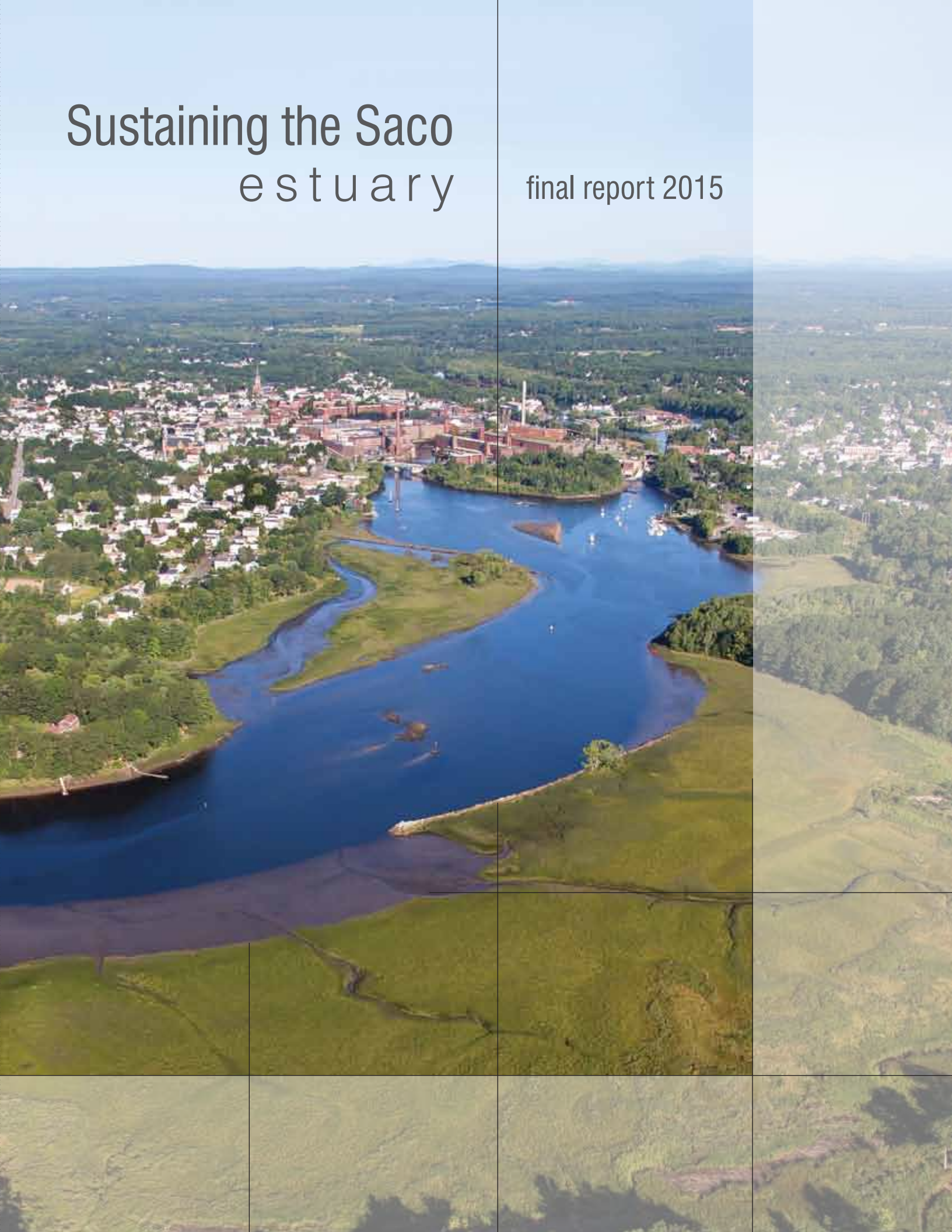
Sustaining the Saco estuary

final report 2015



Sustaining the Saco estuary

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Project Leaders

Christine B. Feurt, Ph.D.
University of New England and
Wells National Estuarine Research Reserve
Tel: (207) 602-2834
Email: cfeurt@une.edu

Pamela A. Morgan, Ph.D.
University of New England
Tel: (207) 602-2227
Email: pmorgan@une.edu

Project Team

University of New England

Mark Adams, Ph.D.
Anna Bass, Ph.D.
Carrie Byron, Ph.D.
Michael Daley, Ph.D.
Michael Esty
Noah Perlut, Ph.D.
Michele Steen-Adams, Ph.D.
James Sulikowski, Ph.D.
Stephan I. Zeeman, Ph.D.

Wells National Estuarine Research Reserve

Jacob Aman
Michele Dionne, Ph.D.
Jeremy Miller
Kristin Wilson, Ph.D.

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CHAPTER 8

LAND USE AND LAND COVER ALONG THE SACO ESTUARY'S SHORELINE

BY MARK ADAMS

INTRODUCTION

It is important to consider land use and land cover along the river shoreline when trying to determine the health of the Saco estuary, as they influence many characteristics of estuary functioning. The condition of the shoreline adjacent to the tidal marshes is a major factor in determining the use of the marshes for cover or foraging by animals such as deer, birds, and fish. Land cover also potentially influences the distribution and abundance of plant species in the marshes, contributes to the cycling of nutrients and pollutants through the local marsh ecosystem, and influences the amount of freshwater runoff that enters the estuary's marshes and the river itself. Of course, these functions can also be affected by other factors, such as the land use and cover throughout the entire watershed and the ocean currents and tides, but we chose to focus on the lands immediately adjacent to the estuary's edge given their proximity and potential influence on the estuary ecosystem.

Focusing on the shoreline along the river allowed us to develop highly detailed maps of the upland habitats immediately adjacent to the 16 study sites in the tidal marshes in the estuary. We created two sets of maps calculating the types and extents of land cover within roughly 0.25 mile of the center of the estuary channel. The first set of maps depicts land cover in 2009, roughly concurrent with the collection of other biodiversity data in the estuary, which took place in 2010-2013. The second set depicts land cover in 1984 for comparative purposes. To compare the marshes to each other and to other types of field data collected within them, we designated a buffer area extending 100 m beyond the study sites. The findings presented here focus on land cover data from strictly within these buffer areas.

STUDY OBJECTIVES—LAND USE AND LAND COVER

Our objectives for the land use and land cover study were to answer these questions:

1. Can land cover indicators be developed for monitoring the health of the Saco estuary?
2. Were there historical changes in land cover indicators between 1984 and 2009?

RESEARCH DESIGN AND METHODS

Mapping land cover near the Saco Estuary

Because we were interested in studying the possible effects of shoreline development along the Saco River on the estuary's tidal marshes, we chose to make detailed land cover maps of the upland immediately bordering the estuary. We used a set of aerial photographs taken in fall 2009, close to the time when the UNE project team studied the plant and animal species in the tidal marshes.

