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Natural Resource Stewardship and Science

The Potential Impact of Sea Level Rise on Seabird Nesting Islands in Acadia National Park

Natural Resource Report NPS/ACAD/NRR—2015/1055

ON THE COVER
Northeastern spit on Great Spoon, from the island peak. Note seawall and partially flooded marshy area in foreground.
Photograph courtesy of the National Park Service

The Potential Impact of Sea Level Rise on Seabird Nesting Islands in Acadia National Park

Natural Resource Report NPS/ACAD/NRR—2015/1055

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Executive Summary

A multi-year study of seabird nesting islands owned in fee or under conservation easement to Acadia National Park, Maine was conducted between 2011 and 2014. A total of 13 islands (3 under fee-ownership, 10 with easements) were identified for detailed study. Islands were censused through a combination of boat-counts and direct colony walk-throughs, with detailed nest counts performed for Herring and Great Black-backed gulls and Double-crested cormorants. Presence of nesting Eider ducks and Black guillemots was also noted.

Detailed photographs of island shorelines and key habitats were taken for each island, and a "biological shoreline" marking the lower limit of the area above which wave action was unlikely during the breeding season (May-August) was developed using sub-meter accurate differential GPS and a total-station transit. Island topography was obtained from LIDAR files available from the State of Maine Office of GIS. These files were combined with the GPS/transit data from individual islands and were used to generate probable flood maps under different scenarios ranging from a 1 to a 3m increase in sea level. Islands were classified on the basis of perceived vulnerability ranging from 'unlikely to persist as viable colony site' (Category 1) through 'subject to some habitat loss' (Category 2) to 'minimal loss of effective habitat' (Category 3). Four islands (Milliken, Drum, White Horse and Black Horse) fell into Category 1, mainly because of their small size. Six islands (Schoodic, Heron, Shabby, Great Spoon, Green, and Shag) fell into Category 2; in the case of the larger islands, due to the likelihood of the failure of cobble sea-walls, leading to habitat loss or fragmentation. Three islands (Little Duck, Thrumcap, and Little Spoon) fell into Category 3, with some habitat loss but insufficient to seriously compromise nesting populations.

We observed evidence of significant declines in nesting seabirds throughout the study area when compared to past studies. Much of this decline is probably due to predation and disturbance by Bald Eagles, and possibly in some cases additional disturbance from human intruders. Bald Eagles were present on or around all islands in the study area, and were frequently seen flying over or landing in gull colonies. We found evidence of predation on several islands, including the remains of both adults and birds of the year.

Although no direct NPS mitigation strategies for sea level rise are currently feasible, we encourage the National Park Service to:

- Continue to educate the public about the Park's islands, seabirds, climate change and sea level rise. This could include additional curricula for High School or K-8 students, informational posters and brochures, and Ranger talks at major campgrounds and the Visitor Center.

- Develop adequate signage cautioning visitors to stay off nesting islands during the breeding season (May-Aug).

- Examine possible acquisition of additional nesting islands in partnership with other Federal, State or private conservation groups.

- Establish a regular monitoring program (at least every 3 years) of Park-owned or easement nesting islands. Ideally this program will include both regular nest counts and geo-referenced photographs depicting island shoreline conditions.
- Designate an individual to be responsible for regular update of island information, which should be maintained as a GIS or other searchable database.
- Consider possible acquisition of additional nesting islands if this is within the NPS mandate and fee area.

Acadia National Park is responsible for several key nesting sites in Mid-coastal Maine. It is to be hoped that in spite of recent declines in nesting bird numbers and the long-term challenge of sea level rise and other aspects of climate change, these islands will continue to play an integral role in the park's mission and heritage.

Acknowledgements

I would like to thank Mary Foley, Regional Chief Scientist, National Park Service, for arranging the support of this project from inception to conclusion. Mary had both the courage and the inspiration to take a casual comment by the author as the catalyst for serious study, she then found the resources to make it happen. I would also like to thank Karen Anderson, Geographer, Acadia National Park for assistance with the mysteries of ArcMap, LIDAR, and spatial geodesy, Jane Strader, who collated data, generated the flood model maps, and wrote the accompanying High School curriculum on sea level rise. Field work would not have been possible without Kate Shlepr, team leader for the Great Duck field crew, the crew itself from 2011-2013, and Capt. Toby Stephenson and the crew of the RV Osprey, who took us out and got us back. Write-up of this work benefitted extensively from the comments of two anonymous reviewers. Funding for this study came from the Northeast Region of the National Park Service and the Drury Research Fund of the College of the Atlantic.

Introduction

For more than a century the Gulf of Maine –the region of coastline and ocean that includes Acadia National Park (ANP)- has provided nesting and feeding sites for a broad range of seabirds[i] including gulls, ducks, guillemots, terns and petrels. Estimates have suggested that perhaps as much as 50% of all breeding seabirds in the eastern United States are found on Maine islands, and the region contains a number of Important Bird Areas (IBA).[ii] Islands also serve as significant stop-over points for migratory species in fall and spring.

Seabirds, including members of the Procellariformes (petrels and their allies) and Charadriiformes (gulls, terns and allies) are primarily ground or burrow nesters, and are therefore particularly vulnerable to mammalian predators such as mink, fox or coyotes. They are also susceptible to disturbance by humans, and their tendency to nest in large colonies at relatively few sites can result in serious population-level disruptions with even a few disturbances or active predators. Cormorants, such as the Double-crested cormorant (*Phalacrocorax auritus*) are known to nest in trees, but their nitrogen-rich wastes rapidly kill off nesting trees, and the birds are then forced to nest on the ground, where they become immediately vulnerable to terrestrial mammals.

Because of this sensitivity to terrestrial threats, seabirds nest almost exclusively on islands, and their colonies are often located on relatively remote and/or inaccessible sites. Many of these islands are in highly exposed off-shore locations, and as such are vulnerable to over-topping or erosion by storm waves to an extent not found in more protected in-shore areas. Extended periods of incubation, coupled with a high level of pre-fledging care, place adult birds and their young at risk from weather extremes including storm-surge, tidal events, and intense rainfall, all of which can occur during the April-October breeding and immediate post-fledging period.

The shoreline and islands of Maine represent an extremely dynamic landscape,[iii] within which present configurations are less than 5000 years old. The entire area was heavily glaciated up until approx. 15000 years B.P. after which complex interactions between isostatic re-bound and increases in post-glacial water volumes resulted in a series of flooding and recession events. For much of the period 9000 B.P. to approx. 5000 B.P., present day islands would have been alternately connected to the mainland or under water, and in either case unsuitable as sites for nesting seabirds. Archaeological evidence of Native American use of seabirds other than the Great Auk (*Pinguinus impennis*) is scarce (Spiess and Lewis 2001) [iv], while remains of the (now extinct) Sea Mink (*Neovison macrodon*) in island shell middens are common. The implication is that seabird numbers in pre-Colonial times were probably much lower than that recorded in the early 20th century, however we lack any systematic surveys prior to the late 1890's. Present conditions must be regarded as somewhat transitory, however the historical record [v] makes it clear that islands in eastern Maine in the vicinity of Acadia National Park have included significant seabird nesting sites since at least the last quarter of the 19th century.

Acadia National Park (ANP) is centered on extensive holdings of over 12,300 ha on Mt Desert Island, Hancock Co. Maine, with significant additional components on Isle au Haut (1092 ha) and the extreme southern end of the Schoodic Peninsula (957 ha). These three units contain many valuable

biological, recreational, and cultural features, and provide recreation opportunities for over 2.5 million visitors per year; however none is of particular significance to nesting seabirds. ANP manages more than 100 outlying islands as components of the park. These islands, while small in total area, include several important seabird colonies.

Bird Islands and the Problem of Sea Level Rise

Sea level rise is of increasing concern to resource managers, land owners, and ecologists involved in coastal environments. A recent report [vi] has suggested four possible scenarios for expected sea level rise along the coastal United States, ranging from a low of 0.2m (0.7 ft.) to a high of 2.0m (6.6 ft.) by the year 2100, using mean sea level height in 1992 as an arbitrary "zero point". Understandably, much of the focus to date has been on effects on human infrastructure, property-protection and safety, but sea level rise is also of great concern in the conservation of species such as ground-nesting seabirds that rely on small islands as safe refuges from terrestrial predators. The Gulf of Maine is an important region for seabird conservation. Islands within the Gulf serve as nesting and loafing areas for a variety of species, including Leach's Storm Petrels (*Oceanodroma leucorhoa),* Black Guillemots (*Cepphus grylle*), Common Eiders (*Somateria mollissima*), Herring and Greater Black-backed Gulls (*Larus argentatus, L. marinus*), Double crested Cormorants (*Phalacrocorax auritus*), several species of terns (*Sterna* sp.), Razorbill Auks (*Alca torda*) and Atlantic Puffins (*Fratercula arctica*). In addition, islands support unique floras, containing rare or endangered species of plants, some of which represent residual stands of species present in the area since the end of the Pleistocene glaciation. Many ledges serve as important "pupping zones" or haul-outs for Gray and Harbor Seals (*Halicoerus grypus* and *Phoca vitulina*).

ANP has easements on, or fee ownership of, over 100 islands between Penobscot Bay (43º49' N, 69º05'W) to Schoodic Point (44º 20'N 68 01' W). Although many of these islands are unsuitable for nesting areas at this time due to human activities or the presence of predatory mammals, some are known to contain –or have histories of containing- significant populations of breeding birds. Unlike the sandy "barrier islands" common to the south, Maine islands are generally granitic or basaltic ledges, often surrounded by a cobble "berm" that is constantly re-arranged by the high energy storm surges of late summer and winter. Even minor changes in sea level could have a profound impact on island size or configuration, reducing the area available for nesting or increasing the likelihood of eggs or chicks being washed away during storm events. Of longer term concern is that some islands will simply disappear as water levels rise; granite and cobble islands lack the ability to move and reform as exhibited by many barrier islands.

As a result of these concerns the National Park Service contracted with College of the Atlantic to conduct a multi-year assessment of Park islands in the Acadia N.P. to assess the probable effects of changes in sea level on nesting seabirds. Additional goals were to get a better sense of the presence of nesting birds within the Park as a whole, and also to record additional ecological and/or natural history information for use in park management decisions. The project was designed as a three year effort in the field, involving collaboration with NPS and CESU partners and including an educational component on the general effects of sea-level rise and climate change on ANP suitable for teaching to High School students.

Assumptions in our Work

For the purposes of this study we focus on a reasonable probability of a 1m rise in mean sea level by 2100 as a "most likely" scenario, though we included examples of greater increases for comparative purposes. This is midway between the low and high models in the report cited above, and is also slightly below the midpoint of estimates published by the National Academies of Science.[vii] Both estimates assume no major loss of the Greenland or Antarctic ice Shelves –events that would make any conclusions in this report largely irrelevant.

