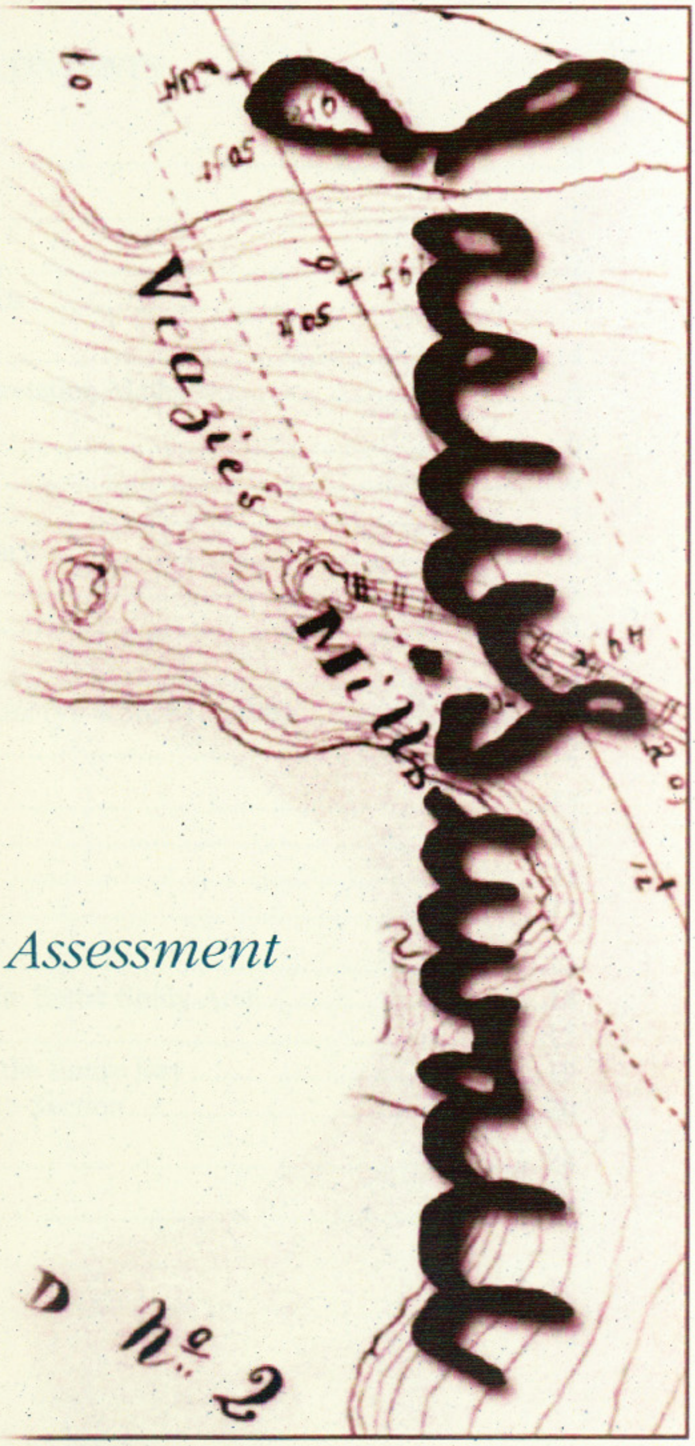
ASSESSMENT REPORT

Prepared for
Friends of Merrymeeting Bay

April 12, 2000



Aquatic & Upland Habitat Assessment of Merrymeeting Bay

F18080

JAMES W. SEWALL COMPANY
ESTABLISHED 1880

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INTRODUCTION

In early 1998, the Friends of Merrymeeting Bay (FOMB) commissioned James W. Sewall Company of Old Town, Maine and Kleinschmidt Associates of Pittsfield, Maine to provide technical support for aerial photography, mapping, and analysis of trends in the Bay and surrounding half-mile upland buffer area. The study would be the latest of several such studies of the Bay proper, but the first to include the neighboring uplands. Previous studies were conducted in 1956, 1961, 1966, and 1981 (Spencer, 1966; Anderson, 1982). The purpose of the present study was to document conditions in the study area in 1998 and report on trends in vegetation and land use since 1956. In order to do this, FOMB wished to replicate the earlier vegetation classifications inside the Bay and, in addition, map upland land use and land cover. Classifications were carried out by photo interpretation of 1956, 1981, and 1998 aerial photography. Mapping and analysis were done using Geographic Information System (GIS) techniques. The following discussion of the study and its results is divided into four sections, three of which present and discuss different aspects of the methodology (field method, photo interpretation, and GIS). The final section presents summary figures, tables, and some discussion on change. Maps, ARC/INFO GIS coverages, an ARCVIEW summary project, and a comprehensive data table in Excel spreadsheet format accompany this report on CD-ROM and may be used as an extension to it.