Our maps of land cover follow the 2006 classification scheme of the National Land Cover Dataset (Figure 1), with a few modifications:

- Barren (#31) is divided into three subclasses: (a) sand, (b) mudflat, and (c) all other barren (mostly rock outcrops). The ecological role of mudflats in the estuary is significant, and we concluded they should be classified separately.
- While we have retained the woody (#90) versus herbaceous (#95) classifications, we only mapped marshes that are tidally influenced, ignoring those in the upland that are not part of the estuary.
- Grassland (#71) is not used for the mown fields in the estuary. Grassland here refers to native, unmaintained grass vegetation; the only examples of such a cover class in the estuary are the small expanses of dune grass behind Hills Beach and Ferry Beach. We chose to classify fields as agriculture-grass (equivalent to #81, pasture/hay), even though it is likely that many such fields are actually not commercial hay harvest operations.

Comparing land cover in 1984 to 2009

We wanted to learn more about the past land cover of the estuary. When researching the availability of historical aerial photographs of the southern Maine coast, we chose to use a set of photographs commissioned by the City of Saco in 1984. The date of the photographs is fairly close to the date of implementation of Maine's mandatory local shoreline zoning ordinance by the City of Saco. Originally passed by the Maine legislature in 1971, this law requires each town in the state to adopt a special category within its land zoning ordinance dealing with the shoreline of rivers,

FIGURE 1 Classification scheme of the National Land Cover Dataset.

ponds, lakes, and the ocean. While towns have some flexibility in determining precisely what land use types are allowed within the special shoreland zone, the law is intended to significantly limit development of new structures within 250 ft of the shoreline. By comparing the 1984 photographs to those from 2009, we can evaluate how much change has occurred within the shoreland zone during nearly the entire duration that the law has been in force in Saco.

When a photograph of the earth's surface is taken from above, only the point on the land surface that is directly perpendicular to the center of the camera lens is rendered in accurate proportion to the elevation above the earth's surface that the plane is flying. Every other point in the photographed scene is proportionally distorted because the earth's surface is curved. Before the points on a map can be accurately located, the distortion must be geometrically corrected through a process known as *orthorectification*. We orthorectified 42 of these 1984 photographs (loaned to the project by the City of Saco) to accurately map the land cover that existed in 1984.

Key land cover indicators for ecosystem health

How can land cover data provide clues to the health of an ecosystem such as the Saco estuary? We highlight three types of land cover information that can contribute to a better understanding of the estuary's health: total developed area, impervious surface area, and characteristics of vegetated, non-developed habitats.

Total developed area

The developed land cover classes encompass all areas of a landscape where people have substantially modified the original vegetation and/or topography. Examples include residential subdivisions, streets, a wastewater treatment plant, a commercial office district, recreational ball fields, and landscaped parks.

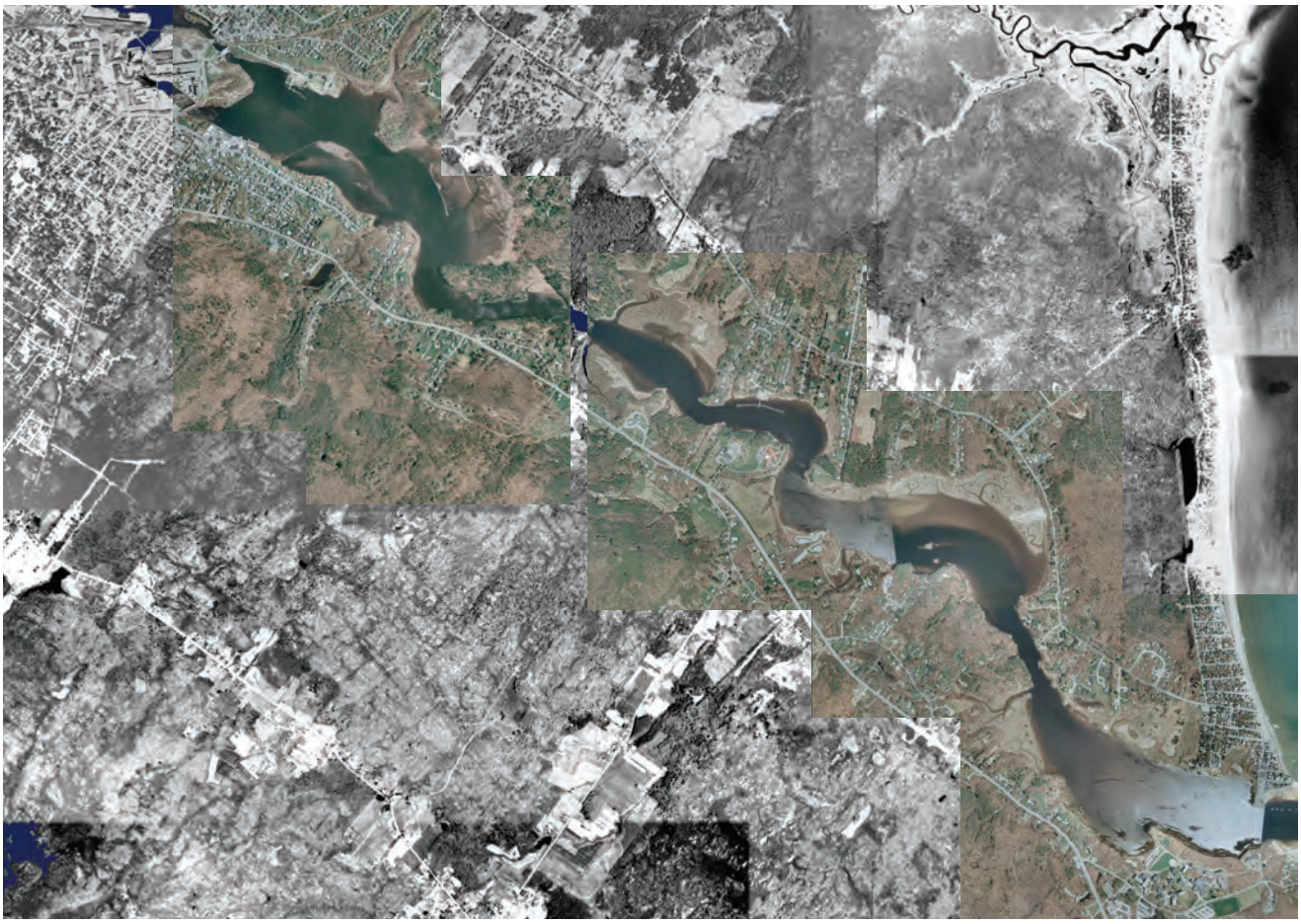
To calculate the area of each land cover type, we measured the size and proportion of the area within each marsh where the project team sampled for plant species and associated indicators, plus an additional area extending 100 m outward from the edge of the sampled area (Figure 2). We then calculated the proportion of each land cover type within the 100-m buffer areas, which includes the hatched sampled areas. Areas of open water extending beyond the mudflat were not included.

