatcher in Virginia. Auk 101: 855-867.

_____, and R. C. Humphrey. 1994. American Oystercatcher. Pages 1-20 *in* The birds of North America, number 82 (A. Poole and F. Gill, Eds.). Academy of Natural Sciences, Philadelphia, PA.

Ozier, J. C., J. L. Bohannon, and J. L. Anderson, project coordinators. 1999. Protected animals of Georgia. Georgia Department of Natural Resources, Wildlife Resources Division, Nongame Wildlife-Natural Heritage Section. Social Circle, GA.

Post, P. W., and G. S. Raynor. 1964. Recent range expansion of the American Oystercatcher into New York. Wilson Bulletin 76: 339-346.

Rappole, J. H. 1981. Management possibilities for beach-nesting shorebirds in Georgia. Pages 114-126 *in* Proceedings of the nongame and endangered wildlife symposium (R. R. Odum and J. W. Guthrie, Eds.). Georgia Department of Natural Resources, Game and Fish Division, Technical Bulletin WL 5.

Shields, M. A., and J. F. Parnell. 1990. Marsh nesting by American Oystercatchers in North Carolina. Journal of Field Ornithology 61: 431-433.

Siegel-Causey, D. 1991. Foraging habitat selction by American and Megellanic Oystercatchers (*Haematopus pailliatus* and *H. leucopodus*) on Patagonian tidal flats. Canadian Journal of Zoology 69: 1636-1643.

Toland, B. 1992. Use of forested spoil islands by nesting American Oystercatchers in southeast Florida. Journal of Field Ornithology 63: 155-158.

_____. 1999. Nest site charactersitics, breeding phenology, and nesting success of American Oystercatchers in Indian River County, Florida. Florida Field Naturalist 27: 112-116.

Tomkins, I. R. 1947. The oyster-catcher of the Atlantic coast of North America and its relation to oysters. The Wilson Bulletin. 59: 204-208.

_____. 1954. Life history notes on the American oyster-catcher. The Oriole 19: 37-45.

Tuckwell, J., and E. Nol. 1997a. Foraging behavior of American Oystercatchers in response to declining prey densities. Canadian Journal of Zoology 75: 170-181.

_____, and _____. 1997b. Intra- and inter-specific interactions of foraging American Oystercatchers on an oyster bed. Canadian Journal of Zoology 75: 182-187.

Winn, B. 2000. The spatial distribution of American Oystercatchers in Georgia. The Oriole 65: 41-49.

CHAPTER 2

REPRODUCTIVE SUCCESS OF AMERICAN OYSTERCATCHERS IN GEORGIA[1]

[1] George, R. C., S. H. Schweitzer, and B. Winn. 2002. To be submitted to *Waterbirds*.

ABSTRACT

Surveys of American Oystercatcher (*Haematopus palliatus*) pairs and their clutches were conducted at three sites in coastal Georgia (Wassaw, St. Catherine's, and Altamaha) from March to July, 2000 and 2001. Clutches were documented and followed until fledging or failure, and the number of mated pairs at each site was estimated. Mean clutch size, hatching success, fledging success, probability of clutch survival to hatching (Mayfield estimates), and fledgling production were calculated for each site and year. Hatching and fledging success were also calculated with respect to beach, sand spit, and marsh habitats. Overall clutch size was 2.0 eggs per clutch in 2000 and 2001. Hatching success ranged from 0 to 30% among sites and years; Mayfield estimates were slightly higher (3-33%). Fledging success ranged from 0 to 25% and fledgling production ranged from 0.00 to 0.25 fledglings per pair. Measures of reproductive success were lowest at Wassaw in 2000 and 2001 where no young fledged. Most clutches failed because of flooding (34%) and predation (17%), although 47% of clutches failed for undetermined reasons. Hatching success and fledging success were slightly lower at marsh habitats than at beaches and sand spits in 2000 and 2001, due to increased rates of flooding at marshes. Clutch size was smaller than documented in previous studies; hatching and fledging success, Mayfield estimates, and fledgling production were consistent with previous studies in North Carolina and Virginia, where oystercatcher populations may be in decline.

Key Words

American Oystercatcher, *Haematopus palliatus*, shorebirds, Georgia, productivity, reproductive success.

INTRODUCTION

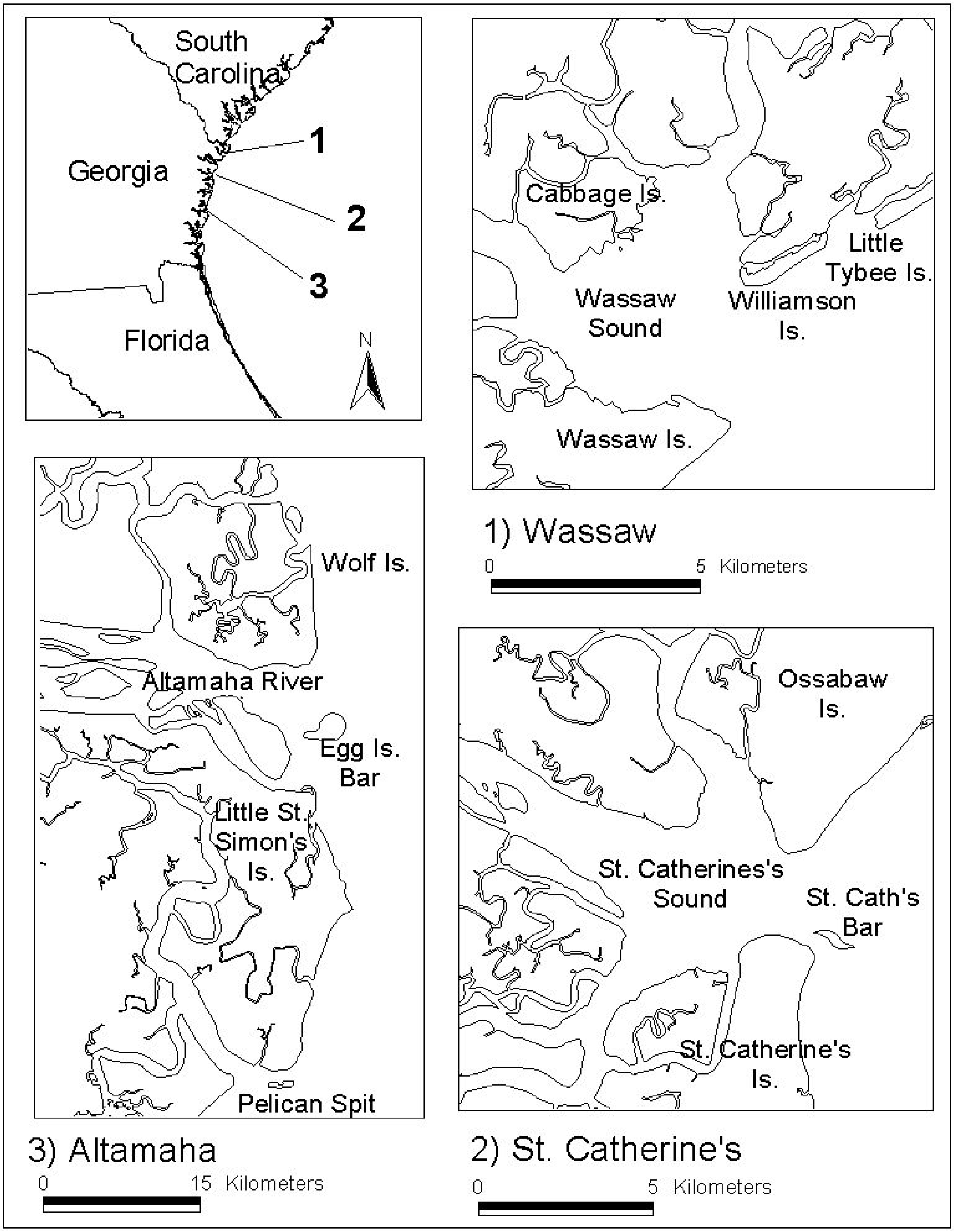
Compared to much of the Atlantic coast, Georgia's coastline remains relatively pristine and undeveloped. Nonetheless, human impacts on Georgia's coastal resources have increased markedly in recent decades due to a rapidly increasing human population (Georgia Coastal Management Program 1997). The resulting increase in coastal development and recreation throughout the region has generated new concern over the status of Georgia's nesting shorebird species, in particular, the American Oystercatcher (*Haematopus palliatus*). American Oystercatchers are currently listed as a species of extremely high priority in the Southeastern Coastal Plain–Carribean Regional Shorebird Plan (Hunter 2000) because of loss of habitat along the southeastern coast and perceived population declines on the Atlantic coast of Florida and in the species' historical stronghold of Virginia, North Carolina, and South Carolina (Hunter 2000; Davis *et al*. 2001). With a total U.S. population of as few as 3,000 individuals, naturally low levels of annual productivity, and diminishing habitat due to coastal development, oystercatchers could be especially susceptible to long-term population declines (Nol and Humphrey 1994; Davis 1999; Davis *et al*. 2001). Despite their listing as a Georgia state-listed rare wildlife species (Ozier *et al*. 1999), few studies have been conducted in Georgia and the status of the state's oystercatcher population has remained largely speculative.

Considered common in Georgia during the nineteenth century, American Oystercatcher numbers were reduced considerably by the early twentieth century from unregulated hunting and egg collecting (Erichsen 1921; Bent 1929). Oystercatchers began a slow recovery following the passage of the Migratory Bird Treaty Act (1918) and as many as 35 pairs nested on the Georgia coast by mid-century (Burleigh 1958). The first Georgia coastal-wide survey of American Oystercatchers in 1980 produced an estimate of 70 nesting pairs (Rappole 1981) and aerial surveys in 1999 placed the state breeding population at about 100 pairs (Winn 2000). Despite this increase, oystercatchers have proliferated only in Georgia's more remote areas: only one pair was known to have nested on one of Georgia's four developed islands between 1999 and 2001 (Winn 2000; Brad Winn *pers. comm.*). About half of the state's oystercatchers currently nest on undeveloped barrier island beaches that are accessible only by boat. The remaining half of the population nests on sand spits, marsh islands, dredge spoil islands, and oyster-shell rakes scattered throughout Georgia's extensive network of inshore marshes and estuaries (Winn 2000). Logistical concerns associated with conducting studies in such remote habitats confined previous studies of oystercatchers in Georgia to individual islands with relatively low densities of nesting pairs, thus limiting their scope (Corbat 1980; Plauny 1999, *unpublished data*). This study was initiated in 2000 and sought to provide sound baseline data for selected sites in coastal Georgia with high densities of oystercatchers nesting in a variety of habitats. The purpose of this paper is to summarize reproductive effort, reproductive success, and productivity data for American oystercatchers nesting at three such sites.

METHODS

Surveys of nesting American Oystercatchers were conducted by boat and on foot from March to July, 2000 and 2001, at three study sites in coastal Georgia: 1) Wassaw, 2) St. Catherine's, and 3) Altamaha (Fig. 2.1). Altogether, the three study sites constituted about 38 linear km (~25%) of Georgia's 160-km shoreline. When a mated pair was observed, its location was charted on a map. If incubating, the nest was marked at a distance with a numbered stake and nest number, nest coordinates (using a Trimble Geoexplorer handheld Global Positioning System unit), clutch size, and habitat type were recorded. Sites were revisited approximately every five to six days and clutch status was noted. Hatching success and fledging success were defined as hatching or fledging one egg or fledgling, respectively. Cause of clutch failure during

Figure 2.1. Locations of three study sites in coastal Georgia, USA: 1) Wassaw, 2) St. Catherine's, and 3) Altamaha.


South Carolina
Georgia
Florida
1
2
3
N
Cabbage Is.
Little Tybee Is.
Wassaw Sound
Williamson Is.
Wassaw Is.
1) Wassaw
0
5 Kilometers
Wolf Is.
Altamaha River
Egg Is. Bar
Little St. Simon's Is.
Pelican Spit
3) Altamaha
0
15 Kilometers
Ossabaw Is.
St. Catherines's Sound
St. Cath's Bar
St. Catherine's Is.
2) St. Catherine's
0
5 Kilometers

the egg stage was surmised when possible from predator tracks, broken eggs, or evidence of flooding.

Hatching success and fledging success were calculated as percentages of total nesting attempts. Probability of clutch survival to hatching was calculated using the Mayfield method (Mayfield 1961, 1975) and an average incubation period of 26 days. The 26-day average incubation period was calculated from a set of 14 clutches documented during 2001 and was within the range of previous studies (Nol and Humphrey 1994). Following Davis *et al.* (2001), fledgling production at each site was estimated as the ratio of fledglings produced per estimated number of breeding pairs. Differences in hatching success, fledging success, and probability of nest survival among sites were compared using 95% confidence intervals (Samuels 1989). Hatching success and fledging success were also compared among three habitat types: 1) beach, 2) sand spit, and 3) marsh (included oyster-shell rakes and small marsh islands). Sand spits did not exist at Wassaw and oystercatchers did not use marsh habitats at Altamaha, so nest data were pooled across study sites for comparisons among habitat types. Consequently, analysis of habitat effects could be confounded by differences in overall habitat quality among respective study sites.

RESULTS

The first American Oystercatcher clutches were found on 31 March 2000 and 22 March 2001. Clutch initiation peaked in late April both years, with replacement clutches peaking in mid-May. During 2001, smaller peaks of second and possibly third replacement clutches occurred in early and late June. Final clutches were found on 21 June 2000 and 29 June 2001. Of 72 nests documented during 2000, clutch size averaged 2.0 eggs (mode = 2.0 eggs, SE = 0.1 eggs). More nests were documented in 2001 (N = 137), but mean clutch size was also 2.0 eggs (mode = 2.0 eggs, SE = 0.01 eggs). The increase in nests found during 2001 was due to a 9%

increase in pairs, more replacement clutches due to widespread clutch failure early in the season, and more complete surveys at Little St. Simon's Island (located within the Altamaha site).

During 2000, 21% of clutches hatched at least one egg and 13% of clutches fledged at least one chick (N = 72). Based on a 26-day incubation period, the probability of clutch survival to hatching in 2000 was 26% (Table 2.1). Hatching success and probability of clutch survival were similar among study sites in 2000, but fledging success was greater at Altamaha (24%) than at Wassaw (0%; Table 2.1) in 2000. Eight of nine clutches producing fledglings in 2000 were located at Altamaha. During 2001, 12% of clutches hatched at least one egg and 5% fledged at least one chick (N = 137). Probability of clutch survival to hatching was 13% in 2001. Hatching success and probability of clutch survival in 2001 were greater at Altamaha (17% and 18%, respectively) and St. Catherine's (20% and 25%, respectively) than at Wassaw where all clutches failed (N=40; Table 2.1). Five of six clutches that fledged young during 2001 occurred at Altamaha (N = 77). One clutch fledged young at St. Catherine's both years (Table 2.1). An estimated 65 pairs defended territories within the 3 study sites during 2000, resulting in total production of 0.17 fledglings per pair (N = 11 fledglings; Table 2.2). During 2001, 75 pairs were documented, resulting in total production of 0.12 fledglings per pair (N = 9 fledglings). Productivity was similar among the Altamaha and St. Catherine's study sites during 2000, but was lower at St. Catherine's than at Altamaha during 2001 (Table 2.2). Pairs at Wassaw did not produce fledglings during this study.

Clutch loss was due primarily to flooding during spring tides and storms (34%) and depredation (17%). However, cause of failure was undetermined for 47% of clutches. The effects of avian predators were difficult to assess in all habitats and tracks of mammalian predators were indiscernible in coarse substrate of shell rakes, so depredation was probably underestimated. Raccoon (*Procyon lotor*) and Mink (*Mustela vison*) were common at marsh and

Table 2.1. Clutch size, hatching, success, fledging success, and probability of clutch hatching of American Oystercatchers nesting at three study sites in Georgia, March-July, 2000 and 2001. Like superscripts indicate similar means or percentages among study sites during respective years as determined by overlap of 95% confidence intervals (CI). Success was defined as hatching or fledging one hatchling or fledgling, respectively.

Year	Study site	No. of clutches	Clutch size		No. hatched clutches	Hatching success		No. fledged clutches	Fledging success		Probability of clutch hatching	
			mean	SE		%	CI		%	CI	%	-,+ CI
2000	Altamaha	34	1.9	0.1	10	30	14^{A}	8	24	14^{A}	33	$12, 84^{A}$
	St. Catherine's	17	2.2	0.2	2	12	17^{A}	1	6	$15^{A,B}$	17	$10, 58^{A}$
	Wassaw	21	2.0	0.2	3	14	16^{A}	0	0	0^{B}	22	$11, 66^{A}$
	Total	72	2.0	0.1	15	21	9	9	13	8	26	8, 62
2001	Altamaha	77	2.0	0.1	13	17	8^{A}	5	7	6^{A}	18	$12, 28^{A}$
	St. Catherine's	20	2.4	0.1	4	20	17^{A}	1	5	$13^{A,B}$	25	$12, 50^{A}$
	Wassaw	40	1.8	0.1	0	0	0^{B}	0	0	0^{B}	3	$1, 8^{B}$
	Total	137	2.0	0.01	17	12	6	6	5	4	13	9, 20

Table 2.2. Fledgling production in American Oystercatchers at three study sites in Georgia, March-July, 2000 and 2001.