STUDY AREA DEFINITION

The 1998 photos were classified for upland types in an area within 1/2 mile of the Bay and its major tributaries to head of tide. For the purpose of defining the 1/2-mile buffer, the 1:24000 USGS map of the Bay and its tributary rivers (Androscoggin, Muddy, Cathance, Abagadasset, Eastern, and Kennebec) was used. The 1998 photos provided coverage of the Bay and to the head of tide on all major tributaries except the Kennebec, which was covered only to the north end of Swan Island. A small portion of the 1/2-mile buffer along the western side of the Eastern River was also not covered by the 1998 photography. A GIS file (mmb98covarea) shows the effective study area (the intersection of the study area as defined by the above mentioned 1/2-mile buffer and stereo photo coverage). For the trend analysis, the study area consisted of the area common to the photo coverages of 1998, 1981, and 1956 (Figure 1).

FIELD METHODS

Field work involved ground truthing of preliminary photo interpretation work using 1998 color infrared (CIR) aerial photos, and data gathering for detailed reference wetland work. This fieldwork was completed during the last few days of July and the first half of August 1999 to coincide with the phenology of the aerial photographs. The study area was also divided into subsections corresponding as much as possible to those defined in earlier studies (Anderson, 1982). A portion of each sub-section was visited. Fieldwork was also used to establish or confirm aerial photo signatures for the various marsh types and substrates (silt, sand, rock). Out of a total of 13 person-days of fieldwork, only a portion of one day was dedicated to ground truthing of upland habitat types. The vast majority of the time was used to establish reference wetland data and to ground truth marsh types. A summary of the results of the reference wetland study, including species detail and photographs of representative stands, may be found in the separate “Wetlands Document,” prepared in September 1999 by Alan Haberstock of Kleinschmidt Associates.

Discussion and Observations on Field Methods

- Timing of fieldwork and aerial photography dates is important. Many marshes appear to be dominated by species other than wild rice through June and even into July. Wild rice is an annual and, in the beginning part of the growing season in mixed marshes, it is relatively inconspicuous beneath the foliage of perennial vegetation. Perennial species exhibit quicker starts due to stored energy but are overtopped by wild rice by July. Therefore, many wetlands were called “mixed” (no single species had an areal coverage of 70% or more) that might have been called a single-species wetland other than wild rice (such as pickerelweed or soft-stemmed bulrush) in the beginning part of the growing season. Many of the “mixed” marshes contained a dominance of wild rice (usually around 25-70% of the total area coverage attributable to wild rice) but not enough to reach the 70% threshold.
- Exotic/invasive species such as purple loosestrife (*Lythrum salicaria*) and common reed (*Phragmites australis*) are not prevalent in the Bay. Purple loosestrife occurs in small patches throughout the Bay near the high water mark. This species could affect the ecological integrity of the Bay if it increases. It is displacing native, water-edge species like cardinal flower (*Lobelia cardinalis*) and blue vervain (*Verena hastata*), not emergent species like pickerelweed and wild rice. Common reed is not a problem at present in the Bay.
- We have observed that Merrymeeting Bay is dynamic. There are wetlands that have changed shape and extent between 1981 and 1999, particularly at the mouth of rivers and in the central part of the Bay. Some of the marsh complexes out in the middle of the Bay seem to have even changed shape a bit between ‘98 and ‘99. The sediment dynamics result in shifting wetland locations and coverage. Wild rice in fact may thrive in part due to these shifting sediments, easily seeding-in where the sediment is just right and where perennial species may get smothered (in depositional environments) or removed (erosion). Factors such as ice dynamics in the winter may also favor pioneer species due to physical action of the ice on substrates.
- Wild rice CIR signatures (i.e., tone, texture, color) varied from stand to stand depending on how robust the stand was whereas other species had more uniform signatures.
- Perhaps the most dynamic and ubiquitous species in the Bay is wild rice. This annual, non-persistent, wind-pollinated, emergent grass grows to a height of more than 2 meters. It favors soft, muddy or silt areas where there is at least some movement of water and