In assessing the impact of sea level rise on nesting seabird populations it is important to consider a number of factors and aspects of particular species' natural history. Simple linear measures of sea level rise, while important in some cases, need to be weighed in relation to their likely effect on long term storm damage and erosion. Because the primary charge of this project was to examine impacts on *nesting* birds, the importance of data on tide height, storm surges, etc. are strongly, though not exclusively, of seasonal import. A major storm likely to occur in September or October may have very little impact on nesting success (although it could create or destroy habitat useful in subsequent breeding seasons), whereas the same storm in mid-July could be devastating. Obvious winter storm lines could be found on several of the islands that we studied, but on rocky shores not prone to erosion, they are probably of minimal importance compared to possible surges in May-July. Maine is fortunate in that, although it sits in the storm track of Atlantic hurricanes, the majority of these storms have historically arrived from late August until the end of October.[viii] While there is some discussion about possible increased frequency of major storms [ix], at least at present, this pattern seems to be holding true.

One must recognize that different species require different habitat substrates, which may themselves be a product of existing shorelines or may be affected by wave action to a greater or lesser extent. These substrates in turn may limit the proportion of an island that may be suitable for nesting. We assume that the surfaces of many shorelines are the direct result of long-term wave processes, and that vegetation structure is in turn affected by both substrate and frequency of wash-over and spray. Storm activity may eliminate habitat on one area of a large island while simultaneously creating new habitat in another. For example Black Guillemots require rocky clefts or crevices for nesting sites – habitat that is produced along particular shores by the action of winter waves moving large granite boulders (Fig. 1). Smaller rounded cobbles tend to fit together too tightly to provide adequate nesting crevices, while overly large slabs may provide access to predators. Observations over the past 16 years on Great Duck Island have shown that, whereas guillemots tend to frequent the same general areas of shoreline from one year to the next, they may abandon a particular crevice as it is closed between one storm season and the next, and make use of a new neighboring site that has opened up as a result of wave "engineering". Once one recognizes the relationship between exposure, rock slab formation and positioning, and guillemot nesting behavior, even a superficial survey of a given shoreline can provide the observer with a high probability of correctly identifying where guillemots are *not* likely to be found. Further assessment is required to confirm actual nesting. Guillemots can nest within 3m of the upper tide line, and as such, are the first to be exposed to changes in overall sea level.

Figure 1. Typical Guillemot nesting habitat, Great Duck Island.

The unconsolidated nature of guillemot habitat and its proximity to the shoreline, places this sort of habitat (and species' dependence on it) at greatest risk to increases in sea level or storm-surge frequency compared to species utilizing more upland or consolidated areas. By contrast, gulls typically partition small islands, with Great Black-backs occupying the highest (least vulnerable) areas and Herring Gulls forming a band between them and the guillemots.

Methods

The bulk of the project during the late winter and spring of 2011 was devoted to assembling a Geographic Information System (GIS) containing Park ownership and easement data for islands and tying this to existing data on nesting islands. The primary source of nesting information was Erwin and Korschgen (1979) [x] supplemented with more recent information from the U.S. Fish and Wildlife Service (Anonymous 2010) [xi] and the author's personal observations. Data for park boundaries, easements, and fee ownership were obtained from the ANP Resource Management Division, who also provided preliminary LIDAR data for the islands.

As a result of the initial examination of GIS and seabird data, a total of 13 islands were selected for further inspection (Fig. 2).

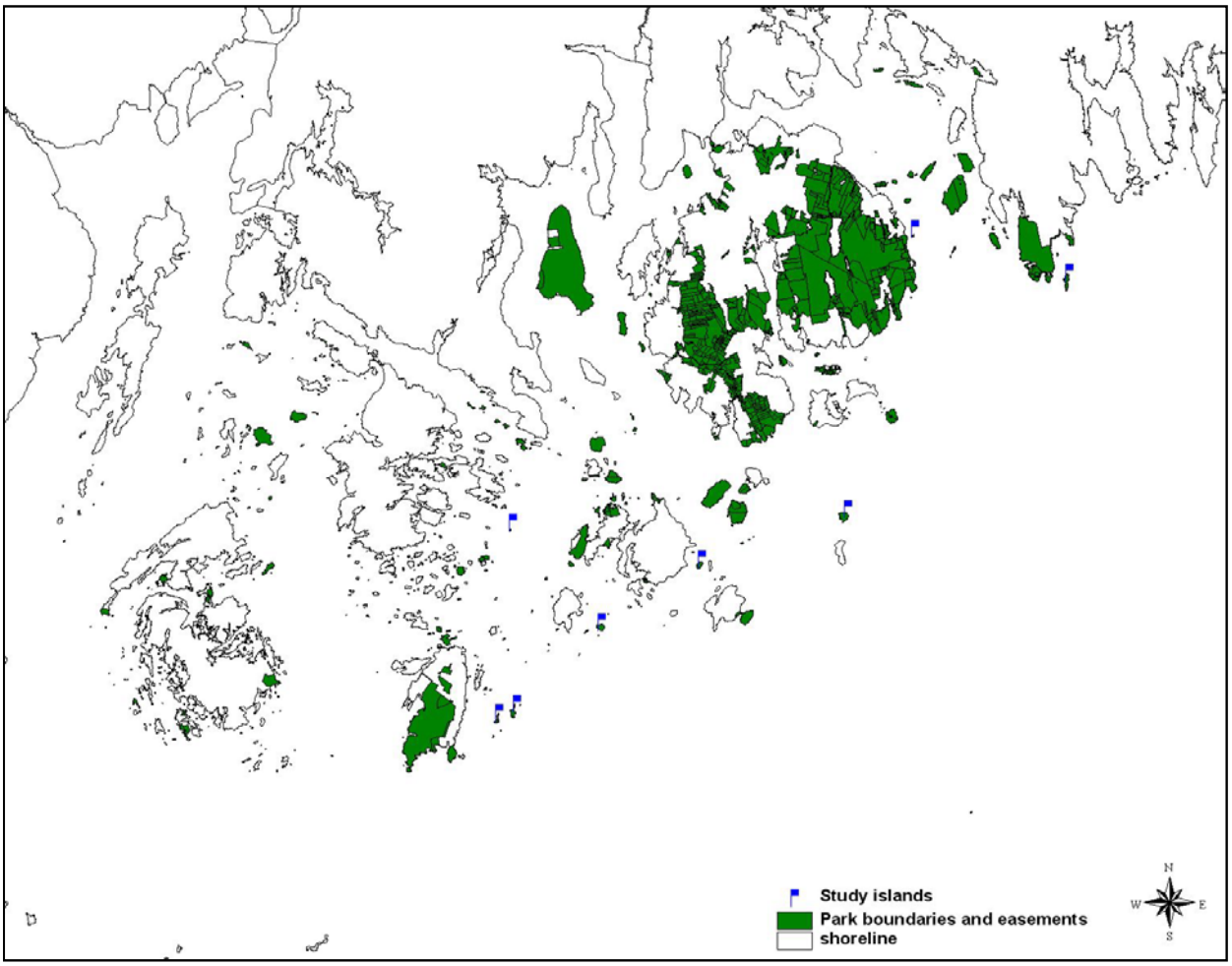

Figure 2. Study area showing existing ANP holdings and easements and study islands selected for the project.

Selected study islands consisted of:

1) Thrumcap Island, lower Frenchman Bay, Coastal Registry # 59-300 owned in fee by the National Park Service.

2) Schoodic Island, southwest of Frenchman Bay, Coastal Registry # 59-062 owned in fee by the National Park Service

3) Little Duck Island, south of Mount Desert Island, Coastal Registry # 59-439 privately owned, NPS easement.

4) Heron Island, south of Swan's Island, Coastal Registry # 59-480 owned in fee by the NPS.

5) Great Spoon Island east of Isle au Haut, Coastal Registry # 63-287 an easement island.

6) Little Spoon Island east of Isle au Haut Coastal Registry # 63-289 an easement island.

7) Shabby Island, Jericho Bay Coastal Registry # 59-996, an easement island.

8) Green Island south of Blue Hill Bay Black Island , Coastal Registry # 59-446, an easement island

9) Scrag Island south of Blue Hill Bay Black Island, Coastal Registry # 59-445 an easement island

10) Drum Island south of Blue Hill Bay Black Island, Coastal Registry # 59-444 an easement island

11) White Horse south of Isle au Haut Coastal Registry # 63-293 an easement island

12) Black Horse south of Isle au Haut Coastal Registry # 63-294 an easement island

13) Indian Point Ledge/Milliken Island Blue Hill Bay Island Coastal Registry # 59-127 an easement island

All of these islands have been reported [xii] to have numbers of nesting seabirds within the past 15 years.

Additional information on specific aspects of nest site selection and phenology was collected on Great Duck Island, south of the Cranberry Islands (Coastal Registry # 59-440), focusing on precise locations of nesting seabirds in relation to the existing shoreline. Great Duck was selected for these data as the island is the site of College of the Atlantic's Eno Field Station, and gulls, guillemots and petrels are already under study at and around the station. We could thus get spatial information with minimal additional disturbance to nesting birds. Ultimately it would seem advisable to obtain comparable information from at least some of the other study islands, however this would require longer stays and greater levels of disturbance than the present study permitted.

Elevations for most islands were obtained from LIDAR data and in some cases a total station transit (Fig. 3).

Figure 3. Determining elevations using total station. Great Spoon Island.

The exact location of the relevant “high tide line” in relation to seabird nesting is, as mentioned above, difficult to determine. For purposes of this study we elected to use an elevation determined from a minimum of 4 points exhibiting either sessile marine invertebrates or attached algae to represent the most likely region of frequent wetting. After our initial season (2011) we mapped this “biological shoreline” using Trimble Geo XT 2005 series GPS units differentially corrected through post-processing using the CORS-BAR HARBOR reference station for correction. Corrected GPS data provided sub-meter horizontal accuracy for greater than 90% of all positions in most cases.

While our selection of biological cues for current shoreline is an approximate assessment of basal height, it is probably within acceptable margins of error for the purposes of this study. We tested our assignment of the shoreline on both Schoodic and Thrumcap islands by having different researchers, each equipped with an identical GPS unit walk the shoreline in opposite directions and then overlaid the resulting polygons on each other. The results were within the expected margin of error for the equipment, and suggest that there is a high degree of repeatability in this sort of estimate at least for some islands.

LIDAR and survey data were incorporated into a common GIS using ARCMAP 10.2 (ESRI 2014) and flooding models were generated for 8 of the 13 islands using the ARCMAP software and estimates of best (no significant rise), optimistic (0-1m rise) pessimistic (1-2m rise) and catastrophic (2-3m rise) scenarios were generated. In addition to our own surveying work, we assisted ANP

personnel in establishing fixed benchmarks on Thrumcap, Schoodic, Heron and Little Duck islands for future monitoring. These monuments were then surveyed using survey grade GPS units with sub-centimeter accuracy. The points are the backbone of a park-wide height monitoring network.