Year	Study site	Estimated no. of pairs	No. of fledglings produced	Fledglings produced per pair
2000	Altamaha	33	8	0.24
	St. Catherine's	12	3	0.25
	Wassaw	20	0	0.00
	Total	65	11	0.17
2001	Altamaha	44	8	0.18
	St. Catherine's	12	1	0.08
	Wassaw	19	0	0.00
	Total	75	9	0.12

beach habitats, and were suspected in depredating most clutches at those habitats. Mammalian predators were absent from sand spits, but nests were frequently depredated by Laughing Gulls (*Larus atricilla*) where oystercatchers and Laughing Gulls nested in close proximity. Aggressive interactions among a neighboring pair of breeding oystercatchers was confirmed in one clutch failure in 2001 and was suspected in others. Crows (*Corvus* spp.) were observed frequently in all habitats and probably contributed to some clutch failures. Humans were not implicated directly in any failures.

Although no statistically significant difference in hatching or fledging success was detected among habitat types in 2000 or 2001, success was slightly lower at marsh habitats than at beaches and sand spits both years (Table 2.3). One clutch fledged young at an isolated marsh island in 2000 and 2001, but no clutches fledged at oyster-shell rakes during this study. Increased frequency of flooding was the chief cause of low reproductive success at marsh habitats: 51% of marsh clutches were lost to flooding during the egg stage, compared to 23% (N = 14) of beach clutches and 28% (N = 17) of sand spit clutches. The greatest success was documented at sand spits in 2000 where 35% of clutches hatched and 25% of clutches fledged young. Success at sand spits was lower in 2001 than in 2000, with 14% of clutches hatching and 4% of clutches fledging young. Hatching and fledging success were moderate at beach habitats in 2000 and 2001 (Table 2.3). All of the beach clutches that fledged young during this study were located at Altamaha.

DISCUSSION

Average clutch size of 2.0 eggs in this study was lower than clutch size previously documented for American Oystercatchers in Virginia (2.6 eggs per clutch, N = 257; Nol *et al*. 1984) and Florida (2.6 eggs per clutch, N = 58; Toland 1999). The only previous estimate of American Oystercatcher clutch size in Georgia was also relatively low (2.25 eggs per clutch, N = 32; Corbat 1980). Reduced clutch size in Georgia could be due to numerous environmental

Table 2.3. Reproductive success of American Oystercatchers at three habitat types in Georgia, March-July, 2000 and 2001. Data were pooled across study sites for comparison. No significant differences among habitats were detected: all 95% confidence intervals (CI) overlapped.

Year	Habitat type	No. of clutches	No. of hatched clutches	Hatching success %	Hatching success CI	No. of fledged clutches	Fledging success %	Fledging success CI
2000	Beach	21	4	19	17	2	10	14
	Sand spit	24	8	35	18	6	25	17
	Marsh[1]	27	3	11	13	1	4	10
2001	Beach	49	6	12	10	3	6	8
	Sand spit	51	7	14	10	2	4	7
	Marsh[1]	37	4	11	11	1	3	8

[1] Includes oyster-shell rakes and marsh islands.

factors including relatively poor foraging resources, high rates of nest predation, frequent flooding, or some combination thereof. Over time, such environmental factors could select for reduced investment per nesting attempt in exchange for a greater number of nesting attempts per breeding season (L'Hyver and Miller 1991). This mechanism does not appear to explain reduced clutch size in Georgia, as the occurrence of second and third replacement clutches in this study was consistent with findings from Virginia (Nol *et al*. 1984; Nol 1989). Additionally, greater clutch size in Florida than Georgia indicates that low clutch size in Georgia is probably not the result of latitudinal changes in reproductive effort.

The variability in hatching success in this study (0-30%) was similar to variability at Cape Lookout, North Carolina (7-27%; Davis *et al*. 2001) and along the barrier islands of Virginia (14%, SD = 20%; Nol 1989). Similarly, fledgling production at Cape Lookout (0.03-0.36 fledglings/pair; Davis *et al*. 2001; Davis, *unpublished data*), is comparable to our findings of 0.00 fledglings per pair at Wassaw during 2000 and 2001, and 0.24 and 0.25 fledglings per pair at Altamaha and St. Catherine's, respectively, during 2000. Low and variable rates of annual productivity are apparently commonplace in American Oystercatchers: the combination of exposed coastal nesting habitats, frequent predation, and K-selected life history traits (long incubation period, delayed reproduction, low reproductive effort, and extensive parental care of offspring), is presumably offset by the species' long life span and high annual rates of adult survival (Nol *et al*. 1984; Nol and Humphrey 1994; Baicich and Harrison 1997; Davis 1999). Consequently, occasional successful breeding seasons may be ample to sustain, or even increase, oystercatcher populations (Davis 1999). However, the resemblance of reproductive success and annual productivity estimates in this study to estimates from studies in Virginia and North Carolina may warrant concern considering the evidence that oystercatcher populations along the barrier islands of Virginia and North Carolina appear to be in decline (Davis *et al*. 2001).

High rates of clutch failure from depredation and flooding in this study were consistent with previous studies in New York (Post and Raynor 1964), New Jersey (Lauro and Burger 1989), Virginia (Nol 1989), and North Carolina (Davis 1999). Although human factors were not implicated directly in any clutch failures, our methods were poorly suited to detect such interactions if they occurred. Nonetheless, deficient fledgling production at Wassaw, combined with the site's proximity to Savannah and its popularity with recreationists, warrants consideration. Evidence from Florida suggests that frequent recreational disturbance reduces reproductive success by forcing adults away from eggs or chicks, thus increasing the chance of hyper- or hypothermia, or depredation by avian predators and domestic pets (Toland 1999). In North Carolina, areas of increased human activity were associated with increased Raccoon abundance (Davis *et al*. 2001); this association could explain the frequency of Raccoon sign and sightings on beaches at Wassaw. On the contrary, the remoteness of the Altamaha study site, coupled with recreation restrictions at government-owned property and private ownership of remaining property, may account, in part, for the abundance of oystercatcher pairs and successful clutches at that study site.

The decrease in hatching and fledging success at sand spits from 2000 to 2001 was probably due to habitat changes at a sand spit with the largest number of pairs of nesting oystercatchers (2000: N = 18; 2001: N = 25). A prescribed burn was completed at the spit in March 2000, producing sparsely-vegetated, sandy habitats that are favorable to nesting oystercatchers (Soots and Parnell 1975). Re-colonization of sandy substrates by annual and perennial vegetation in 2001, coupled with a 39% increase in oystercatcher pairs at the spit, reduced the area of available nesting habitat, increased inter-and intraspecfic interactions, and likely contributed to the overall 84% decrease in fledging success at sand spits from 2000 to 2001. Although storms, tidal overwash, and erosion appeared to control vegetation at the remaining two sand spits in this study, the low topography of those sites resulted in frequent flooding of nests. The constant flux in habitat quality at sand spits in Georgia and its effect on oystercatcher productivity appears similar to situations documented at dredge spoil islands in previous studies (Soots and Parnell 1975; Zarudsky 1985; Shields and Parmell 1990; Toland 1992). As at dredge spoil islands, the absence of mammalian predators at sand spits in this study was a potential advantage over beach and marsh habitats. Additionally, regulations prohibiting recreation at sand spits in this study (Georgia Board of Natural Resources Rule 391-4-7) reduced probable effects of human disturbance on nesting oystercatchers. Nonetheless, continued vegetational succession at sand spits, followed by loss of nesting habitat and increased negative interspecific interactions, could cause future declines in the number of nesting American Oystercatchers at such sites (Soots and Parnell 1975). Therefore, future management at sand spits should emphasize proactive control of perennial vegetation, in addition to maintaining low levels of human disturbance.

Unlike the sand spits in this study, beaches were affected by mammalian predators, more extensive human recreation, and at some sites, Feral Hog (*Sus scrofa*) populations, and disturbance from Loggerhead Sea Turtle (*Caretta caretta*) management programs. Depredation of eggs by hogs and disturbance from all-terrain vehicles (ATV's) used by sea turtle management personnel have been shown to affect nesting oystercatchers negatively at Cumberland Island, Georgia (Plauny, *unpublished data*). All clutches that hatched and fledged young on beaches in this study were located at a privately-owned barrier island at the Altamaha site where recreation was controlled and sea turtle management utilized bicycles rather than ATV's. Consequently, reduction or removal of hog populations and a reduction in the use of ATV's for sea turtle management should be investigated as future management options for oystercatchers nesting at beach habitats.

Although hatching and fledging success did not vary significantly among habitat types, relatively lower success at shell rakes and marsh islands may be of considerable biological significance. During spring tides and storms, shell rakes and marsh islands were frequently submerged, which resulted in loss of eggs and chicks. In contrast, the relatively higher topography of beaches and sand spits reduced the probability of nest wash-out. Once hatched, dunes provided refuge for chicks even during extreme tidal events (Lauro and Burger 1989). Tidal events may have also increased depredation rates at marsh habitats indirectly by concentrating chicks on diminishing areas of dry ground where they were susceptible to mammalian predators. Previous studies of marsh nesting in oystercatchers have led to the hypothesis that use of lower quality marsh habitats is resulting from a loss of higher quality beach habitats due to coastal development and recreation (Frohling 1965; Lauro and Burger 1989; Shields and Parnell 1990; Toland 1999). Although intuitive, historical accounts indicate that oystercatchers have been nesting on shell rakes and marsh islands in Georgia since at least the early twentieth century (Erichsen 1921; Burleigh 1958), when development and recreation at beaches were presumably much reduced. Additional monitoring will be required to determine whether low fledging success at marsh habitats documented in this study is routine or was simply the result of seasonal variation. If the former proves to be the case, any future net movement of pairs away from beaches and sand spits toward shell rake and marsh islands would warrant concern. Furthermore, active management of marsh habitats for nesting oystercatchers would probably be ineffective because of the low elevation of those habitats.

ACKNOWLEDGMENTS

This study was made possible by funding from the Georgia Department of Natural Resources' Nongame/Natural Heritage Section, the University of Georgia's D. B. Warnell School of Forest Resources, and the Georgia Ornithological Society. Assistance with on-site housing was provided by The Nature Conservancy's Altamaha Bioreserve and the Georgia Department of Natural Resources' Wildlife Resources Division. Thanks to Eric Kellon and Tyler Gault at the Lodge on Little St. Simon's and Royce Hayes at the St. Catherine's Island Foundation for assistance and access to sites. Thanks also to Andrew Walde, Angie Cone, Terry Norton, and Jennifer George for field assistance, and thanks to Chris Fonnesbeck and Robert Cooper for suggestions with this paper.

LITERATURE CITED

Baicich, P. J., and C. J. O. Harrison. 1997. A guide to the nests, eggs and nestlings of North American birds. Second edition. Academic Press, London.

Bent, A. C. 1929. Life histories of North American shore birds. Part 2. U.S. National Museum Bulletin, Number 146. Washington, D.C.

Burleigh, T. D. 1958. Georgia birds. University of Oklahoma, Norman, OK.

Corbat, C. A. 1990. Nesting ecology of selected beach-nesting birds in Georgia. Dissertation, University of Georgia, Athens, GA.

Davis, M. B. 1999. Reproductive success, status, and viability of the American Oystercatcher (*Haematopus palliatus*). Thesis, North Carolina State University, Raleigh, NC.

_____, T. R. Simons, M. J. Groom, J. L. Weaver, and J. R. Cordes. 2001. The breeding status of the American Oystercatcher on the east coast of North America and breeding success in North Carolina. Waterbirds 24: 195-202.

Erichsen, W. J. 1921. Notes on the habits of the breeding water birds of Chatham County, Georgia. Wilson Bulletin 33: 82.

Frohling, R. C. 1965. American Oystercatcher and black skimmer nesting on salt marsh. Wilson Bulletin 77: 193-194.

Georgia Coastal Management Program. 1997. Combined coastal management program and final environmental impact statement for the state of Georgia. U.S. Department of Commerce, Office of Ocean and Coastal Resource Management, National Oceanic and Atmospheric Administration. Silver Spring, MD.

Hunter, W. C. 2000. U.S. shorebird conservation plan: southeastern coastal plain—Carribean regional shorebird plan. U.S. Fish and Wildlife Service. Atlanta, GA.

Lauro, B., and J. Burger. 1989. Nest-site selection of American Oystercatcher (*Haematopus palliatus*) in salt marshes. Auk 106: 185-192.

L'Hyver, M. A., and E. H. Miller. 1991. Georgraphic and local variation in nesting phenology and clutch size of the black oystercatcher. Condor 93: 892-903.

Mayfield, H. 1961. Nesting success calculated from exposure. Wilson Bulletin 73: 255-261.

_____. 1975. Suggestions for calculating nest success. Wilson Bulletin 87: 456-466.

Nol, E.. 1989. Food supply and reproductive performance of the American Oystercatcher in Virginia. Condor 91: 429-435.

_____, A. J. Baker, and M. Cadman. 1984. Clutch initiation dates, clutch size, and egg size of the American Oystercatcher in Virginia. Auk 101: 855-867.

_____, and R. C. Humphrey. 1994 American Oystercatcher. Pages 1-20 *in* A. Poole, and F. Gill, editors. The birds of North America, number 82. Academy of Natural Sciences of Philadelphia, Philadelphia, PA.

Ozier, J. C., J. L. Bohannon, and J. L. Anderson, project coordinators. 1999. Protected animals of Georgia. Georgia Department of Natural Resources, Wildlife Resources Division, Nongame Wildlife-Natural Heritage Section. Social Circle, GA.

Post, P. W., and G. S. Raynor. 1964. Recent range expansion of the American Oystercatcher into New York. Wilson Bulletin 76: 339-346.

Rappole, J. H. 1981. Management possibilities for beach-nesting shorebirds in Georgia. Pages 114-126 *in* R. R. Odum, and J. W. Guthrie, editors. Proceedings of the nongame and endangered wildlife symposium. Georgia Department of Natural Resources, Game and Fish Division, Technical Bulletin WL 5.

Samuels, M. L. 1989. Statistics for the life sciences. Dellen, San Fransisco, CA.

Shields, M. A., and J. F. Parnell. 1990. Marsh nesting by American Oystercatchers in North Carolina. Journal of Field Ornithology 61: 431-433.

Soots, R. F., Jr., and J. F. Parnell. 1975. Ecological success of breeding birds in relation to plant success on dredge islands in North Carolina estuaries. University of North Carolina Sea Grant Publication UNC-SG-75-27. Raleigh, NC.

Toland, B. 1992. Use of forested spoil islands by nesting American Oystercatchers in southeast Florida. Journal of Field Ornithology 63: 155-158.

_____. 1999. Nest site characteristics, breeding phenology, and nesting success of American Oystercatchers in Indian River County, Florida. Florida Field Naturalist 27: 112-116.

Winn, B. 2000. The spatial distribution of American Oystercatchers in Georgia. The Oriole 65: 41-49.

Zarudsky, J. D. 1985. Breeding status of the American Oystercatcher in the town of Hempstead. Kingbird 35: 105-113.

CHAPTER 3

REPRODUCTIVE SUCCESS OF AMERICAN OYSTERCATCHERS AT MANAGED SITES IN GEORGIA[1]

[1] George, R. C., S. H. Schweitzer, and B. Winn. 2002. To be submitted to *The Oriole*.

ABSTRACT

Surveys of American Oystercatcher (*Haematopus palliatus*) clutches and breeding pairs were conducted at four Georgia Department of Natural Resources-managed sites (Pelican Spit, Egg Island Bar, St. Catherine's Bar, and Williamson Island) from March to July, 2000 and 2001. Clutches were followed until fledging or failure, and the number of breeding pairs at each site was estimated. Hatching and fledging success were estimated for each site and year. To document human disturbance at sites, point counts of recreationists were conducted at random intervals in 2001. Pelican Spit was eroded by a storm in 1999 and was poor habitat for oystercatchers during this study. Egg Island Bar was the only site from which chicks fledged. Recreation was prohibited (0.0 people/count) and 25 pairs defended territories in 2001. Fledging success decreased from 33% in 2000 to 5% in 2001 because of an increase in vegetation in 2001 and subsequent interspecific interactions and depredation of clutches by Laughing Gulls (*Larus atricilla*). Recreation was prohibited at St. Catherine's Bar (0.0 people/count), but all 13 clutches failed before hatching due to flooding and unknown reasons. Williamson Island was the only site accessible to mammalian predators and recreation was restricted to beaches (4.1 people/count). One of 14 clutches hatched over two years, but none fledged primarily because of depredation by Raccoons (*Procyon lotor*). Any benefits afforded by recreation restrictions were outweighed by a lack of enforcement and the site's large predator population.