Which marshes could potentially be most impacted by development? Values in bold in the right-hand column of Table 1 show marshes where developed land covers comprise the majority of the upland land cover.

FIGURE 2 100-m buffer around tidal marsh study sites; 2009 land cover classification. The 100-m buffer (heavy yellow line) and tidal marsh sample sites (hatched yellow area) at sites S5 and N4. The lower image illustrates the mapping of land cover areas.

TABLE 1 Total developed area within 100 meters of the sixteen tidal marsh study sites.

Marsh site	Proportion of the area within 100 m of the tidal marsh study site that is developed
N2	18.9%
N3	5.9%
N4	19.2%
N1	**42.0%**
N8	16.5%
N10	**38.4%**
N9	**67.8%**
S1	**38.3%**
S5	19.9%
S4	20.9%
S8	**44.6%**
S6	25.7%
S7	9.2%
S9	9.6%
S10	**40.8%**
S11	25.4%



Impervious surface area

Impervious surface refers to a land surface where water cannot penetrate through, but must run off when rain falls or snow melts. *Developed* land cover includes four classes based on the percentage of impervious surface:

- Open Space: 20% or less of the surface area is impervious. Example: Very large, contiguous domestic lawns lacking any permanent structures.
- Low Intensity: 20-50% of the surface area is impervious. Example: Residential subdivisions on the north side of Ferry Road in Saco.
- Medium Intensity: 50-80% of the surface area is impervious. Examples: Some very large single-family residences with large footprints, associated structures, and driveways are in this class. Other high-density subdivisions, such as at Camp Ellis, are also extensive areas of medium-intensity development.
- High Intensity: 80% or more of the surface area is impervious. Examples: Principal streets and highways. Large institutional buildings and parking lots, such as at UNE and the St. Andre Center in Biddeford.

Table 2 illustrates the finding that at some sites, the majority of "developed" area is actually developed-open space, with little or no impervious surface area. However there *is* a significant amount of high-intensity development in the buffer area at a few sites, such as S10 in Biddeford. At S10, 1.2 ha are at least 80% impervious surface; this area includes buildings and parking lots on the UNE

TABLE 2 Intensity of developed area within 100 m of tidal marsh study sites. This table highlights five marshes, showing the four developed land cover classes defined by relative amounts of impervious surface.

Marsh site	Proportion of the area within 100m of the tidal marsh study site that is developed
N3	5.9%
Open Space	5.2%
Low Intensity	—
Medium Intensity	—
High Intensity	0.8%
N10	38.4%
Open Space	8.3%
Low Intensity	15.5%
Medium Intensity	12.7%
High Intensity	2.2%
S5	19.9%
Open Space	8.0%
Low Intensity	6.9%
Medium Intensity	0.7%
High Intensity	4.3%

Marsh site	Proportion of the area within 100m of the tidal marsh study site that is developed
S7	9.2%
Open Space	0
Low Intensity	4.2%
Medium Intensity	3.5%
High Intensity	1.6%
S10	40.8%
Open Space	24.3%
Low Intensity	0
Medium Intensity	1.6%
High Intensity	14.9%

FIGURE 3 Example of developed area with land cover classifications. These images are of the middle reach of Ferry Road in Saco. The white outlines represent parcel boundaries.

campus immediately adjacent to the tidal marsh. Table 3 presents the 13 marsh sites where the 100-m buffer was composed of roughly 20% or greater total developed area in 2009. The right-hand column shows in which of these marsh buffers development is predominantly (50% or more) impervious surface (developed-medium and developed-high classes).

TABLE 3 Relative intensity of development in marshes with at least ~20% developed area within the 100-m buffer.

Marsh site		Proportion of the area within 100m of the tidal marsh study site that is developed
N2	*Total developed*	18.9%
	> 50% impervious	**14.9%**
N4	*Total developed*	19.2%
	> 50% impervious	**1.7%**
N1	*Total developed*	42.0%
	> 50% impervious	**5.4%**
N8	*Total developed*	16.5%
	> 50% impervious	**5.7%**
N10	*Total developed*	38.0%
	> 50% impervious	**14.6%**
N9	*Total developed*	67.8%
	> 50% impervious	**52.3%**
S1	*Total developed*	38.3%
	> 50% impervious	**26.4%**
S5	*Total developed*	19.9%
	> 50% impervious	**5.0%**
S4	*Total developed*	20.9%
	> 50% impervious	**7.9%**
S8	*Total developed*	44.6%
	> 50% impervious	**22.3%**
S6	*Total developed*	25.7%
	> 50% impervious	**17.8%**
S10	*Total developed*	40.8%
	> 50% impervious	**16.5%**
S11	*Total developed*	25.4%
	> 50% impervious	**15.3%**

The data shown in Table 3 allow researchers to begin to group the 16 marshes of the Saco estuary in terms of the degree to which the ecological systems of each are likely to be negatively impacted by moderately (medium) or very (high) intense development. The ranking of likely impact to ecological communities from adjacent upland development is shown in Table 4. At site N9, adjacent to Camp Ellis pier, more than half of the 100-m buffer is covered by 50% or more impervious

TABLE 4 Summary of likely impact of impervious surfaces in medium- and high-intensity development areas on marsh ecosystems in the Saco estuary.

Marsh Sites	Probability that ecological communities are impacted by development	Total developed area (Table 1)	Total area that is >50% impervious surface (Table 3)	Types of impacts
N9	Very high	> 45%	> 30%	• No upland habitat associated with marsh except for human-adapted foraging species (e.g., gulls) • Large discharges of pollutants from impervious surfaces (most developed area is parking lots and structures)
S11, S10, S6, S8, S1, N2	High	20 – 45%	15 – 30%	• Limited or no upland habitat, except for human-adapted foraging species • Large discharges of pollutants from impervious surfaces (significant developed area is parking lots and structures)
N10	Moderate to High	20 – 45%	15 – 30%	• Limited upland habitat, highly modified (e.g., a single row of trees separating a lawn from the river's edge) • Moderate discharges of pollutants from impervious surfaces • Some nutrient pollution delivered by stormwater runoff from developed but permeable land covers (e.g., lawns)
N4, N1, N8, S5, S4	Moderate	10 – 20%	5 – 15%	• Some upland habitat, but favoring edge species; habitat utilization potentially affected by domestic pets and lawn maintenance • Small discharges of pollutants from impervious surfaces • Some nutrient pollution delivered by stormwater runoff from permeable human-modified land covers (e.g., lawns)
S7, S9	Low	0 – 10%	0 – 5%	• Significant upland habitat with small pockets of developed area • Limited or no pollutant discharge from impervious surfaces • Minimal nutrient pollution delivered by runoff from permeable human-modified land covers
N3	Very low	0 – 10%	0%	• Significant upland habitat (also significant modified habitat preferred by edge species) • No runoff from impervious surfaces • Minimal or no nutrient pollution delivered by runoff