Accurate estimates of nesting seabird populations are often difficult to obtain as they may be heavily influenced by seasonality, methodology, and even time of day in the case of species such as guillemots. In making comparisons with past estimates we attempted to duplicate methodologies used in prior counts that had the highest repeatability. Particular attention was paid to a comprehensive survey conducted in 1995, as we felt that the time range involved might be particularly revealing in terms of trends. Not all islands had been surveyed in the same year, and when data for 1995 were absent, we selected the closest available date from information in Allen et al. (2012).

In our own work, island populations of nesting seabirds were determined whenever possible by ground counts of active nests. These counts consisted of a line of 3-7 people walking at arms-length in repeated swaths across an island, recording clutch size and total numbers of nests in the case of gulls, Eider ducks, and cormorants and presence/absence in the case of guillemots and petrels. In 2012 we used plastic rings, supplied by the USFWS to discriminate between Herring and Great Black-backed Gulls based on egg diameter. Unfortunately, a re-evaluation of this methodology in 2013, using nests of known provenance (determined by observation of incubating birds on Great Duck Island) revealed that this technique may seriously over-estimate the actual number of Great Black-backs. As a result, we chose to lump both species into a common category of “gulls” for the purposes of this report. Likewise we chose not to discriminate between Great Cormorants (*Phalacrocorax carbo*) and Double-crested Cormorants (*P. auritus*). Great Cormorants are very rare in Maine and their number has declined significantly in the past 20 years. We were not entirely confident that all observers could distinguish the two species and so, as with gulls, elected to err on the side of caution by lumping both together.

In addition to ground counts, or in situations where time or sea-state prevented landings, we circled a given island as closely as possible, observing birds on nests or territories as well as counting presumed transients in the inter-tidal. Only Black Horse, White Horse and one of the Green islands had only boat counts. Geo-referenced photos were taken of islands during these circumnavigations in order to create a reference library of images for later analysis.

In terms of sensitivity to sea level rise, we qualitatively categorized islands as belonging to one of three general groups:

1) Small low-lying island and/or exposed to significant storm surge

2) Higher island with points greater than 5m above present sea level, but containing low areas subject to flooding or cobble sea-wall likely to erode

3) High rocky island with typical elevations greater than 5m above present sea level.

Islands in category 1 are not expected to survive even moderate levels of sea level rise. Islands in category 2 will continue to provide at least some habitat for nesting seabirds, although areas currently favored by some species may not persist. Islands in category 3 may lose a small proportion of their overall shoreline, but will continue to provide significant nesting habitat under currently expected sea level rise.

Results

The results of our work indicate that 1) islands differ greatly in terms of probable impact of sea-level rise, and 2) factors other than sea-level rise are dramatically altering seabird populations at a much more rapid rate than can be expected from current estimates of shoreline change. Islands surveyed generally show lower recent seabird numbers than were found roughly two decades ago (Table 1). Across three bird groups (gulls, cormorants, and common eiders), recent numbers appear to be lower than the past in roughly two-thirds of the estimates (25 of 39 instances). These changes do not seem to be due to loss of habitat, as the total decline in usable area between the mid 1990's and the present is relatively minor compared to available nesting space. One island (Thrumcap) has lost all of its large trees since the 1980's. Double crested Cormorants are known to have a preference for tree-nesting, and some of the continued decline in numbers on that island may be attributable to loss of nesting platforms, however substantial numbers of birds continued to nest on the island for more than a decade after the last tree fell.

Of potentially greater short-term significance, we were struck by the large number of foraging and loafing Bald Eagles (*Haliaeetus leucocephalus)* that we observed on or around every island that we visited. Our high count of 9 individuals on Heron Island in 2012 was followed in 2013 by 5 on the same island. Three were seen on Great Spoon, 2 to 5 were regularly seen over Little Duck, and 2 or more were seen at or near Thrumcap, Shabby, and the Horses. A figure in Todd and Matula (2008) [xiii] shows more than 50 active Bald Eagle nests within the study area, and overall populations of Bald Eagles in Maine have been exhibiting near-exponential growth since the mid-1980's. Bald Eagles are known predators on seabirds, and their presence in or over colonies results in immediate disruption as adult birds rise to "mob" the approaching predator. We witnessed frequent mobbing events during all three years of this study. It is important to note that in many cases eagles were not nesting on islands that they were seen foraging over. Nisbet (pers. comm.) has suggested that the presence of a nesting pair may reduce attacks by roaming immature eagles at least during the early part of the season. While this may be true in some cases, our observations on Great Duck suggest that any relief from nesting territoriality may be more than exceeded by subsequent adult and fledgling predation later.

Table 1. Estimates of nesting seabirds on study islands. In cases where no count had been conducted in 1995, we selected the closest year to that date when a count had been conducted. It should be noted that not all counts used the same methodologies, and these results should be used for general comparisons only. Eider counts on larger islands are probably underestimates because eiders begin hatching in late May or early June, prior to our counting window. Eider females and chicks leave the nest as soon as hatching is completed.

Island	Gulls 1995*:2013	Cormorants 1995*:2013	Common Eiders 1995*:2013	Other species present 2013
Millikan/Indian Point	0:0	0:0	0:0	50 Common Terns in 2000, 0 in 2013
Thrumcap	141:105	430:12	10:1	Canada Goose
Schoodic	796:479	138:359	1000:23+	20+ Guillemots
Little Duck	434:26	378:0	400:20+	100+ guillemots
Green	37:16	168:0	50:0	Guillemots present
Drum	0:0	0:0	0:0	
Scrag	37:24	55:75	20:3	4+ guillemots
Heron	1526:245	0:0	200:10+	1+ guillemot
Great Spoon	734:65	63:0	494:17+	3 common terns
Little Spoon	255:157	253:14	100:14	8+ nesting guillemots
White Horse	0:0	4:0		
Black Horse	0:0	0:3		
Shabby	190:113	312:36	150:8	Guillemots present

The Islands

Millikan

Millikan Island (44 2305.75 N 68 22 46.81 W) is a park easement island located approx. 0.22 km from Mt Desert Island. Its greatest significance lies in the long ledge extending to the Southeast (Fig. 4) that has been used for periodically by nesting Common terns (*Sterna hirundo*). These birds seem to move between the Milliken ledges and other small islands in upper Blue Hill Bay, nesting for a year or two on one spot before moving on as their nest site is discovered by predators. It seems possible that this strategy of frequent movement by small numbers of birds between multiple ledges may represent a long-term historical pattern for some species. No terns or other seabirds were found when the island was censused in 2012. The nesting ledges fall into our Category 1 islands, highly susceptible to even minor rises in sea level. Virtually all areas used by nesting terns are within 2m of the current tide line, and there is little or no upland area that would allow an orderly retreat as waters rise (Fig. 5). The island is already subject to periodic flooding/overtopping, and whereas its sheltered location in an inlet of the bay reduces the effects of storm surge, it is apparent that much of the island floods periodically. Whereas individual terns have been known to nest occasionally on even small rocks, it seems likely that once the island ledge is divided into multiple “nubbles” its utility as a nesting area will be compromised.

Figure 4. Nesting ledge off Milliken Island Blue Hill Bay.

Figure 5. Milliken Island nesting ledge. Note shoreline/seaweed wrack along crest of island.

Thrumcap

Thrumcap Island (44 21 08 N, 68 10 36 W), located 0.4 km east of Mt Desert Island, is one of the three most significant nesting islands within ANP. Although the population of all species of seabirds has been significantly reduced (Table 1) the island still supports limited numbers of Herring and Great Black-backed Gulls, Common Eiders, and Double-crested Cormorants. A recent arrival, as of 2014, was a single pair of Canada geese (*Branta canadensis*) that appeared to be nesting on the west side. The crown of the island was tree-covered until the early 1990's when the dominant spruce stand was killed off by the build-up of nitrogen rich guano from nesting cormorants. Once the dead snags had blown over, the cormorants continued to nest on the ground, constructing elaborate nests from a mixture of sticks, mud, seaweed, etc. (Fig. 6a-b).

Figure 6. a) Cormorant nests, Thrumcap. Island, b) Cormorant nest (detail).

Thrumcap Island's location near the western shore of Frenchman Bay (Fig. 7) makes it the most easily observed seabird island in Acadia National Park. In spite of the island's relatively small area (1.3 hectare), its high steep sides (Fig. 8) reduce the likely effects of sea level rise, at least within the foreseeable future. As such we regard it as a Category 3 (least sensitive) island.

Figure 7. Thrumcap Island from the West. Note height of breaking wave.

Figure 8. Eastern side of Thrumcap Island showing current shoreline and partial elevation.

The cormorant colony has traditionally nested on the extreme peak of the island, while Black-backed gulls have gradually pressed Herring gulls into occupying the lower slopes of the island. All three species have declined significantly in recent years, while Bald Eagles are increasingly common, both passing over and roosting on the island.

GIS modelling of possible flooding scenarios on Thrumcap (Fig. 9) confirm our impression that the island is relatively resilient to expected sea level rise.

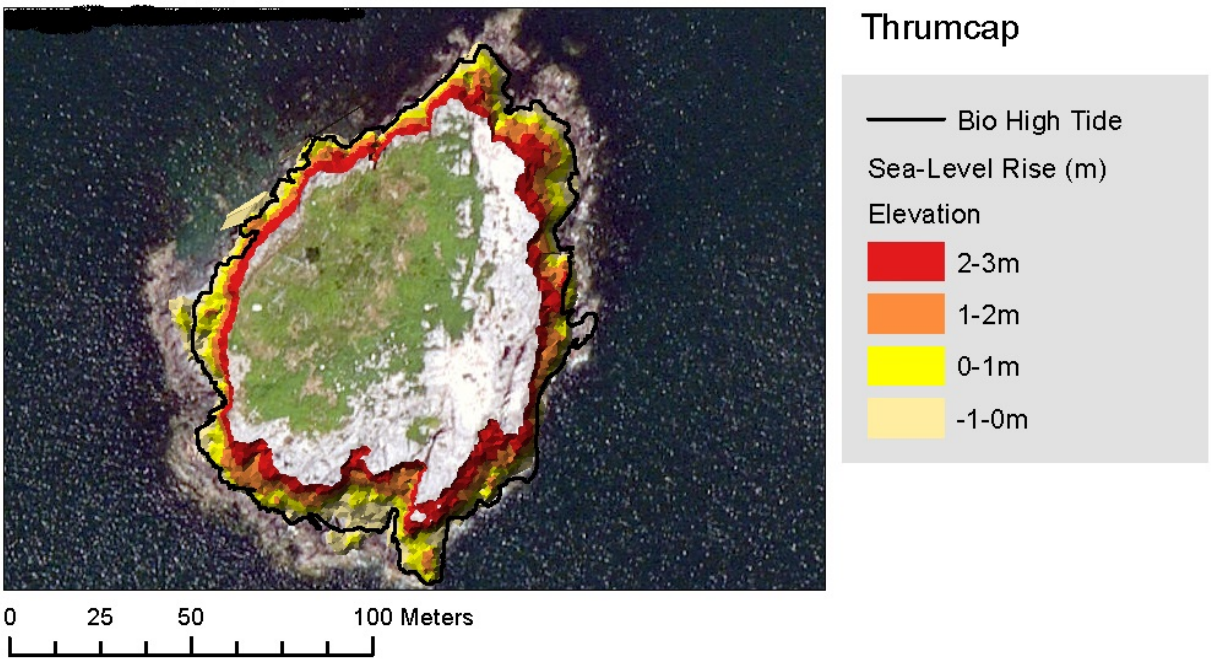

Figure 9. Flooding model of Thrumcap Island generated using ARCMAP10.2. The white area is guano from nesting seabirds.