Key Words

American Oystercatchers, *Haematopus palliatus*, shorebirds, management, predation, productivity, recreation, human disturbance.

INTRODUCTION

Increased development and recreation throughout the Georgia coastal region in recent decades has generated new concern over the status of Georgia's beach-nesting shorebird species (Georgia Coastal Management Program 1997). With a total U.S. population of as few as 3,000 individuals and naturally low levels of annual productivity (Nol and Humphrey 1994; Davis 1999; Davis *et al*. 2001), American Oystercatchers (*Haematopus palliatus*) could be especially vulnerable to habitat loss and other human-mitigated factors. American Oystercatchers are currently listed as a species of extremely high priority in the Southeastern Coastal Plain–Carribean Regional Shorebird Plan (Hunter 2000) because of habitat loss along the southeastern coast and perceived population declines on the Atlantic coast of Florida and in the species' historical stronghold of Virginia, North Carolina, and South Carolina (Hunter 2000; Davis *et al*. 2001). Despite their listing as a Georgia state-listed rare wildlife species (Ozier *et al*. 1999), few studies have been conducted in Georgia and the status of the state's oystercatcher population has remained largely speculative.

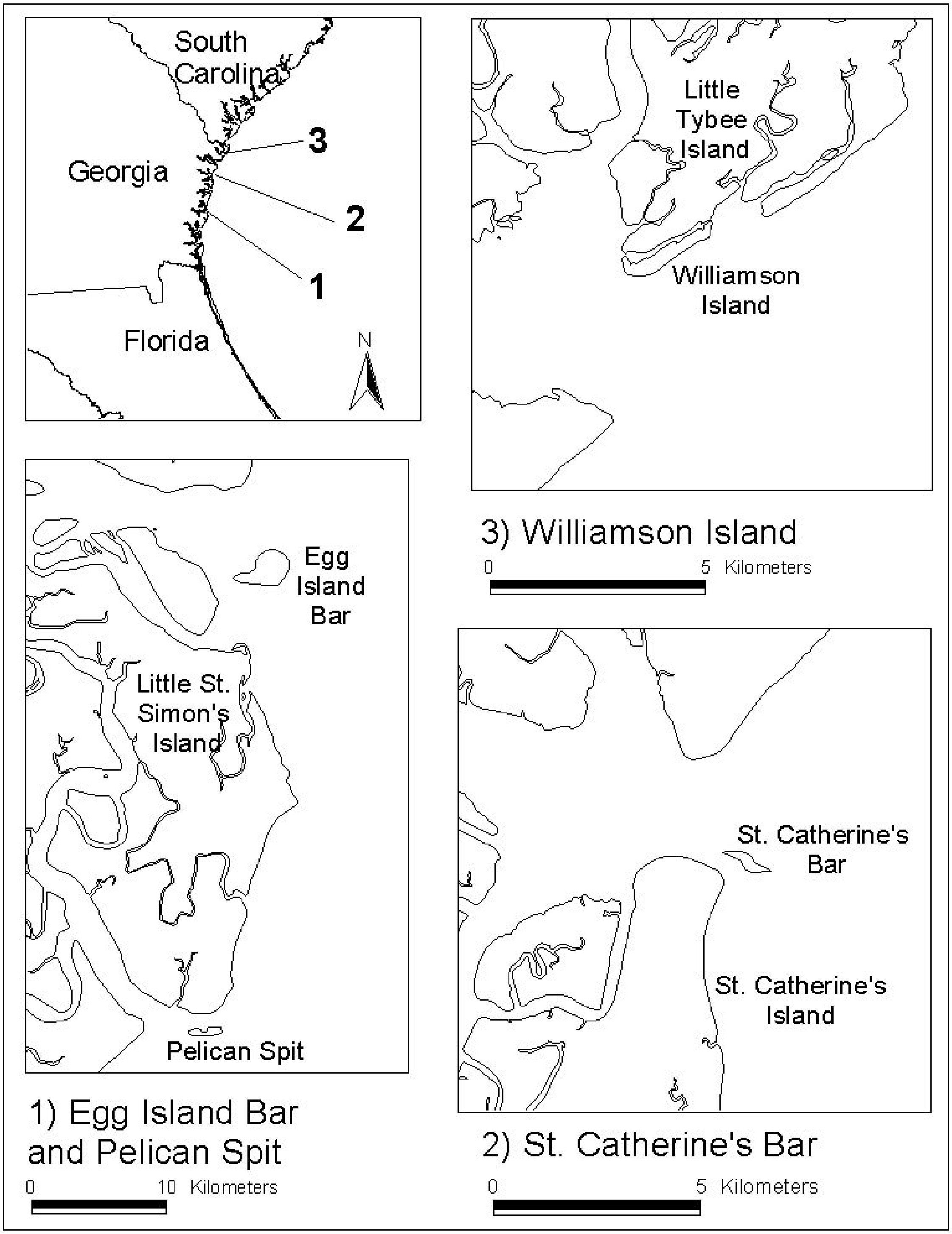
Once considered common in Georgia, American Oystercatcher numbers were reduced considerably by the early twentieth century by unregulated hunting and egg collecting (Erichsen 1921; Bent 1929). Oystercatchers began a slow recovery following passage of the Migratory Bird Treaty Act (1918) and as many as 35 pairs nested on the Georgia coast by mid-century (Burleigh 1958). The first coast-wide survey of American Oystercatchers conducted in 1980 produced an estimate of 70 nesting pairs (Rappole 1981). Aerial surveys in 1999 placed the state breeding population at about 100 pairs (Winn 2000). Despite this increase, oystercatchers have proliferated only in Georgia's remote areas (Winn 2000). Recent expansion of recreation into remote areas, combined with studies suggesting that human disturbance may affect Georgia's shorebirds negatively (Rappole 1981; Corbat 1990), led the Georgia Department of Natural

Resources (DNR) to establish recreation restrictions at five DNR-managed sites in 1998 (Board of Natural Resources Rule 391-4-7). Our study was initiated in 2000 with the goal of providing sound baseline data for a subset of Georgia's breeding American Oystercatchers, including those breeding at DNR-managed sites. The purpose of this paper is to present reproductive success, fledgling production, and recreational disturbance data for the four DNR-managed sites used by breeding American Oystercatchers in 2000 and 2001.

METHODS

Surveys of nesting American Oystercatchers were conducted from March to July, 2000 and 2001, at three DNR-managed sites: Egg Island Bar, St. Catherine's Bar, and Williamson Island (Fig. 3.1). A fourth DNR-managed site, Pelican Spit, was surveyed from March to July, 2001. Although previously an important site for nesting shorebirds, Pelican Spit was destroyed during a storm in late 1999 and was unavailable to nesting birds in 2000. Accretion of sediments continued through 2000 and a small section of the spit (~1 ha) was available to nesting birds by March 2001. Recreation was prohibited on a portion of Pelican Spit, but signs were not posted during this study because of the spit's small size. The spit was not accessible to mammalian predators. Egg Island Bar's large size (~60 ha), extensive topography, and an absence of mammalian predators provided high-quality nesting habitat for oystercatchers and other shorebirds. Management at the site included prohibitive regulations against recreation, indicated by a large sign, and use of fire to control emergent vegetation. St. Catherine's Bar was influenced heavily by tides and storms in 2000 and 2001. The 10-ha spit consisted of a tidally-influenced interior mud flat, encircled by a perimeter of low-elevation, sparsely-vegetated dunes and sand flat. Management at the site included prohibitive restrictions on recreation, indicated by a large sign. Mammalian predators were absent from the site. Williamson Island was similar in size to Egg Island Bar (~60 ha) and provided ample high-topography, sparsely-vegetated habitat. Unlike

Figure 3.1. Location of four Department of Natural Resources-managed sites along the Georgia coast: 1) Pelican Spit and Egg Island Bar, 2) St. Catherine's Bar, and 3) Williamson Island.


South Carolina
Georgia
Florida
3
2
1
N
Little Tybee Island
Williamson Island
3) Williamson Island
0
5 Kilometers
Egg Island Bar
Little St. Simon's Island
Pelican Spit
1) Egg Island Bar and Pelican Spit
0
10 Kilometers
St. Catherine's Bar
St. Catherine's Island
2) St. Catherine's Bar
0
5 Kilometers

the other DNR-managed sites, Williamson Island was linked to an adjacent barrier island by tidal salt marsh and was accessible to mammalian predators, including Raccoon (*Procyon lotor*), Mink (*Mustela vison*), and River Otter (*Lontra canadensis*). Management at the site included a prohibition on dogs and other domestic pets. Recreation was permitted along the island's beach and southwest tip, but the interior was protected as shorebird nesting habitat. These regulations were indicated by signs at numerous locations throughout the island.

All sites were accessed by boat and surveyed on foot. When a mated pair was observed, its location was charted on a map and its behavior was recorded. If incubating, the nest was marked at a distance with a numbered stake and nest number, clutch size, and nest coordinates (using a handheld Trimble Geoexplorer Global Positioning System unit) were recorded. Sites were revisited approximately every five to six days and clutch status was documented. Cause of failure during the egg stage was surmised when possible from predator tracks, broken eggshells, or evidence of flooding. Hatching success and fledging success were defined as hatching or fledging one egg or chick, respectively, and were calculated as a percentage of total nesting attempts. Following Davis *et al*. (2001), production of fledglings at each site was calculated as the ratio of fledglings produced per total number of nesting oystercatcher pairs estimated at each site. To assess levels of recreation at each site, point counts of all recreationists within a 1-km radius were conducted at randomly chosen intervals from March to July 2001. Recreationists were counted when on land, in the surf, or in moored boats, but not when in boats at sea.

RESULTS

Pelican Spit

Two American Oystercatcher clutches were documented at Pelican Spit on 19 June 2001. These clutches were apparently initiated by two oystercatcher pairs that nested unsuccessfully on the south tip of nearby Little St. Simon's Island earlier in 2001. One clutch was washed out during a high tide and the other hatched one of three eggs. The chick disappeared before fledging during a spring tide that submerged the entire spit. Other avian species were not known to nest at Pelican Spit in 2001. Recreational use was frequent and point counts conducted in 2001 averaged 1.4 people per count (N = 13; SE = 0.8).

Egg Island Bar

This site provided nesting habitat for numerous avian species in 2000 and 2001, including American Oystercatchers, Brown Pelicans (*Pelicanus occidentalis*), Royal Terns (*Sterna maxima*), Sandwich Terns (*S. sandvicensis*), Gull-billed Terns (*S. nilotica*), Laughing Gulls (*Larus atricilla*), Black Skimmers (*Rynchops niger*), Willets (*Catoptrophorus semipalmatus*), Wilson's Plovers (*Charadrius wilsonia*), Mottled Ducks (*Anas fulvigula*), Clapper Rails (*Rallus longirostris*), and Marsh Wrens (*Cistothorus palustris*). The spit was burned to reduce vegetation in March, 2000, which created an abundance of open, sandy nesting habitat. An estimated 17 pairs of American Oystercatchers defended territories at Egg Island Bar in 2000 (Table 3.1). Eighteen clutches were documented and 44% of clutches (N = 8) hatched at least one chick. Fledging success was calculated as 33% (N = 6) and 0.35 fledglings were produced per pair (N = 6 fledglings). Although cause of clutch failure during the egg stage was undetermined in 90% (N = 9) of cases, depredation by Laughing Gulls was suspected. Signs or sightings of mammalian predators did not occurr at the spit in 2000 and one clutch failed because of flooding. Area of available nesting habitat was visibly reduced in 2001 due to re-colonization of sandy substrate by annual and perennial vegetation. Nonetheless, an estimated 25 pairs of oystercatchers defended territories in 2001, representing a 47% increase in oystercatcher pairs from 2000. More clutches were documented in 2001 (N = 42) than in 2000 because of an increase in nesting pairs and an apparent increase in the number of replacement clutches. Hatching and fledging success in 2001 was 14% (N = 6) and 5% (N = 2), respectively, and

Table 3.1. Clutch size, hatching success, and fledging success in American Oystercatchers at four Department of Natural Resources-managed sites in Georgia, March-July, 2000 and 2001. Oystercatchers did not nest at Pelican Spit in 2000.

Year	Site	No. of clutches	Mean clutch size	No. of hatched clutches (%)	No. of fledged clutches (%)	No. of pairs	No. of fledglings produced	Fledglings produced per pair
2000	Egg Island Bar	18	2.0	8 (44)	6 (33)	17	6	0.35
	St. Catherine's Bar	6	2.2	0 (0)	0 (0)	4	0	0.00
	Williamson Island	4	2.0	1 (25)	0 (0)	3	0	0.00
	Total	28	2.0	9 (32)	6 (21)	24	6	0.25
2001	Egg Island Bar	42	2.0	6 (14)	2 (5)	25	3	0.12
	Pelican Spit	2	2.0	1 (50)	0 (0)	2	0	0.00
	St. Catherine's Bar	7	2.3	0 (0)	0 (0)	3	0	0.00
	Williamson Island	10	1.7	0 (0)	0 (0)	3	0	0.00
	Total	61	2.0	7 (11)	2 (3)	33	3	0.09

fledgling production was estimated as 0.12 fledglings per pair (N = 3 fledglings). Cause of clutch failure during the egg stage was undetermined in 39% (N = 14) of cases and 31% (N = 11) of failures were attributed to avian predators, primarily Laughing Gulls. At least one clutch failure resulted from aggressive interactions among a pair of nesting oystercatchers. Nine nests flooded in 2001 (25%) and two nests were apparently abandoned. Recreationists were only observed at the site on one occasion in 2000 and had no appreciable effect on nesting shorebirds. Accordingly, point counts of recreationists in 2001 averaged 0.0 recreationists per count (N = 42).

St. Catherine's Bar

Four pairs of oystercatchers defended territories at St. Catherine's Bar in 2000. Of the 6 clutches documented in 2000, all failed before hatching. Five clutches flooded and 1 clutch failed for unknown reasons. Three pairs nested at the spit in 2001, but all seven clutches failed before hatching. One clutch washed out during floods, one was lost to an unknown avian predator, four clutches failed for unknown reasons, and one clutch was abandoned. The abandoned clutch and two clutches of unknown fate were incubated for the full 26-day incubation period, yet failed to hatch. Bird tracks and droppings observed on higher points following spring tides in 2000 and 2001 indicated that the spit was used as a roost by Brown Pelicans, gulls, and other birds during spring tide events. Wilson's Plovers were the only other species of shorebirds known to nest on St. Catherine's Bar during the study; a single Wilson's Plover chick was observed in 2000. Despite the spit's close proximity (~250 m) to the north beach of St. Catherine's Island, which is frequented by recreationists, no recreationists were observed on the spit during the study. Human footprints were observed on one occasion in 2001. Point counts of recreationists in 2001 averaged 0.0 people per count (N = 17).

Williamson Island

Three pairs of oystercatchers nested at Williamson Island in 2000. One of four clutches hatched two eggs, but the chicks were lost prior to fledging for unknown reasons. Of the three failed clutches, one flooded, one was depredated (apparently by Raccoons), and the last clutch was lost for unknown reasons. Three pairs were again documented in 2001, but ten clutches were located, suggesting the possibility of a fourth pair. Regardless, all ten clutches failed before hatching. Six clutches were depredated by Raccoons and the other four clutches disappeared for unknown reasons. Based on the abundance of tracks and other sign, Raccoons were suspected in most uncertain clutch failures in 2000 and 2001. Human factors were not implicated directly in any clutch failures at Williamson, but human and dog footprints were frequently observed within the protected area. Dogs were observed on the island on 31% (N = 5) of visits in 2000 and 37% (N = 7) of visits in 2001. Forty-nine boats and over 200 recreationists were observed on the southwest tip on one occasion in 2000. Randomly conducted point counts in 2001 averaged 4.14 people per count (N = 22; SE = 2.2) and ranged as high as 46 people. Wilson's Plovers nested at the northeast tip of the island in 2000 and 2001. Willets used the marsh on the leeward side of the island in 2000 and 2001, but nests were not confirmed.

DISCUSSION

The small size and low topography of Pelican Spit was responsible for the low number of American Oystercatcher pairs, failure of one nest, and loss of one chick at that site. However, the arrival of two breeding pairs midway through the breeding season indicated greater plasticity in oystercatcher nest site selection than is generally cited in the literature (Nol and Humphrey 1994). If enlargement of the spit continues and the number of nesting oystercatchers increases, it may be beneficial to reinstate recreation regulations at a portion of the spit. Such actions could also benefit Least Terns (*Sterna antillarum*) which have nested at Pelican Spit in the past (Brad Winn, *personal communication*).

