Osprey Abundance, Distribution, and Reproductive Success in Casco Bay, Maine, 1982-1983 and 2011-2013.

2015

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OSPREY NEST ABUNDANCE, DISTRIBUTION, AND PRODUCTIVITY IN CASCO BAY, MAINE, 1982- 1983 AND 2011- 2013

BIODIVERSITY RESEARCH INSTITUTE
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WILDLIFE SCIENCE CHANGING OUR WORLD

SUBMITTED TO:

The Casco Bay Estuary Partnership

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SUBMITTED ON:

April 24, 2015

DEDICATION: This study is dedicated to the memory of our friend and beloved pilot, Ray Fogg, and his family. His confident expertise and kind-hearted nature enabled the completion of this study – he will be greatly missed.

Biodiversity Research Institute (BRI) is a 501(c)(3) non-profit organization located in Portland, Maine. Founded in 1998, BRI is dedicated to supporting global health through collaborative ecological research, assessment of ecosystem health, improving environmental awareness, and informing science-based decision making.

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FRONT PHOTO CAPTION*:* Osprey nestlings in Conswegan Narrows, Maine. BRI photo.

Suggested citation: DeSorbo, C. R. and R. B. Gray. 2015. Osprey Abundance, Distribution, and Reproductive Success in Casco Bay, Maine, 1982-1983 and 2011-2013. Biodiversity Research Institute, Portland, Maine. BRI Report 2015-13 submitted to the Casco Bay Estuary Partnership, Portland, Maine. 32 pp.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

1.0 EXECUTIVE SUMMARY

Using aerial survey methods, we conducted an inventory of Ospreys in Casco Bay during breeding seasons 2011-2013 (late period) and evaluated their reproduction. We checked up to 185 nest sites annually over the three-year survey, and detected between 106-161 intact nests annually. Of the sites with noted nest substrates, 85% were on natural substrates, while the remainder nested on artificial structures. Confirmed breeding pairs were present at 86 – 120 nest sites, and individuals with unconfirmed breeding status (non-breeding or failed breeders) were present at 12-16 sites annually. Breeding pairs produced between 78 and 85 young annually over the three-year survey period. Mean annual nest success ranged from 48-62% and mean annual productivity based on confirmed breeding pairs (active nests) ranged from 0.65 – 0.93 young per confirmed breeding pair. Mean annual brood size ranged from 1.3 – 1.5 young per successful nesting pair. All reproductive measures (nest success, productivity, and brood size) declined annually; however, only means for productivity and brood were different at marginal significance levels.

We summarized data on Osprey reproduction collected by MDIFW during 1982-1983 (early period) in a portion of Casco Bay. Of the sites with known nest structures, 96% were in trees and the remaining 4% were on artificial structures. Mean annual nest success ranged between 65-68%, and productivity based on confirmed breeding pairs ranged from 1.11-1.26 young per confirmed breeding pair. Brood size ranged from 1.7-1.9 young per successfully nesting pair. Comparisons of mean nest success, productivity, and brood size between early and late survey periods revealed that mean nest success did not differ significantly between the two periods. Mean productivity and mean brood size were significantly lower during the late period compared to the early period roughly thirty years earlier. We suspect that after accounting for measurement error, the Casco Bay population may be stable; however, the current population may lie closer to the level associated with population stability compared to many reported populations. We evaluate potential causes for differences in reproductive measures between the two periods and make recommendations for further study.

2.0 INTRODUCTION

Osprey nest density and reproductive success are highly responsive to changes and patterns in the local foodweb. This characteristic in combination with others relating to their natural history (i.e., a strict fish diet, high annual fidelity to nesting territories, and a long lifespan) make ospreys one the most valued bioindicators of aquatic ecosystem health. As a result, Osprey populations are commonly monitored and sampled throughout their range, and information gathered helps inform decisions pertaining to management of aquatic resources (Poole et al. 2002, Grove et al. 2009). Osprey populations in the U.S. and in Europe underwent dramatic declines in the mid 20th century due primarily to the drastic adverse effects of the pesticide DDT on reproduction (Spitzer et al. 1978, Watts and Paxton 2007). The eventual ban on DDT in 1972 and extensive management efforts focused on providing nesting platforms played a large role in the widespread recovery of the species. While dozens of studies have documented the decline and subsequent recovery of Osprey populations throughout much of its range, few efforts have focused on the Osprey population residing along Maine's coastline, which harbors a significant portion of the Atlantic breeding population north of Chesapeake Bay. Efforts to survey Maine's Osprey population over the past several decades were limited to opportunistic monitoring during regular statewide Bald Eagle surveys which occur on a timetable less appropriate for properly monitoring Ospreys. Over a decade ago, Maine's Osprey population was estimated to exceed 2,000 pairs, making it then one of the largest state populations in the contiguous U.S. (Poole et al. 2002).

Casco Bay is a unique coastal ecosystem along the southern Maine Coast with 578 miles of shoreline and 758 islands. Five main rivers flow into Casco Bay: the Fore, Stroudwater, Presumpscot, Royal, and New Meadows Rivers. The Casco Bay watershed covers 986 square miles and has one of the densest human populations in Maine. Twenty percent of Maine's population lives in the Casco Bay watershed (CBEP 2010). Casco Bay was designated as an "estuary of national significance" in 1990 by the U.S. Environmental Protection Agency, thus promoting increased environmental monitoring efforts in the bay for subsequent decades.

Ospreys and their nests are common throughout much of Casco Bay, but their abundance has never been evaluated. In the early 1980s, the Maine Department of Inland Fisheries and Wildlife (MDIFW) conducted aerial surveys of Ospreys nesting in Casco Bay, Machias Bay, Penobscot Bay, Downeast Maine's lake region, and the Moosehead vicinity. These surveys aimed to identify large concentrations of Ospreys in these five regions and to evaluate productivity of Ospreys within them, enabling regional comparisons of reproductive success to gauge whether Ospreys were experiencing lingering reproductive difficulties still prevalent in Maine's Bald Eagle population. Limited portions of Casco Bay were included in those early surveys; these areas now provide a baseline for long-term comparisons of reproductive success in the region.

In this study, we conducted surveys to determine the abundance, nest distribution, and reproduction of Ospreys in Casco Bay. This portion of Maine's Osprey population was an appropriate subpopulation to study because: (1) no efforts have previously attempted to estimate the abundance of the population in Casco Bay, (2) broad-scale ecological changes are being observed in the bay that may affect a broad range of organisms across trophic levels, (3) preliminary contaminant investigations revealed elevated levels of some emerging compounds in Osprey eggs in Casco Bay, (4) increases in the human and Bald Eagle populations are occurring in Casco Bay, both of which will likely shape the characteristics of future Osprey populations. Additionally, this study was timely given Osprey populations in other regions of the state (Penobscot Bay, Penobscot River, and Kennebec River) were being conducted concurrently by BRI, MDIFW, and the University of Maine, which provide valuable regional comparisons for findings in Casco Bay (Call et al. 2013).

The objectives of this study are to: (1) determine the abundance and nest distribution of Ospreys in Casco Bay during the 2011-2013 breeding seasons, (2) evaluate nest success, productivity, and brood size for Osprey populations surveyed in Casco Bay during 1982-1983 and 2011-2013, and (3) determine if reproductive measures differed between early (1982-1983) and late (2011-2013) periods.

3.0 STUDY AREA

Our study area contains the majority of the region formally recognized as Casco Bay in southern Maine. This study area includes all mainland and island shorelines from Danforth Cove (South Portland) to Bald Head (Phippsburg). Casco Bay islands and shorelines vary widely in their extent of development including both undeveloped island and mainland shorelines in addition to areas with extensive residential, commercial, or industrial development. The Fore River is undoubtedly the most notable in terms of development in the region; this area supports a wide range of industrial development including heavy shipping, oil-based power generation, and fossil fuel distribution. The Fore River marks the westernmost periphery of our survey area. The New Meadows River, the easternmost tributary of Casco Bay, marks the eastern periphery of our study area. This region is characterized by mixed and coniferous forests and contains minimal to moderate levels of shoreline development. Several freshwater rivers input into Casco Bay, and these rivers vary widely in character and use.

We divided Casco Bay into three subregions for comparison purposes: (1) the Casco Bay subregion; which contains all mainland and island shorelines in Casco Bay, (2) the Fore River subregion; which includes only the Fore River shorelines and river channel, and (3) the New Meadows River subregion; which encompasses island and mainland shorelines within the New Meadows River watershed, including Winnegance Bay. We refer to the entire study area surveyed as “Casco Bay”’ throughout this report. While there may be a hydrological basis for making comparisons between populations in the Fore River and the New Meadows River, these delineations are relatively arbitrary. The population emphasized in this study is that within all of Casco Bay, and caution is advised in making comparisons among subregions that consider them different populations. Subregions may be useful in future efforts attempting to monitor portions of the population surveyed during this study.

4.0 METHODS

BRI and MDIFW jointly conducted osprey nesting and productivity surveys during 2011-2013. Data collected during these surveys was compared to information collected during more spatially limited surveys during 1982 -1983 (further described below) conducted by the MDIFW in collaboration with University of Maine. Surveys during both periods followed standard methodology used to monitor Osprey reproduction. Survey timing was based on known Osprey phenology and weather patterns. Specific timing of surveys was refined annually based on clues of seasonal timing gathered opportunistically during other surveys conducted throughout the state. During the first survey (nesting survey hereafter), typically conducted during the second or third week of May, we surveyed all island and mainland shorelines in Casco Bay, visiting all previously known Osprey nest sites during searches for new nests. Surveyors gathered information on Osprey pair residency, and nesting activity during the nesting survey. The second survey (productivity survey hereafter), typically conducted in late July or early August was timed to coincide with the development of young aged at 6-8 weeks. During this survey, surveyors visited nests determined to be intact during the nesting survey to evaluate continued pair occupancy and to determine the number of fledglings surviving.

4.1 Survey 2011-2013

We inventoried nesting ospreys in the Casco Bay region using a combination of low level aerial surveys and boat and land-based surveys during 2011-2013 (late period hereafter). In 2011 and 2012 all of the study area was surveyed by aerial surveys with the exception of the Fore River and mainland shorelines immediately to the south and north of the mouth of the Fore River and the mouth of Back Cove due to Class-D airspace limitations within 5 miles of the Portland International Jetport. In 2013, we altered our take-off and landing locations at the Jetport, enabling us to include the Fore River and the mouth of Back Cove in the aerial surveys. All but one osprey nest within the five-mile radius of the jetport was surveyed by aircraft. This single osprey nest was discovered opportunistically in the fore River in 2013.

Aerial surveys during 2011-2013 were conducted in a Cessna 172 Skyhawk piloted by contractor Ray Fogg, d.b.a. Aerial Photo Service of Maine. The primary observer was seated in the front right seat, while the secondary observer was seated in the rear right seat. Charlie Todd (MDIFW) was the primary observer for the majority of the surveys, with Rick Gray, Chris DeSorbo, and Ian Johnson (Biodiversity Research Institute, BRI) serving as secondary or substitute primary observers. Survey speeds were generally 90 – 120 miles per hour at altitudes of 300 – 700 feet above the surface. Flight tracks and reference locations in 2011 were recorded by the secondary observer on a portable GPS unit. Nest status and general observations were recorded on a digital voice recorder. The primary observer recorded limited flight notes on printed nest plot maps. For the survey seasons of 2012 and 2013, we used a USFWS computer program (RECORD) linked to a Garmin GPS antenna to simultaneously record flight tracks, reference locations and voice recordings. Nest locations plotted during flights were refined by visual plots on aerial photos shortly after the nesting survey. Observers recorded nest condition, nest substrate, osprey residency, breeding activity, and the number of fledglings observed.