surface. A second group includes sites S11, S10, S6, S8, N2, and S1. For each of these, except for S1, the developed area comprises a combination of a few very large structures and an associated parking lot (i.e., the UNE campus, the Biddeford public boat launch, St. Joseph's Convent, and the Saco wastewater treatment plant, respectively). S1 is adjacent to an inner-Biddeford neighborhood that has been built out for at least a century. A third group, composed of sites N4, N8, N1, S5, and S4, includes marshes adjacent to residential subdivisions where most of the human-modified area is classified as developed-open space or developed-low intensity. Sites S9 and S7, which are not in Table 4, are bordered by just a few residences on large and only partially modified parcels, and the amount of medium- or high-intensity development is limited to the streets that access the properties. Sites N3 and N10 are special cases. For N3, the only adjacent developed area is the lawn of Laurel Hill Cemetery. N10 is the only one of the 16 marshes where significant amounts of land within the buffer are developed for single-family residences, and the residential area also includes significant amounts of medium-intensity area.

Non-developed cover classes

The converse of developed land cover is *natural* land cover, i.e., vegetation that is substantially unmodified by humans. In the Saco estuary in 2009, there were only two types of natural upland land cover: forest and shrub-herb. Mapping the size and extent of non-modified land covers should provide insight into species abundance and diversity at each marsh site. Many species need habitat for foraging or nesting that is as far from an edge as possible. This characteristic can be described using a simple perimeter-to-area (PA) ratio. If the PA ratio is small (e.g., < 0.05), then the shape is compact and its center is roughly equidistant from all the edges of the patch; this is the best configuration for species that need to forage or nest as far from edges as possible. A large PA ratio (e.g., > 0.2) indicates that there is a great deal more perimeter length relative to total area in the patch. The patch is linear in shape, which reduces the distance from an edge to the interior; such patches are less likely to be used by species that need interior habitat. We compared each of the 16 sites for area of forest and shrub habitat as well as for the average of the PA ratios of each patch of forest and shrub within the buffer (Table 5).

Limiting the observations to the 2009 land cover dataset, Table 6 ranks the sites according to their total developed area, intensity of development within developed areas, and extent and configuration of non-modified upland land cover types.

RESULTS AND DISCUSSION

2009 Land Cover Data

Land cover alone does not directly equate to ecosystem health in the estuary system. Rather, the land cover maps and data can guide land managers who may wish to use land use policy tools to favor certain kinds of land covers. The study also provides a baseline dataset on land cover that can assist scientists in

further study of the relationships between upland land cover and their observations of plant, bird, invertebrate, and fish species and other ecosystem functions in the Saco estuary. The relative placement of each site's upland land cover characteristics on a scale of 1 to 7 does not necessarily mean that a higher-order site is healthier than a lower-order one. It does mean that the two are highly likely to have very differently functioning ecological systems.

Historical change in key indicators 1984–2009

A potentially powerful explanatory variable for predicting the ecological health of these estuary marshes is a representation of the historical change in the upland cover adjacent to each site. Towns were implementing shoreland zoning ordinances around 1984 to limit development within 250 ft of shorelines as required by Maine state law. For each of the three indicators (i.e., total developed area, relative degree of impervious surface within developed areas, and non-modified habitat types), we examined both the current character of the landscape (derived from interpretation of the 2009 aerial photographs) and the change in landscape character between 1984 and 2009. Table 7 summarizes these findings.

TABLE 5 Forest and shrub land cover types within 100 m of the tidal marsh study sites.

Marsh site	Percent of total area that is forest	Average perimeter-area ratio for all forest areas	Percent of total area that is shrub-herb	Average perimeter-area ratio for all shrub-herb areas
N2	24.5%	0.09	—	—
N3	14.9%	0.09	6.0%	0.11
N4	14.8%	0.08	4.7%	0.09
N1	17.5%	0.10	8.1%	0.14
N8	12.8%	0.11	0.6%	0.17
N10	0.4%	0.19	6.4%	0.12
N9	—	—	—	—
S1	2.2%	0.15	5.8%	0.06
S5	16.9%	0.11	—	—
S4	51.1%	0.09	—	—
S8	21.9%	0.08	—	—
S6	32.2%	0.09	—	—
S7	68.9%	0.06	—	—
S9	24.6%	0.08	—	—
S10	23.9%	0.08	—	—
S11	51.8%	0.04	—	—

TABLE 6 Ranking of Saco Estuary marsh study sites according to proportion of developed area, intensively developed area (i.e., >50% of developed surface is impervious) and non-modified land covers within 100-m buffers.

Rank	Site	Comparative extent of developed area (Table 5)	Relative intensity of development (Table 5)	Comparative extent of non-modified land cover (Table 6)
1	N3	0 – 10%	0	Good to very good (forest); good to very good (shrub)
2	S7	0 – 10%	< 5%	Good to very good (forest); none (shrub)
	S9	0 – 10%	< 5%	Good to very good (forest); none (shrub)
3	N4	10 – 20%	5 – 15%	Good to very good (forest); fair (shrub)
	N8	10 – 20%	5 – 15%	Good to very good (forest); fair (shrub)
	N1	10 – 20%	5 – 15%	Good to very good (forest); fair (shrub)
4	S5	10 – 20%	5 – 15%	Good to very good (forest); none (shrub)
	S4	10 – 20%	5 – 15%	Good to very good (forest); none (shrub)
5	S11	20 – 45%	15 – 30%	Good to very good (forest); none (shrub)
	S6	20 – 45%	15 – 30%	Good to very good (forest); none (shrub)
	N2	20 – 45%	15 – 30%	Good to very good (forest); none (shrub)
6	S8	20 – 45%	15 – 30%	Fair (forest); none (shrub)
	S10	20 – 45%	15 – 30%	Fair (forest); none (shrub)
7	S1	20 – 45%	15 – 30%	Poor to none (forest); fair (shrub)
	N10	20 – 45%	15 – 30%	None (forest); fair (shrub)
8	N9	> 45%	> 30%	None (forest); none (shrub)

TABLE 7 Summary of historical change (1984–2009) in key land cover indicators (developed area, intensely developed area, forest, shrub-herb) adjacent to tidal marshes of the Saco Estuary.