The greater number of oystercatcher pairs and increased productivity at Egg Island Bar compared to the other DNR-managed sites were due to the spit's large size, an absence of mammalian predators, relatively high-topography habitat, and minimal human disturbance to nesting birds. Previous studies in New York (Zarudsky 1985) and Florida (Toland 1999) have also documented increased productivity of oystercatchers at isolated islands with low levels of disturbance and no mammalian predators. The sudden decrease in reproductive success and fledgling production at Egg Island Bar in 2001 was possibly a result of increased vegetation and subsequent inter- and intraspecific competition, and is consistent with previous studies elsewhere (Post and Raynor 1964; Soots and Parnell 1975; Zarudsky 1985). Movement of individual pairs to low-elevation, less-vegetated sites in response to decreased habitat availability also could account for the increase in flooded clutches in 2001. If vegetational succession continues at Egg Island Bar at the current rate, the number of oystercatchers nesting at the site could decrease over time (Soots and Parnell 1975). Consequently, more vigorous control of vegetation, including use of fire and herbicides, should be considered as a possible management option on at least a portion of the spit. The use of herbicides in restoring shorebird habitat has been demonstrated in numerous other cases (Evans 1986; Linz *et al*. 1994; Root 1996; Linz and Blixt 1997). In addition to benefitting nesting oystercatchers directly, restoration of open, sandy habitat would discourage nesting by gulls (Soots and Parnell 1975; Buckley and McCarthy 1994; Mallach and Leberg 1999), which impact oystercatchers negatively (Post and Raynor 1964; Zarudsky 1985; Nol and Humphrey 1994). Such management would also directly benefit other Georgia state-listed shorebird species, including Wilson's Plovers, Gull-billed Terns, and Least Terns (Ozier *et al*. 1999) which also prefer sandy, sparsely-vegetated nesting habitat (Soots and Parnell 1975;

Parnell *et al*. 1995; Thompson *et al*. 1997; Corbat and Bergstrom 2000). If recreational use increases in the region, better placement of more visible regulatory signs at Egg Island Bar may also be warranted.

Despite an absence of recreation and mammalian predators, the small size and low topography of St. Catherine's Bar resulted in frequent flooding of oystercatcher nests. Use of the spit as a roost site by gulls, terns, and pelicans also may have contributed to clutch failures indirectly through abandonment of nests or directly through increased depredation of eggs and chicks. Nonetheless, the relatively large number of clutches that failed despite being incubated the full 26-day term is disconcerting and warrants future monitoring. Unfortunately, significant erosion has occurred at St. Catherine's Bar since the completion of this study (*personal observation*), which may inhibit successful nesting by oystercatchers and other shorebirds into the near future.

The abundance of mammalian predators at Williamson Island was the primary cause of low reproductive success at that site. Other studies of oystercatchers have found that, when present, depredation by Raccoons and other mammals is the most frequent cause of clutch failure (Nol 1989; Davis *et al*. 2001). Although not implicated in any clutch failures, recreational disturbance may have contributed to low reproductive success at Williamson Island. Davis (1999) found that recreational use was correlated with increased Raccoon density on North Carolina beaches. High Raccoon densities likely increase predation rates, thereby reducing reproductive success of beach-nesting birds. Recreation can also directly reduce reproductive success in oystercatchers and other shorebirds through trampling of nests, increased nest abandonment, slowed chick growth, and increased exposure of eggs and chicks to natural or domestic predators (Erwin 1980; Safina and Burger 1983; Rodgers and Smith 1995; Toland 1999).

Regardless of the mechanism, the current approach to management at Williamson Island seems unlikely to benefit nesting oystercatchers. Even if regulations were strictly enforced (which they currently are not), most of the island would remain accessible to recreationists. Furthermore, such actions would have little or no effect on the chief cause of clutch failure: mammalian predators. On the contrary, predator removal has been shown to improve reproductive success of shorebirds (Witmer *et al*. 1996) and would probably benefit oystercatchers and other shorebirds at Williamson Island. Unfortunately, predator removal can be prohibitively expensive, logistically difficult, politically controversial, and can have unintended ecological effects (Garretson *et al*. 1996; Witmer *et al*. 1996; Hecht and Nickerson 1999). Regardless, barring a substantial decrease in the number of mammalian predators, Williamson Island will continue to provide relatively poor habitat for breeding American Oystercatchers, irrespective of increased enforcement of current recreation regulations.

ACKNOWLEDGMENTS

This study was made possible by funding from the Georgia Department of Natural Resources' Nongame/Natural Heritage Section, the University of Georgia's D. B. Warnell School of Forest Resources, and the Georgia Ornithological Society. Assistance with on-site housing was provided by The Nature Conservancy's Altamaha Bioreserve and the Georgia Department of Natural Resources' Wildlife Resources Division. Thanks to Royce Hayes at the St. Catherine's Island Foundation for access to sites. Thanks also to Andrew Walde, Angie Cone, Terry Norton, Deb Beirrero, and Jennifer George for field information and assistance.

LITERATURE CITED

Bent, A. C. 1929. Life histories of North American shore birds, part 2. U.S. National Museum Bulletin, No. 146. Washington, D.C.

Buckley, P. A., and M. G. McCarthy. 1994. Insects, vegetation, and the control of laughing gulls (*Larus atricilla*) at Kennedy International Airport, New York City. Journal of Applied Ecology 31: 291-302.

Burleigh, T. D. 1958. Georgia birds. University of Oklahoma, Norman, OK.

Corbat, C. A. 1990. Nesting ecology of selected beach-nesting birds in Georgia. Dissertation, University of Georgia, Athens, GA.

_____, and P. W. Bergstrom. 2000. Wilson's plover (*Charadrius wilsonia*). *In* The Birds of North America, No. 516. (A. Poole and F. Gill, eds.). The Birds of North America, Inc. Philadelphia, PA.

Davis, M. B. 1999. Reproductive success, status, and viability of the American Oystercatcher (*Haematopus palliatus*). Thesis, North Carolina State University, Raleigh, NC.

_____, T. R. Simons, M. J. Groom, J. L. Weaver, and J. R. Cordes. 2001. The breeding status of the American Oystercatcher on the east coast of North America and breeding success in North Carolina. Waterbirds 24: 195-202.

Erichsen, W. J. 1921. Notes on the habits of the breeding water birds of Chatham County, Georgia. Wilson Bulletin 33: 82.

Erwin, R. M. 1980. Breeding habitat use by colonially nesting waterbirds in two mid-Atlantic U.S. regions under different regimes of human disturbance. Biological Conservation 18: 39-51.

Evans, P. R. 1986. Use of the herbicide "Dalpon" for control of *Spartina* encroaching on intertidal mudflats: beneficial effects on shorebirds. Waterbirds 9: 171-175.

Garretson, P. R., F. C. Rohwer, J. M. Zimmer, B. J. Mense, and N. Dion. 1996. Effects of mammalian predator removal on waterfowl and non-game birds in North Dakota. Pages 94-101 *in* Issues and problems in predation management to enhance avian recruitment. (K. G. Wadsworth and R. E. McCabe, eds.). The Berryman Institute, Department of Fisheries and Wildlife, Logan, UT.

Georgia Coastal Management Program. 1997. Combined coastal management program and final environmental impact statement for the state of Georgia. U.S. Department of Commerce, Office of Ocean and Coastal Resource Management, National Oceanic and Atmospheric Administration. Silver Spring, MD.

Hecht, A., and P. R. Nickerson. 1999. The need for predator management in conservation of some vulnerable species. Endangered Species Update 16: 1-5.

Hunter, W. C. 2000. U.S. shorebird conservation plan: southeastern coastal plain—Carribean regional shorebird plan. U.S. Fish and Wildlife Service. Atlanta, GA.

Linz, G. M., D. L. Bergman, D. C. Blixt, and W. J. Bleier. 1994. Response of black terns (*Childonias niger*) to glyphosate-induced habitat alterations on wetlands. Waterbirds 17: 160-167.

_____, and D. C. Blixt. 1997. Black terns benefit from cattail management in the northern Great Plains. Waterbirds 20: 617-621.

Mallach, T. J., and P. L. Leberg. 1999. Use of dredged material substrates by nesting terns and black skimmers. Journal of Wildlife Management 63: 137-146.

Nol, E. 1989. Food supply and reproductive performance of the American Oystercatcher in Virginia. Condor 91: 429-435.

_____, and R. C. Humphrey. 1994. American oystercatcher (*Haematopus palliatus*). *In* The Birds of North America, No. 82. (A. Poole and F. Gill, eds.). The Birds of North America, Inc. Philadelphia, PA.

Ozier, J. C., J. L. Bohannon, and J. L. Anderson, project coordinators. 1999. Protected Animals of Georgia. Georgia Department of Natural Resources, Wildlife Resources Division, Nongame Wildlife-Natural Heritage Section. Social Circle, GA.

Parnell, J. P., R. M. Erwin, and K. C. Molina. 1995. Gull-billed Tern (*Sterna nilotica*). *In* The Birds of North America, No. 140. (A. Poole and F. Gill, eds.). The Birds of North America, Inc. Philadelphia, PA.

Post, P. W., and G. S. Raynor. 1964. Recent range expansion of the American Oystercatcher into New York. Wilson Bulletin 76: 339-346.

Rappole, J. H. 1981. Management possibilities for beach-nesting shorebirds in Georgia. Pages 114-126 *in* Proceedings of the Nongame and Endangered Wildlife Symposium. (R. R. Odum and J. W. Guthrie, eds.). Georgia Department of Natural Resources, Game and Fish Division, Technical Bulletin WL 5.

Rodgers, J. A., Jr., and H. T. Smith. 1995. Set-back distances to protect nesting bird colonies from human disturbance in Florida. Conservation Biology 9: 89-99.

Root, B. G. 1996. Alkaline wetland vegetation dynamics at North Dakota piping plover besting beaches. Dissertation, University of Missouri, Columbia, MO.

Safina, C., and J. Burger. 1983. Effects of human disturbance on reproductive success in the Black Skimmer. Condor 85: 164-171.

Soots, R. F., Jr., and J. F. Parnell. 1975. Ecological success of breeding birds in relation to plant success on dredge islands in North Carolina estuaries. University of North Carolina Sea Grant Publication UNC-SG-75-27. Raleigh, NC.

Toland, B. 1999. Nest site charactersitics, breeding phenology, and nesting success of American Oystercatchers in Indian River County, Florida. Florida Field Naturalist 27: 112-116.

Thompson, B. C., J. A. Jackson, J. Burger, L. Hill, E. M. Kirsch, and J. L. Atwood. 1997. Least Tern (*Sterna antillarum*). *In* The Birds of North America, No. 290. (A. Poole and F. Gill, eds.). The Birds of North America, Inc. Philadelphia, PA.

Winn, B. 2000. The spatial distribution of American Oystercatchers in Georgia. The Oriole 65: 41-49.

Witmer, G. W., J. L. Bucknall, T. H. Fritts, and D. G. Moreno. 1996. Predator management to protect endangered avian species. Pages 102-108 *in* Issues and Problems in Predation Management to Enhance Avian Recruitment. (K. G. Wadsworth and R. E. McCabe, eds.). The Berryman Institute, Department of Fisheries and Wildlife, Logan, UT.

Zarudsky, J. D. 1985. Breeding status of the American Oystercatcher in the town of Hempstead. Kingbird 35: 105-113.

CHAPTER 4

THE EFFECTS OF HUMAN RECREATION ON AMERICAN OYSTERCATCHER REPRODUCTIVE SUCCESS AND NESTING HABITAT SELECTION IN GEORGIA[1]

[1] George, R. C., S. H. Schweitzer, B. Winn, and C. Fonnesbeck. 2002. To be submitted to *Waterbirds*.

ABSTRACT

Surveys of American Oystercatcher (*Haematopus palliatus*) pairs and clutches were conducted at three sites in coastal Georgia from March to July, 2000 and 2001. Clutches were categorized according to habitat and were monitored until fledging or failure. The number of mated pairs at each site was also estimated. To assess levels of disturbance, point counts of recreationists were conducted at random intervals at each site from March to July, 2001. Point count data were analyzed with a Geographic Information System, producing a spatial index of recreational disturbance for each study area. Spatial recreation index values were assigned to 2000 and 2001 clutches, and average clutch recreation indices were compared graphically with respect to site, reproductive success, and habitat type, and against recreation indices of randomly distributed points. Although reproductive success tended to be lower at sites with greater recreational use, recreation indices did not differ among successful and unsuccessful clutches. Rather, clutches were initiated in areas of lower recreational use at each site than would be expected at random. At sites where beaches were frequented by recreationists, a greater proportion of clutches were initiated in marsh habitat, resulting in greater rates of clutch failure because of flooding. In contrast, no clutches were initiated in marsh habitat at a site with low levels of beach recreation and reproductive success was elevated. These data suggest that human recreation affects oystercatcher reproduction negatively by influencing nesting habitat selection.
Key Words

American Oystercatcher, *Haematopus palliatus*, Georgia, reproductive success, GIS, recreation, human disturbance.

INTRODUCTION

Once considered common in Georgia, American Oystercatchers (*Haematopus palliatus*) were nearly extirpated by the early twentieth century because of unregulated hunting and egg collecting (Erichsen 1921; Bent 1929). Numbers increased slowly following passage of the Migratory Bird Treaty Act (1918), but the American Oystercatcher remains a Georgia state-listed rare species (Ozier *et al*. 1999) with an estimated state breeding population of fewer than 100 pairs (Winn 2000). Commensurate with their modest recovery, oystercatchers have proliferated only in Georgia's more remote areas. Only one nest has been confirmed at any of Georgia's developed islands since 1999 (*personal observation*), and 36% of pairs surveyed in 1999 nested on oyster-shell rakes and other remote marsh habitats (Winn 2000). Recent expansion of recreation into remote areas, combined with studies suggesting that human disturbance may affect Georgia's shorebirds negatively (Rappole 1981; Corbat 1990), has generated new concern over the status of Georgia's beach-nesting shorebird species (Georgia Coastal Management Program 1997).

With a total U.S. population of as few as 3,000 individuals and low annual productivity, American Oystercatchers could be especially vulnerable to habitat loss and other human-mitigated factors (Nol and Humphrey 1994; Davis 1999; Davis *et al*. 2001). American Oystercatchers are currently listed as a species of extremely high priority in the Southeastern Coastal Plain–Carribean Regional Shorebird Plan (Hunter 2000) because of habitat loss along the southeastern coast and perceived population declines in Virginia, North Carolina, South Carolina, and Florida (Hunter 2000; Davis *et al*. 2001). To date, assessment of the effects of human disturbance on American Oystercatcher breeding has involved considerable speculation. Increased use of marsh, dredge-spoil, and other atypical nesting habitats has been widely viewed as a direct response to increased development and recreation on beaches (Frohling 1965;

Zarudsky 1985; Lauro and Burger 1989; Shields and Parnell 1990; Lauro *et al*. 1992; Toland 1992, 1999), but empirical data have been lacking. Although the effects of recreational disturbance on other shorebirds have been well documented (Anderson and Keith 1980; Erwin 1980; Safina and Burger 1983; Burger 1986, 1994; Rogers and Smith 1995; Goldin and Regosin 1998), only one published study (Toland 1999) has addressed the topic explicitly in American Oystercatchers. All oystercatchers in Toland's study nested at dredge spoil islands and other atypical sites, and quantitative measures of recreation were not conducted.