4.2 Survey 1982-1983

Surveys during 1982-1983 (‘early’ period hereafter) were conducted by Charlie Todd (at the time a student at Univ. of Maine) and pilot Andy Stinson (a retired MDIFW warden pilot). The objective of these surveys was to evaluate productivity for an opportunistically selected sample of nests within five predetermined areas known to harbor nesting Ospreys. Data collected during ‘early’ surveys were used to assess regional variations in reproductive success of Ospreys in order to gauge if persistent contaminants, particularly DDT, were having and residual effects on Osprey nesting as had been observed in Maine Bald Eagles throughout the state.

Surveys during the early period were conducted in a Cessna Skymaster 337 (high wing, push pull twin engine configuration) aircraft at a flight speed of approximately 140 mph. Due to limited visibility in the rear seat of this aircraft, this survey relied exclusively upon a primary observer in the front right seat next to the pilot to collect and record all information. The timing of nesting and productivity surveys followed standard survey methodology described for the late period above.

Unlike surveys conducted during the late period, surveys during the early period were not ‘bay wide’ and they were not intended to determine (and thus cannot be used to make evaluations of) the abundance of resident pairs. Surveyed areas specifically targeted the following areas in the northwestern portion of Casco Bay known to contain some of the higher densities of Ospreys in the state: Merepoint Bay, Quahog Bay, Ewins Narrows, and Upper and Lower Coombs Island area. The boundaries of these area surveyed included the upper New Meadows River, the channels and coves of the upper half of Harpswell Neck (the peninsula), and all of Middle Bay and Maquoit Bay islands starting at Bustins Ledge (located at the mouth of both of these bays) (Figure 2). Three nests surveyed fell outside of these boundaries. One nest was on a navigational aid south of Cousins Island, two nests were located in the far eastern portion of Casco Bay on Flag and Mark Islands. No surveys were conducted in the Fore River and most of southern, western, and eastern Casco Bay during the early period.

4.3 Definition of Terms

We evaluated the condition of newly found and previously known Osprey nest sites during surveys. Osprey nests (the majority of which are on natural sites in our study area) that are not maintained tend to fall into disrepair or fall to the ground entirely following the winter. Other clues, such as weed growth in the nest bowl, are often evident at unoccupied nests. While these characteristics do not necessarily characterize all unoccupied sites, they significantly aid in distinguishing occupied from unoccupied nests. We categorized nests as either **intact** (nest integrity and evidence of activity suggested it could be used by Ospreys) or **not intact** (nest structure in disrepair, evidence did not suggest occupancy by ospreys). Nests deemed intact during the nesting survey were visited during the productivity survey. We define a **nesting territory** as an area that was observed or presumed to contain a nest within the home range of a mated pair (Steenhof and Newton 2007).

We categorized Ospreys associated with nest sites as either **confirmed breeding pairs** or **possible resident pairs**. We define **confirmed breeding pairs** as those in which surveys revealed breeding activity, as indicated by the presence of incubating adults, eggs, or young. These pairs are traditionally referred in published literature as “active pairs”(Postupalsky 1974, Poole 1989). Inconsistent use of the term active resulted in the recommendation that this term no longer be used (Steenhof and Newton 2007). For the purpose of this report, confirmed breeding pairs are equivalent to active pairs when reported. Osprey pairs were considered **possible resident pairs** when surveys revealed one or two adults attending intact nests in good condition, but no evidence of breeding was apparent during nesting or productivity surveys. Because we only conducted a single nesting survey, the status of these pairs cannot be further confirmed. Nest sites determined to contain possible resident pairs might be: (a) pairs associated with nests that attempted breeding and failed prior to the nesting survey, (b) non-breeding pairs, or (c) individuals that were incorrectly assumed to be associated with a nest site based on their behavior patterns during the survey. The sum of confirmed breeding pairs and possible resident pairs represents an estimate of the total number of **maximum resident pairs** (renamed from ‘potential resident pairs’ in our previous Casco Bay reports) detected during the survey.

Following traditional aerial survey methodology, we counted the number of live young in nests during productivity surveys to calculate nest success and productivity measures. We defined **nest success** as the proportion of pairs that successfully produced ≥1 young. All successful nests were considered to contain young aged approximately 80% of fledging age, approximately 42d based on fledging at 53d; (Poole et al. 2002) during the productivity survey. We defined **productivity** as the number of young produced per pair (further defined below).

Due to the uncertainty associated with the often unknown and inconsistent influence of non-breeders on productivity, many Osprey studies generally consider Osprey reproduction measures based upon confirmed breeding pairs the most reliable for evaluating population status or making comparisons (Spitzer et al. 1983, Poole 1989). However, several studies have also reported reproductive measures relative to the number of “occupied nests” that incorporates the influence of non-breeders. In this study, we report Osprey nest success and productivity measures relative to both confirmed breeding pairs and maxiumum resident pairs. The pairing of these two measures produces a range, with measures based upon maximum resident pairs reflecting the potential influence of non-breeders and the measure based upon confirmed breeders representing only the breeding component of the population. Lastly, we report **mean brood size**, the mean number of young produced by successful pairs (Poole 1989, Steenhof and Newton 2007).

4.4 Long Term Comparisons

To evaluate whether temporal differences existed in Osprey nest success, productivity, and brood size between early and late periods, we compared multi-year means for nest success, productivity, and brood size between early and late periods. To evaluate if geographic differences in reproductive success between areas surveyed in 1982-1983 versus 2011-2013 might bias comparisons between periods (i.e, if observed differences in reproductive measures between periods were caused by higher reproductive success in the areas surveyed in 1982-1983), we calculated 2011-2013 reproductive measures for the subset of nests overlapping with areas surveyed in 1982-1983 and compared them to the remainder of the nests in the study area surveyed during 2011-2013.

4.5 Data Analysis

We evaluated normality in datasets using a Goodness of Fit test. Because datasets were not normally distributed, we used a non-parametric Wilcoxon test to compare means. When comparing reproductive measures between early and late periods, we weighted by the number of years each nest was surveyed per period. All analyses in this report were conducted using JMP 9.0 (SAS Institute Inc. 2010). All maps were created using ArcMap 10.2 (ESRI 2013). Arithmetic means ± SD are reported in text and figures.

5.0 RESULTS

5.1 Survey 2011-2013

5.1.1 Nest Distribution, Abundance and Nest Substrate

Overall: Throughout our 2011-2013 survey, the status of 197 current and traditional (i.e, previously/traditionally known) osprey nests / territories in the Casco Bay study area were checked. The number of nests checked increased annually; 123 in 2011, and 164 and 185 in 2012 and 2013 respectively. In 2011, 106 nest sites were considered intact, 161 in 2012, and 150 in 2013 (Figure 1). The range between the number of confirmed breeding pairs and the number of maximum resident pairs (possible resident pairs + confirmed breeding pairs) represents a range of potential breeding pairs that includes non-breeding or failed pairs. The number of pairs that had the potential to produce young ranged from 86-98 in 2011, 117-133 in 2012, and 120-135 in 2013 (Table 1). Of the 181 nest sites at which nesting substrate was noted, 82% (n = 150) of the surveyed population nested on natural substrates (1 was a ground nest, 140 were in trees) and the remaining 17% (n = 31) nested on artificial structures. Of the nests built on structures, 32% (n = 10) were on navigational aids, 29% (n = 9) were built on platforms, poles, and light posts, 23% (n = 7) were built on bridges, cranes, docks, and scaffolding, and 16% (n = 5) were on transmission lines or power poles. We found no significant differences in nest success, productivity, or brood size between pairs nesting on natural vs. artificial sites ($p > 0.05$); however artificial structures showed a tendency for higher measures.

Sub-region Comparisons: The Casco Bay sub-region harbored the majority of intact nests found in Casco Bay (Figure 1). Over the three-year period, the number of occupied nests in the Casco Bay subregion ranged from 76-107, while the number of nests ranged from 16-21 in the New Meadows River subregion and 6-8 in the Fore River subregion (Figure 1, Figure 2). On average, the Casco Bay subregion contained 77% of the nests surveyed, the New Meadows River contained 17%, and the Fore River contained 6%. Of the confirmed breeding pairs found annually, 66-96 nests were in the Casco Bay subregion, 14-19 were in the New Meadows River subregion, and 6-8 were in the Fore River subregion (Table 1).

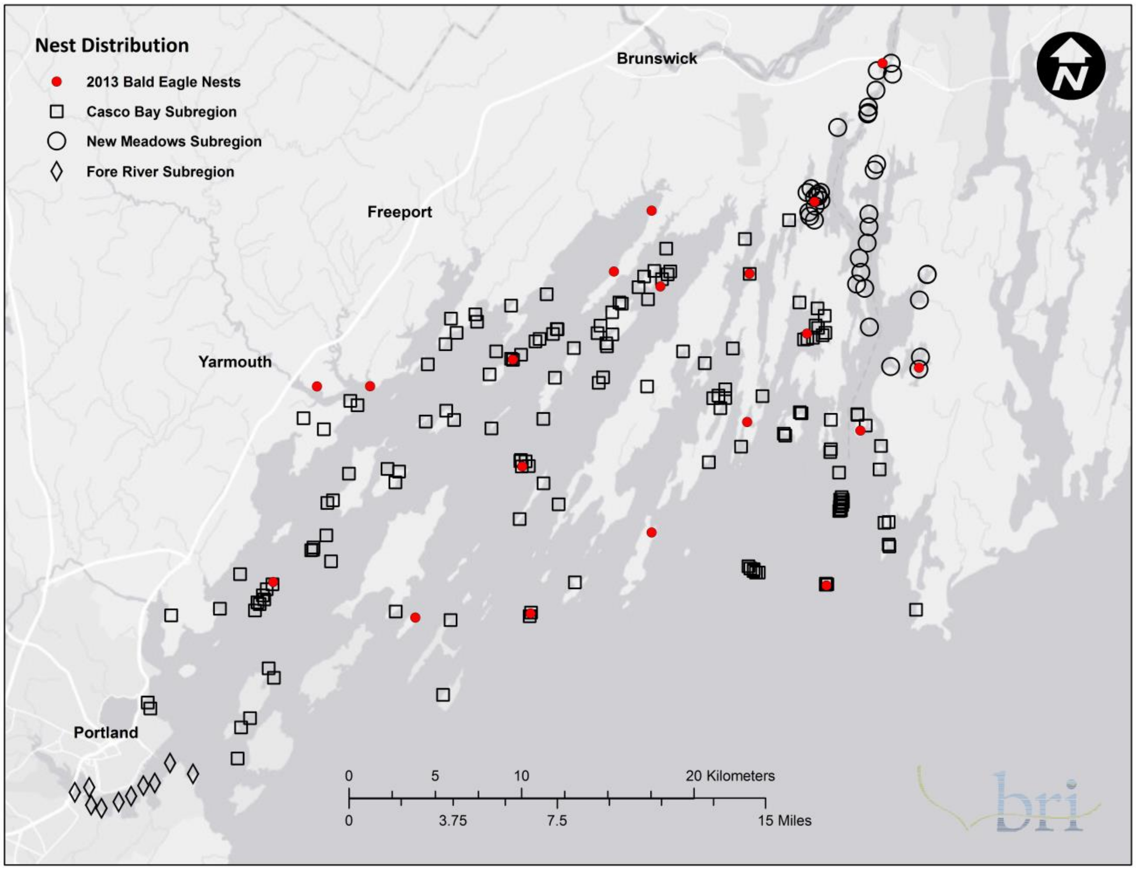

Figure 1. Distribution of intact Osprey nests in the Casco Bay study area, determined during fixed-wing aerial surveys of Casco Bay, 2011-2013.2013 Bald Eagle Nest locations provided courtesy of MDIFW and USFWS.