little competition from other species (at least some patches of bare substrate). This species does not like stagnant water. Its survival into the next year depends entirely on its yearly seed crop. The population of wild rice in the Bay can swing from year to year in response to many variables including disease (certain fungi occasionally infect the plant), weather, sediment dynamics, seed consumption, and even wind direction during pollination, water flows during germination and seed dispersal, and carp numbers and habits (carp like to uproot and eat young plants). Spencer (1966) points out that the variability of wild rice can cause problems for photo-interpretation and for trend analysis, because "in years of good crops a dense stand of rice sometimes forms an overstory that provides the photo image but which may obscure a moderately dense understory of such plants as yellow water lily."

PHOTO-INTERPRETATION METHODS

Three dates of photos were interpreted: 1998, 1981 and 1956 (all in August). The 1998 photos were color infrared (CIR) film positives at a scale of 1"=1000'. The 1981 photos were true color prints at a scale of 1"=660'. The 1956 photos were true color positive transparencies, also at a scale of 1"=660'. All photo-interpretation labels were a single alphabetic code that would allow expansion by computer routine into component codes of land use class, land use sub-class, vegetation, and (in 1998) forest cover type.

Upland land use was classified using a modified version of Anderson's (1976) classification, with alphabetic rather than numeric codes and with sub-classes added as deemed necessary. In 1998 only, forested areas were broken down into softwood, mixed wood, and hardwood as well as typed for height and density. In other years, the forest land use type was not subdivided into subclasses. Wetlands were classified as "WET" under land use class and also typed under the Cowardin *et al* (1979) wetlands classification system. The Bay's emergent vegetation areas were sub-classified for the same target species classes as were used in previous studies (cf. Spencer, 1966). A summary of all codes is given in a later section of this document (DESCRIPTION OF GIS COVERAGES).

In classifying emergent vegetation, a vegetated area was given a single species code if that species covered 70% or more of the area. Density of the coverage had to be at least 30% for an area to be considered vegetated. Areas with lower vegetation density than 30% were classified in terms of the substrate (silt, sand, rock, open water). If there was less than 70% coverage of one species it was classified mixed. If a wetland had a species other than the target species that had coverage of 70% or more of the vegetated area, the wetland was also classed as mixed. For example, three square bulrush was a species that sometimes formed small monocultures (stands with 70% or more of the total area). These areas were put in the mixed emergent class.

The upland classification was modified on the 1981 and 1956 true color photos. The forest was not broken down into general composition class or height and density for these years. Otherwise, uplands were classified to land use as in 1998. The wetland areas were also classified the same as on the 1998 photos. A basis for truthing of the aquatic vegetation portion of the classification was provided by annotated 1957 black-and-white photography in David P. Olson's MS thesis (Olson, 1958).

The 1956 and 1981 photos did not cover the entire project area. Figure 1a shows the relationship between the three years' effective study areas, and the area where they overlap. This is the study area referred to in all summary tables in the trend analysis section of this report. Figure 1b shows the subsections used in this study. Although the subsections in earlier studies did not extend into upland areas, they have been extended in this study for purposes of reporting upland land use trends by subsection. The lines from the earlier studies were extended so that upland areas were also assigned to a sub-section. This allows analysis not only of changes in the bay, but also of the land use changes by sub-section.