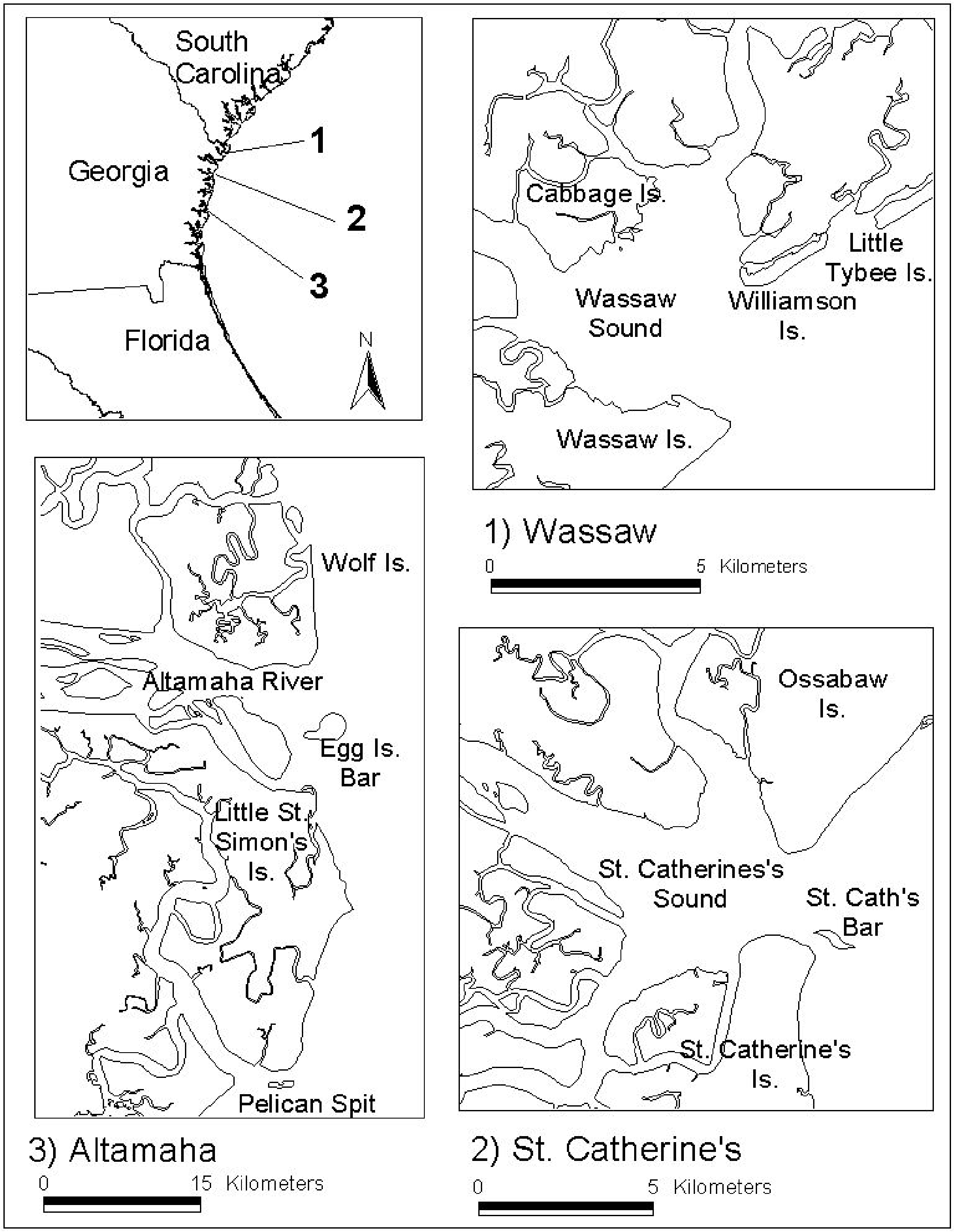
This study was initiated in 2000 with the goal of providing sound breeding data for a substantial portion of Georgia's breeding American Oystercatchers. The purpose of this paper is to present productivity data for oystercatchers breeding in multiple habitats and over a range of recreational disturbance levels.

METHODS

Surveys of breeding American Oystercatchers were conducted March to July, 2000 and 2001, at three sites in coastal Georgia (Fig. 4.1): 1) Wassaw, 2) St. Catherine's, and 3) Altamaha. Altogether, the three sites constituted about 38 linear km (~25%) of Georgia's 160-km shoreline. Sites contained beach habitat (barrier island beaches and isolated sand spits) and marsh habitat (marsh islands, dredge-spoil islands, and oyster-shell rakes). Habitats within each site were accessible only by boat or air, and all beaches were free of commercial and residential development.

During surveys, location and behavior of mated pairs were recorded. If incubating, nests were marked at a distance with a numbered stake, and nest number, nest coordinates (using a Trimble Geoexplorer handheld Global Positioning System (GPS) unit), and habitat type were recorded. Sites were revisited approximately every five to six days to assess clutch status. Cause of failure during the incubation stage was inferred when possible from predator tracks, broken

Figure 4.1. Location of three study sites in coastal Georgia, USA: 1) Wassaw, 2) St. Catherine's, and 3) Altamaha.


South
Carolina
Georgia
Florida
1
2
3
N
Cabbage Is.
Little
Tybee Is.
Wassaw
Sound
Williamson
Is.
Wassaw Is.
1) Wassaw
0
5 Kilometers
Wolf Is.
Altamaha River
Egg Is.
Bar
Little St.
Simon's
Is.
Pelican Spit
3) Altamaha
0
15 Kilometers
Ossabaw
Is.
St. Catherines's
Sound
St. Cath's
Bar
St. Catherine's
Is.
2) St. Catherine's
0
5 Kilometers

eggshells, or evidence of flooding. Any clutch producing at least one fledgling was deemed successful and fledging success was calculated as the proportion of successful clutches per total clutches initiated. The total number of mated pairs was estimated at each site in 2000 and 2001, based upon repeated observations of pairs, not upon the discovery of clutches. To document recreational disturbance at each site, point counts of all recreationists within a 1-km radius of the observer were conducted at random intervals from March to July, 2001. Recreationists on land, in the surf, or in moored boats were counted, but not recreationists in boats at sea.

GIS Analysis

Point count and nesting data were entered into ArcView 3.2 Geographic Information System (GIS) software (Environmental Systems Research Institute, Inc. 1999) to create a spatial index of recreational use at each site. A total of 68, 66, and 106 recreationist point counts were collected at random intervals at Wassaw, St. Catherine's, and Altamaha, respectively. The extent of each site was gridded to an arbitrary 100-m^2 resolution and a recreational index value was computed for each grid cell, calculated as the average value of all recreationist point counts within 1 km of the cell center. The 1-km distance corresponded to the 1-km maximum distance of recreationists from the observer during point counts. The resulting recreation index coverage was overlaid on clutch location and recreation index values were assigned to all clutches documented in 2000 and 2001. In doing so, I assumed that: 1) patterns of recreational disturbance were similar in 2000 and 2001, 2) among- and within-day variation in recreational activity were constant throughout the breeding season, and 3) spatial error associated with temporal variation was similar within and among sites. For comparison, recreation index values were also assigned to points distributed randomly throughout a coverage of available nesting habitat at each site. Nesting habitat coverages for each site were hand-digitized from Landat-7TM data recorded on 10 November, 2000, and were clipped to the spatial extent of the recreation index coverage to maximize overlap. Any spatial error in delineating habitat was assumed to be similar within and among sites. A minimum separation of 50 m was maintained among random points, mimicking the minimum distance between clutches documented during this study. The number of random points distributed within each habitat coverage corresponded to the average number of mated pairs at each site in 2000 and 2001.

Statistical Analysis

Consistent with the goals of this study, I employed statistical estimation procedures, rather than conducting hypothesis tests (Johnson 1999). Comparisons of all means and proportions were conducted graphically using 95% confidence intervals. Confidence intervals for proportions (i.e., fledging success) were constructed using the normal approximation method (Samuels 1989). Recreation index data were bimodally distributed, so calculation of means and confidence intervals with normal methods was not appropriate (Kvanli *et al*. 1998). Rather, means and 95% confidence intervals were calculated with maximum likelihood methods, following Kvanli *et al*. (1998). The distribution of each bimodal population was defined by the joint probability density function:

$$f(y) = \begin{cases} p \cdot f(y|\mu, \sigma^2) & \textbf{if } y \neq 0 \\ 1 - p & \textbf{if } y = 0 \end{cases}$$

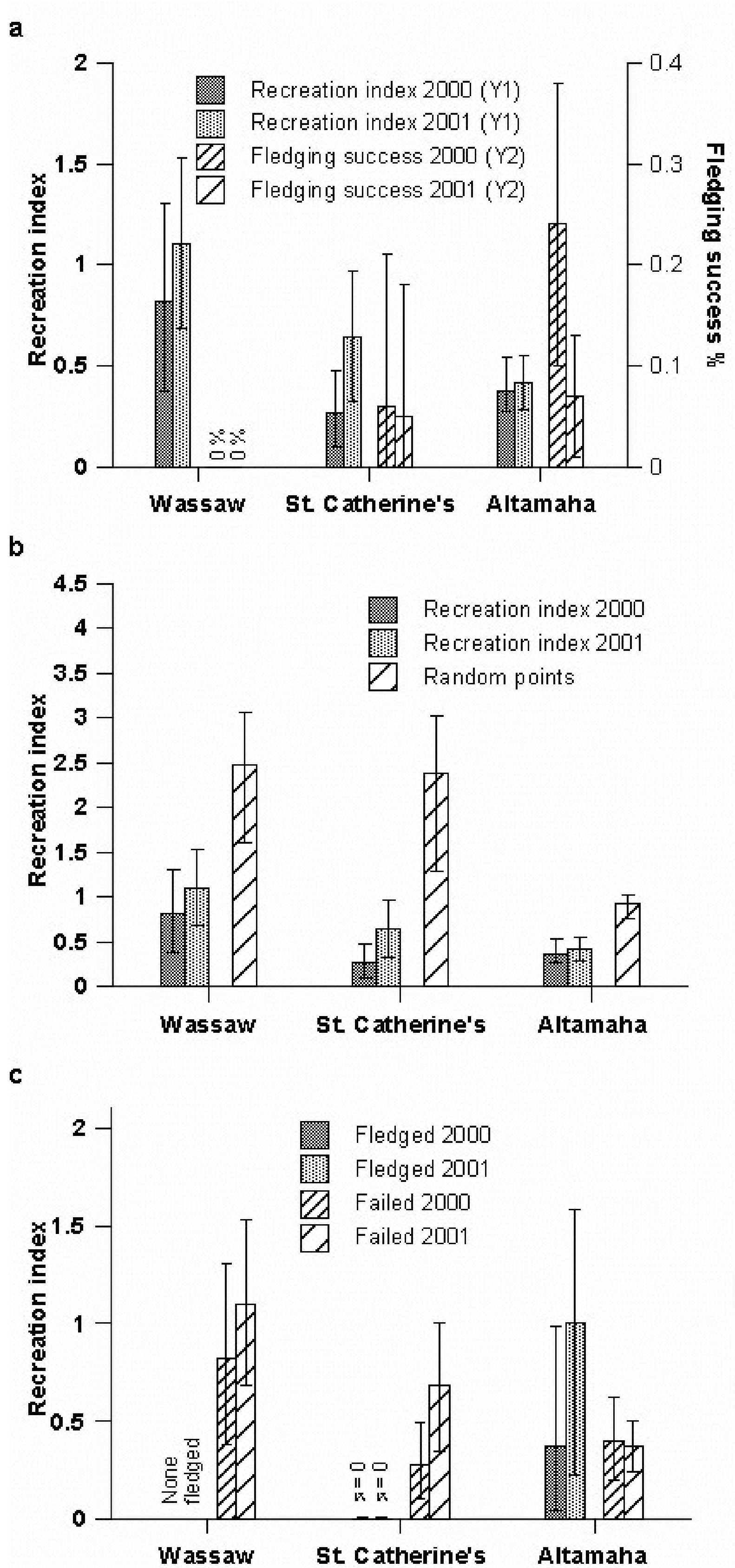
where p is the probability of disturbance and μ, σ^2 are parameters of the normal distribution. As such, the mean of each population was given by the population's maximum likelihood estimate and 95% confidence limits were constructed around the population likelihood profile (Hilborn and Mangel 1997). In a few data sets with small sample sizes, the upper confidence limit was undefined and is therefore represented below by ∞. Following construction of confidence intervals, differences in clutch recreation indices were compared to both fledging success and recreation indices for randomly distributed points at respective sites. Differences in recreation indices for successful and unsuccessful clutches were also compared among study areas. Lastly, distribution of mated pairs, clutch recreation indices, and fledging success were compared among beach and marsh habitats. Results for 2000 and 2001 were presented together for visual comparison, but do not imply statistical comparison.

RESULTS

Although 95% confidence intervals (CI) overlapped, average recreation index for American Oystercatcher clutches in 2000 tended to be greater and more variable at Wassaw ($\bar{x}$ = 0.82, CI = 0.38-1.31) than at St. Catherine's ($\bar{x}$ = 0.26, CI = 0.09-0.48) and Altamaha ($\bar{x}$ = 0.37, CI = 0.27-0.54; Fig. 4.2a). Fledging success for the same clutches was greater at Altamaha (24%, CI = 10-38%) than at Wassaw (0%). Fledging success at St. Catherine's was moderate in 2000 (6%, CI = 0-21%). In 2001, clutch recreation index was greater at Wassaw ($\bar{x}$ = 1.10, CI = 0.68-1.53) than at Altamaha ($\bar{x}$ = 0.41, CI = 0.28-0.55), and fledging success was greater at Altamaha (7%, CI = 1-13%) than at Wassaw (0%; Fig. 4.2a). At St. Catherine's, recreation index ($\bar{x}$ = 0.65, CI = 0.32-0.97) and fledging success (5%, CI = 0-18%) were moderate in 2001. A comparison of clutch recreation indices with randomly distributed points illustrated that average recreation index for random points at Wassaw ($\bar{x}$ = 2.48, CI = 1.60-3.06, N = 20), St. Catherine's ($\bar{x}$ = 2.38, CI = 1.29-3.02, N = 12), and Altamaha ($\bar{x}$ = 0.93, CI = 0.76-1.03, N = 39) were greater than clutch recreation indices at those sites in 2000 and 2001 (Fig. 4.2b).

A comparison of recreation indices among successful and unsuccessful clutches presented conflicting results (Fig. 4.2c). All clutches that fledged young at St. Catherine's were located in undisturbed areas in 2000 (N = 1) and 2001 (N = 1), whereas clutches that failed were located in areas used by recreationists in 2000 ($\bar{x}$ = 0.28, CI = 0.10-0.50) and 2001 ($\bar{x}$ = 0.68, CI = 0.34-1.00). On the contrary, successful clutches at Altamaha in 2001 were located in areas of

Figure 4.2. a) Clutch recreation index and fledging success, b) clutch recreation index and recreation index of randomly distributed points, and c) recreation index of successful and unsuccessful clutches for breeding American Oystercatchers at three sites in coastal Georgia, U.S.A, from March-July, 2000 and 2001. Brackets represent 95% confidence intervals.

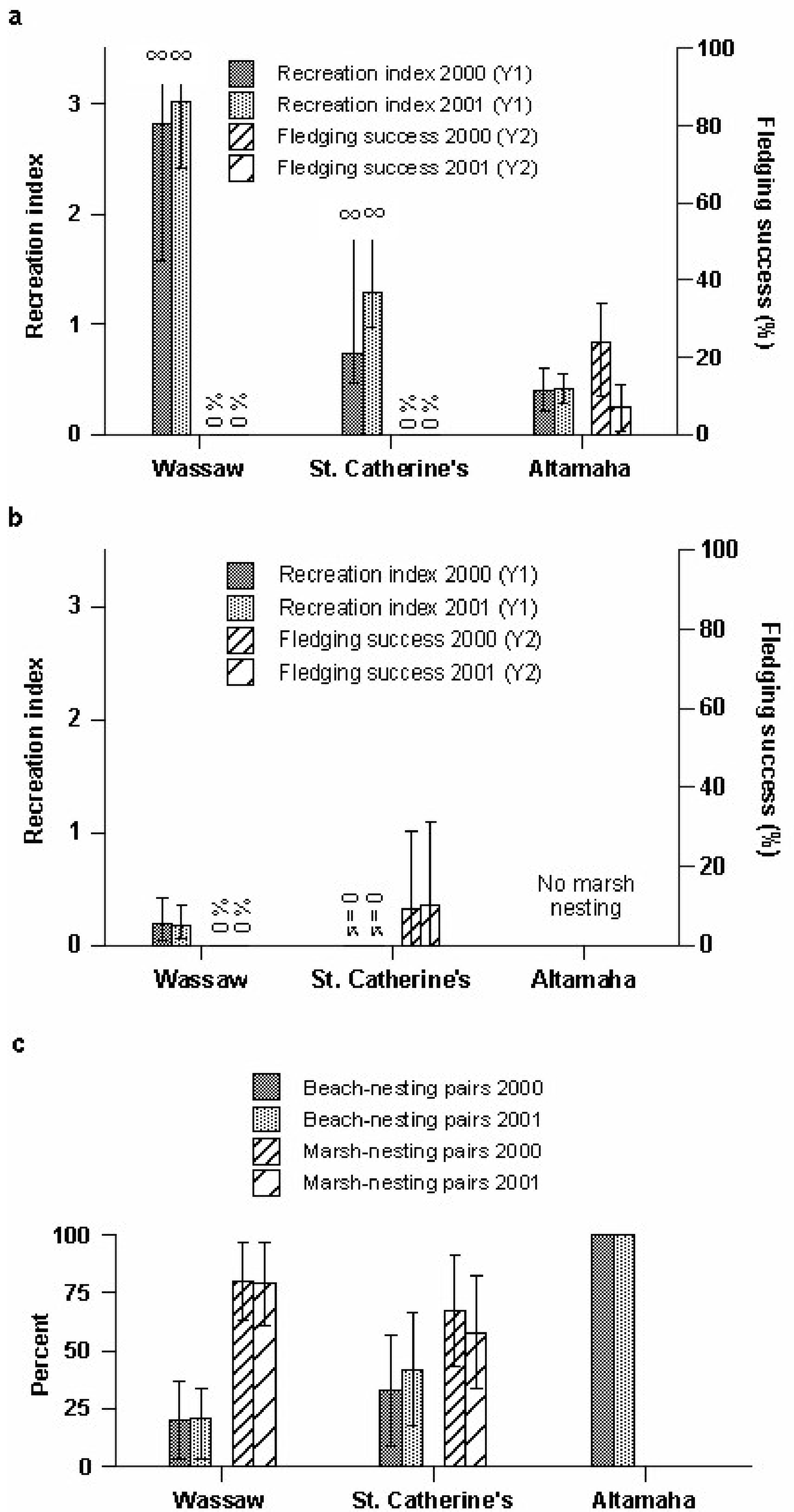

a
Recreation index 2000 (Y1)
Recreation index 2001 (Y1)
Fledging success 2000 (Y2)
Fledging success 2001 (Y2)
Recreation index
Fledging success %
0 %
0 %
Wassaw
St. Catherine's
Altamaha
b
Recreation index 2000
Recreation index 2001
Random points
Recreation index
Wassaw
St. Catherine's
Altamaha
c
Fledged 2000
Fledged 2001
Failed 2000
Failed 2001
Recreation index
None fledged
n = 0
n = 0
Wassaw
St. Catherine's
Altamaha