Site	Total Developed Area			Intensely Developed Area			Non-modified Area			
	Extent: 2009 (ha)	% of buffer area: 2009	Change in % 1984 –2009	Extent: 2009 (ha)	% of buffer area: 2009	Change in % 1984 –2009	Forest: extent, 2009 (ha)	Forest: % of buffer area, 2009	Change in Forest: % of buffer area, 1984–2009	Change in Shrub-Herb: % of buffer area, 1984–2009
N3	1.21	5.9	(NS)	0.15	0.8	(NS)	3.03	14.9	+1.7	– 2.7
S7	0.36	9.2	+ 7.3	0.20	5.1	+ 5.1	2.67	68.9	+10.2	– 14.0
S4	1.30	20.9	(!) – 4.5	0.49	7.9	(NS)	3.18	51.1	+9.3	– 2.5
S9	1.07	9.6	+ 5.8	0.25	2.3	+ 2.7	2.73	24.6	+5.5	– 8.5
N8	2.84	16.5	(!) – 2.6	0.98	5.7	+ 1.3	2.19	12.8	+5.2	– 2.8
N4	2.21	19.2	+ 2.9	0.20	1.7	(NS)	1.66	14.8	-0.7	+ 3.6
S6	2.00	25.7	+ 2.3	1.39	17.8	+3.4	2.51	32.2	+11.4	– 6.8
S11	0.97	25.4	+ 24.8	0.57	15.3	+ 15.3	1.99	51.8	-18.0	– 4.5
N2	1.15	18.9	(NS)	0.90	14.9	+ 9.6	1.49	24.5	+20.6	– 18.1
N1	2.97	42.0	(!) – 6.4	0.39	5.4	(NS)	1.23	17.5	+5.3	+ 3.3
S5	2.72	19.9	(NS)	0.68	5.0	(NS)	2.31	16.9	+5.7	– 2.6
N10	4.60	38.0	+ 11.9	1.75	14.6	+ 10.2	0.04	0.4	-6.7	(NS)
S10	3.47	40.8	(NS)	1.41	16.5	+ 2.1	2.03	23.9	+11.0	– 9.6
S8	2.19	44.6	+ 43.9	1.10	22.3	+ 22.3	1.08	21.9	+8.6	– 14.4
S1	4.29	38.3	+ 5.3	2.97	26.4	+ 2.4	0.25	2.2	(NS)	– 8.6
N9	5.84	67.8	(#) + 5.1	4.50	52.3	+ 7.1	0	—	—	(NS)

(#) The area mapped in the 1984 and 2009 images is not always exactly the same. Differences occur when the area that is *mudflat*, relative to the area of *open water, tidal*, is not the same. The open water portion of each buffer is excluded from the total area that is used for the proportional calculation.

(!) Negative changes may occur in the percent developed area. Developed means human-modified, and not strictly paved over land. If an area of vegetation has been cleared and maintained, then later is unmaintained, woody shrubs or young saplings invade the formerly modified, maintained vegetation. These are classed as non-developed land cover on the 2009 even if the 1984 land cover was developed. The non-utilized Notre Dame Center property adjacent to site S4 illustrates this process well.

Change in developed area 1984-2009

The main conclusion to draw from the data is that, for the most part, there were only modest increases in the total developed area adjacent to the estuary marshes since 1984. The pattern of rural large lot subdivision development along the estuary was mostly already established by 1984. Only at site N10 in Saco did development increase significantly within 100 m of the marsh sampling areas during the time period as a result of residential subdivision development (Figure 4). Single-family home construction did occur around the estuary, but it is typically scattered in isolated parcels rather than concentrated in major subdivision developments. Site S9, where four large single-family homes (one with a very large associated lawn and three with more modest ones) were constructed near the marsh, illustrates this moderate increase in developed area. In addition, most of the additional developed area is modified vegetation (e.g., lawn) rather than pavement or structures.

Change in intensity of development 1984–2009

The buffer areas of only four sites experienced significant increases in moderate to very intense development after 1984. Two of these resulted from major construction projects instigated by institutional expansion. At S8, the construction of St. Joseph's Convent adds roughly 1.1 ha of 100% impervious surface to the buffer area after 1984 (Figure 5). The construction of the East Hall and West Hall dormitories by UNE adds just under 0.6 ha of impervious surface to the buffer area at site S11. The impact of these construction projects may have been different, however. The convent was built on an already developed area, classified as agriculture-grass in 1984. The dormitories and service road replaced part of a compact and fairly extensive stand of deciduous forest.

Change in area of unmodified upland vegetation 1984-2009

The most obvious trend in change in forest cover since 1984 is a general tendency toward greater forest area (Figure 6). The area within the 100-m buffers covered by deciduous, evergreen, and coniferous forests combined in 2009 is 59.3 ha larger than in 1984. Six sites gained 7 ha or more of forest cover within their buffers and/or the area in the buffer that is forest increased by 10%. Almost all the forest cover increase is the result of transition from shrub-herb or open land cover to forest. There are only two sites where forest cover area was significantly reduced after 1984: N10 and S11.

Shrub-herb land cover declined across the 16 sites by nearly 67 ha. Note that the area of shrub-herb lost is greater than the area of forest gained. This implies that some shrub-herb land cover was replaced by development.

FIGURE 4 1984 and 2009 aerial images for marsh N10, Saco. Red arrows identify ten single-family residential structures and associated outbuildings within or adjacent to the 100-m buffer that were constructed after 1984. Note the position of the 250-ft shoreland zone boundary.