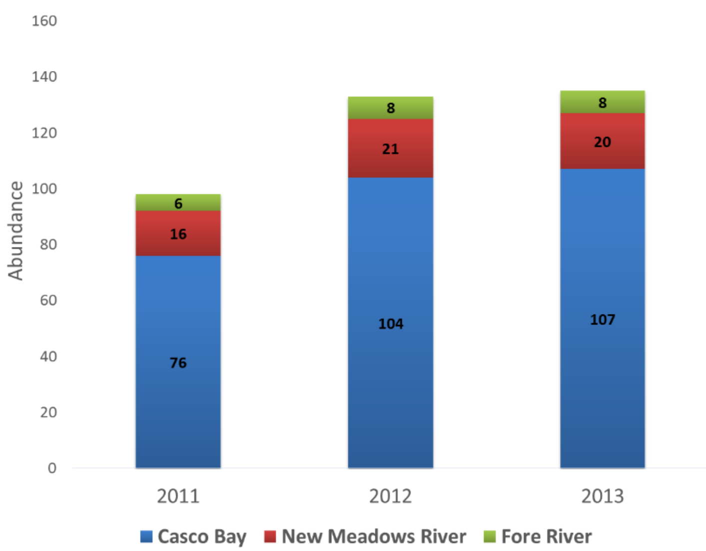

Figure 2. Nest abundance of occupied Osprey nests in the Casco Bay study area, determined during fixed-wing aerial surveys of Casco Bay, 2011-2013. Abundance measures are based on maximum resident pairs.

Table 1. Status of Resident and Breeding Pairs of Ospreys in Casco Bay as determined during fixed-wing aerial surveys, 2011-2013 and 1982-1983.

2011	Checked Nests	Intact Nests	Unoccupied Nests	Poss. Res. Prs.	Confirmed Breeding Prs.	Max. Res. Prs.	Successful Nests	Chicks Fledged
Casco Bay	95	81	6	10	66	76	37	54
New Meadows River	22	19	3	2	14	16	10	14
Fore River	6	6	0	0	6	6	6	12
Total	123	106	9	12	86	98	53	80
2012								
Casco Bay	128	126	22	14	90	104	54	69
New Meadows River	27	27	6	2	19	21	7	9
Fore River	9	8	0	0	8	8	4	7
Total	164	161	28	16	117	133	65	85
2013								
Casco Bay	143	121	14	11	96	107	43	55
New Meadows River	32	24	4	4	16	20	10	14
Fore River	10	9	1	0	8	8	5	9
Total	185	154	19	15	120	135	58	78
1982								
Casco Bay	50	50	8	2	40	42	26	45
New Meadows River	15	15	1	0	14	14	9	15
Total	65	65	9	2	54	56	35	60
1983								
Casco Bay	54	54	9	1	44	45	29	57
New Meadows River	15	15	4	2	9	11	7	10
Total	69	69	13	3	53	56	36	67

** See methods for term definitions.*

5.1.2 Number of Fledglings and Successful Nests

Overall: Between 78-80 young were fledged annually from all study area nests. An annual range of 53-65 Osprey nests were confirmed to be successful in producing ≥1 young in the entire Casco Bay study area (Table 1).

Sub-region Comparisons: As with the nest distribution, number of fledged chicks and successful nests are reflective of the area of the subregions. The number of young produced annually ranged 54-69 in Casco Bay subregion, 9-14 in New Meadows River subregion, and 7-12 in the Fore River subregion (Table 1). Thus, the Casco Bay subregion produced 73% of fledged chicks, the New Meadows River subregion produced 15%, and Fore River subregion produced 12%. Over the three years of the survey, the number of successful nests in the Casco Bay subregion ranged from 37-54, 7-10 in the New Meadows River subregion, and 4-6 in the Fore River subregion (see Table 1).

5.1.3 Nest Success, Productivity, and Brood Size

Overall: Nest success for confirmed breeding pairs across the entire Casco Bay study area ranged from 48-62% across the three years surveyed (Figure 3). Inclusion of non-breeding or failed nesting pairs in the calculation (maximum resident pairs) changed annual nest success means to 43-54%. Spatial evaluations of mean 2011-2013 osprey nest success in Casco Bay revealed no distinct geographic areas of high or low nest success (Figure 4).

Annual mean productivity in Casco Bay ranged 0.58-0.82 over the three-year period (Table 2, Figure 5), with 2011 exhibiting the most favorable productivity and 2012 exhibiting the poorest productivity. Productivity based upon maximum resident pairs ranged 0.58-0.82 chicks per resident pair. Spatial evaluations of mean 2011-13 osprey productivity revealed no distinct area of high or low productivity (Figure 6). Mean annual brood size in Casco Bay ranged 1.4 -1.69 chicks per successfully nesting pair (Figure 7).

Annual Comparisons: While mean nesting success of confirmed breeding pairs declined annually, means were not significantly different among 2011 (62 ± 48%), 2012 (55 ± 50%) and 2013 (48 ± 50%) ($p = 0.17$, $\chi^2 = 3.57$). Mean productivity declined between 2011 (0.93 ± 0.87), 2012 (0.72 ± 0.78) and 2013 (0.65 ± 0.77); differences in these means were marginally significant ($p = 0.06$, $\chi^2 = 5.6$). Differences in mean brood size during 2011 (1.51 ± 0.61), 2012 (1.31 ± 0.56) and 2013 (1.34 ± 0.51) were also marginally significant ($p = 0.09$, $\chi^2 = 4.60$).

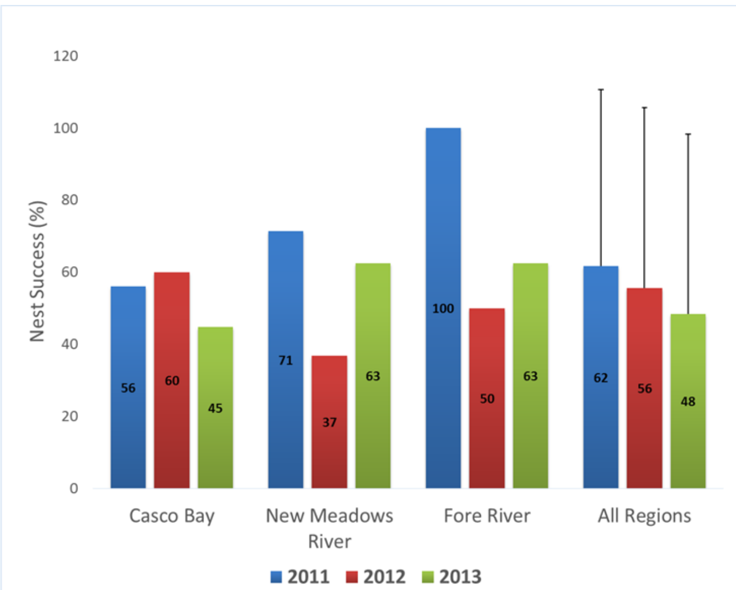

FIGURE 3. MEAN ANNUAL NEST SUCCESS OF CONFIRMED BREEDING PAIRS OF OSPREYS IN THREE SUBREGIONS WITHIN CASCO BAY, AS DETERMINED DURING FIXED-WING AERIAL SURVEYS, 2011-2013. ERROR BARS ON ALL REGIONS BARS REPRESENT STANDARD DEVIATION.

Subregion Comparisons: Nest success in the Casco Bay subregion based upon confirmed breeding pairs ranged annually from 45-60%, while nest success based upon maximum resident pairs ranged 40-52% over the period (Table 2). Mean annual nest success ranged 37-71% and 33-63% in the New Meadows River subregion based upon confirmed and maximum resident pairs, respectively. Nest success for the small sample of nests in the Fore River subregion ranged 50-100% using both confirmed breeding pairs and maximum resident pairs (Table 2, Figure 3). Productivity based on confirmed breeding pairs across all years ranged 0.57-0.82 in the Casco Bay subregion, 0.47-1.00 in the New Meadows River subregion, and 0.88-2.00 in the Fore River subregion (Figure 5). Ranges in mean annual productivity based on maximum resident pairs dropped to 0.51 – 0.71 and 0.43 – 0.88 young per resident pair in the Casco Bay and New Meadow subregions, respectively. The annual productivity range based on maximum resident pairs for the Fore River subregion was the same as for confirmed breeding pairs. Over the three-year period, brood size (chicks fledged / successful nest) ranged 1.3-1.5 in the Casco Bay subregion, 1.3-1.4 in the New Meadows River subregion, and 1.8-2.0 in the Fore River subregion (Figure 7).

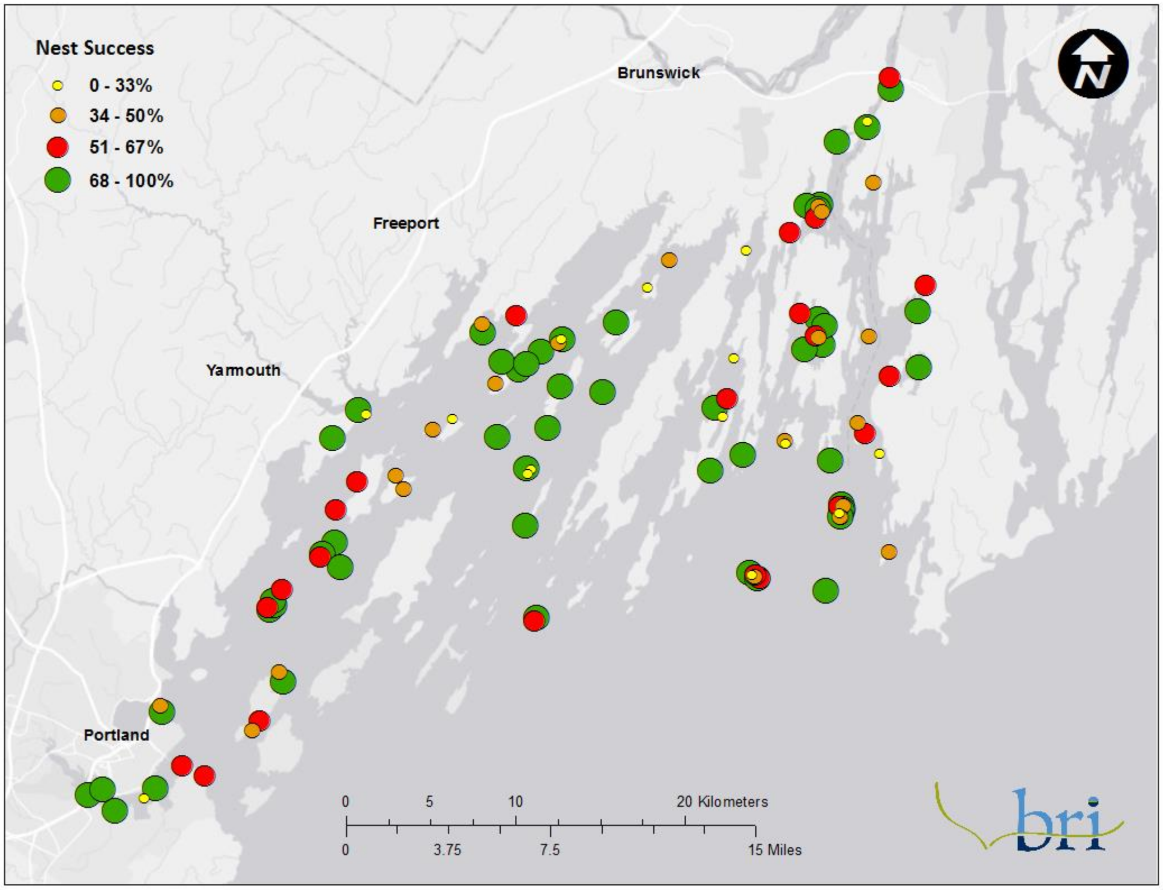

FIGURE 4. NEST SUCCESS OF CONFIRMED BREEDING PAIRS OF OSPREY IN THE CASCO BAY STUDY AREA, DETERMINED DURING FIXED-WING AERIAL SURVEYS OF CASCO BAY, 2011-2013. DIVISIONS OF NUMERICAL DATA IN LEGEND ARE BASED ON NATURAL BREAKS.