relatively greater recreational use ($\bar{x}$ = 1.0, CI = 0.23-1.59) than unsuccessful clutches ($\bar{x}$ = 0.37, CI = 0.25-0.50). Recreation index was similar at Altamaha in 2000 for successful ($\bar{x}$ = 0.37, CI = 0.04-0.98) and unsuccessful clutches ($\bar{x}$ = 0.40, CI = 0.20-0.62). Such comparisons could not be made at Wassaw because all clutches failed before fledging in 2000 (N = 21) and 2001 (N = 40). Cause of clutch failure during the egg stage was difficult to estimate accurately. Pooled across years, 47% of clutches (N = 83) failed for unknown reasons. Of the remaining clutches, 34% (N = 60) showed evidence of flooding, 17% (N = 30) showed evidence of depredation, and 4% (N = 2) were apparently abandoned. Human disturbance was not implicated directly in any clutch failures.

The magnitude and distribution of recreation at Wassaw and St. Catherine's was more obvious when analyzed with respect to habitat type (Fig. 4.3). In 2000, recreation index for clutches at beach habitats (Fig. 4.3a) was greater at Wassaw ($\bar{x}$ = 2.81, CI = 1.57-∞) than at Altamaha ($\bar{x}$ = 0.39, CI = 0.21-0.61), whereas recreation index was moderate at St. Catherine's ($\bar{x}$ = 0.74, CI = 0.46-∞). In 2001, recreation index was greater at Wassaw ($\bar{x}$ = 3.01, CI = 2.41-∞) and St. Catherine's ($\bar{x}$ = 1.29, CI = 0.97-∞) than at Altamaha ($\bar{x}$ = 0.41, CI = 0.28-0.55). Conversely, fledging success was greater at Altamaha in 2000 (24%, CI = 10-38%) and 2001 (7%, CI = 1-13%) than at Wassaw in 2000 (0%, N = 5) and 2001 (0%, N = 13), and St. Catherine's in 2000 (0%, N = 6) and 2001 (0%, N = 10) where all beach clutches failed before fledging.

Recreationists used marsh habitats infrequently (Fig. 4.3b). Average recreation index was lower for marsh clutches at Wassaw in 2000 ($\bar{x}$ = 0.19, CI = 0.05-0.42) and 2001 ($\bar{x}$ = 0.18, CI = 0.06-0.35), and at St. Catherine's in 2000 ($\bar{x}$ = 0, N = 11) and 2001 ($\bar{x}$ = 0, N = 10), than for beach clutches at those respective sites (Fig. 4.3a, b). Additionally, recreation indices for marsh clutches were greater at Wassaw where no marsh clutches fledged young in 2000 (N = 16) or .

Figure 4.3. Clutch recreation index and fledging success at a) beach habitats and b) marsh habitats, and c) distribution of pairs among habitats for breeding American Oystercatchers at three sites in coastal Georgia, U.S.A., from March to July, 2000 and 2001. Brackets represent 95% confidence intervals and "∞" indicates an undefined upper confidence limit.


a
Recreation index 2000 (Y1)
Recreation index 2001 (Y1)
Fledging success 2000 (Y2)
Fledging success 2001 (Y2)
Recreation index
Fledging success (%)
0%
0%
Wassaw
St. Catherine's
Altamaha
b
Recreation index 2000 (Y1)
Recreation index 2001 (Y1)
Fledging success 2000 (Y2)
Fledging success 2001 (Y2)
Recreation index
Fledging success (%)
No marsh nesting
Wassaw
St. Catherine's
Altamaha
c
Beach-nesting pairs 2000
Beach-nesting pairs 2001
Marsh-nesting pairs 2000
Marsh-nesting pairs 2001
Percent
Wassaw
St. Catherine's
Altamaha

2001 (N = 27), than at St. Catherine's where one clutch fledged at a small marsh island in 2000 (N= 11) and 2001 (N = 10). No clutches were found in marsh habitat at Altamaha during this study. The distribution of nesting pairs varied with respect to habitat within and among sites (Fig. 4.3c). Despite the presence of oyster-shell rakes, dredge spoil deposits, and marsh islands at Altamaha, all oystercatcher pairs nested at beach habitat in 2000 (N = 33) and 2001 (N = 44). At St. Catherine's, more pairs nested at marsh habitat in 2000 (67%, CI = 43-91%) and 2001 (58%, CI = 34-82%) than nested at beach habitat in 2000 (33%, CI = 9-57%) and 2001 (42%, CI = 18-66%), but 95% confidence intervals overlapped. At Wassaw, the proportion of marsh-nesting pairs in 2000 (80%, CI = 63-97%) and 2001 (79%, CI = 61-97%) was greater than beach-nesting pairs in 2000 (20%, CI = 3-37%) and 2001 (21%, CI = 3-39%). Cause of clutch failure during the egg stage also differed among habitats. At beach habitat, 48% of clutches (N = 58) failed for unknown reasons, 26% (N = 31) showed signs of flooding, 23% (N = 27) showed signs of depredation, and 3% (N = 4) were apparently abandoned. At marsh habitats, 51% (N = 29) showed signs of flooding, 44% (N = 25) failed for unknown reasons, and 5% (N = 3) of clutches showed signs of depredation.

DISCUSSION

Our results indicate a pattern of reduced American Oystercatcher fledging success in response to increased recreational disturbance. Assuming that the situation is not the result of sampling error, numerous biological factors could explain this pattern. Toland (1999) hypothesized that recreation reduced oystercatcher productivity directly by forcing adults from nests, resulting in depredation of eggs and chicks by domestic pets and avian predators, hypo- or hyperthermia of eggs or chicks, or increased rates of nest abandonment. Although recreational disturbance was not attributed directly to any clutch failures in this study, domestic dogs were often observed in areas of frequent recreational use (pers. obs.). Oystercatcher pairs were also routinely flushed from nests by approaching recreationists in such areas. Unfortunately, the causes of many clutch failures were undetermined and our methods were insufficient for quantifying the direct effects of recreation on individual clutches if they occurred. Additionally, depredation and flooding were the causes of most identifiable clutch failures, even in areas of frequent recreational use. A previous study of American Oystercatchers found a correlation between areas of increased recreational use and increased Raccoon (*Procyon lotor*) density (Davis 1999), suggesting that recreation may suppress reproductive success indirectly by increasing rates of mammalian depredation. Regardless of the mechanism, the success of numerous clutches (N = 3) at disturbed areas within the Altamaha site in 2001 demonstrated that oystercatchers are capable of fledging young successfully in areas of moderate disturbance, even in the presence of mammalian predators. Further monitoring will be necessary to determine whether the inability of oystercatchers to fledge young in areas of greater recreation at Wassaw and St. Catherine's was due to disturbance at those sites or was simply the result of seasonal variation in productivity. With numbers of recreationists ranging as high as 50 to 100 people on beaches at St. Catherine's and Wassaw, it seems likely that recreation would have some negative effects. I hypothesize that a threshold level of disturbance exists, beyond which oystercatchers either abandon habitat or are incapable of raising young successfully.

Although the effects of recreation on the success of individual clutches were less certain, the effects of recreation on nesting habitat selection appeared more conclusive. A comparison of clutch recreation indices with recreation at randomly distributed points showed that oystercatchers chose areas of lower levels of recreational use within each site than one would expect if nest sites were selected randomly. At Altamaha, this response had little effect on oystercatcher fledging success because ample, high-quality beach habitat remained that was undisturbed by recreationists. At Wassaw and St. Catherine's, however, the majority of beach habitat was affected by recreation and was avoided by oystercatchers. As a result, a greater proportion of nesting pairs initiated clutches in marsh habitats at those sites. These findings provide support for Frohling's (1965) hypothesis that marsh nesting by American Oystercatchers occurs in response to increased human use of beach habitats. Moreover, productivity appeared to be lower at marsh habitat than at beach habitat. In the two years of this study, only one marsh clutch fledged young each year. As noted in previous studies (Zarudsky 1985; Lauro and Burger 1989), the low elevation of marsh habitats in this study resulted in greater rates of flooding at marshes than at beach nests. Additional monitoring will be required to determine whether low productivity at marsh habitats is typical across years. If so, the long life-span of American Oystercatchers (10-17 years; Nol and Humphrey 1994), coupled with an abundance of marsh-nesting adults, could mask reductions in productivity and contribute to long-term population declines (Davis 1999; Davis *et al*. 2001). Consequently, significant changes in the number of breeding pairs or in the distribution of breeding pairs with respect to habitat should warrant concern. Furthermore, current attempts to maintain low levels of recreation at important breeding sites in Georgia should continue.

ACKNOWLEDGMENTS

This study was made possible by funding from the Georgia Department of Natural Resources' Nongame/Natural Heritage Section, the University of Georgia's D. B. Warnell School of Forest Resources, and the Georgia Ornithological Society. Assistance with on-site housing was provided by The Nature Conservancy's Altamaha Bioreserve and the Georgia Department of Natural Resources' Wildlife Resources Division. Thanks to Andrew Walde, Angie Cone, and Jennifer George for field assistance. Thanks also to Robert Cooper and Cecil Jennings for their suggestions on this paper.

LITERATURE CITED

Anderson, D. W., and J. O. Keith. 1980. The human influence on seabird nesting success: conservation implications. Biological Conservation 18: 65-80.

Bent, A. C. 1929. Life histories of North American shore birds. Part 2. U.S. National Museum Bulletin, Number 146. Washington, D.C.

Burger, J. 1986. The effect of human activity on shorebirds in two coastal bays in northeastern United States. Environmental Conservation 13: 123-130.

_____. 1994. The effect of human disturbance on foraging behavior and habitat use in Piping Plover (*Charadrius melodus*). Estuaries 17: 695-701.

Corbat, C. A. 1990. Nesting ecology of selected beach-nesting birds in Georgia. Dissertation, University of Georgia, Athens, GA.

Davis, M. B. 1999. Reproductive success, status, and viability of the American Oystercatcher (*Haematopus palliatus*). Thesis, North Carolina State University, Raleigh, NC.

_____, T. R. Simons, M. J. Groom, J. L. Weaver, and J. R. Cordes. 2001. The breeding status of the American Oystercatcher on the east coast of North America and breeding success in North Carolina. Waterbirds 24: 195-202.

Erichsen, W. J. 1921. Notes on the habits of the breeding water birds of Chatham County, Georgia. Wilson Bulletin 33: 82.

Erwin, R. M. 1980. Breeding habitat use by colonially nesting waterbirds in two mid-Atlantic U.S. regions under different regimes of human disturbance. Biological Conservation 18: 39-51.

Frohling, R. C. 1965. American Oystercatcher and Black Skimmer nesting on salt marsh. Wilson Bulletin 77: 193-194.

Georgia Coastal Management Program. 1997. Combined coastal management program and final environmental impact statement for the state of Georgia. U.S. Department of Commerce, Office of Ocean and Coastal Resource Management, National Oceanic and Atmospheric Administration. Silver Spring, MD.

Goldin, M. R., and J. V. Regosin. 1998. Chick behavior, habitat use, and reproductive success of Piping Plovers at Goosewing Beach, Rhode Island. Journal of Field Ornithology 69: 228-234.

Hilborn, R., and M. Mangel. The ecological detective: confronting models with data. Princeton University, Princeton, NJ.

Hunter, W. C. 2000. U.S. shorebird conservation plan: southeastern coastal plain—Carribean regional shorebird plan. U.S. Fish and Wildlife Service. Atlanta, GA.

Kvanli, A. H., Y. K. Shen, and L. Y. Deng. 1998. Construction of confidence intervals for the mean of a population containing many zero values. Journal of Business and Economic Statistics 16: 362-369.

Johnson, D. H. 1999. The insignificance of statistical significance testing. Journal of Wildlife Management 63: 763-772.

Lauro, B., and J. Burger. 1989. Nest-site selection of American Oystercatcher (*Haematopus palliatus*) in salt marshes. Auk 106: 185-192.

_____, E. Nol, and M. Vicari. 1992. Nesting density and communal breeding in American Oystercatchers. Condor 94: 286-289.

Nol, E., and R. C. Humphrey. 1994. American Oystercatcher. Pages 1-20 *in* The birds of North America, No. 82 (A. Poole and F. Gill, Eds.). Academy of Natural Sciences, Philadelphia, PA.

Ozier, J. C., J. L. Bohannon, and J. L. Anderson, project coordinators. 1999. Protected Animals of Georgia. Georgia Department of Natural Resources, Wildlife Resources Division, Nongame Wildlife-Natural Heritage Section. Social Circle, GA.

Rappole, J. H. 1981. Management possibilities for beach-nesting shorebirds in Georgia. Pages 114-126 *in* Proceedings of the nongame and endangered wildlife symposium (R. R. Odum and J. W. Guthrie, Eds.). Georgia Department of Natural Resources, Game and Fish Division, Technical Bulletin WL 5.

Rogers, J. A., Jr., and H. T. Smith. 1995. Set-back distances to protect nesting bird colonies from human disturbance in Florida. Conservation Biology 9: 89-99.

Safina, C., and J. Burger. 1983. Effects of human disturbance on reproductive success in the Black Skimmer. Condor 85: 164-171.

Samuels, M. L. 1989. Statistics for the life sciences. Dellen, San Fransisco, CA.

Shields, M. A., and J. F. Parnell. 1990. Marsh nesting by American Oystercatchers in North Carolina. Journal of Field Ornithology 61: 431-433.

Toland, B. 1992. Use of forested spoil islands by nesting American Oystercatchers in southeast Florida. Journal of Field Ornithology 63: 155-158.

_____. 1999. Nest site charactersitics, breeding phenology, and nesting success of American Oystercatchers in Indian River County, Florida. Florida Field Naturalist 27: 112-116.

Winn, B. 2000. The spatial distribution of American Oystercatchers in Georgia. The Oriole 65: 41-49.

Zarudsky, J. D. 1985. Breeding status of the American Oystercatcher in the town of Hempstead. Kingbird 35: 105-113.

CHAPTER 5

CONCLUSIONS

Reproductive Success and Productivity

- Average clutch size of 2.0 eggs per clutch documented for American Oystercatchers (*Haematopus palliatus*) in Georgia in 2000 and 2001 was lower than documented in previous studies. The only previous published study of oystercatchers in Georgia (Corbat 1990) also documented relatively low clutch size of 2.3 eggs per clutch. This situation could be related to numerous factors, including but not limited to: poor foraging resources, increased rates of depredation and flooding, increased number of replacement clutches per female, or some combination thereof.
- Hatching success, fledging success, probability of clutch survival to hatching, and fledgling production were low and variable among sites and years, but similar to results from previous studies in Virginia (Nol 1989) and North Carolina (Davis 1999). These findings may warrant concern because oystercatcher populations in Virginia and North Carolina appear to be in decline (Davis *et al*. 2001).
- It is unclear whether the failure of all oystercatcher pairs to produce fledglings at Wassaw in 2000 and 2001 reflects natural lulls in reproduction or is a routine phenomenon. Additional monitoring is necessary.
- Primary causes of clutch failure during the egg stage were depredation (34%) and flooding (17%), consistent with previous studies of oystercatchers (Zarudsky 1985; Lauro and Burger 1989; Nol 1989; Corbat 1990; Toland 1999; Davis *et al*. 2001). However, cause of clutch failure was undetermined in 47% of cases. Avian depredation was difficult to document in all

habitats and mammalian depredation was difficult to document in marsh habitats, so depredation rates were probably underestimated.