As shown in Figure 9, the expected 1-meter rise in sea level over the next century has only minimal impact on the island's total area, and even the 2-3 meter sea level rise scenario leaves substantial portions of the island above the tide line. It should be noted that we were not in a position to model the effects of potential storm surge on erosion, spray, or additional flooding. It must be remembered that, at least in reference to historical conditions, peak storm activity occurs after the nesting season for the majority of birds utilizing park islands. In addition, Thrumcap consists largely of a rocky dome with only minimal soil layers along the summit. Loss of this soil and the vegetation that utilizes it would have minimal impact on gulls and cormorants. Eider ducks are generally more reliant on vegetation for nesting habitat, but they continue to nest on Mt Desert Rock in the complete absence of covering vegetation. Other studies [xiv] have suggested that while eiders may lose some eggs and chicks to gulls, they also benefit from gulls driving off more serious predators, especially corvids. Loss of gull populations may therefore be expected to have a negative effect on eiders.

Thrumcap is in close proximity to Bar Harbor and provides excellent opportunities for water-based viewing of sensitive wildlife during the summer months. The island is accessible to sea-kayakers, although there is only one moderately safe landing place along the present shoreline. As of this

writing (July 2015) this landing place has no signage cautioning would-be intruders to avoid the island during breeding season (May-August).

Schoodic

Schoodic Island (44 19 51 N, 68 01 57 W), located 0.94 km from Schoodic Peninsula, is without question the most important seabird island currently owned in fee by Acadia National Park. The island has a long history of seabird nesting, extending back at least into the early 1940's [xv]. The island has contained a Bald Eagle nest in spruce trees at the southern end for a number of years. As mentioned earlier, it has been suggested (I.C.T. Nisbet, *pers. comm.*) that the presence of nesting eagles or territorial adults may reduce predation on seabirds by roaming juvenile eagles. This situation may however be changing as eagle populations continue to increase. We saw up to four immature Bald Eagles at the extreme Northeastern end of the island, and immature and juvenile eagles at the southern end. The island supports a large number of nesting Common Eiders, particularly in the dense vegetation in the center of the island (Fig. 10), and both Herring and Great Black-backed gulls nest in clusters near the shore and along high points at the north and south ends of the island. There is a large colony of Double-crested cormorants on the Northeast shore (Fig. 11). In addition, we saw large numbers of Black Guillemots in the waters immediately around the island, and a number emerged from rock crevices on the island's periphery as we conducted surveying operations. We did not attempt any sort of formal census of guillemots, but are confident that they are nesting on the island. There have been periodic reports of Leach's Storm Petrels nesting on Schoodic, but a systematic survey in 2007 failed to turn up any burrows, and we did not see any during the course of this study. The island's dense vegetation may serve as a deterrent to petrels, but it is entirely possible that they may attempt to nest in the northern and southern ends in the future.

Figure 10. Nesting Common Eider on Schoodic Island.

Figure 11. Cormorant colony on Schoodic Island, aerial photograph June 20 2007.

In spite of its relatively large size (26ha), Schoodic Island's topography makes it a Class 2 island, likely to be impacted by moderate sea level rise through the loss of key nesting areas. Most prominent among these is the low marshy area in the center of the island that is at, or near, present sea-level. This area is densely vegetated (Fig. 12) and supports the majority of the island's nesting Common Eider population. Even though they may be found nesting under rock ledges or even along large-cobble shorelines, Eiders prefer tall vegetation for nesting as this provides maximal camouflage for nests. Eider females travel to and from their nests along tunnels in the vegetation, which often branch repeatedly, possibly to further confuse would-be predators. At the moment this area is protected from wave incursion by high cobble seawalls (Fig. 13a-b).

Figure 12. Dense vegetation and ideal eider habitat in center of Schoodic Island.

Figure 13. a) Central section of Schoodic Island. Note cobble berm facing each side. Portions of the interior behind the seawall are near or at current sea level, and brackish pools form in areas of poor drainage, b) Western berm or seawall protecting center of Schoodic Island, c) Low-lying marshy “core” of Schoodic Island looking north to higher rocky outcropping.

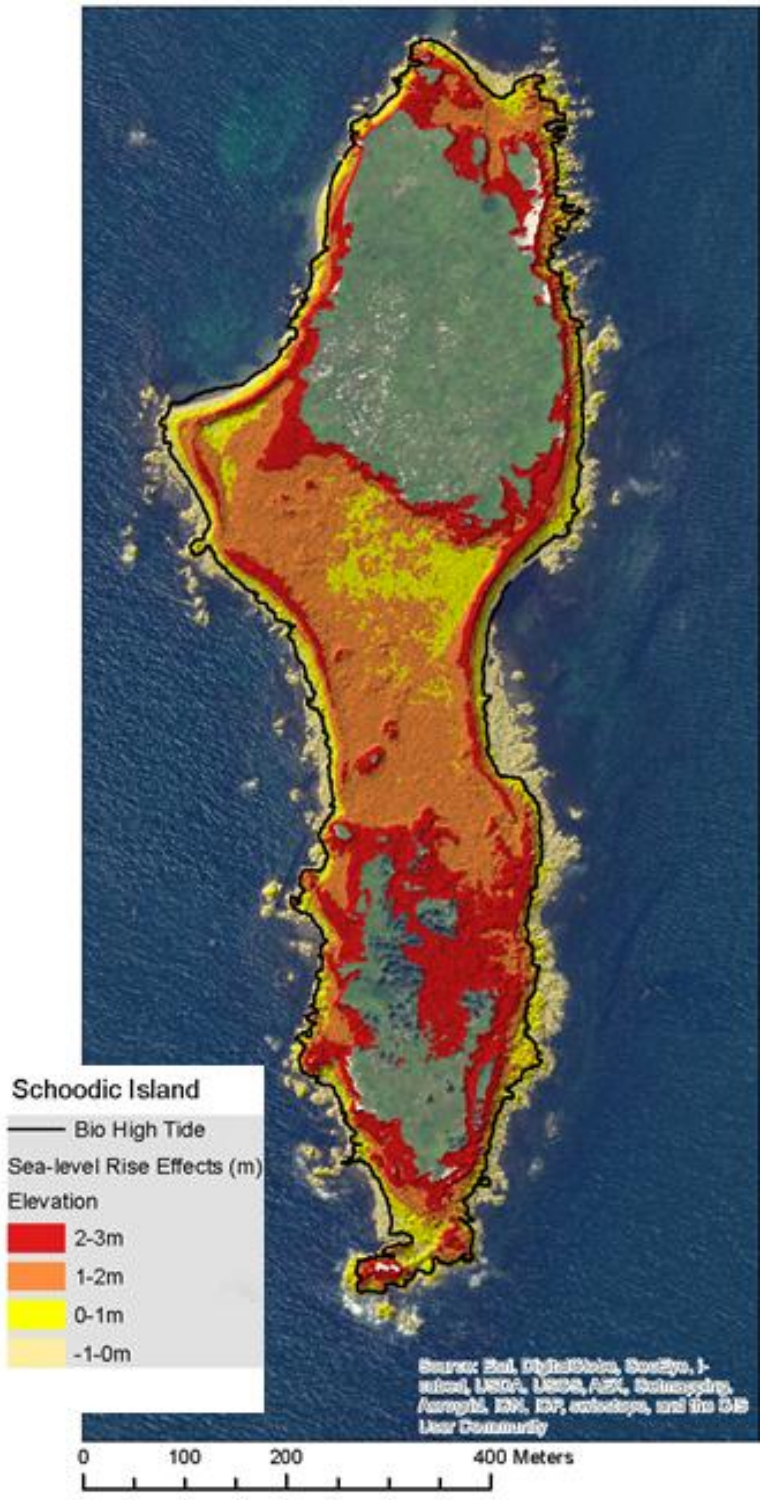

Figure 14. Flood simulations for Schoodic Island. Note that this is actually an optimistic assessment as it assumes no erosion of the mid-island cobble berms.

Flood modelling (Fig. 14) suggests that even moderate increases in sea level will reduce the integrity of Schoodic Island as a nesting area.

Because the island consists of two higher rocky outcroppings connected at present by cobble sea walls protecting a low-lying marshy core, even a slight increase in erosion and sea level is likely to split Schoodic into two roughly equal fragments. Schoodic is heavily exposed to weather from the south and southeast, and the combination of rising sea and increased storm frequency (whether or not storms come during the breeding season) is likely to eventually break the sea walls and flood prime eider habitat. Each of the remaining high segments is likely to contain suitable nesting habitats for gulls and cormorants, and some eiders are likely to continue to nest in the more vegetated areas of the uplands, but all current guillemot nesting habitat is likely to be flooded. Salt intrusion into the fragmented southern “islet” may kill the stand of spruce trees currently used for nesting by the island’s resident Bald Eagles. At the same time, vegetation die-back may open up habitat for Storm petrel nesting, although data from Great Duck suggest that petrels may prefer to nest along areas of spruce forest edge. Conflicting pressure (decreased understory and also loss of mature trees) may result in relatively little gain for the petrels.

Little Duck

Little Duck Island (44 10 23.7 N 68 14 40.5 W) is located 7.44 km South of Mount Desert Island. It is a park easement island, currently owned by the National Audubon Society. The island was protected starting at the end of the 19th century because of its significant populations of gulls, eiders, guillemots [xvi] and storm petrels. A plaque commemorating the island's status as a sanctuary may be found on the rocks along the Northeast portion of the island's coastline. A large Double-crested cormorant colony occupied spruce trees on the island's western side during the 1970's and 1980's. The last nesting cormorants were documented in 2011. Little Duck's relatively high contour (Fig. 15a-b), size (36ha), and structure as a rounded dome of rock renders it relatively impervious to significant impact from sea level rise, making it a Category 3 (least sensitive) island.

Figures 15. Little Duck Island shoreline, a) distant and b) close-up.

This level of resilience is supported by our flood models (Fig. 16) which show only limited impact on shorelines at even the most pessimistic level of sea level rise.