TABLE 2. NEST SUCCESS AND PRODUCTIVITY ESTIMATES FOR OSPREY IN THE CASCO BAY STUDY AREA, DETERMINED DURING FIXED-WING AERIAL SURVEYS OF CASCO BAY, 2011-2013 AND 1982-1983.

	Nest Success (%)		Chicks Fledged /		
	Confirmed Breeding Pairs	Maximum Residents Pairs	Confirmed Breeding Pairs	Maximum Resident Pairs	Successful Nests
2011					
Casco Bay	56	49	0.82	0.71	1.5
New Meadows River	71	63	1.00	0.88	1.4
Fore River	100	100	2.00	2.00	2.0
All Regions	62	54	0.93	0.82	1.5
2012					
Casco Bay	60	52	0.77	0.66	1.3
New Meadows River	37	33	0.47	0.43	1.3
Fore River	50	50	0.88	0.88	1.8
All Regions	56	49	0.73	0.64	1.3
2013					
Casco Bay	45	40	0.57	0.51	1.3
New Meadows River	63	50	0.88	0.70	1.4
Fore River	63	63	1.13	1.13	1.8
All Regions	48	43	0.65	0.58	1.3
1982					
Casco Bay	65	62	1.13	1.07	1.7
New Meadows River	64	64	1.07	1.07	1.7
All Regions	65	63	1.11	1.07	1.7
1983					
Casco Bay	66	64	1.30	1.27	2.0
New Meadows River	78	64	1.11	0.91	1.4
All Regions	68	64	1.26	1.20	1.9

** SEE METHODS FOR TERM DEFINITION*

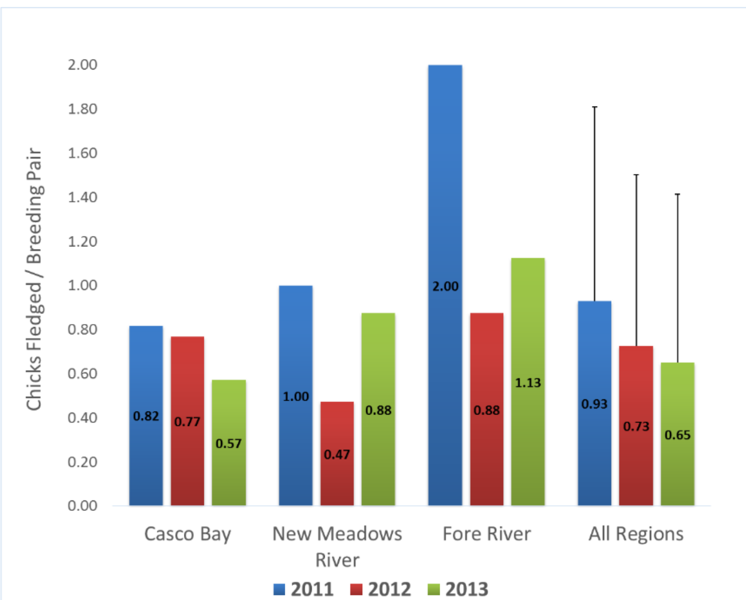

FIGURE 5. MEAN ANNUAL PRODUCTIVITY OF CONFIRMED BREEDING PAIRS OF OSPREYS IN THREE SUBREGIONS WITHIN CASCO BAY, AS DETERMINED DURING FIXED-WING AERIAL SURVEYS, 2011-2013. ERROR BARS ON ALL REGIONS BARS REPRESENT STANDARD DEVIATION.

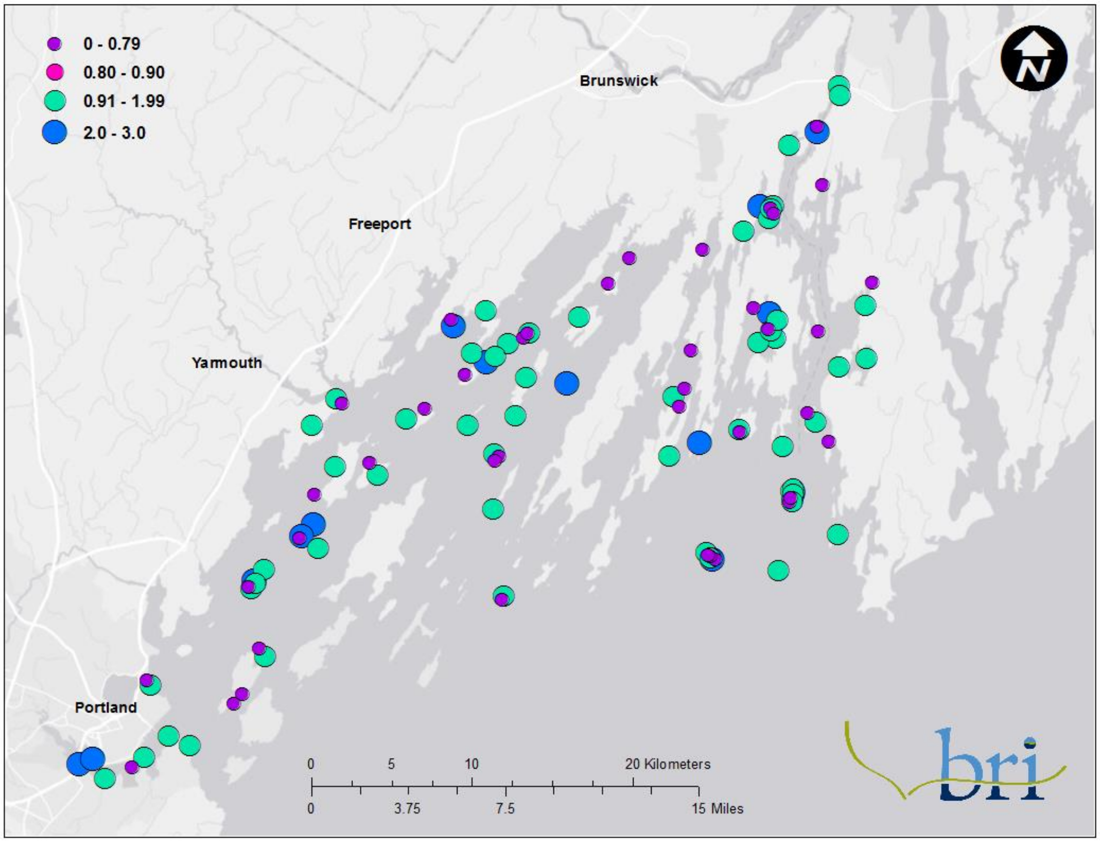

FIGURE 6. MEAN PRODUCTIVITY OF CONFIRMED BREEDING PAIRS OF OSPREYS IN THE CASCO BAY STUDY AREA, DETERMINED DURING FIXED-WING AERIAL SURVEYS, 2011-2013. DIVISIONS OF NUMERICAL DATA IN LEGEND ARE BASED UPON 0.80 – 0.90 YOUNG PER ACTIVE NEST PRODUCTIVITY ONCE POSTULATED AS REQUIRED TO MAINTAIN A STABLE POPULATION.

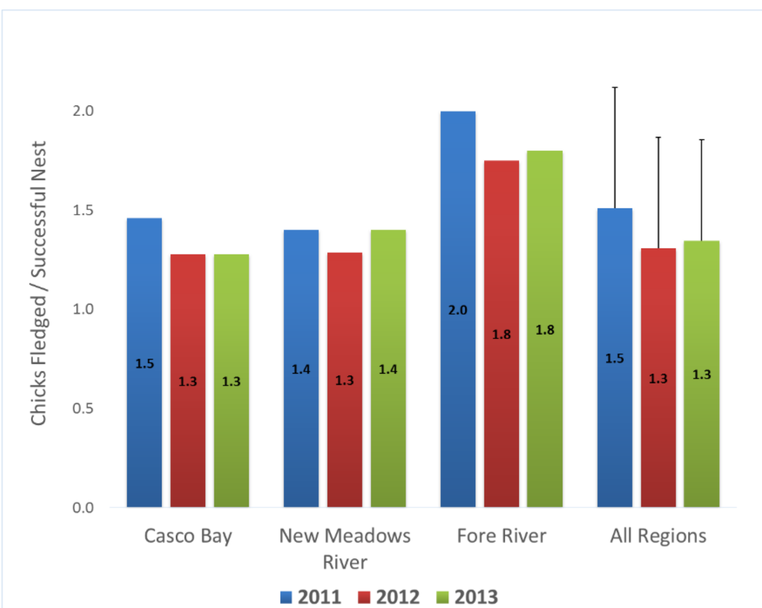

FIGURE 7. MEAN ANNUAL BROOD SIZE OF NESTING OSPREYS WITHIN THREE SUBREGIONS OF CASCO BAY AS DETERMINED DURING FIXED-WING AERIAL SURVEYS, 2011-2013. ERROR BARS ON ALL REGIONS BARS REPRESENT STANDARD DEVIATION.

5.2 Survey 1982 – 1983

5.2.1 Nest Distribution, Abundance and Nest Substrate

Overall: As noted previously, surveys during the early period were not intended to be used to estimate nest abundance. Thus, figures presented below represent a subset of the population surveyed.

Throughout the two-year survey, the status of 69 traditional osprey nests / territories in the Casco Bay study area were checked (Figure 8). The number of intact nests were relatively similar between years; 65 were detected in 1982 and 69 were detected in 1983. The range between confirmed breeding pairs and maximum resident pairs was consistent between years, ranging from 54-56 and in 1982 to 53-56 in 1983 (Table 1). Of the 51 nest sites surveyed in the early period at which nest substrate was noted, only two were on artificial structures. Thus, 96% of the surveyed population nested in trees and 4% of nests were on artificial structures.

Subregion Comparisons: (Figure 8). During the early period a range of 42-45 intact nests surveyed were within the Casco Bay subregion (77%), while 11-14 (23%) were within the New Meadows River subregion. No nests were surveyed in the Fore River during the early period. Between years, 40-44 of the **confirmed breeding pairs** from the early period were located in the Casco Bay subregion, while 9-14 were within the New Meadows River subregion (9-14) (Table 1).