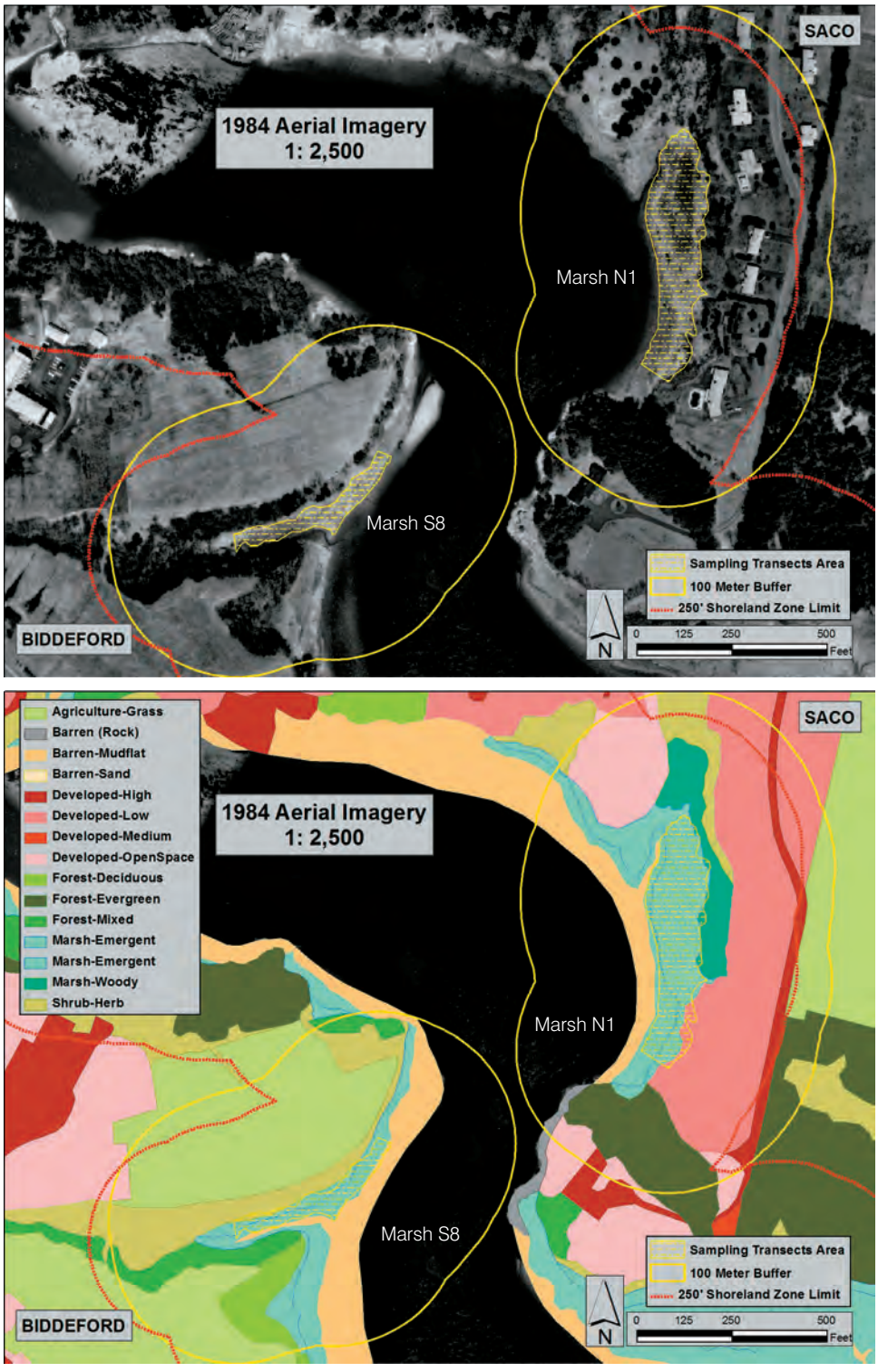


FIGURE 5A 1984 aerial images for marsh N1, Saco and marsh S8, Biddeford.

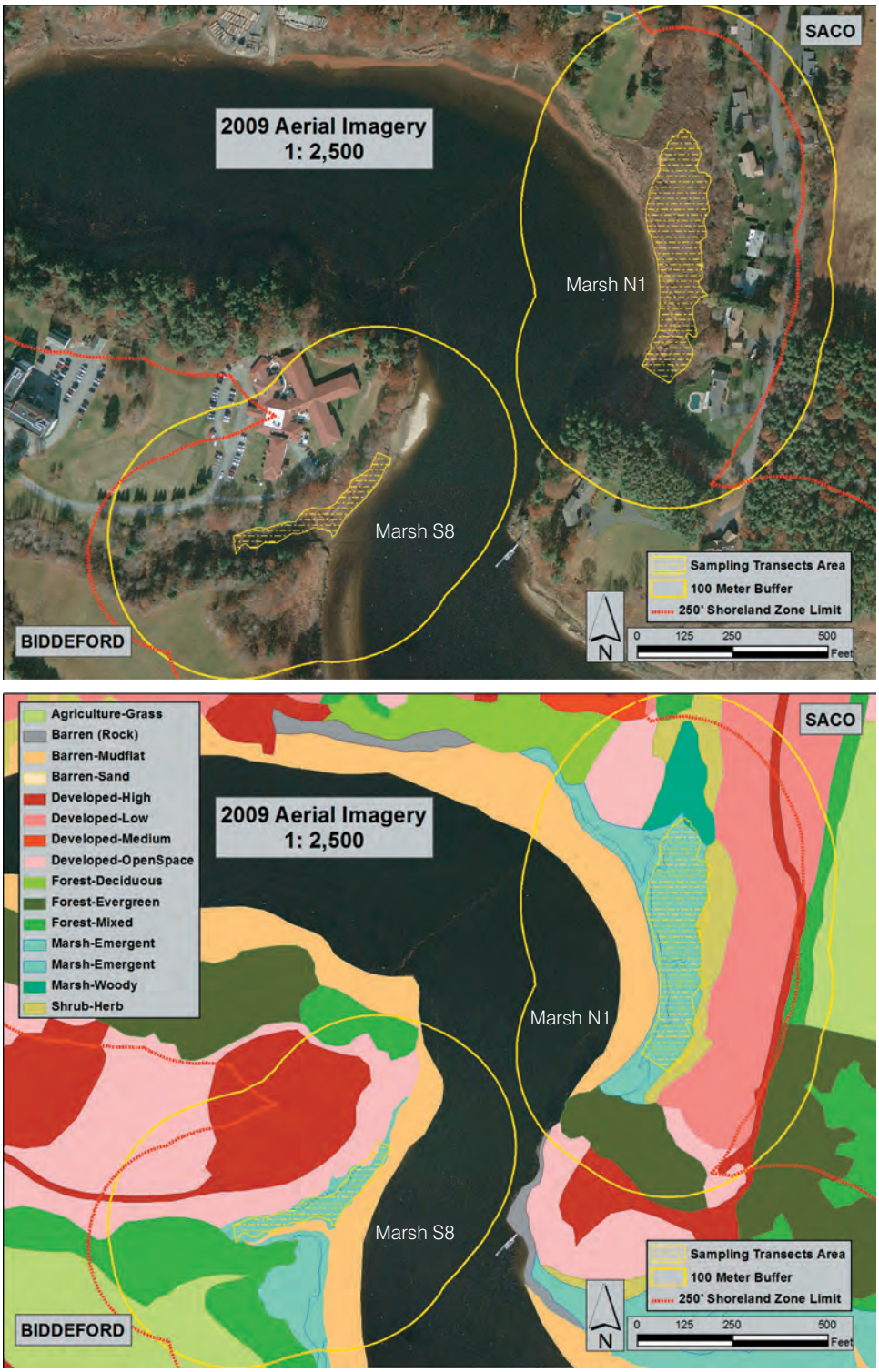


FIGURE 5B 2009 aerial images for marsh N1, Saco and marsh S8, Biddeford.