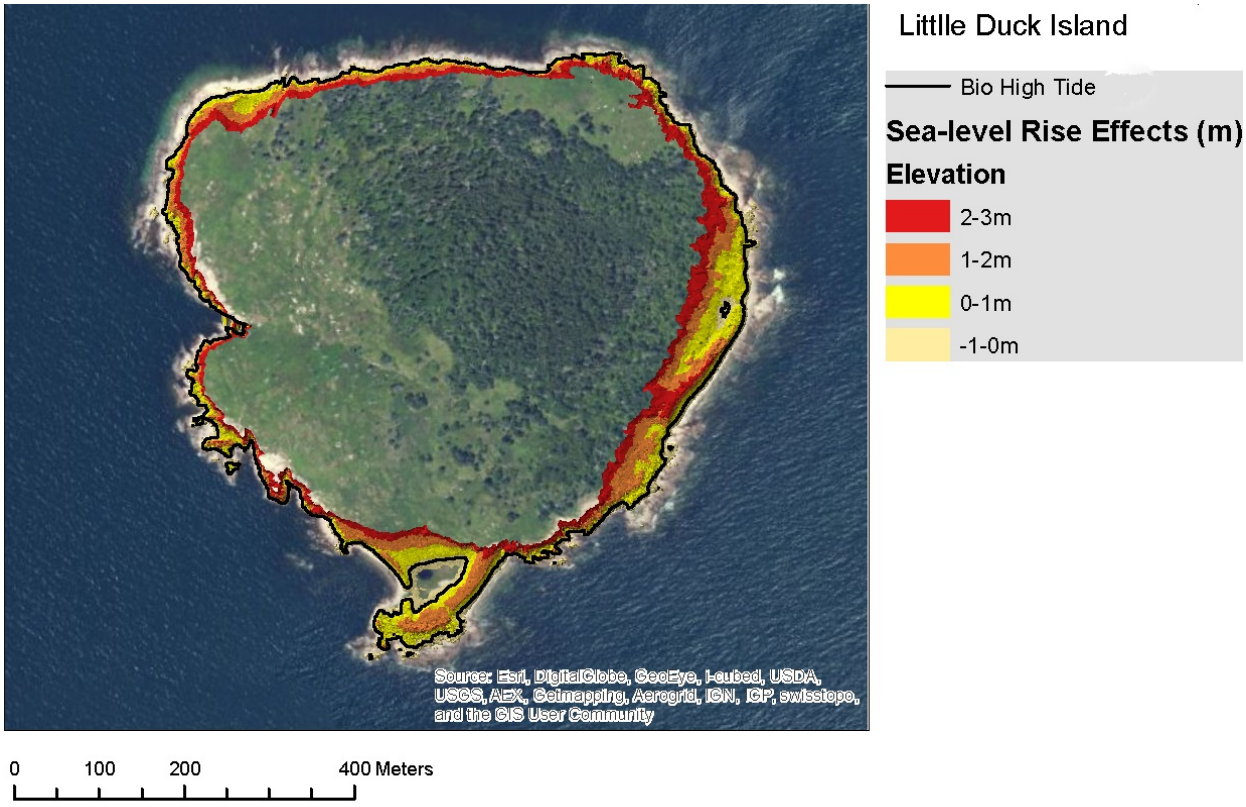

Figure 16. Projected impact of sea level rise on Little Duck Island.

Flooding effects would be most significant along the island's south and east shores, but negligible for much of the rest of the island. The primary significance of this would be to the island's Black Guillemot population, many of which are known to nest in rocky crevices along the northeastern shore. It seems likely however that so long as sea-level rise occurs relatively gradually additional habitat would be created in more upland areas. There is plenty of remaining habitat, even under the highest sea-level rise scenario, for other species to continue nesting. This is particularly important given Little Duck's status as a major Eider nesting colony.

Green, Drum, and Scrag Islands

Green (44 09 11.3 N, 68 20 58 W) located 7.5 km SW of Mount Desert Island, Drum (44 09 30.9 N, 68 19 52.45 W) located 6.96 km SW of Mount Desert Island, and Scrag (44 09 20.6 N, 68 20 26.35 W) located 7.2 km SW of Mount Desert Island, are sometimes referred to collectively as "the Green Ledges". The Park holds conservation easements on all three islands. Both Green and Scrag Islands have been listed as periodic nesting areas for seabirds - particularly gulls, eiders and cormorants - and both of these islands contain current nesting habitat for Black Guillemots. We saw guillemots emerging from crevices in the rocks during our census activities, but did not attempt a systematic survey.

All three islands are small, ranging from approx. 2.2 hectares (Green) to less than 0.35 hectares (Drum). As shown in Figures 17 a-c the islands are high-sided ledges, with vegetation on the upper ridges (Green and Scrag), or essentially naked rock (Drum).

Figure 17. a) Green Island, NW shore, b) Scrag Island from NW and c) Drum Island from NW.

We did not land on Drum Island because of the lack of a suitable landing place and the absence of any obvious seabirds. The island was listed in 1995 as having 2 guillemots present, although it seems unlikely that the birds were nesting. The island is probably already over-topped by waves in winter storms, and there appears to be little or any habitat available for seabirds other than loafing individuals. We consider it a Category 1 (most sensitive) island, but its status as a “nesting” island is questionable.

Scrag Island currently maintains a small colony of cormorants as well as nesting gulls, eiders, and guillemots. Although it tapers slowly to the east and west, the central portion of the island is greater

than 10m above the current biological high tide line [xvii], and it supports permanent vegetation along its upper ridge lines. We regard it as a category 2 island (moderately sensitive) as it is likely to lose guillemot nesting habitat under even limited sea level rise, and current seal haul-out and bird loafing ledges will be flooded. However, as mentioned above, the island's tapered shape suggests that additional habitat will be created as the sea advances.

Green Island is the largest of the three islands in this cluster, and while portions of the island reach at least 10m above current sea level, its long low shape (Fig. 18) suggests that it is likely to lose significant area in the foreseeable future.

In spite of this however, the island is large enough that it seems likely that nesting habitat will remain available in all but the most catastrophic flooding scenarios, leaving it in a Category 2 status.

Figure 18. Green Island N. Shore.

Heron Island

Heron Island (44 06 02 N, 68 28 24 W), located 4.5 km SW of Swan's Island, is the third most important "fee ownership" seabird island within Acadia National Park. It has traditionally supported large populations of nesting gulls and eiders, although as with other islands the seabird population has declined dramatically in recent years (Table 1). In 2012 we sighted 9 Bald Eagles on Heron and in 2013 we saw 5 immature eagles. In both cases the eagles were in areas that had supported nesting gulls. Heron is also unique in that it has a population of muskrat (*Ondatra zibethicus*) that was introduced during the mid-20th century.

Much of the island consists of a low marshy center surrounded by a high cobble sea-wall (Figs. 19 a-c). Another prominent feature of Heron Island is the large glacial erratic boulders (Fig. 19d) that dot the landscape within the island's core. In some cases these boulders support their own micro-flora, significantly different from the surrounding boggy landscape (Fig. 19e).

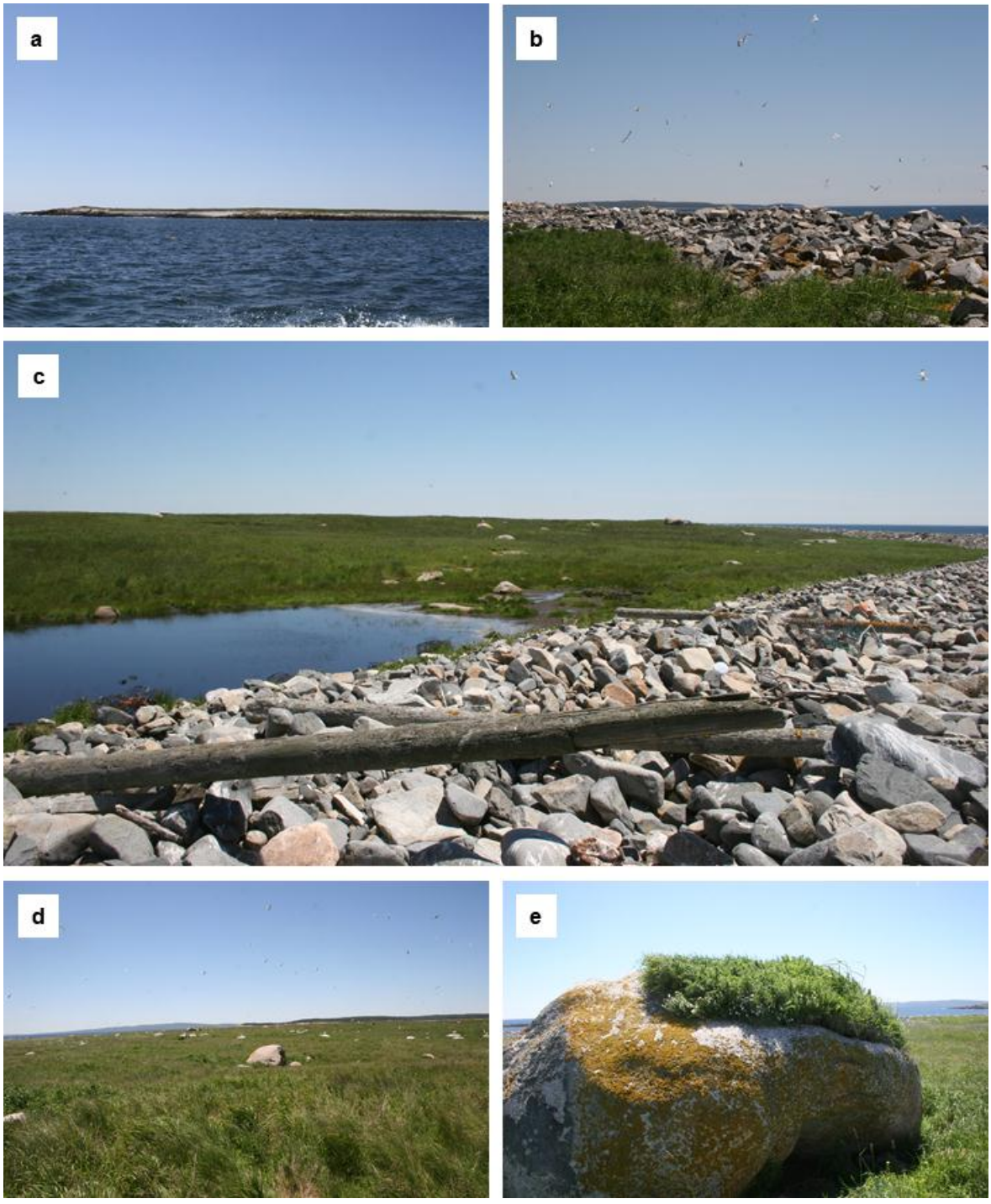

Figure 19. a) N. shore Heron Island, b) sea-wall, Heron Island, c) sea-wall on Heron Island (note flooded area behind the wall), d) glacial erratics within central area of Heron Island, and e) detail of glacial erratic, Heron Island.