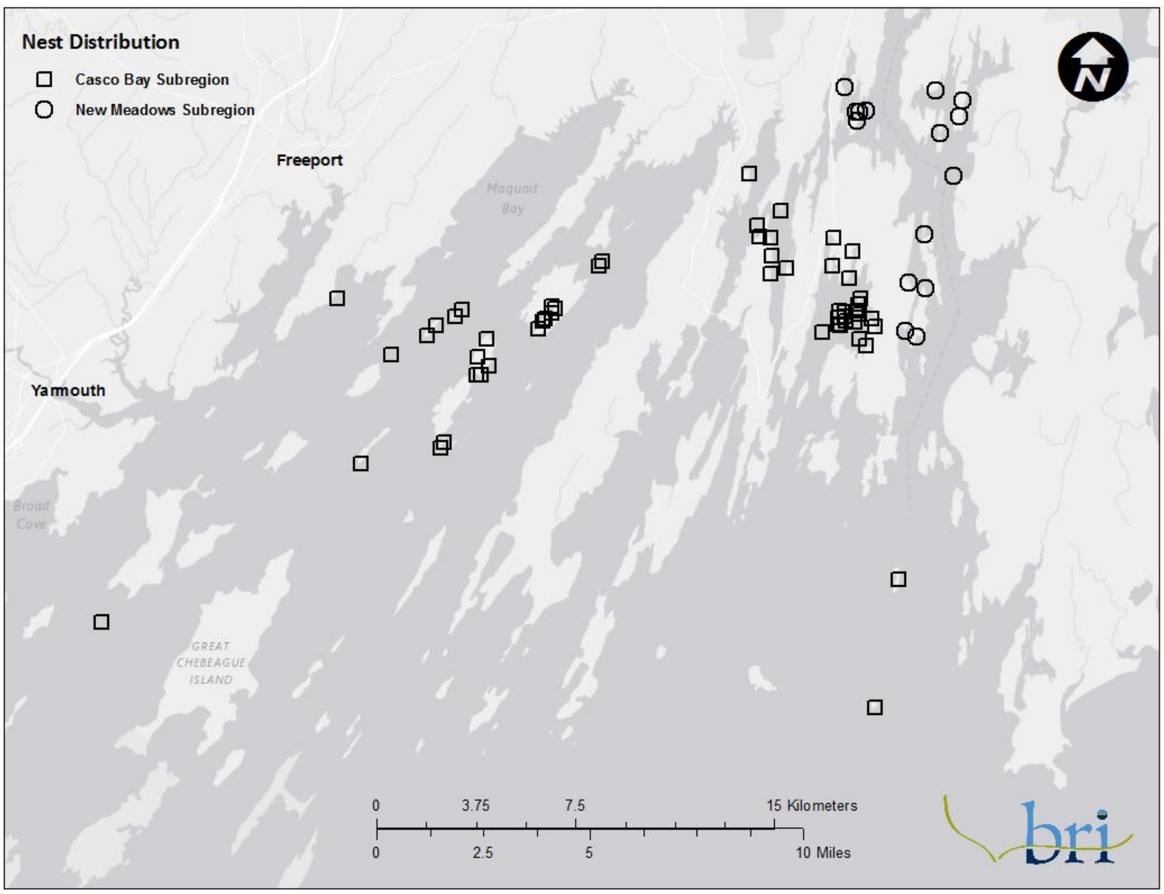

FIGURE 8. DISTRIBUTION OF INTACT OSPREY NESTS IN THE CASCO BAY STUDY AREA, DETERMINED DURING FIXED-WING AERIAL SURVEYS OF SELECTED PORTIONS OF CASCO BAY, 1982 - 1983.

5.2.2 Number of Fledglings and Successful Nests Surveyed

Overall: The number of young presumed to have fledged during the early period in Casco Bay ranged from 60-67 between years. The number of nests successful in producing ≥1 young over the two years varied little between years (35-36; Table 1).

Sub-region Comparisons: The number of fledged young and successful nests reflect proportional differences in size and number of nests in subregions. The number of nests successful in producing ≥1 young ranged 26-29 in the Casco Bay subregion and 7-9 in the New Meadows River subregion over the early period (Table 1). The number of young produced ranged between 45-57 in the Casco Bay subregion and 10-15 in the New Meadows River subregion (Table 1).

5.2.3 Nest Success, Productivity, and Brood Size

Overall: Nest success for confirmed breeding pairs across the Casco Bay study area ranged 65 – 68% (**Error! Reference source not found.**). Mapping of mean two-year nest success at nests revealed no distinct spatial patterns (Figure 10). Nest success measures changed little during early period nests sampled when including possible resident pairs; mean annual nest success based on maximum resident pairs ranged 62-64%. Productivity across the Casco Bay study area ranged 1.11 – 1.26 chicks per breeding pair between years (Figure 11) based upon the maximum resident pairs ranged from 1.07-1.20 per resident pair. Spatial evaluations of mean 1982-83 osprey productivity revealed no distinguishable geographic patterns in productivity between surveyed areas (Figure 12**Error! Reference source not found.**). Brood size ranged from 1.71-1.86 chicks per successful nest between years (Figure 13).

Annual Comparisons: Mean reproductive measures were similar between 1982 and 1983. Mean annual nesting success of confirmed breeding pairs was not significantly different between 1982 (65 ± 48%) and 1983 (68± 47%) ($p = 0.73$, $\chi^2 = 0.11$). Annual mean productivity was similar between 1982 (1.11 ± 1.04) and 1983 (1.26 ± 1.08) ($p = 0.45$, $\chi^2 = 0.55$). Mean brood size was not significantly different between 1982 (1.71 ± 0.79) and 1983 (1.86 ± 0.76) ($p = 0.38$, $\chi^2 = 0.748$).

Subregion Comparisons: Mean annual nest success in the Casco Bay subregion ranged from 65-66% based on confirmed breeders, and 62-64% based on maximum resident pairs. Nest success in the New Meadows subregion ranged 64-78% based on confirmed breeding pairs and was 64% (no range) based upon maximum resident pairs. (Table 2). Productivity was similar between subregions, ranging from 1.13-1.30 young per confirmed breeding pair in the Casco Bay subregion and 1.11-1.30 young per confirmed breeding pair in the New Meadows River subregion (

Figure 11). Productivity measures based upon the maximum resident pairs had relatively minimal effects on productivity (Table 2). Brood size ranged slightly higher in the Casco Bay subregion, (range: 1.73-1.97 young per successful nest) in the Casco Bay subregion between years compared to the New Meadows subegion (1.43-1.67 young per successful nest) (Figure 13).

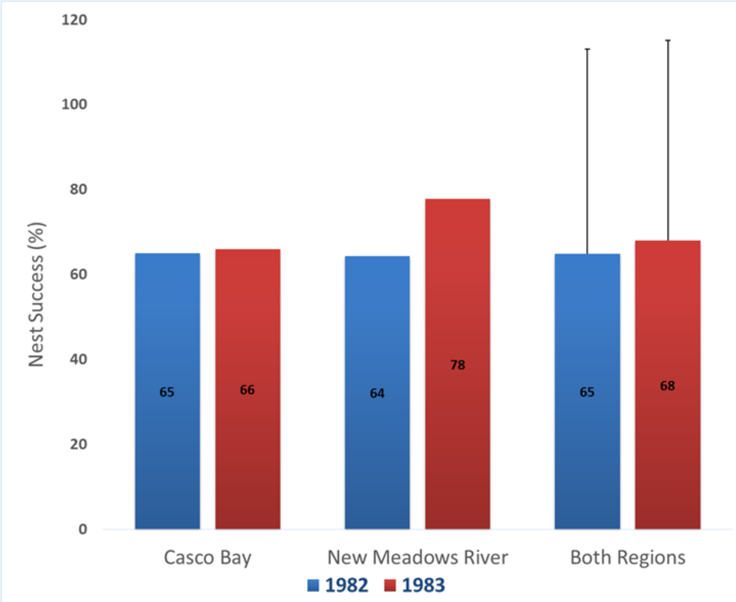

Figure 9. Mean annual nest success of confirmed breeding pairs of Ospreys in three subregions within Casco Bay, as determined during fixed-wing aerial surveys, 1982-1983. Error bars on both regions bars represent standard deviation.

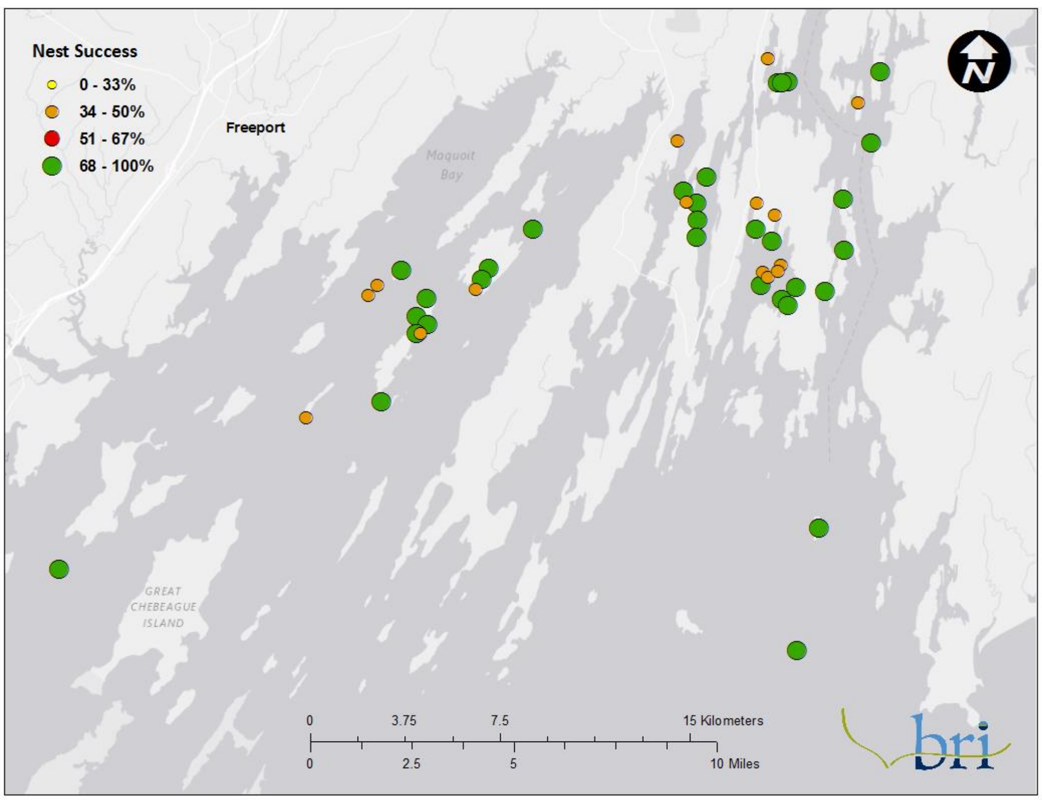

Figure 10. Mean Nest success (%) of confirmed breeding pairs of Ospreys in Casco Bay, as determined during fixed-wing aerial surveys of a portion of Casco Bay, 1982-1983.

*Nest success categories based upon natural breaks in the data.