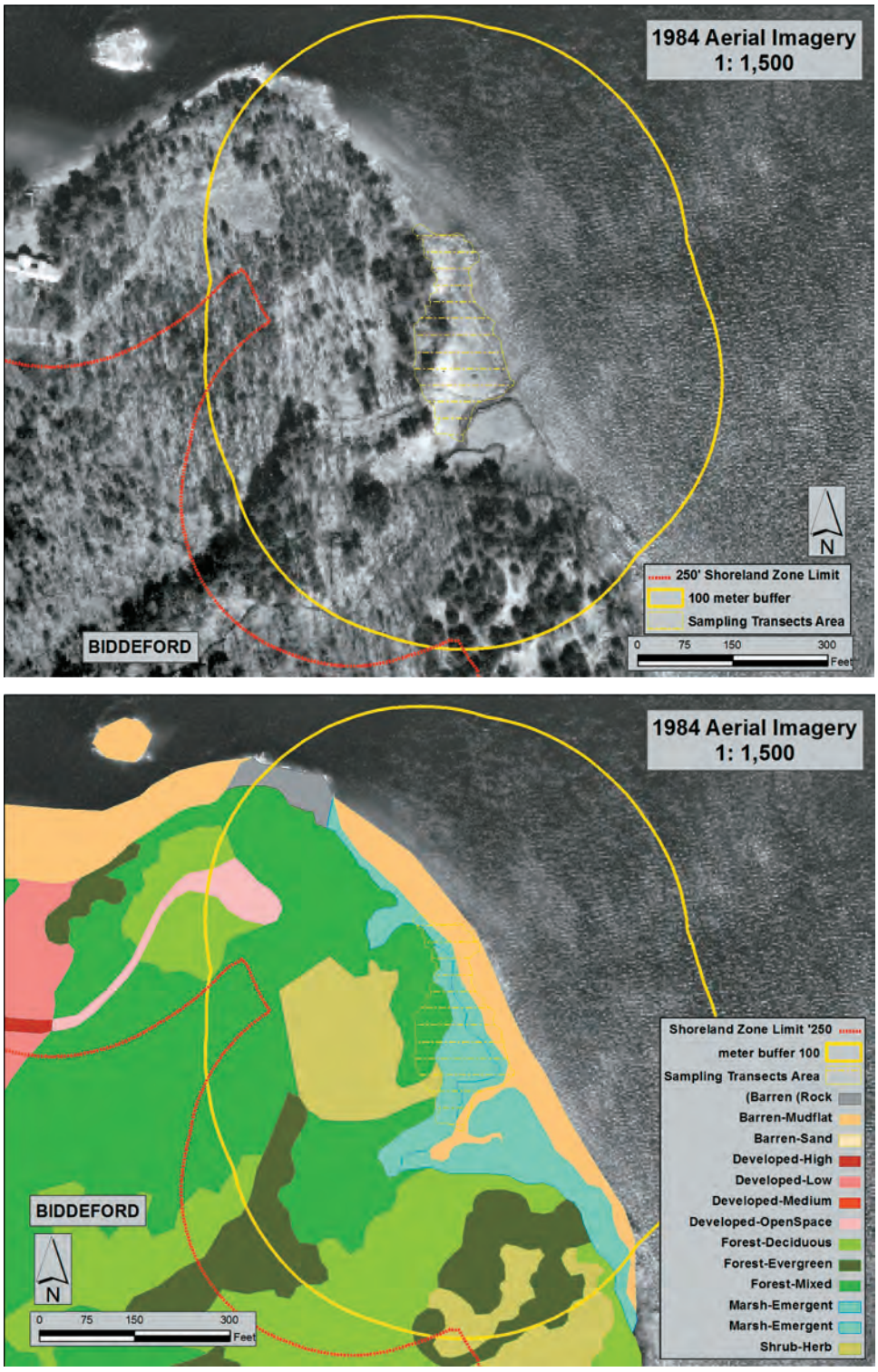


FIGURE 6A 1984 aerial images for marsh S7, Biddeford.