Models of likely flooding scenarios (Fig. 20) suggest that Heron is a Category 2 island –moderately susceptible to sea level rise.

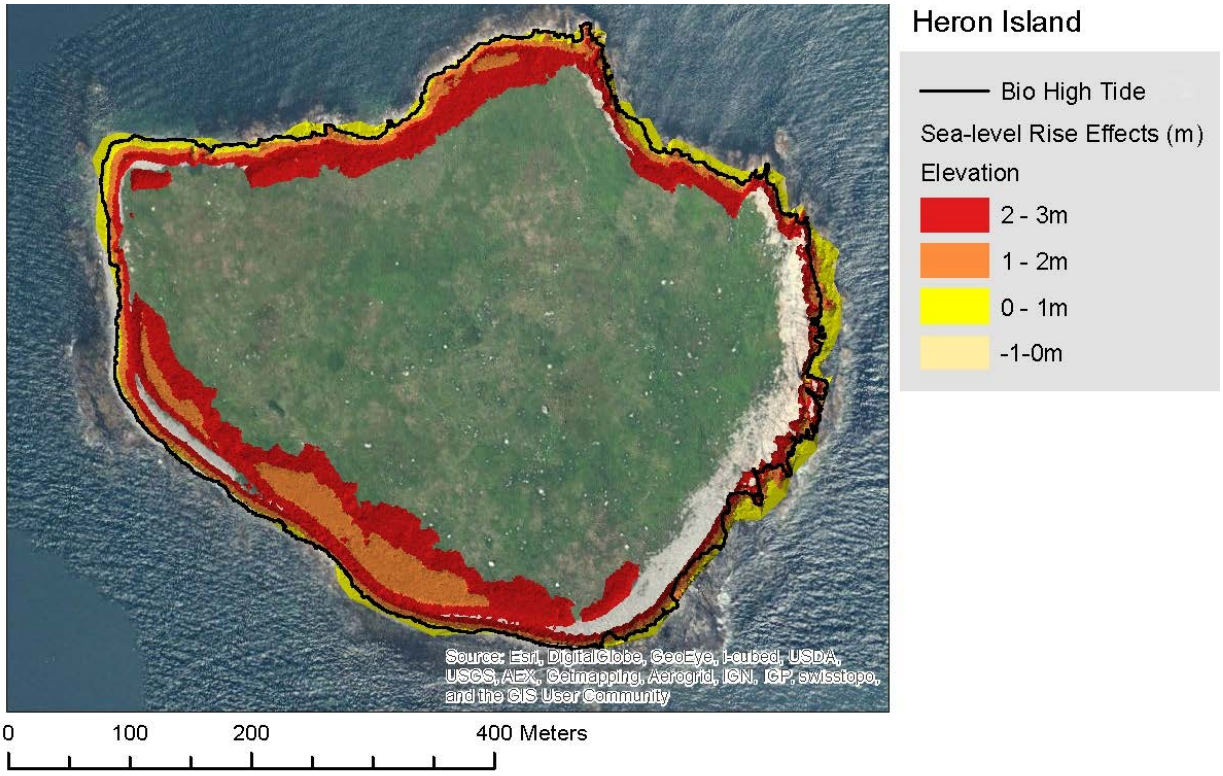

Figure 20. Flood models for Heron Island.

The island's size (approx. 21.0 ha) and elevation ensure that at least some nesting habitat will remain, even under the highest sea-level rise scenario, however we feel that this estimation may be overly optimistic for the following reasons: 1) the central portion of the island is currently protected by medium sized cobble sea-walls that are likely to be breached by large storms (there is already some evidence of over-topping in places); this sea-wall currently provides most of the available nesting habitat for gulls. 2) Guillemot nesting areas in portions of the sea-wall made up of larger stone slabs are likely to be impacted early and by even relatively minor increases in sea-level. Because of the overall construction of the island, there is no suitable additional habitat to which birds can retreat. 3) The center of the island is already largely swampy, with numerous channels excavated by the resident muskrats. While there are still sufficient drier areas to permit nesting by eider ducks, as water intrusion increases, these areas may flood more rapidly than would be expected in rockier terrain. Vegetation structure is likely to be affected as the swampy areas become more brackish, and this may further reduce available eider nesting habitat.

Great Spoon Island

Great Spoon (44 02 31.5 N, 68 33 26.6 W), located 3.36 km E of Isle au Haut, is a park easement island, and at approx. 29m maximum elevation [xviii], is the highest island in our study (Fig. 21a).

In spite of this comfortable elevation, taken on the island's Northwestern peak, we rate Great Spoon a Category 2 island (moderately susceptible to flooding). At present, the island consists of three distinct "units" –a vegetated upland, well beyond the reach of even catastrophic flooding, and presently occupied by a few nesting gulls; a marshy lowland, protected by a high cobble sea-wall to the North (Fig. 21b, see also background of Fig. 3), at or at most slightly above the present biological high tide line, that is used by nesting eiders; and a low rocky spit (Fig. 22a and b), that extends to the Northeast. This latter portion of the island forms the "handle" to the eponymous "spoon" and is only connected to the rest of the island at low tide. This region provides nesting habitat to most of the island's remaining population of gulls as well as a transitory nesting colony of terns.

Figure 21. a) Great Spoon from north, showing highest elevation and a portion of the cobble berm (left), and b) cobble berm on northern side of Great Spoon (note adult Bald Eagle perched immediately to the right of the driftwood pile).

Figure 22. a) Northeastern spit on Great Spoon, from the island peak (note seawall and partially flooded marshy area in foreground), and b) south face of Great Spoon sea-wall (note storm-line half way down).

Great Spoon was a major nesting colony for both Herring and Great Black-backed gulls as recently as 2008, with over 300 nests of each species reported present. In addition, the island was known to provide nesting habitat for over 400 Eider ducks, Black guillemots, and was periodically colonized by small groups of Arctic and Common terns (*Sterna paradisaea* and *S. hirundo*). As with other islands in this survey, seabird populations have declined significantly in recent years. Three to five Bald eagles were seen on the island in 2012 and 2013.

Our flood models (Fig. 23) suggest that in the event of even minor increases in sea-level, much of the marshy wetland area will be completely flooded, eliminating prime eider nesting habitat. This process will be accelerated and enhanced if the cobble sea-wall is breached by an increase in storm intensity. It seems likely however that, given the overall size (approx. 20 ha) and slope of the island, at least some new habitat is likely to develop ahead of the rising sea. The bulk of the main island will remain intact in even the most severe projections of sea level rise, with little change to the island's southern shores, whose high cliffs and rock crevices provide nesting sites for Black guillemots and a few remaining gulls.

The greatest obvious impact will be to the northern "spoon handle" which seems likely to be broken up into a series of much smaller ledges, some of which are likely to be over-topped by moon tides and/or summer storms. Because this area is currently the region most heavily occupied by gulls, and the only region in which terns have been seen nesting, it is of particular concern.

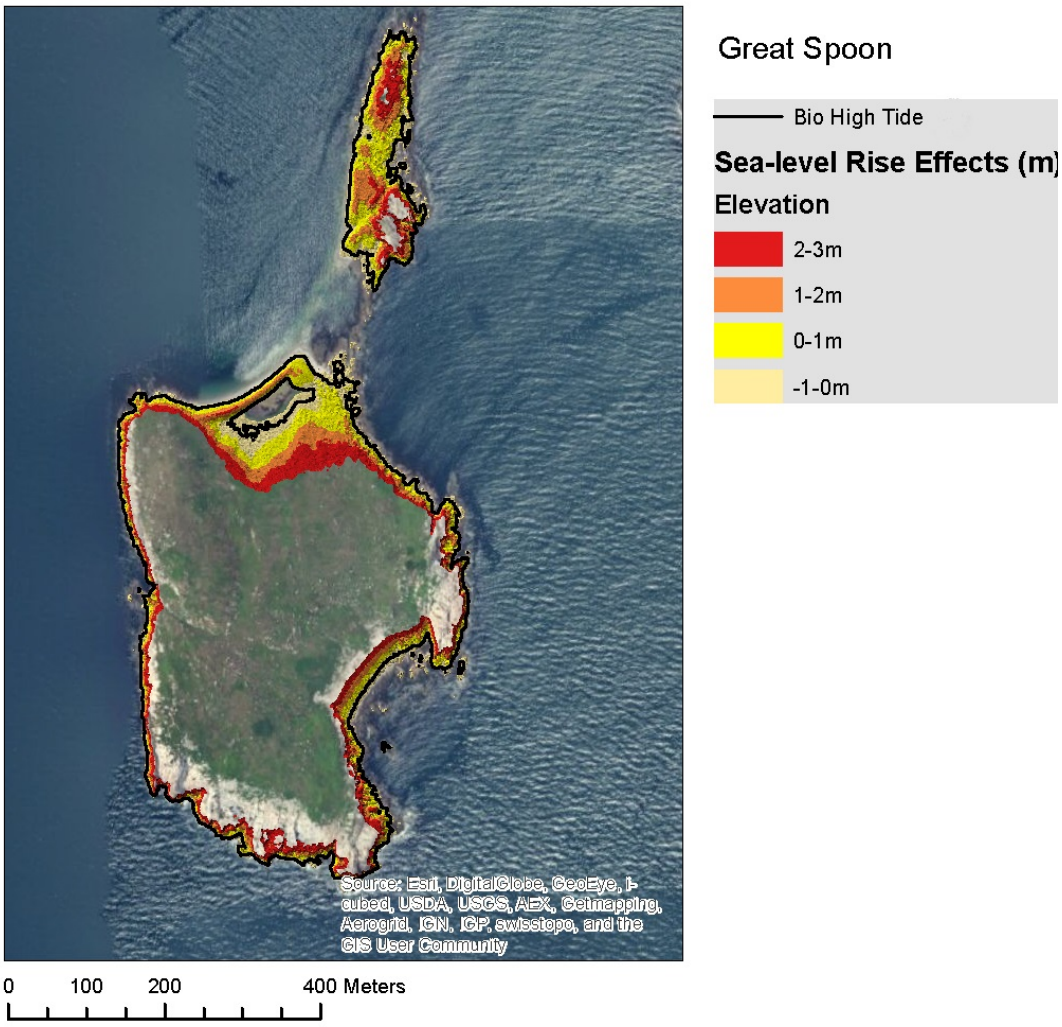

Figure 23. Flood models for Great Spoon Island. Note that the northern "handle" is currently connected to the main island only at low tide.

Little Spoon

Little Spoon (44 02 18.33 N, 68 34 16.34 W), located 2.45 km E of Isle au Haut, is a park easement island and a significant nesting area for gulls, eiders, and guillemots. The island's relatively high sides (Fig 24a), rocky composition, and overall area (approx. 9 ha) cause us to place it into category 3 (least sensitive) in regards to concern over the effects of sea-level rise. Gulls and eiders were found nesting over much of the island, while guillemot nests were common in the rocky areas at the eastern end of the island (Fig. 24b).