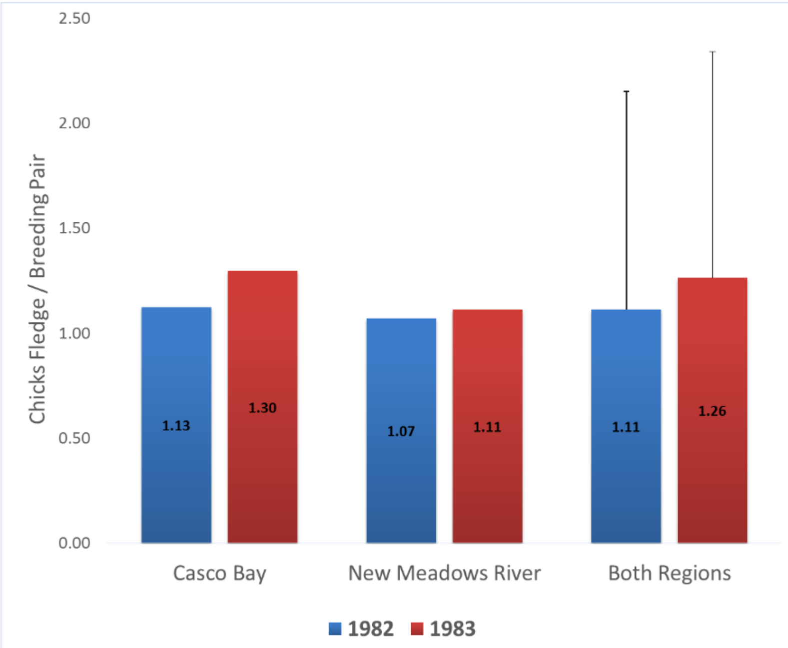

FIGURE 11. MEAN ANNUAL PRODUCTIVITY OF CONFIRMED BREEDING PAIRS OF OSPREYS IN THREE SUBREGIONS WITHIN CASCO BAY, AS DETERMINED DURING FIXED-WING AERIAL SURVEYS, 1982 - 1983. ERROR BARS ON BOTH REGIONS REPRESENTS STANDARD DEVIATION.

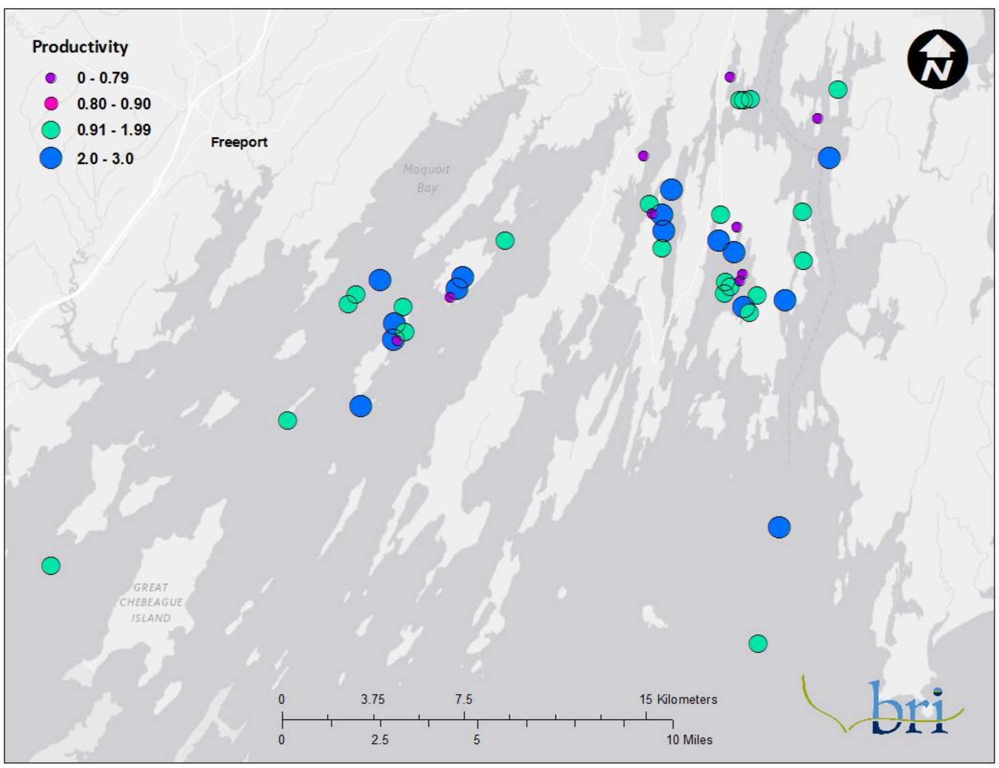

FIGURE 12. PRODUCTIVITY OF CONFIRMED BREEDING PAIRS OF OSPREY IN THE CASCO BAY STUDY AREA, DETERMINED DURING FIXED-WING AERIAL SURVEYS OF CASCO BAY, 1982 – 1983.

*Productivity categories based upon consideration of 0.80 – 0.90 as the productivity level required to maintain a stable population.

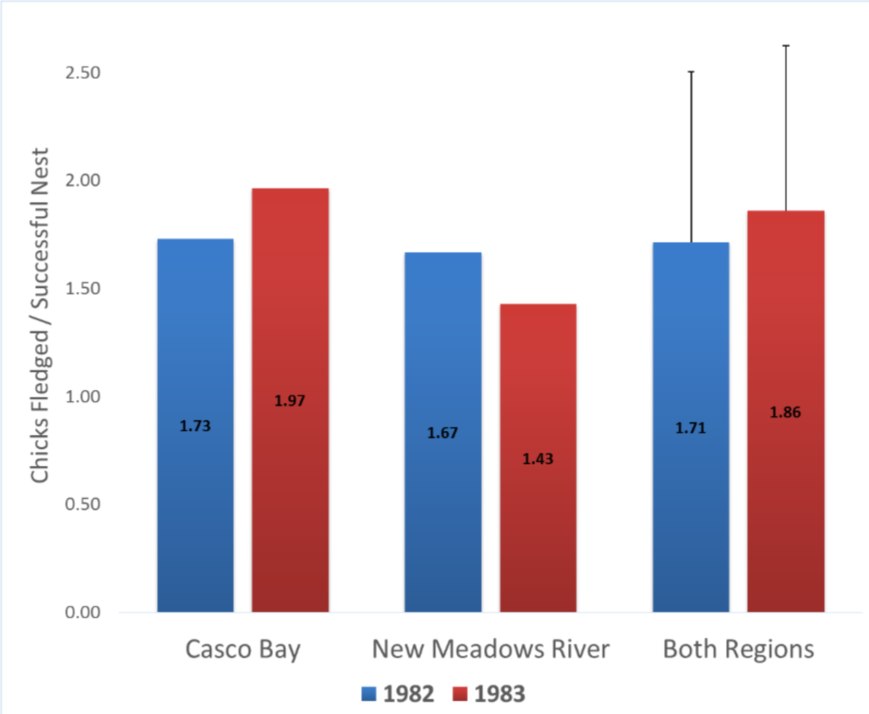

FIGURE 13. BROOD SIZE OF SUCCESSFUL OSPREY NEST IN THE CASCO BAY STUDY AREA, DETERMINED DURING FIXED-WING AERIAL SURVEYS OF CASCO BAY, 2011-2013 AND 1982-1983. ERROR BARS ON BOTH REGIONS REPRESENTS STANDARD DEVIATION.

5.3 Long-term Population Comparison

Long-term comparisons of nest success, productivity, and brood size between sampled periods suggest that Ospreys in the early 1980s had higher overall reproductive success measures compared to the 2011-2013 period. Mean (± SD) nest success showed a tendency to be higher in the early period (63 ± 58%) compared to the late period (54 ± 63%); however these means were not significantly different (p = 0.0746, χ^2 = 3.18). Mean productivity was significantly higher in the early period (1.10 ± 1.21) compared to the late period (0.73 ± 1.02) (p = 0.0032, χ^2 = 8.70) and brood size was also higher in the early period (1.74 ± 0.95) compared to the late period (1.34 ± 0.75) (p = 0.0005, χ^2 = 12.184). To evaluate if geographic differences in reproductive success between areas surveyed in 1982-1983 versus 2011-2013 might be causing the observed decline between periods (i.e, if observed differences in reproductive measures between periods were caused by higher reproductive success in the areas surveyed in 1982-1983), we calculated 2011-2013 reproductive measures for a subset of nests overlapping with areas surveyed in 1982-1983 and compared them to the remainder of the nests in the study area in the 2011-2013 period (Figure 14). None of the reproductive measures differed between nests in this subset compared to those in the remainder of the bay (p> 0.05 for all three measures), suggesting that the areas sampled in the early period were representative of the reproductive success of the nests in the remainder of the bay (during the late period).

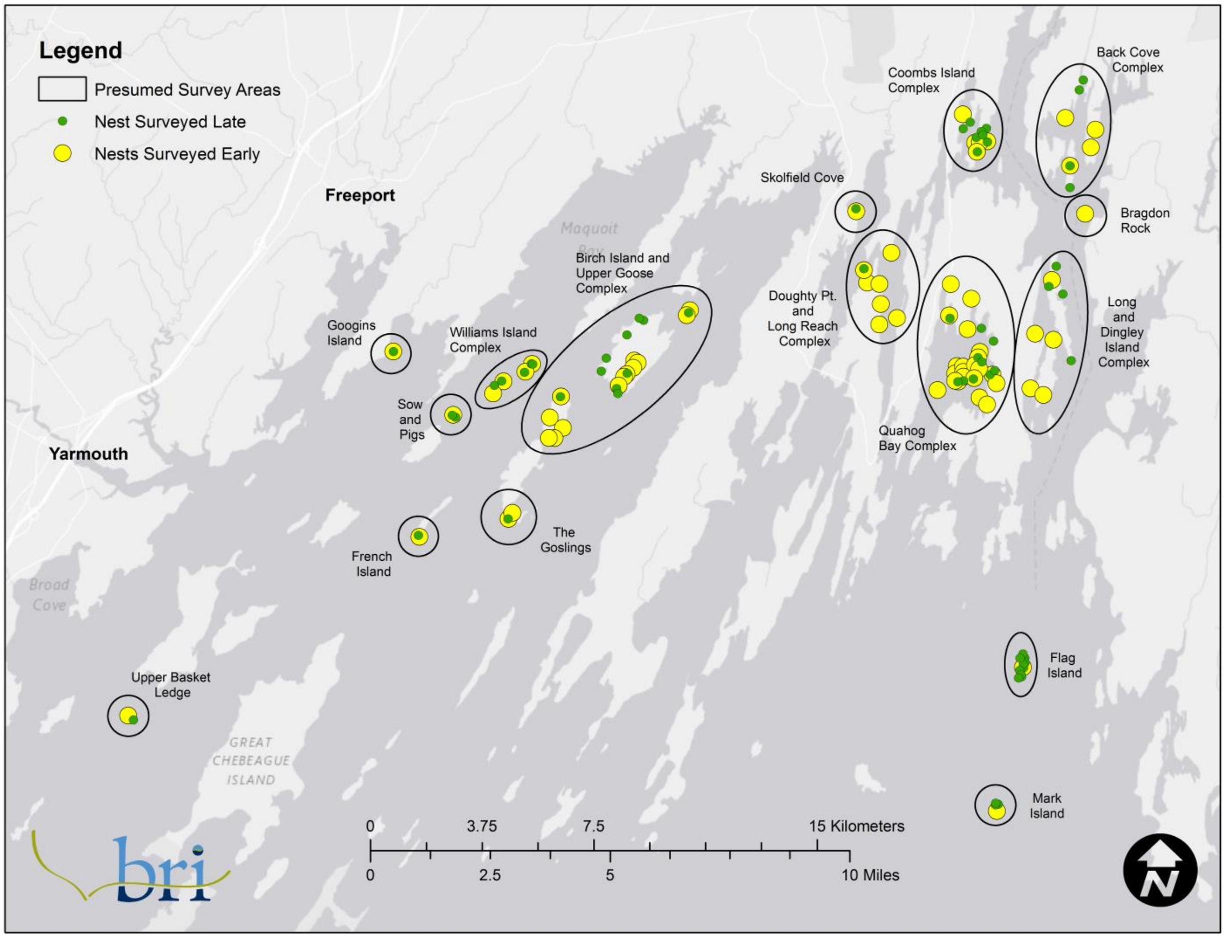

FIGURE 14. LOCATIONS OF OSPREY NESTS DETECTED DURING FIXED-WING AERIAL SURVEYS, 1982-1983 (EARLY PERIOD) AND 2011-2013 (LATE PERIOD). CIRCLED AREAS ARE REGIONS SEARCHED DURING SURVEYS IN BOTH EARLY (PRESUMED) AND LATE PERIODS.