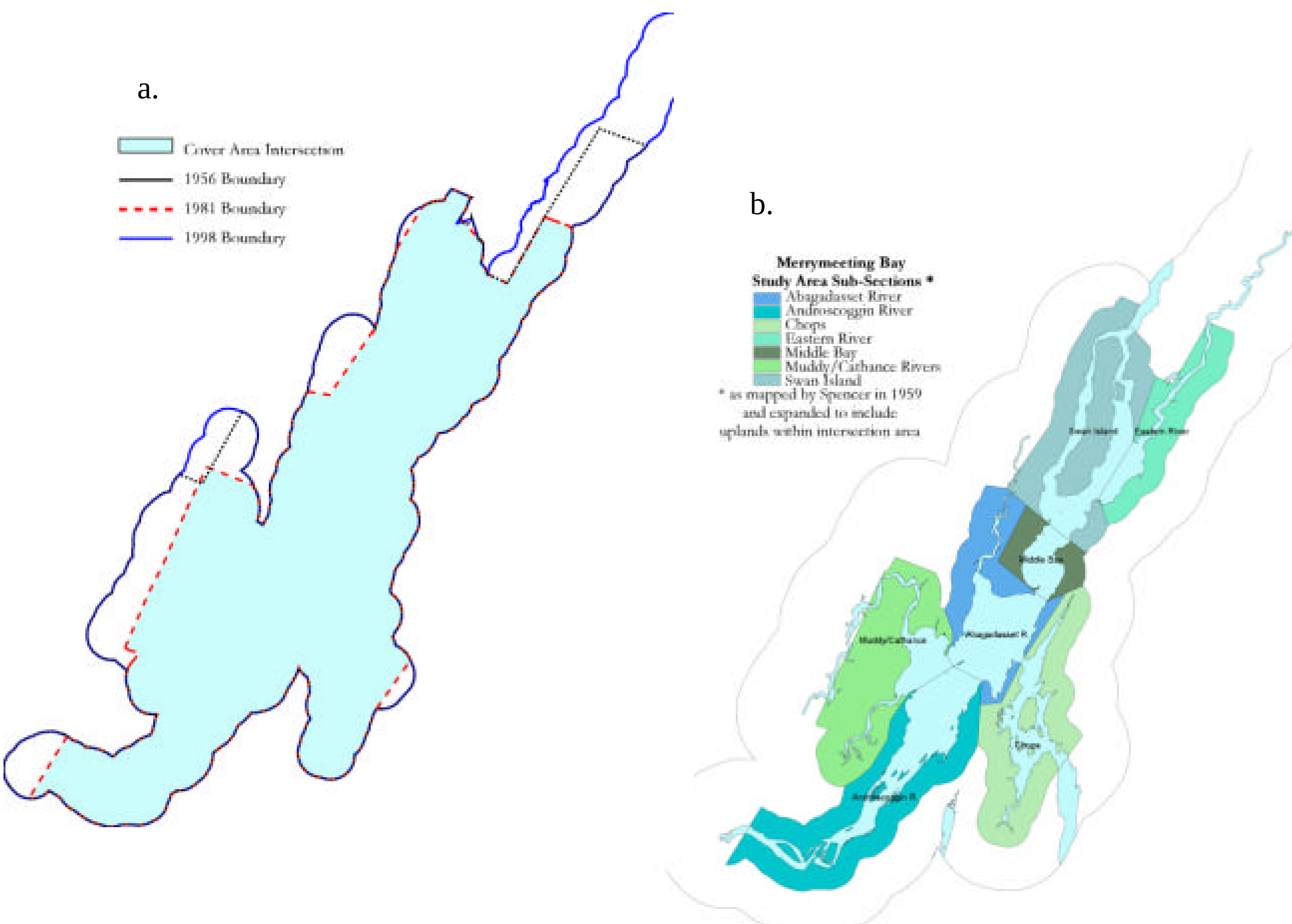


Figure 1. a) The study area a defined by the intersection of three years of photo coverage, and (b) the definition of subsections.

Discussion and Observations on Photo-Interpretation Methods

- No definite limit of the Bay was defined by the previous studies. The limit used for 1998 corresponds to the area coded as "YES" in the Estuary attribute of each of the MMByy_ALL coverages and is approximately 10,700 acres in all three years. This limit includes the inter-tidal and sub-tidal areas as well as these could be determined, and also includes the emergent vegetation areas of target species adjacent to the Bay.
- The photography varied among different years. 1998 photos were at a smaller scale and color infrared; 1956 photos were badly faded, true color transparencies, and 1981 were true color prints that varied in quality over the entire area but were somewhat better in quality than 1956.
- Aquatic beds are submerged even at low tide (see also Spencer, 1966). The high responsiveness of CIR film to vegetation probably makes aquatic beds more visible (1998) than on true color film (1956, 1981).
- Of the three years of photography used in the present study, 1998 had the lowest tide at the time of photography, followed by 1956, then 1981 (see further data under TREND ANALYSIS).
- The methodology of previous photo-interpretation of the Bay was to interpret spots under a dot grid (H. E. Spencer personal communication to L. B. Feero). This method has different properties than the polygon method used in the present study. What was being interpreted in the earlier studies was the condition that fell immediately to the upper left of each dot. Every such spot was interpreted, dots were counted by category, and acreage determined for the category by multiplying the category count by the dot acreage factor. For example, on the 1"=660' photography of the earlier studies, each square inch covers 10 acres. In a 16 dots/ inch grid, each dot would have represented .625 acres. Even though the minimum area of the present study's polygons is 1/8 acre, the polygon method may possibly increase the "mixed emergents" category for complicated mosaics of species that could have been separated into individual species in the dot method.