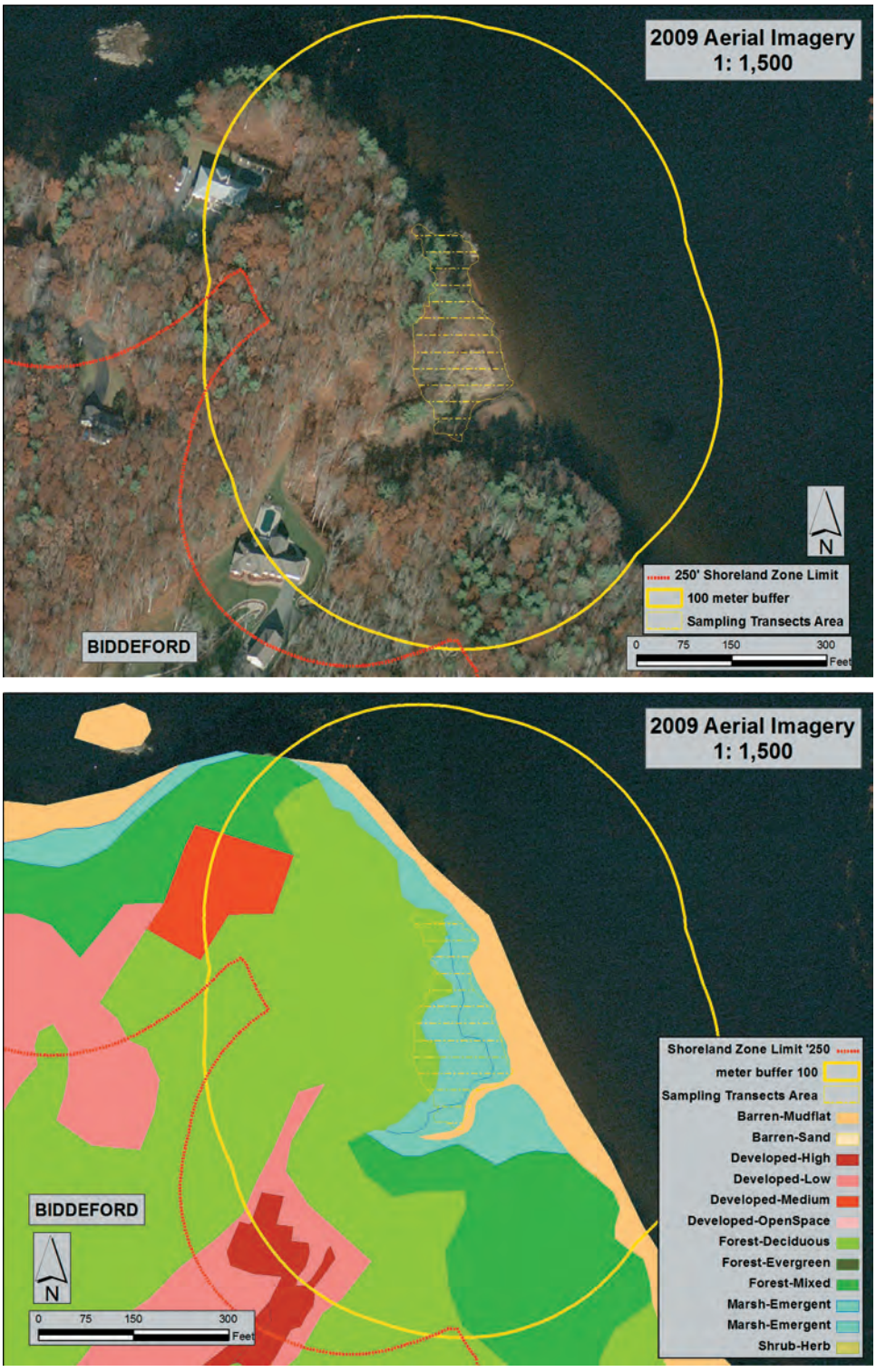


FIGURE 6B 2009 aerial images for marsh S7, Biddeford. All remaining shrub-herb cover in 1984 disappears, replaced by forest cover through an expected successional pathway. Areas of evergreen forest give way to mixed forest (lower right) and to development of a residence (lower center). Mixed forest transitions to all deciduous.

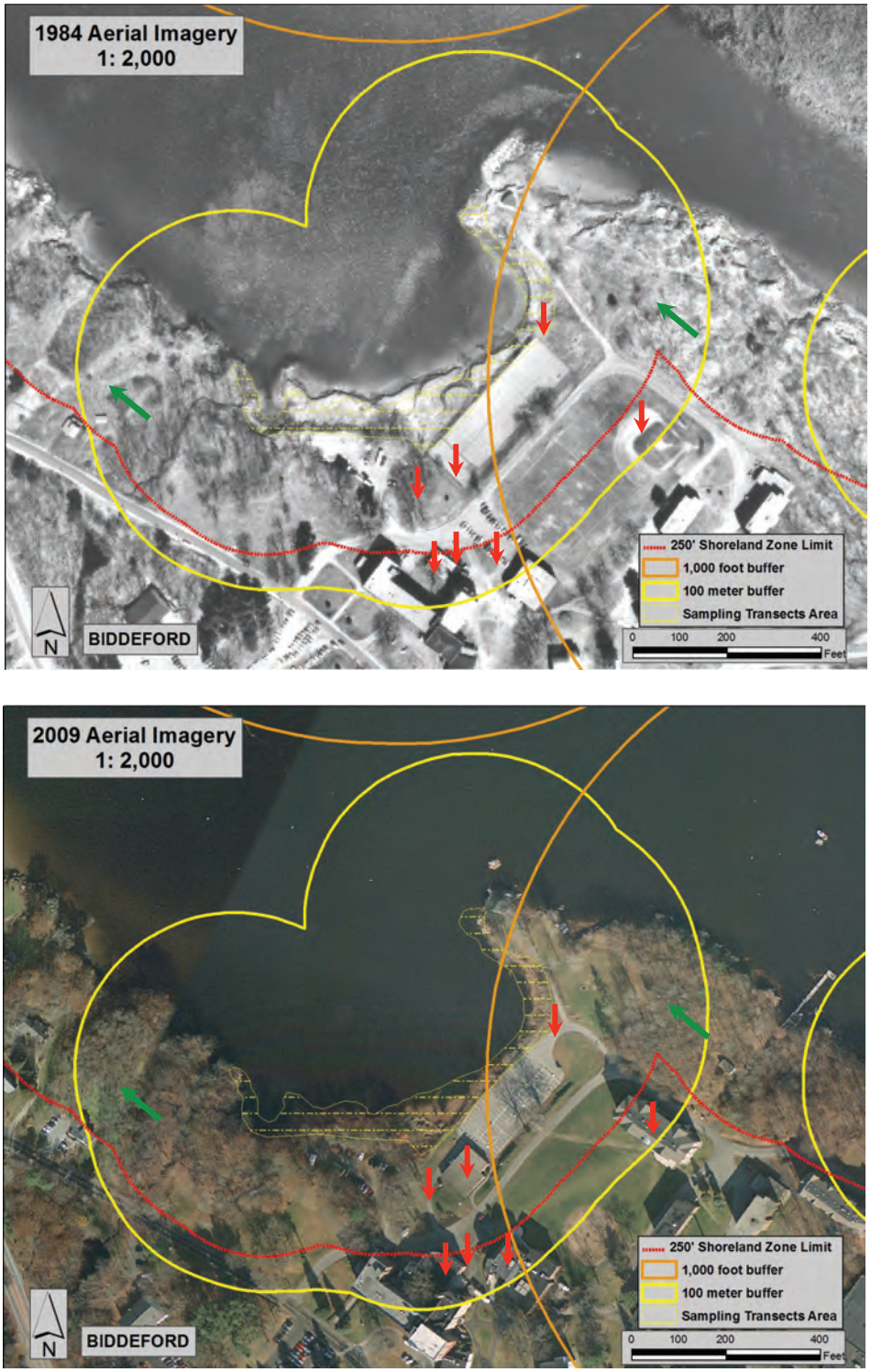


FIGURE 7 1984 and 2009 aerial images for marsh S10, Biddeford. The completion of new structures and roadways (red arrows) on the UNE campus illustrates impacts to the upland borders of a marsh as well as forest succession (green arrows). This is one of the few sites in the estuary where the area of developed-open space actually shrinks during the 25-year interval, as it is replaced with either forest cover or new structures and roadways.

CONCLUSIONS

We made the following conclusions from our study of land cover change data (1984-2009) in the Saco River watershed:

- Major development occurred at three sites after 1984. These are sites where the proportion of the buffer area that is intensely developed increased more than 10%: S11, N10, and S8.
- There was the accumulation of an additional 54 ha of forest area within the 16 buffer areas between 1984 and 2009, and the disappearance of 68 ha of shrub-herb area.
- The overall picture of the estuary that emerges from examining land cover in 2009 and 1984 is one of relative stability.

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