6.0 DISCUSSION

In this study, we conducted a three-year (2011-2013) 'baywide' inventory of the Osprey population in Casco Bay. Surveys, conducted in 2011-2013, enabled estimates of the abundance, distribution, and reproductive success for the 'current' Casco Bay Osprey population at a level of intensity that has never been previously attempted in the bay. We also summarized historical Osprey productivity data collected by MDIFW during 1982-1983. Comparisons of data from the late period (2011-2013) with the early period (1982-1983) enabled first-time evaluations of long-term trends in Osprey reproductive success in Casco Bay.

6.1 Why is monitoring Ospreys important?

Ospreys are among the most well-established bioindicator species. Natural history traits such as a long lifespan, high site fidelity, and an exclusive fish diet make Ospreys highly effective monitors of contaminant patterns in the aquatic systems (Henny et al. 2004, Grove et al. 2009). During the mid 20th century, Ospreys were among several species key in detecting and demonstrating the adverse effects of the pesticide DDT on wildlife, eventually leading to the ban on DDT and other landmark environmental policies. Previous investigations revealed that Ospreys in Casco Bay contained elevated levels of emerging contaminants such as PFOS and PBDEs (Goodale 2010), but exposure patterns and health effects of these compounds on wildlife remain poorly understood. Information baselines on Osprey nest distribution, abundance, and reproductive success, such as those collected during this study, are important in future efforts to evaluate spatial and temporal contaminant patterns and to evaluate the potential health effects associated with contaminant exposure on wildlife.

Ospreys are valuable ecological indicators as their nest distribution and productivity are highly responsive to changes and patterns in the local foodweb (Poole 1989, Watts et al. 2004). A substantial amount of environmental monitoring and research has been conducted in Casco Bay over the last several decades. Intensive monitoring and research efforts by the Casco Bay Estuary Partnership and partners have elucidated numerous broad-scale ecological changes in the bay relevant to Ospreys and other wildlife including evidence of: (a) sea level rise estimated at 0.7 inches per decade (1912 – 2007) and associated changes in water chemistry, (b) existing water quality issues, including low dissolved oxygen at sites throughout the bay, (c) elevated concentrations of heavy metals, PAHs, legacy contaminants (PCBs, DDT), and emerging contaminants (PBDEs, PFOS) in biotic and/or abiotic samples, and (d) evidence that green crabs are responsible for a more than 50% decline in Casco Bay's eelgrass beds over the last few years (CBEP 2005, 2010, 2013, Goodale 2010). Broad scale ecological changes in Casco Bay may cause indirect or cascading impacts on the Casco Bay ecosystem.

Establishment of Osprey nest abundance, distribution, productivity, and breeding density baselines enabled by this study will prove important to a wide variety future monitoring and research efforts, including those focusing on other species such as Bald Eagles. Unlike the remainder of coastal Maine where Bald Eagles nest in higher densities, Casco Bay is the only region in Maine in which the influence of an expanding Bald Eagle population on an abundant Osprey population can be examined. Information collected during this study provides valuable baseline data critical in future investigations on toxicological exposure, nesting habitat preferences, foraging habits, and other topics with notable conservation and management value.

6.2 Summary of Early and Late Period Findings

Our 2011-2013 surveys confirmed that Ospreys are relatively abundant and widely distributed in Casco Bay. We detected between 106-161 intact Osprey nests in Casco Bay during late period surveys. Eighty-two percent of nests were built in trees, while the remaining 18% were built on artificial structures, many of which were in the Fore River. Just over three-quarters of the intact nests and confirmed breeding pairs were located within the Casco Bay subregion (76-79% of intact nests), while close to a fifth (15-18%) were in the New Meadows River subregion, and 5-6% were located in the Fore River subregion. The number of confirmed breeding pairs detected in Casco Bay increased annually, from 86 pairs in 2011, to 117 in 2012, and 120 in 2013. The number of possible resident pairs – the subset of pairs representing a combination of failed and non-breeders – ranged little over the three years (12-16); comprising 11-12% of annual totals of the number of maximum resident pairs (confirmed breeders + failed/non-breeders).

The total number of young produced annually during 2011-2013 did not change in proportion to the number of confirmed breeding pairs; the number of chicks fledged was 80, 85, and 78 over 2011, 2012, and 2013 respectively. As a result, productivity declined from 0.93 young / confirmed breeding pair in 2011 to 0.73 young per breeding pair in 2012, and further declined to 0.65 young / confirmed breeding pair in 2013. Nest success declined annually over 2011-2013 from 63%, to 56% and 48% in 2011, 2012, and 2013, respectively. Inclusion of possible resident pairs in reproductive success measures resulted in 5-8% declines in nest success and 0.07 – 0.11 young per pair declines in productivity. Of the three years, the 2013 breeding season appeared the poorest in terms of both nest success and productivity. During 2013 pairs produced the fewest number of young (78) from the highest number of confirmed breeding pairs observed over the period (120). Brood size (the number of young produced by successful nesting pairs) ranged from 1.5 young per successful nest in 2011, and dropping to 1.3 young per successful nest in both 2012 and 2013. Marginally significant declines were detected in annual means of productivity and brood size. Spatial evaluations of nest success, productivity, and brood size did not reveal any notable spatial patterns throughout Casco Bay.

Aerial surveys conducted during 1982-1983 checked the occupancy and fledgling survival for 65-69 Osprey nests in Casco Bay. Unlike surveys during the early period, these surveys were not intended for use in evaluating abundance, but were conducted in known high density nesting areas to evaluate whether DDT might be suppressing Osprey productivity as had been demonstrated in Bald Eagles. Of these nests, roughly 77-78% were in the Casco Bay subregion and the remaining 22-23% were in the New Meadows River subregion. Only two (4%) of the 51 nests with known nest structure types were built on artificial structures, while the remaining 96% (n = 49) were built in trees. Surveys during the early period confirmed the presence of 53-54 breeding pairs and 2-3 pairs categorized as either non-breeders or failed breeders (possible resident pairs). Reproductive measures were similar between 1982 and 1983; pairs produced between 60-67 young, and mean annual nest success ranged from 45-53%. Annual mean productivity was favorable during the early period, ranging from 1.11 - 1.26 young / confirmed breeding pair between years. Brood size ranged from 1.7 – 1.9 young per successful nesting pair. Our study detected marginally lower nest success, and significantly lower productivity and brood size in the late period compared to the early period.

6.3 Factors Affecting Osprey Reproduction and Comparability among Populations

A wide variety of factors affect Ospreys' ability to successfully fledge young (Poole 1989, Poole et al. 2002), and many of the most important factors vary significantly among populations. Food availability has a strong influence on reproduction measures in birds, particularly raptors (Newton 1979). Ospreys typically lay more eggs and are able to raise more young to fledging age during years and regions associated with higher food availability (VanDaele and VanDaele 1982, Bowman et al. 1989, Steidl et al. 1991, Poole et al. 2002). In years where food is limited, young commonly starve and sibling rivalry increases. While Osprey reproductive measures and nesting density can reflect changes in local foodwebs, substantial differences in food abundance and quality between regions complicates comparisons among regions. For example, much data exists on the Osprey population in Chesapeake Bay; however, this is the largest Osprey population in the world, and it resides in one of the largest and most productive estuaries in the world (Watts et al. 2004, Watts and Paxton 2007).

Complications also arise in making productivity comparisons among populations using different nest site types. In general, Ospreys nesting on artificial structures (i.e., duck blinds, nest platforms, channel markers) produce more young compared to natural nests typically built in trees (Henny et al. 1977, Poole et al. 2002, Watts and Paxton 2007). Poole (1989) summarized Osprey productivity by nest substrate reported in various studies (MI, FL, MD, NY, ID). Productivity of Ospreys nesting on artificial sites ranged from 1.04 to 2.2 young per active nest, while those using natural sites ranged from 0.6 – 1.3 young per active nest. Exceptions to this pattern have been reported in the Canadian Great Lakes region, where natural sites typically comprised nests on stumps with equal or greater stability as artificial sites (Ewins 1996, Martin et al. 2005). While exceptions exist throughout our study area (i.e., the Fore River), the majority of Osprey nests in Casco Bay are primarily built at the very top of conifers – many of which are marginally stable considering their year-round exposure to weather conditions along the Maine coast. Maine's Osprey population may be unique in this regard compared to many populations elsewhere along the Atlantic coast. A general tendency for nest site selection favoring trees in Casco Bay may naturally limit the productivity of this population.

6.4 Uncertainty Inherent in Aerial Surveys

Uncertainty in reproduction statistics is inherent when conducting aerial raptor surveys, particularly in populations that nest asynchronously and in low densitites (Ewins and Miller 1995, Steenhof and Newton 2007). While Poole (1989) suggested that five visits to nests were ideal to comprehensively survey Ospreys, this approach has practical and cost limitations, thus many Osprey surveys rely upon information collected during one or two surveys (Henny et al. 1974, 2008, Postupalsky 1974, Watts et al. 2004) as we did. As a result, breeding pairs that failed prior to the nesting survey, or those that initiated nesting and failed between surveys, can go undetected. Further uncertainty, or measurement error, can be introduced into reproductive measures depending on whether ground-based or aerial-based surveys are used.

Aerial surveys are often used to survey raptor populations because they can cover large areas in a cost-efficient manner. However, detecting nests and counting young from an aircraft are associated with limitations such as differing detection rates due to observer differences, fatigue, and aircraft type. These and other factors can contribute to aerial visibility bias, which can be considerable during aerial surveys. Based upon characterizations in Marsh and Sinclair (1989), Bowman and Schempf (1999) measured perception and availability bias during aerial Bald Eagle surveys. They estimated that they detected 79% and 51% of observable adult and immature Bald Eagles, respectively, during aerial surveys, and that 21% of all adult eagles were unavailable for detection. Perception bias (also referred to as aerial-visibility bias) refers to animals (or nests) that are available to observers but not seen (i.e., missed), while availability bias refers to nests or individuals that were obscured from observers and not ‘available’ for detection. When combining the two types of biases, Bowman and Schempf (1999) estimated that 62% of adult eagles were detected. Grier et al. (1981) estimated that 76% of Bald Eagle nests and 85% of breeding areas were found during aerial surveys. Henny et al. (1974) conducted Osprey surveys in Chesapeake Bay and found nest detection rates were lower in aerial surveys compared to ground surveys, and also that detection rates were lower for tree nests vs. artificial nests. Henny et al. (1977) estimated that 5% of the Osprey nests in Chesapeake Bay (many of which were on artificial structures) found during boat-based surveys were not detected during aerial surveys. Differences in detectability of Osprey vs. Bald Eagle nests complicate application of Bald Eagle aerial survey bias estimates to Osprey surveys. Bald Eagle nests are substantially larger, but they are typically below the canopy and rarely use artificial structures in Maine. Maine Ospreys typically nest at the very tops of trees and will use artificial structures when present. Lesser use of artificial structures in Maine would presumably result in a higher proportion of nests not detected compared to the 5% reported by Henny et al. (1977).