- Although not significantly different, hatching and fledging success were lower at marsh habitats than at beach and sand spits habitats in 2000 and 2001. One clutch fledged young at the same marsh island in 2000 and 2001; no clutches fledged young at oyster shell rakes. Rates of flooding were greater at marsh clutches than at beach and sand spit clutches, which is consistent with previous studies of marsh nesting in oystercatchers (Zarudsky 1985; Lauro and Burger 1989; Shields and Parnell 1990).
- Beach habitat afforded the greatest protection from flooding and storms, but chicks and eggs were exposed to mammalian and avian predators, recreationists, and at some islands, Feral Hogs (*Sus scrofa*) and all-terrain vehicles (ATV's) used for Loggerhead Sea Turtle (*Caretta caretta*) management. The only beach clutches that fledged young were located at an island with moderate to low recreation, no hog population, and a sea turtle management program that used bicycles, rather than ATV's.
- Although sand spit habitats were not accessible to mammalian predators, numerous factors affected oystercatchers negatively at those sites, including: seasonal variation in habitat quality, frequent flooding, inter- and intraspecific competition for nesting habitat, depredation by gulls (*Larus* spp.), and recreation. Nonetheless, the greatest fledging success documented during this study (24%) was documented at sand spits in 2000.

Department of Natural Resources-Managed Sites

- Pelican Spit was relatively unimportant to nesting American Oystercatchers during this study because it was destroyed by a storm in late 1999. Considerable accretion of sediments occurred by 2001 and two pairs nested at the spit in late 2001. The spit may be productive habitat for nesting oystercatchers if accretion continues.

- Egg Island Bar was the only managed site that produced oystercatcher fledglings during this study. The site was burned before the 2000 nesting season, resulting in an abundance of high-quality habitat and increased fledging success (33%). Recolonization of sandy habitats by perennial and annual vegetation in 2001, coupled with a 47% increase in oystercatcher pairs, resulted in greater inter- and intraspecific competition for resources, increased depredation of eggs and chicks by nesting Laughing Gulls (*Larus atricilla*), and reduced fledging success (5%). Prohibition of recreation at the site benefitted nesting oystercatchers and many other species of nesting and roosting shorebirds, waders, seabirds, and waterfowl.
- All oystercatcher clutches at St. Catherine's Bar failed before hatching in 2000 and 2001. Low topography and depredation of clutches by roosting gulls could have attributed to failure of clutches at the spit. Recreation was prohibited at the spit and did not appear to factor in any clutch failures. Continued erosion at the site since the completion of this project may further reduce the probability of successful nesting by oystercatchers.
- One clutch hatched, but none fledged at Williamson Island during this study. Depredation by Raccoons (*Procyon lotor*) appeared to limit productivity at the site. Recreation was allowed along the island's beach and domestic dogs (*Canis familiaris*) were prohibited. Regulations were poorly enforced; dogs were frequently observed and recreationists' footprints were often seen within prohibited areas. Although not implicated directly in any clutch failures, recreationists may have reduced oystercatcher productivity indirectly by discouraging nesting, forcing incubating birds from nests, exposing eggs and chicks to dogs (Toland 1999), or by attracting greater numbers of Raccoons (Davis 1999).

Effects of Human Recreation

- As a general trend, fledging success increased as recreational use decreased within each site.
- Oystercatchers at Altamaha were capable of fledging young at beaches with low to moderate

recreational use. No pairs fledged young at beaches at Wassaw and St. Catherine's, where the magnitude of recreational use was greater.

- Oystercatchers selected nesting habitat within each site that was significantly less disturbed than the habitat available; nest selection did not occur randomly.
- Recreation appears to affect oystercatcher productivity negatively by influencing nesting habitat selection. As recreation increased, a greater proportion of oystercatcher pairs nested at marsh habitats and fewer pairs nested at beaches and sand spits. Since reproductive success appears to be lower at marsh habitats, because of greater rates of flooding, increases in recreation could precipitate long-term declines in oystercatcher productivity. These findings provide support for Frohling's (1965) hypothesis that marsh nesting by oystercatchers occurs in response to human disturbance on beaches.

FUTURE RESEARCH NEEDS

- Further monitoring is necessary to determine whether low reproductive success of American Oystercatchers at Wassaw was related to recreational disturbance, high predation rates, or some greater problem confronting oystercatchers at that site.
- Better estimates of predation rates are needed, especially for oystercatchers nesting in marsh habitats. Chicks at oyster shell rakes may be especially susceptible to predation when high tides force them onto diminishing areas of dry land.
- The effects of sea turtle management (particularly the use of ATV's) should be examined further. The disturbance associated with use of ATV's appears to discourage nesting by oystercatchers and other shorebirds. Better cooperation between shorebird and sea turtle managers could help to help mitigate this problem.
- Managers should be especially mindful of any dramatic changes in the number and distribution of nesting oystercatchers at these sites, especially as they might relate to

increases in recreation. Small changes in number and distribution should expected over time as natural changes in habitat occur, but dramatic changes may warrant more aggressive management. It should be noted that the estimated number of pairs documented in this study reflect the maximum number of pairs at each site as determined through repeated, frequent surveys. Less frequent surveys (as would probably be conducted by shorebird managers) would produce lower estimates as a function of reduced survey effort and may not reflect actual reductions.

- More outreach to the public regarding the importance of shorebird resources is sorely needed. Many recreationists are completely unaware of Georgia's shorebird resources and may be more understanding and supportive of shorebird management and regulations were they better informed.

MANAGEMENT SUGGESTIONS

- Further monitoring of breeding American Oystercatchers should address fledgling production (the number of fledglings produced per pair), rather than hatching and fledging success. Calculations of hatching and fledging success require systematic, frequently-repeated surveys which are expensive, logistically difficult, and disruptive to nesting birds (Anderson and Keith 1980). Additionally, hatching and fledging success calculations change dramatically as the number of replacement clutches varies and may overestimate actual changes in fledgling production. Estimates of fledgling production would require fewer surveys (perhaps as few as 3 surveys per month per site from May to July) and would reduce researcher disturbance. At sand spits and marshes, the number of pairs and fledglings can be estimated from a boat, thereby minimizing disturbance to nesting birds. On beaches, surveys should be conducted from a distance with a spotting scope to minimize disturbance. Surveys for pairs should be conducted at the last half of a rising tide to maximize the chance that pairs are on territory.

Surveys for chicks and fledglings should be conducted at the last half of a falling tide, preferably in the morning, when chicks are easily observed foraging along the shoreline with their parents. Banding fledglings with color bands can also aid in confirmation of fledging.

- Further management at Egg Island Bar should address the need for open, sparsely vegetated habitat on at least a sizeable portion of the spit. Such management would benefit American Oystercatchers, Wilson's Plovers (*Charadrius wilsonia*), Gull-billed Terns (*Sterna nilotica*), Least Terns (*S. antillarum*), and Black Skimmers (*Rhynchops niger*) (Soots and Parnell 1975; Ozier *et al*. 1999), while discouraging nesting by Laughing Gulls (Soots and Parnell 1975; Buckley and McCarthy 1994; Mallach and Leberg 1999). If management of habitat is ineffective in controlling Laughing Gulls, direct control of Laughing Gulls through lethal means may be warranted. Maintaining minimal levels of recreational disturbance at the site should also remain a priority. If recreation continues to increase in the region, more signs and enforcement of regulations would be warranted.
- Greater plasticity is needed in regulating recreation in the future. As currently imposed and enforced, regulations at Williamson Island (Board of Natural Resources Rule 391-4-7) provide no apparent benefit to oystercatchers or other nesting shorebirds. The magnitude of disturbance at the site and access of the entire beach to recreationists, coupled with an apparent lack of enforcement, has done little to mitigate the effects of recreation on nesting birds. On the contrary, current regulations have served to fuel animosity for environmental regulations by many local residents. Perhaps it would be more practical to designate the entire southwest half of the island for recreation and preserve the other half, including the beach, as shorebird nesting habitat. If properly enforced, such management would probably be more beneficial to nesting shorebirds than the current approach which protects nesting habitat, but

not brooding and foraging habitat. If accretion continues at Pelican Spit, reimposing regulations at that site may be warranted.

LITERATURE CITED

Anderson, D. W., and J. O. Keith. 1980. The human influence on seabird nesting success: conservation implications. Biological Conservation 18: 65-80.

Buckley, P. A., and M. G. McCarthy. 1994. Insects, vegetation, and the control of laughing gulls (Larus atricilla) at Kennedy International Airport, New York City. Journal of Applied Ecology 31: 291-302.

Corbat, C. A. 1990. Nesting ecology of selected beach-nesting birds in Georgia. Dissertation, University of Georgia, Athens, GA.

Davis, M. B. 1999. Reproductive success, status, and viability of the American Oystercatcher (Haematopus palliatus). Thesis, North Carolina State University, Raleigh, NC.

_____, T. R. Simons, M. J. Groom, J. L. Weaver, and J. R. Cordes. 2001. The breeding status of the American Oystercatcher on the east coast of North America and breeding success in North Carolina. Waterbirds 24: 195-202.

Frohling, R. C. 1965. American Oystercatcher and black Skimmer nesting on salt marsh. Wilson Bulletin 77: 193-194.

Lauro, B., and J. Burger. 1989. Nest-site selection of American Oystercatcher (Haematopus palliatus) in salt marshes. Auk 106: 185-192.

Mallach, T. J., and P. L. Leberg. 1999. Use of dredged material substrates by nesting terns and black skimmers. Journal of Wildlife Management 63: 137-146.

Nol, E. 1989. Food supply and reproductive performance of the American Oystercatcher in Virginia. Condor 91: 429-435.

Ozier, J. C., J. L. Bohannon, and J. L. Anderson, project coordinators. 1999. Protected Animals of Georgia. Georgia Department of Natural Resources, Wildlife Resources Division, Nongame Wildlife-Natural Heritage Section. Social Circle, GA.

Shields, M. A., and J. F. Parnell. 1990. Marsh nesting by American Oystercatchers in North Carolina. Journal of Field Ornithology 61: 431-433.

Soots, R. F., Jr., and J. F. Parnell. 1975. Ecological success of breeding birds in relation to plant success on dredge islands in North Carolina estuaries. University of North Carolina Sea Grant Publication UNC-SG-75-27. Raleigh, NC.

Toland, B. 1999. Nest site charactersitics, breeding phenology, and nesting success of American Oystercatchers in Indian River County, Florida. Florida Field Naturalist 27: 112-116.

Zarudsky, J. D. 1985. Breeding status of the American Oystercatcher in the town of Hempstead. Kingbird 35: 105-113.

APPENDIX A

PARAMETERS OF AMERICAN OYSTERCATCHER CLUTCHES AT THREE SITES IN COASTAL GEORGIA, MARCH-JULY, 2000 AND 2001.

Table A.1. American Oystercatcher clutch data for three sites in coastal Georgia from March-July 2000 (continued on following page).

I D	LOCATION [1]	EASTING [2]	NORTHING [2]	HABITAT [3]	CLUTCH SIZE	HATCHED	FLEDGED	DATE FOUND	HATCH/FAIL	FLEDGE/FAIL	CAUSE [4]
4	ARD	472556.463	3468610.136	1	1	0	0	40700	42000		1
5	ARD	473546.000	3463820.000	2	1	1	1	40700	51200	60300	0
6	ARD	474016.642	3464104.277	2	2	0	0	40700	50600		4
7	ARD	473524.862	3463612.583	2	3	0	0	41200	51200		4
8	ARD	474210.000	3463955.000	2	3	1	1	41200	50600	52400	0
13	ARD	474121.000	3463620.000	2	3	1	0	42000	61900	61900	0
14	ARD	474005.000	3463481.000	2	2	0	0	42000	51200		4
15	ARD	473886.000	3463467.000	2	2	0	0	42000	51200		4
16	ARD	473644.000	3463583.000	2	2	0	0	42000	51200		2
18	ARD	473533.000	3463909.000	2	3	2	1	42000	51200	61900	0
19	ARD	473686.000	3464051.000	2	1	0	0	42000	50600		4
20	ARD	473734.000	3464073.000	2	1	1	1	42000	52400	70400	0
21	ARD	471153.011	3453805.810	1	1	0	0	42100	53100		4
22	ARD	472777.480	3455517.329	1	3	1	1	42100	61000	62300	0
23	ARD	472875.965	3456259.306	1	2	0	0	42100	53100		4
34	ARD	473094.000	3461898.000	1	1	0	0	42900	51600		4
35	ARD	473037.000	3461943.000	1	1	0	0	42900	51600		4
36	ARD	473241.200	3460658.150	1	3	0	0	42900	53100		4
37a	ARD	474180.666	3458100.629	1	2	0	0	42900	53100		4
38	ARD	473162.282	3456915.516	1	1	1	1	42900	53100	70900	0
39	ARD	472343.486	3469945.350	1	1	0	0	50600	51200		1
40	ARD	473964.000	3464100.000	2	2	0	0	50600	52400		4
41	ARD	474216.000	3463928.000	2	1	1	1	50600	61400	70400	0
45	ARD	473704.000	3463558.000	2	1	1	1	51200	52400	70400	0
46	ARD	473704.000	3464065.000	2	2	0	0	51200	60400		4
49	ARD	474147.000	3463558.000	2	2	0	0	51600	60400		4
61	ARD	472952.211	3461921.765	1	2	0	0	52600	61000		2
62	ARD	473136.761	3461008.468	1	3	0	0	52600	61000		2
37b	ARD	474148.892	3458025.136	1	2	0	0	53100	61000		4
63	ARD	473071.653	3461882.817	1	3	0	0	53100	70500		4
64	ARD	473824.142	3459474.643	1	2	0	0	53100	61000		2
65	ARD	472964.000	3466952.000	1	1	0	0	53100	53100		2
73	ARD	473465.000	3463637.000	2	2	0	0	61400	70400		4
74	ARD	473895.000	3464123.000	2	3	1	0	61600	70400		0
1	SCS	482958.100	3509906.494	3	3	3	3	33100	42700	61200	0
10	SCS	481349.007	3505892.035	3	3	0	0	41800	50900		2
28	SCS	487966.168	3506811.494	2	2	0	0	42700	51700		2

Table A.1, *continued*.

I D	LOCATION	EASTING	NORTHING	HABITAT	CLUTCH SIZE	HATCHED	FLEDGED	DATE FOUND	HATCH/FAIL	FLEDGE/FAIL	CAUSE
29	SCS	488170.033	3506764.232	2	2	0	0	42700	51700		2
30	SCS	488219.802	3506644.957	2	3	0	0	42700	60100		2
31	SCS	488066.304	3506607.532	2	3	0	0	42700	51700		2
32	SCS	482104.561	3507415.160	3	3	0	0	42700	51700		2
33	SCS	480017.830	3511814.739	3	2	0	0	42700	50900		2
43	SCS	485490.902	3512368.316	3	3	3	0	50900	60100	60100	0
44	SCS	480843.841	3505101.763	3	3	0	0	50900	51700		2
56	SCS	481962.186	3508104.410	3	2	0	0	52300	52700		4
57	SCS	480915.081	3504008.165	3	1	0	0	52300	60100		4
58	SCS	481345.159	3505889.848	3	2	0	0	52300	60100		4
66	SCS	488257.782	3506727.083	2	2	0	0	60100	60900		2
67	SCS	481250.130	3505773.959	3	2	0	0	60100	62000		4
68	SCS	482148.098	3507377.959	3	1	0	0	60100	61000		2
70	SCS	488078.317	3506640.075	2	1	0	0	60900	62000		4
2	WAS	499114.596	3538014.624	3	2	0	0	40600	50800		4
3	WAS	500889.673	3535162.708	3	3	0	0	40600	50800		4
11	WAS	501022.317	3535133.117	3	3	0	0	41900	50800		4
24	WAS	501526.573	3532929.992	3	3	3	0	42600	51400	51400	0
25	WAS	503258.724	3530885.152	3	2	0	0	42600	51400		4
26	WAS	507040.172	3533696.843	1	2	0	0	42600	51300		1
42	WAS	502627.737	3534110.538	3	1	0	0	50800	51800		1
47	WAS	507971.441	3534129.841	1	2	2	0	51300	52800	52800	0
48	WAS	508602.173	3534884.881	1	2	1	0	51300	60800	60800	0
50	WAS	500951.361	3535151.246	3	1	0	0	51800	52800		2
51	WAS	502023.695	3534584.735	3	2	0	0	51800	52800		4
52	WAS	508489.309	3534563.186	1	2	0	0	51800	60200		2
53	WAS	504564.404	3535657.584	3	2	0	0	51800	60200		2
54	WAS	499595.289	3536822.444	3	1	0	0	51800	60200		2
55	WAS	499097.932	3537990.419	3	3	0	0	51800	60200		2
60	WAS	504047.360	3530598.066	3	3	0	0	51800	60800		2
59	WAS	499113.608	3538014.481	3	2	0	0	52500	61300		2
69	WAS	507351.170	3533771.794	1	2	0	0	60200	62700		4
71	WAS	499043.883	3537928.893	3	2	0	0	61300	70200		2
72	WAS	504629.628	3535701.533	3	1	0	0	61300	62100		1
75	WAS	499108.279	3538007.267	3	1	0	0	62100	70200		2

[1] ARD = Altamaha River Delta, SCS = St. Catherine's Sound, and WAS = Wassaw Sound.
[2] Easting and northing coordinates in meters; UTM Zone 17N projection.