Figure 24. a) Northwestern end of Little Spoon Island (note high sides, basalt/granite composition, and tapering of island's extremities), and b) close-up of northeastern shoreline of Little Spoon Island. Gulls, including both Herring and Great Black-backs were found nesting in short vegetation along the ridge line, whereas Black guillemots nested in rocky crevices, particularly in the eastern end.

Our flood models (Fig. 5c) reinforce the notion that Little Spoon is relatively safe from the effects of sea level rise at this time.

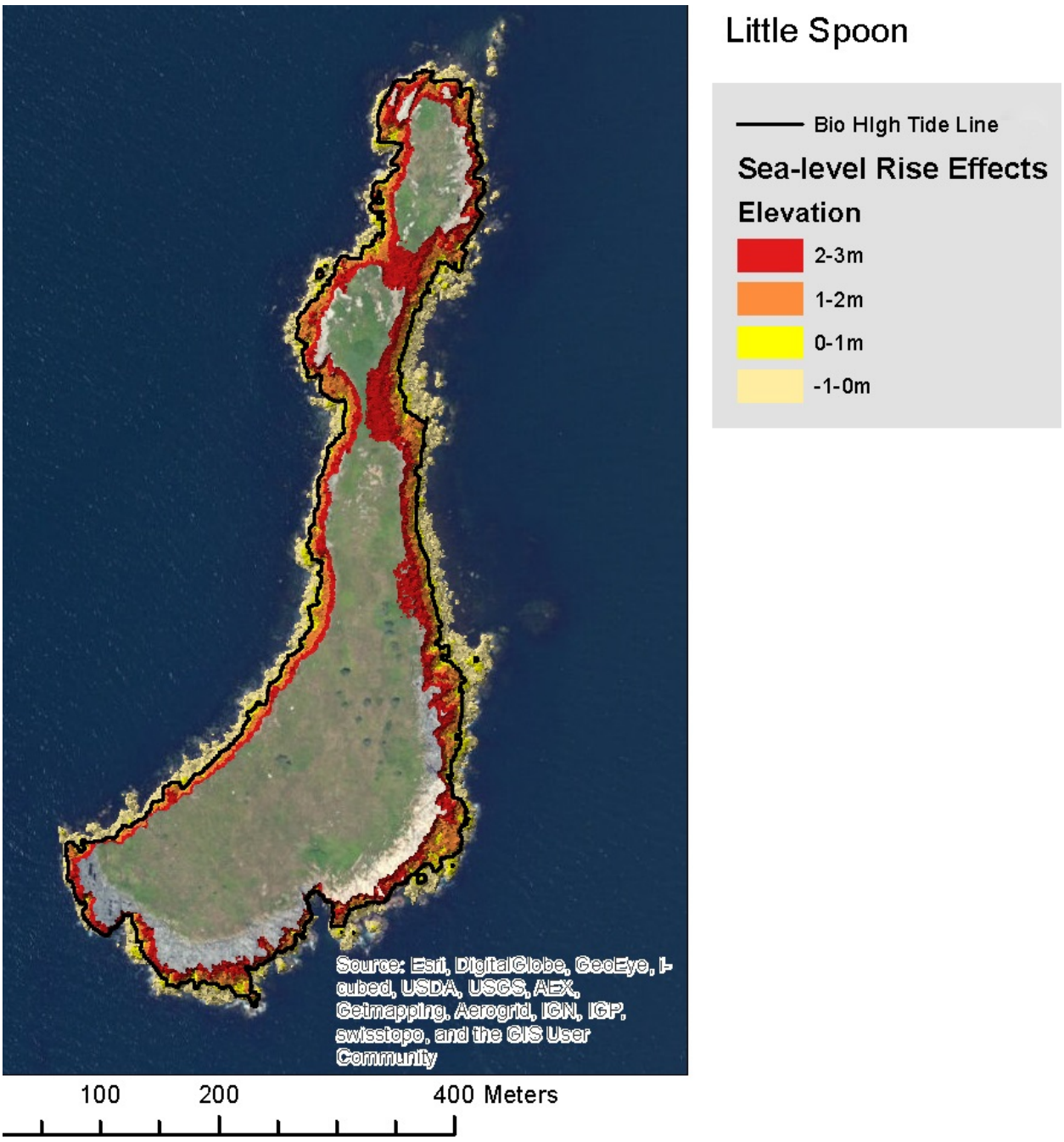

Figure 25. Flood models for Little Spoon Island.

Even under a worse-case scenario, significant portions of the island will remain, although the northern end may be split into one or two separate ledges. As with other islands, guillemot habitat is likely to be most heavily impacted, although there is sufficient interior relief to the island to allow the possibility of new nesting areas developing as the sea advances.

White Horse and Black Horse

White Horse (44 01 53.3 N, 68 34 07.7 W) located 2.95 km E of Isle au Haut (Fig 26a), and Black Horse (44 01 37.4 N, 68 34 32.07 W) located 2.62 km E of Isle au Haut (Fig 26b), are both easement islands. While both have occasional records of nesting seabirds, neither can be regarded as particularly significant at this time.

Figure 26. a) White Horse Island, and b) Black Horse Island.

Both islands are small (0.28 ha for White Horse; 0.55 ha for Black Horse), are relatively high sided and consist of consolidated rock. As such they are relatively resistant to erosion. Flood models (Fig. 27) suggest that even drastic sea level rise will not cover much additional area on Black Horse, though the island's long, thin shape and exposed location more-or-less ensures that there will be an increase in spray, which may make what limited habitat exists untenable in future. In any case, neither island has substantial populations of nesting seabirds. We list both islands as Category 1 (most sensitive to sea-level rise).

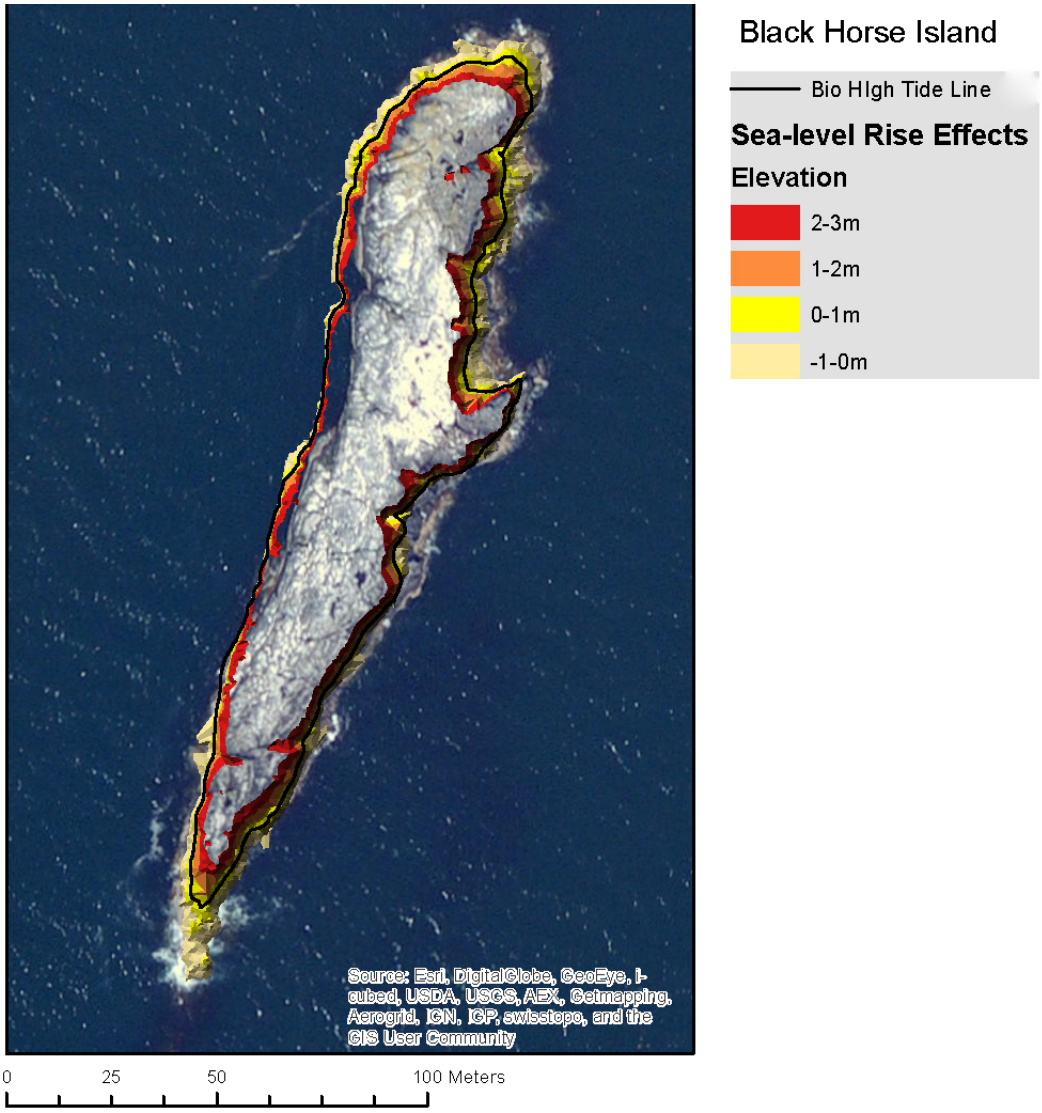

Figure 27. Flood models of Black Horse Island.

Shabby Island

Shabby Island (44 10 00.88 N, 68 33 31.45 W), located 4.7 km W of Swan's Island, is a park easement island containing populations of gulls, guillemots, cormorants and eiders. The island is small (1.45ha) but with relatively high-sided, sloping shorelines (Fig. 28a) consisting of consolidated ledge (Fig 28b). As such we rate it a Category 2 island (moderately impacted). Gulls were nesting in

all parts of the island in 2013, including on the sandy shoreline within 2m of the biological high tide line. Cormorants were restricted to the rocky point at the islands southwest end. We noted with some concern that although when we circled the island for our initial count the cormorants appeared to be "sitting tight" as if incubating eggs or young chicks, when we actually examined the nests they contained neither eggs nor chicks. There was no obvious sign of predation other than a single broken egg-shell, but we found one predated adult cormorant a little distance from the nest site. An immature Bald eagle was roosting on the northern ledge when we approached and circled the island while we counted seabirds. We located 8 active Eider nests on the island, a marked decline from previous estimates. We also recorded Black guillemots in the water around the island but made no effort to make a formal count for fear of further disturbing the other species present.

Figure 28. a) Shabby Island from the East, and b) Shabby Island close-up of shoreline.

Flood modelling (Figure 29) supports our general classification of Shabby Island's level of vulnerability. Low to moderate increases in sea-level will reduce the island's total area, but even in our most catastrophic scenario, significant nesting area remains.