Ewins and Miller (1995) evaluated the measurement error associated with Osprey productivity estimates in the Canadian Great Lakes region by comparing aerial survey findings to direct nest inspections. That study found rotor-winged aircraft had higher accuracy compared to fixed-wing aircraft, and that fixed-wing aircraft could underestimate mean productivity by 10-33% (Ewins and Miller 1995). That study also found that high fledgling mortality subsequent to the productivity survey in a portion of their study area resulted in an overestimate of the number of young in nests for fixed-wing aircraft surveys, and consequently, an overestimate in Osprey productivity.

We have no means of estimating measurement error in our study. Adjusting our highest annual (2011-2013) nest count figures to account for perception bias by 5% - 25% would adjust figures to 169 – 201 intact nests and 126 – 150 confirmed breeding pairs in the late period. Similar adjustments are not possible for the early period.

6.5 Status of the Casco Bay Osprey population

A considerable amount of research emphasis has been dedicated to population regulation in Ospreys due primarily to intensive investigations of DDT-induced reproductive failure in raptors throughout the latter half of the 20th century. Intensive studies on Osprey populations during this period estimated that the reproductive rate required for population stability lies between 0.80 – 1.3 young per active nest (Spitzer et al. 1983, Poole 1989, Postupalsky 1989, Poole et al. 2002). The reproductive rate required for population stability changes temporally, geographically and demographically depending on a variety of factors, particularly the age of first reproduction (Poole 1989). Growing populations with fewer limitations on the quantity of nest sites will breed at an earlier age, thereby contributing more young to the population. As a result, the reproductive rate required for population stability in this case is lower compared to populations in which nest site or other limitations cause birds to delay their first reproduction until a later age (Poole 1989).

Surveys of the Casco Bay Osprey population in 2011-2013 suggest that Ospreys are common and widely distributed throughout Casco Bay. Notable variability in annual reproductive measures overall and within subregions demonstrated the value of multi-year survey efforts. Our surveys indicated that, prior to any adjustments for fixed-wing survey measurement error; the subset of the Osprey population surveyed in 1982-1983 had a mean productivity level of 1.10 young per confirmed breeding pair, while the productivity of the 'baywide' population in 2011-2013 was 0.73 young per confirmed breeding pair.

If we attempted to account for the effects of measurement error on Osprey productivity in Casco Bay based on Ewins and Miller's (1995) estimate for fixed-wing aircraft, a 10 – 33% upwards adjustment to three-year mean productivity figures in the late period survey would produce 0.81 – 0.98 young per breeding pair. Similar adjustments to productivity in the early period would result in 1.3 – 1.6 young per breeding pair. We suspect that, after accounting for measurement error associated with fixed-wing aerial survey techniques, the Casco Bay Osprey population is likely stable. However, the 'present' population likely lies closer to the lower proposed margin of population stability (0.80 young per active nest; Spitzer 1980) compared to many other populations, including the that residing in Casco Bay in the mid 1980s. Our analyses suggest that Osprey productivity and brood size are significantly lower during the late period compared to thirty years ago. We did not see the same relationship in nest success, which is not sensitive to the number of young produced. Osprey productivity is dynamic, changing spatially and temporally in response to numerous factors including contaminant exposure, availability of artificial nest substrates, and food availability (Watts et al. 2004, Watts and Paxton 2007).

We suspect the observed declines in productivity between the two periods is likely best explained by changes in prey availability to Ospreys. Prey availability is among the most important factors influencing Osprey productivity (Van Daele and Van Daele 1982). Marine fisheries have declined in New England over the last 40 years mainly due to lack of regulatory control and overfishing (Shelley et al. 1996). For example, anadromous alewife and blueback herring (collectively referred to as "river herring") have declined dramatically along the Atlantic coast due to overharvest, dam construction, and reduced water quality (Willis 2009, Palkovacs et al. 2014). Due to their notable abundance prior to dramatic population level declines, River herring likely comprised a substantial proportion of the diet of Bald Eagles, Ospreys and other piscivorous wildlife along the Maine coast.

Ospreys are capable of travelling great distances for food, giving them increased flexibility during times of food shortage; however, this extra effort increases energy expenditure and decreases prey delivery rates. Food stress is associated with increased sibling rivalry and decreased chick survival. BRI researchers have previously observed highly food stressed Ospreys at Flag Island in Casco Bay and may be indicative of broader food limitation issues in this population.

Density dependence has been suspected in some Osprey populations and could be proposed as an explanation for the observed decline in productivity between early and late periods. A 30-year study of Ospreys in Corsica found that as Osprey population size and density increased, that the average productivity of breeding pairs decreased (Bretagnolle et al. 2008). Numerous factors, including adult survivorship, immigration, and the availability of nest sites have strong influences on Osprey population growth rates (Poole 1989, Wahl and Barbraud 2014). Nest distribution data gathered in this study may lead to increased perspectives on nest site availability and carrying capacity of the Casco Bay Osprey population.

Changes in Bald Eagle densities between early and late periods could also be proposed as an explanation for observed differences in productivity and brood size between the two periods. Bald Eagles were fully extirpated from Casco Bay during the DDT era. The first Bald Eagle pair known to recolonize Casco Bay occurred in Freeport at Sow and Pigs Island in 1992 (C. Todd, MDIFW, pers. comm.). As of a 2013 survey, there were under 20 Bald Eagle nesting territories in Casco Bay (Figure 1). Bald Eagles can have a notable influence on the nest distribution and productivity of Ospreys (Ogden 1975). A study in Florida found that territorial behavior of eagles during their first year at a nest site caused Ospreys to relocate nests and reduced their nesting success (though interspecific tolerance increased in subsequent breeding years) (Ogden 1975). Prevost (1979) observed interactions between Bald Eagles and Ospreys in Nova Scotia at a common foraging site where Ospreys lost hunting time due to the presence of eagles. Bald Eagles' kleptoparasitism of Ospreys is commonly observed (Stalmaster 1987). Bald Eagles are currently at an early stage of recovery in Casco Bay and populations remain at low densities compared to all coastal areas to the east. Preliminary nest distribution data suggests eagles are having only a local influence on the distribution and abundance of Ospreys Casco Bay (i.e, Snow Island in Harpswell) (C. Todd, MDIFW, pers. comm.).

Recommendations

1. This study documented a long-term decline in Osprey productivity in brood size for the Casco Bay Osprey population. These findings emphasize the conservation value of long-term monitoring. Continuing declines in productivity over the next thirty years could be of concern as the reproductive rate for the current population lies closer to the level required to maintain a stable population. We recommend repeating all or a portion of the surveys conducted in this study at regular intervals (i.e., 5-10 years) to evaluate changes in Osprey abundance, distribution, and reproduction. Future efforts should include efforts to account for measurement error.
2. The Casco Bay Osprey population represents the only place along coastal Maine where Ospreys are abundant and Bald Eagles remain in early stages of recovery. As a result, Casco Bay is uniquely suited statewide to evaluate the influence of an expanding Bald Eagle population on an abundant Osprey population. Both of these species are valued bioindicators and may reflect broad-scale ecological changes in Casco Bay. We recommend continued efforts to monitor Bald Eagle abundance, distribution, and productivity in the future in parallel with future efforts to monitor Ospreys.
3. Given limited funds to conduct long-term monitoring, alternative options for survey continuation should be considered. We assert that a significant portion of the Casco Bay Osprey population could be monitored using citizen science volunteers. The Maine River Bird Project successfully used citizen scientists to collect data on bird abundance along the Penobscot River corridor and other regions of Maine in response to dam removals. Ospreys are easily distinguished from other birds by trained volunteers and detailed information on Osprey phenology, behavior, and reproduction. We recommend developing a program to use citizen volunteers to continue data collection efforts at selected sites throughout Casco Bay.
4. Dietary characterizations. Surprisingly little is known about the foraging ecology of Ospreys, particularly along the Maine coast. Information documenting food habits and locating foraging areas would help elucidate changes in abundance, distribution, and reproductive measures. A wide variety of tools are available to researchers gain perspectives on Osprey dietary habits and foraging patterns including stable

isotope analysis, nest/trail cameras, and animal tracking technologies (satellite and GPS transmitters, automated telemetry). Such information would be useful in explaining toxicological findings.

5. Prey abundance and food stress. We suspect prey abundance and food stress may be the primary factor influencing observed declines in Osprey reproductive measures between the two periods. Evidence of food stress have been observed in Casco Bay by BRI researchers. Further efforts to estimate prey abundance to Ospreys and to measure food stress in Casco Bay Ospreys would provide perspectives on observed declines in Osprey reproductive measures in this study.
6. Habitat analysis. Osprey nests were not distributed evenly throughout Casco Bay and the reasons for their absence from some shorelines require further explanation. Nest distribution information collected in this study provides an opportunity to evaluate patterns of nest distribution relative to land cover, habitat type, and other variables. Such information would aid in gaining perspectives on future changes in Osprey distribution, abundance, and reproductive success.
7. Continued contaminant sampling. Osprey tissues (eggs, blood, feathers) are an effective way to monitor contaminants in the Casco Bay ecosystem. Previous studies documented high levels of several emerging contaminants in Casco Bay Osprey eggs, and notable spatial variability in exposure (Goodale 2010). Efforts to collect samples from Ospreys for continued contaminant analyses and archives are warranted, since contaminants such as mercury are considered to be increasing globally (and Casco Bay represents an ideal population for long-term monitoring), elevated levels of some contaminants have been revealed previously (Goodale 2010), and newly emerging contaminants will continue to be of monitoring relevance.

Acknowledgments

We thank Curtis Bohlen, Beverly Bayley-Smith of the CBEP for assistance administering supporting grants. Wing Goodale, BRI, was instrumental in the approval and implementation of this project. We thank Charlie Todd, of the Maine Department of Inland Fisheries and Wildlife, for his expertise leading aerial surveys and extensive assistance managing survey plots and data. We are grateful to the Maine Outdoor Heritage Fund for their support of proposal #111-01-17, the Maine River Bird Project, and its authors, Erynn Call, Mac Hunter, University of Maine, Orono, and Charlie Todd. Surveys supported by the MOHF grant provided valuable data on Ospreys from other Maine regions that will improve interpretations of data collected during this study and improve our understanding of the status of the statewide Osprey population. Lauren Gilpatrick assisted with background research included in this report. Ian Johnson aided in aerial surveys and GIS assistance early in this project.

This research was funded wholly or in part by the Casco Bay Estuary Partnership (CBEP) under cooperative agreements CE 96105601, CE 96127201 and CE 961605010, between the U.S. Environmental Protection Agency, National Estuary Program and the Casco Bay Estuary Partnership, University of Southern Maine. Although the research described in the report has been funded wholly or in part by the U.S. Environmental Protection Agency, it has not been subjected to the Agency's peer review and therefore does not necessarily reflect the views and policies of the Agency, and no official endorsement should be inferred.

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