[3] 1 = beach, 2 = sand spit, and 3 = oyster shell rake/marsh island

[4] Cause of clutch failure during egg stage: 0 = hatched, 1 = predation, 2 = flooded, 3 = abandoned, and 4 = unknown cause.

Table A.2. American Oystercatcher clutch data for three sites in coastal Georgia from March-July 2000 (continued on following page).

I D	LOCATION [1]	EASTING [2]	NORTHING [2]	HABITAT [3]	CLUTCH SIZE	HATCHED	FLEDGED	DATE FOUND	HATCH/FAIL	FLEDGE/FAIL	CAUSE [4]
4	ARD	473631.606	3463627.409	2	2	2	1	41001	50201	70301	0
11	ARD	473648.630	3464002.128	2	2	0	0	41301	50201		1
12	ARD	473561.725	3463870.202	2	2	0	0	41301	50901		1
13	ARD	474013.694	3463437.291	2	3	0	0	41301	42201		3
16	ARD	471890.870	3453506.638	1	3	0	0	41901	51201		2
17	ARD	471147.572	3453800.406	1	3	0	0	41901	51701		4
18	ARD	472499.040	3454144.662	1	3	2	0	41901	42601	51201	0
19	ARD	472765.220	3455470.389	1	3	3	3	41901	51201	61901	0
20	ARD	473162.231	3461336.964	1	2	0	0	41901	51201		4
21	ARD	473327.539	3459998.304	1	3	0	0	41901	50401		4
22	ARD	473821.656	3459478.665	1	2	0	0	41901	42601		4
23	ARD	474062.644	3459162.104	1	1	0	0	41901	42601		4
24	ARD	474204.264	3458814.321	1	2	0	0	41901	42601		4
25	ARD	473171.560	3456949.268	1	2	1	1	41901	52301	70201	0
30	ARD	472419.954	3469745.251	1	1	0	0	42201	50801		2
31	ARD	472533.067	3468610.249	1	1	0	0	42201	50801		2
32	ARD	473756.638	3464107.349	2	3	0	0	42201	51301		4
33	ARD	473932.314	3464114.638	2	3	0	0	42201	50901		2
34	ARD	474157.203	3463907.909	2	3	0	0	42201	50201		4
35	ARD	474119.354	3463655.715	2	3	0	0	42201	50901		2
36	ARD	474091.067	3463513.605	2	3	0	0	42201	50901		2
37	ARD	474040.692	3463438.300	2	1	0	0	42201	42801		4
38	ARD	473965.726	3463448.413	2	2	0	0	42201	51301		1
39	ARD	473847.212	3463520.044	2	3	0	0	42201	51301		1
40	ARD	473604.663	3463825.576	2	3	2	2	42201	51301	62201	0
41	ARD	473573.512	3463905.191	2	2	0	0	42201	42801		4
42	ARD	473712.160	3464062.252	2	3	0	0	42201	51301		1
46	ARD	473085.243	3461938.303	1	2	0	0	42601	51201		2
47	ARD	474298.978	3457798.044	1	2	1	1	42601	52901	71001	0
51	ARD	473786.424	3464117.809	2	1	0	0	42801	50201		3
52	ARD	472492.162	3468618.075	1	2	0	0	42801	50801		2
55	ARD	473457.225	3463678.295	2	2	0	0	50201	50901		2
56	ARD	473668.227	3464061.394	2	3	0	0	50201	50901		2
57	ARD	472983.777	3465893.317	1	1	0	0	50201	50901		2
65	ARD	472777.232	3455905.943	1	2	0	0	50401	52301		4
66	ARD	472855.593	3467772.210	1	3	0	0	50901	51301		1
67	ARD	473634.105	3464007.696	2	1	0	0	50901	51301		4
97	ARD	471890.971	3453506.833	1	3	0	0	51201	52901		4

Table A.2, *continued*.

I D	LOCATION	EASTING	NORTHING	HABITAT	CLUTCH SIZE	HATCHED	FLEDGED	DATE FOUND	HATCH/FAIL	FLEDGE/FAIL	CAUSE
87	ARD	474081.003	3464034.132	2	1	1	0	51301	52201	61101	0
78	ARD	474001.915	3459254.940	1	2	0	0	51701	60201		4
79	ARD	473756.015	3459561.426	1	2	2	0	51701	61301	62801	0
80	ARD	473541.625	3459464.123	1	1	0	0	51701	52901		1
81	ARD	472895.908	3461934.639	1	1	1	0	51701	60701	61301	0
82	ARD	473107.875	3462150.053	1	1	0	0	51701	52301		2
83	ARD	473909.301	3464116.708	2	1	0	0	51901	61801		1
84	ARD	473562.872	3463896.544	2	1	0	0	51901	52201		4
85	ARD	473495.358	3463663.798	2	1	0	0	51901	52801		1
86	ARD	474104.045	3463581.822	2	1	0	0	51901	51901		1
92	ARD	473805.503	3464114.519	2	1	0	0	52201	52801		4
93	ARD	473661.924	3464034.867	2	1	0	0	52201	60101		1
94	ARD	473586.605	3463595.272	2	3	0	0	52201	62201		1
95	ARD	473698.529	3463543.395	2	1	0	0	52201	61801		4
96	ARD	474181.195	3463882.762	2	1	0	0	52201	61101		4
98	ARD	472520.697	3454502.082	1	2	0	0	52301	52901		4
99	ARD	474287.784	3458239.781	1	2	0	0	52301	52901		4
106	ARD	473684.364	3464078.265	2	2	1	0	60101	62701	71501	0
107	ARD	473784.501	3463519.768	2	2	0	0	60101	60701		4
108	ARD	473912.069	3463485.641	2	1	0	0	60101	61801		1
109	ARD	473308.426	3459911.712	1	3	0	0	60201	62801		1
110	ARD	473040.314	3461872.946	1	3	0	0	60201	71001		1
111	ARD	471682.212	3453476.709	1	1	0	0	60201	60701		3
116	ARD	473711.141	3464100.701	2	2	0	0	60601	61101		2
117	ARD	473625.751	3464028.600	2	2	0	0	60601	62701		2
118	ARD	473557.948	3463888.450	2	1	0	0	60601	61801		4
119	ARD	473009.750	3456489.887	1	2	0	0	60601	61901		2
124	ARD	473798.781	3464128.404	2	3	2	0	61101	70801	71701	0
125	ARD	474157.881	3463697.611	2	2	1	0	61101	62701	71501	0
126	ARD	473122.779	3461777.371	1	2	0	0	61301	61901		4
129	ARD	473515.892	3463653.218	2	1	0	0	61801	62201		2
130	ARD	471834.079	3453044.550	2	1	0	0	61901	62301		2
131	ARD	471667.405	3453071.577	2	3	1	0	61901	71001	72601	0
134	ARD	473670.527	3464066.335	2	2	0	0	62701	71501		4
135	ARD	474169.717	3463883.917	2	2	0	0	62701	70801		4
136	ARD	474051.668	3464061.215	2	3	0	0	62701	71501		4
137	ARD	473608.451	3463974.525	2	2	0	0	62701	70301		2
138	ARD	473549.423	3459646.857	1	1	0	0	62801	71701		4
139	ARD	472891.770	3461941.543	1	2	0	0	62801	71001		4
1	SCS	482982.407	3509896.511	3	3	3	1	32201	42701	53101	0

Table A.2, *continued*.

I D	LOCATION	EASTING	NORTHING	HABITAT	CLUTCH SIZE	HATCHED	FLEDGED	DATE FOUND	HATCH/FAIL	FLEDGE/FAIL	CAUSE
3	SCS	487958.677	3506717.553	2	3	0	0	40801	51001		2
10	SCS	482087.936	3507429.838	3	3	0	0	41201	50101		4
26	SCS	482547.672	3505575.877	3	3	0	0	42101	50101		4
27	SCS	485490.569	3512369.632	3	3	2	0	42101	52001	61501	0
28	SCS	487548.771	3506443.268	1	2	0	0	42101	50101		1
29	SCS	488168.185	3506766.375	2	2	0	0	42101	51001		4
48	SCS	488035.864	3506654.409	2	2	0	0	42701	51001		4
49	SCS	479430.617	3511007.669	3	3	0	0	42701	51001		2
50	SCS	481625.473	3508518.789	3	3	0	0	42701	51001		2
68	SCS	480937.689	3505246.928	3	3	2	0	51001	53101		0
73	SCS	481851.409	3507939.357	3	2	1	0	51501	60901	61501	0
88	SCS	488191.319	3506716.455	2	2	0	0	52001	62901		3
89	SCS	481958.850	3508107.584	3	2	0	0	52001	52501		2
100	SCS	487945.515	3506719.427	2	3	0	0	52501	60501		1
101	SCS	488157.315	3506772.408	2	2	0	0	52501	62901		4
105	SCS	487546.045	3506522.529	1	1	0	0	53101	60501		1
114	SCS	481688.701	3508438.460	3	2	0	0	60501	62101		2
115	SCS	486371.116	3510548.187	1	2	0	0	60501	62101		2
140	SCS	488180.986	3506751.227	2	2	0	0	62901	71201		4
2	WAS	503239.473	3530884.612	3	1	0	0	40701	42901		4
5	WAS	500958.055	3535148.806	3	3	0	0	41101	42301		4
6	WAS	501505.319	3532941.037	3	1	0	0	41101	50301		4
7	WAS	508477.825	3534506.789	1	3	0	0	41101	42301		4
8	WAS	508620.693	3534879.032	1	3	0	0	41101	42901		4
9	WAS	507555.039	3533903.384	1	1	0	0	41101	42301		1
14	WAS	500899.569	3535162.608	3	1	0	0	41401	42901		4
15	WAS	507384.760	3533805.400	1	2	0	0	41401	42301		1
43	WAS	499108.995	3538010.156	3	3	0	0	42301	42901		4
44	WAS	501318.238	3535144.841	3	3	0	0	42301	42901		4
45	WAS	504422.252	3535603.959	3	2	0	0	42301	50301		1
53	WAS	499038.758	3537929.067	3	2	0	0	42901	51101		2
58	WAS	508552.707	3534551.046	1	2	0	0	50301	51101		1
59	WAS	507124.620	3533707.894	1	3	0	0	50301	51101		1
60	WAS	504593.542	3535680.333	3	1	0	0	50301	51101		2
61	WAS	503713.173	3530712.867	3	3	0	0	50301	52601		4
62	WAS	503342.133	3530855.089	3	1	0	0	50301	51101		2
63	WAS	502784.244	3531189.581	3	1	0	0	50301	51601		4
64	WAS	502023.045	3534584.457	3	1	0	0	50301	51101		2
69	WAS	499105.052	3538004.239	3	2	0	0	51101	52601		4
70	WAS	508592.642	3534886.244	1	2	0	0	51101	51601		4

Table A.2, *continued*.

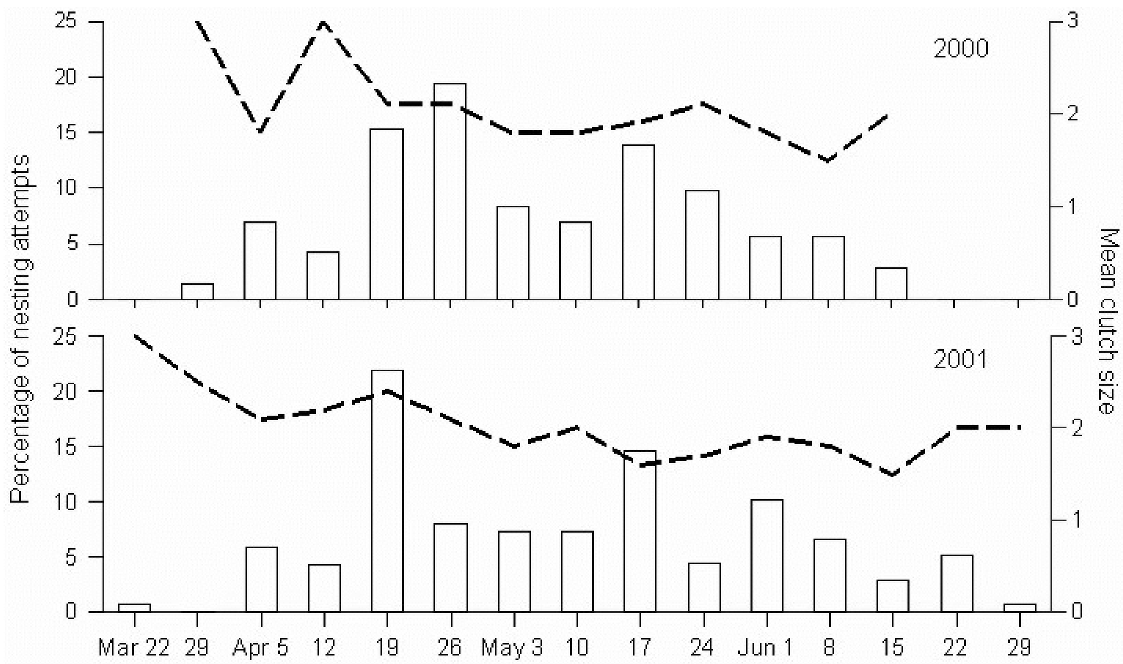
I D	LOCATION	EASTING	NORTHING	HABITAT	CLUTCH SIZE	HATCHED	FLEDGED	DATE FOUND	HATCH/FAIL	FLEDGE/FAIL	CAUSE
74	WAS	507301.757	3533734.383	1	1	0	0	51601	52101		1
75	WAS	501397.340	3532414.939	3	3	0	0	51601	52601		2
76	WAS	500891.266	3535165.674	3	2	0	0	51601	52101		2
77	WAS	499033.442	3537923.958	3	1	0	0	51601	52101		2
90	WAS	501490.203	3533728.694	3	2	0	0	52101	52601		4
91	WAS	503407.500	3530814.602	3	3	0	0	52101	60401		4
102	WAS	507830.204	3534048.197	1	2	0	0	52601	60401		1
103	WAS	504466.080	3535620.156	3	1	0	0	53001	60801		4
104	WAS	508515.963	3534494.385	1	1	0	0	53001	60401		4
112	WAS	501489.278	3532953.454	3	1	0	0	60401	61401		4
113	WAS	499033.018	3537924.511	3	3	0	0	60401	61401		2
120	WAS	499095.761	3537990.029	3	2	0	0	60801	62501		2
121	WAS	507306.854	3533730.227	1	1	0	0	60801	62001		4
122	WAS	507493.667	3533854.546	1	1	0	0	60801	61401		4
123	WAS	508642.995	3534902.234	1	2	0	0	60801	62001		4
127	WAS	501344.879	3535149.946	3	2	0	0	61401	62001		2
128	WAS	503327.824	3530863.647	3	1	0	0	61401	62001		2
132	WAS	504508.960	3535637.704	3	1	0	0	62001	70101		2
133	WAS	501517.806	3532928.787	3	2	0	0	62501	71801		4

[1] ARD = Altamaha River Delta, SCS = St. Catherine's Sound, and WAS = Wassaw Sound.
[2] Easting and northing coordinates in meters; UTM Zone 17N projection.

[3] 1 = beach, 2 = sand spit, and 3 = oyster shell rake/marsh island

[4] Cause of clutch failure during egg stage: 0 = hatched, 1 = predation, 2 = flooded, 3 = abandoned, and 4 = unknown cause.

Figure A.1. Nesting chronology (vertical bars) and mean clutch size (dotted line) of American Oystercatcher clutches in coastal Georgia, from March to July, 2000 (top graph) and 2001 (bottom graph).


2000
2001
Percentage of nesting attempts
Mean clutch size
0
5
10
15
20
25
0
1
2
3
Mar 22
29
Apr 5
12
19
26
May 3
10
17
24
Jun 1
8
15
22
29