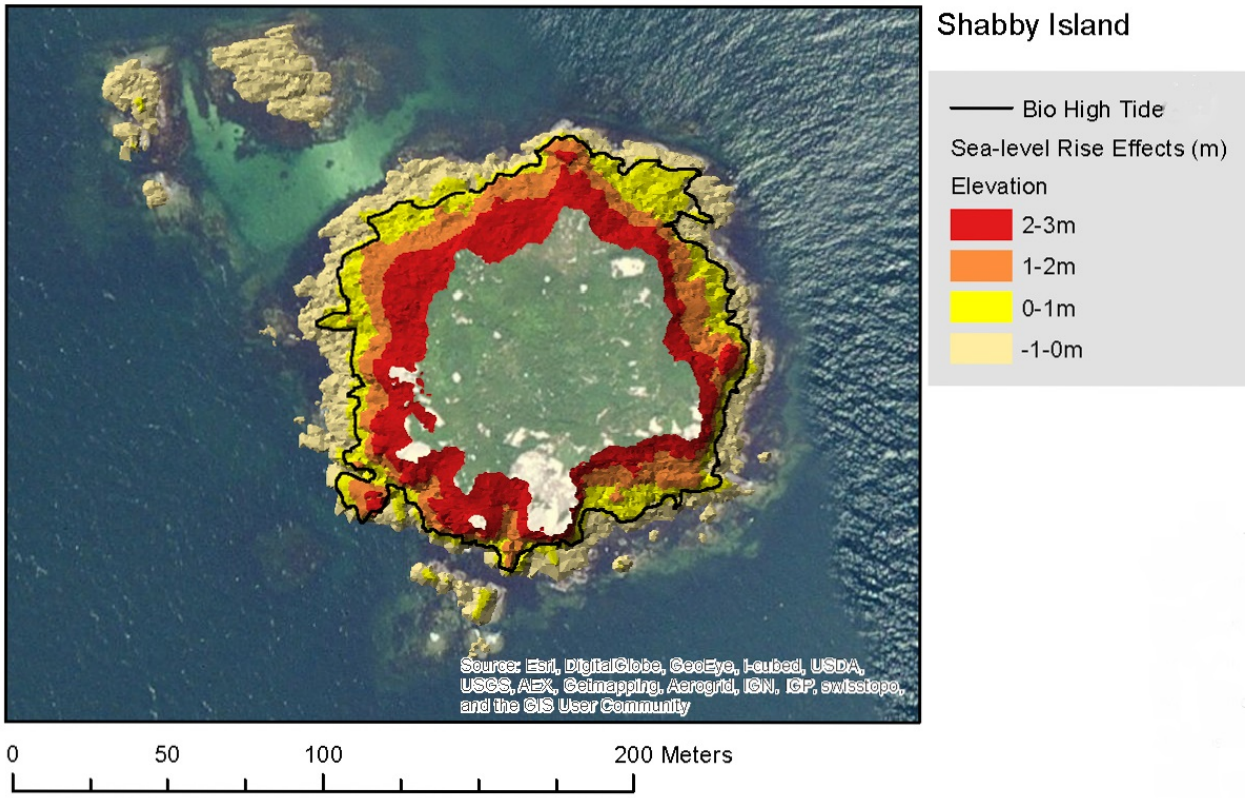

Figure 29. Flood models of Shabby Island. Ledges to northwest are already largely submerged at extreme high tide.

Conclusions

While the majority of Acadia National Park's island properties and easements do not support nesting seabirds at this time, the park owns in fee, or has an interest in, several historically important nesting colonies. All of these islands are likely to undergo some degree of change in the next century as the climate changes and sea level continues to rise. At the same time, other more immediate forces are already having an enormous impact on nesting seabird populations, both within the park and throughout much of the coastal North Atlantic. Regionally, the recovery of Bald Eagles seems to be playing a major role in reducing the number of nesting gulls, cormorants, and eiders in the Gulf of Maine. We were struck by the large numbers of eagles that we saw in close association with every island that we surveyed over the past three years. Eagles prey on both chicks and adults, and also disrupt entire colonies, making nests more vulnerable to corvids and other smaller predators. We urge the Park Service to engage in regular monitoring programs on park islands to assess the long-term effects of the loss of seabirds on both regional populations and local vegetation. In addition, we were concerned by the lack of adequate signage on many islands. The steadily increasing sea-kayak traffic in coastal waters is likely to have an ever greater impact on nesting birds as kayakers take advantage of recreational opportunities and land on sensitive islands. It would be advisable to post all nesting islands with large signs readable from the water indicating that the island is closed from May through August.

In terms of response to sea level rise, it is hard to imagine mitigation strategies that would be either cost-effective or in keeping with current park management principles. Construction of sea-walls, armoring cobble berms or back-filling low-lying areas on islands would be enormously disruptive in every case, and would be prohibitively expensive. In addition it is unclear whether it would have the desired results in terms of maintaining seabird populations, and it is doubtful whether such action would produce measureable results given other changes occurring in the surroundings.

Management responses to sea-level rise and changes in seabird populations and nesting sites include several potential strategies. Here, we explore three strategies: First of all, educating the general public as to the effects of climate change and sea level rise is a vital strategy. This can be done at multiple levels: additional curricula can be prepared for High School and K-8 classroom presentation on the relationships between seabirds, islands, and climate change and the role of the NPS in safeguarding this resource; informational brochures and posters can be developed and made available to Park visitors emphasizing the broader role of Acadia in resource conservation that goes beyond the Mt Desert island core areas of the Park; and finally Ranger-lead "campfire talks" at campgrounds and the Visitor Center can incorporate information on the Park's role in seabird conservation and management.

Second, regular and frequent (minimum every three years) of existing nesting colonies can provide managers with information on long-term trends. This can be done either independently or in collaboration with other State and Federal agencies. Because Acadia has relatively few seabird islands, a regular survey, once established, could be done relatively cheaply and would provide a valuable baseline for measuring change. Ideally, such a survey would include both censuses of

nesting seabirds and also regularly updated geo-referenced photographs that would permit long-term comparisons of shoreline and habitat conditions. A single person should be designated to oversee survey methodology and regular up-dating of databases.

Finally, the National Park Service might consider assessing current non-Park islands for acquisition as future seabird colonies, perhaps in partnership with other Federal, State, or private organizations. The NPS' strategies of resource protection and monitoring could be a valuable addition to work done by other organizations, and could serve as an important "low intervention control" from the more active management schemes imposed by other agencies. Ideally, new islands would be steep sided, with significant consolidated ledge material so as to avoid erosion, they should be at least 0.5 ha in size, and should be located far enough from major land-masses so as to reduce the likelihood of the immigration of terrestrial predators.

While in the end we are faced with the problem of King Canute –the water will rise no matter what we say - we have the opportunity to learn a great deal in the process of watching this long tide come in. It is my hope that this report is but the first step in that learning process.

Literature Cited

[i] Drury, W. H. 1973. Population changes in New England seabirds. *Bird-banding* 40:267-313. See also: Erwin, R. M., and C. E. Korschgen. 1979. Coastal waterbird colonies: Maine to Virginia, 1977. An atlas showing colony locations and species composition. U.S. Fish and Wildlife Service, Biological Services Program, FWS/OBS-79/08.

[ii] http://netapp.audubon.org/iba (accessed 1September 2015)

[iii] Kelley, J. D. F. Belknap, G. L. Jacobson Jr. and H. A. Jacobson.1988. The morphology and origin of salt marshes along the glaciated coastline of Maine, USA. *Journal of Coastal Research* 4:649-666. See also: Donnelly, J. 2006. A Revised Late Holocene Sea-Level Record for Northern Massachusetts, USA. *Journal of Coastal Research* 22:1051-1061 for discussion of regional changes.

[iv] Spiess, A. and R. Lewis. 2001. The Turner Farm fauna: 5000 years of hunting and fishing in Penobscot Bay, Maine. Maine Archaeological Society, Augusta, ME.

[v] Drury, W. H. 1973. Population changes in New England Seabirds. *Bird banding* 44:267-313.

[vi] Parris, A., P. Bromirski, V. Burkett, D. Cayan, M. Culver, J. Hall, R. Horton, K. Knuuti, R. Moss, J. Obeysekera, A. Sallenger, and J. Weiss. 2012. Global Sea Level Rise Scenarios for the US National Climate Assessment. NOAA Tech Memo OAR CPO-1.

[vii] Anonymous 2010. Advancing the science of climate change. America's climate choices. National Research Council. National Academy of Sciences Press. Washington, D.C.

[viii] http://www.pivot.net/~cotterly/hurricane.PDF (accessed 1 September 2015). According to this report, between 1635 and 1996, Maine has been impacted by 45 major tropical storms. Of these 28 have occurred later than Aug 23, well outside the breeding season of most seabirds.

[ix] Grinstad, A. J. Moore, and S. Jevrejeva. 2013. Projected Atlantic hurricane surge threat from rising temperatures. PNAS 110:5369-5373

[x] Erwin, R. M. and C. E. Korschgen 1979. Coastal waterbird colonies: Maine to Virginia, 1977. USFWS Biological Services Program FWS/OBS-79/08

[xi] Anonymous 2010. Maine 2008 coastwise census for gulls and cormorants. Data summarized by Maine Coastal Islands National Wildlife Refuge. U.S. Fish and Wildlife Service, Millbridge, ME.

[xii] Allen, B. G. Mittelhauser, L. Welch, R. Houston, R.Schauffler, and M. Langois. 2012. Maine atlas of breeding seabird and coastal wading bird colonies: 1960-2011. Maine Natural History observatory Gouldsboro, ME.

[xiii] Todd, C,. and G. Matula. 2008. Delisting the bald eagle in Maine: An amazing success story. ME Dept. Inland Fisheries and Wildlife. Available at http://www.maine.gov/ifw/docs/BAEA_Delisting.pdf (accessed 1 September 2015).

[xiv] Bourget, A. 1973. Relation of eiders and gulls nesting in mixed colonies in Penobscot Bay, Maine. *Auk* 90:809-820. See also: Gotmark, F. 1989. Costs and benefits to eiders nesting in gull colonies: A field experiment. *Ornis Scandinavica* 20:283-288

[xv] Gross, A. 1945. The present status of the great black-backed gull in Maine. *Auk* 62:241-256.

[xvi] See for instance Birds of North America No. 675. Ronald G. Butler and Daniel E. Buckley. 2002. Black Guillemot, *Cepphus grylle.* (Charadriiformes : Alcidae). 32 pp. A.O.U. CHECK-LIST p. 211.1

[xvii] http://www.ngs.noaa.gov/cgi-bin/ds_desig.prl (accessed 1 September 2015)

[xviii] http://www.ngs.noaa.gov/cgi-bin/ds_desig.prl (accessed 1 September 2015)

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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