GIS/DATABASE CREATION METHODS

1998 mapping was done first and used as a base for 1956 and 1981.

1998 (upland and aquatic)

- Map features used for control in transferring photo-interpreted data from the 1" = 1000' photo base were plotted manuscripts at the same scale from USGS 7.5' maps on CD-ROM (georeferenced raster images copyrighted by Land Info International). For the Bay region, these maps are of mid- to late-seventies origin.

- Photo-interpreted type boundaries were transferred from photos to the control base using a vertical sketchmaster. This device is suitable for adjustment of minor scale difference between source photo and control base in relatively flat terrain. When transferring from photos to controlled base, significant shoreline features, buildings, and road intersections were used for control. This method does not eliminate distortion due to relief displacement and scale changes within photo frames, but does allow these variations to be controlled by the matching of photo features to their counterparts on the control base. The USGS base provided good control except within the Bay proper, where control detail was sparse. In these areas, adjustments were made between photos to make them fit each other and the boundaries of the bay.
- The transferred lines were checked and then scanned on a TRUSCAN model CS400/10 scanner to .TIF format.
- ARC/INFO GRID software was used to convert .TIF to geo-referenced ARC/INFO line format.
- Lines were edited and label points added to create error-free polygon topology.
- Polygons were assigned attributes using the photo-interpreter's code.
- A 100% check was made to ensure completeness of labeling and an accurate match to the photo-interpreter's classification.
- The polygons were digitally overlaid with US Fish and Wildlife Service National Wetlands Inventory (NWI) maps to supply major wetlands system classes for each polygon. This established the breaks between Riverine and Estuarine systems in essentially the same locations as in the NWI.
- A computer reclassification routine was executed to populate all attributes base on the photo interpretation code.

1956 and 1981 Upland Classification

- Lines and labels of major 1998 upland land use types as well as roads and water were plotted at 1"=660' scale (same as photos) on clear inking film.
- A photo-interpreter overlaid these maps on the 1956 or 1981 photos and interpreted upland land use directly to the clear film overlay. The overlay was shifted as necessary on top of the photo to match major features and adjust for scale variation across the photo. Land use boundaries that were changed (from the 1998 base) were inked and lines needing removal were cross-hatched for later deletion. The rule of thumb used to determine whether to change the line was a minimum variation in a boundary of one tenth of an inch. This is equivalent to 66 feet at ground scale. Any lines on the 1998 base that overlaid a corresponding land use boundary on the photo within a tenth of an inch were left in place. This method was used to avoid creation of spurious sliver polygons and ensure that change was truly change and not variation due to the horizontal positional inaccuracy of the transfer method.

- Using these edited maps as a source, the 1998 polygon file was edited at a digitizing workstation to create 1956 or 1981 upland land use, deleting or adding lines and modifying polygon labels as necessary to create a new polygon layer appropriate to the year.

1956 and 1981 Classification within the Estuary

Because of the great amount of difference in the Bay's water and vegetation polygon configurations between dates, the editing procedure used for uplands was not used for the area within the Bay. Instead, complete new sets of lines were created for aquatic type polygons (vegetation and other wetlands types including open water). The same method as was used for the original 1998 mapping was used to capture polygons, except that control was provided by the already-created 1998 land use types instead of the USGS raster base (same base maps used in the land use transfer). The steps were:

a) Transfer from photo to map using vertical sketchmaster with detail on 1998 land use base providing control.
b) Scan mylar overlays to .TIF format.
c) Automate and convert to geo-referenced ARC/INFO line format.
d) Clean up lines and add label points to create polygon topology.
e) Assign photo interpreter's classification code to polygons.
f) Quality control to ensure completeness of labeling and accurate match to photo-interpreter's classification.

Completion of 1956 and 1981

- Aquatic types were merged with upland land use. The aquatic layer superceded the upland layer in any area of overlap.
- Adjustments were made along the border between the upland land use and aquatic types to eliminate slivers. Routines were used to identify polygons that bordered sliver polygons and assign the attribute of the major adjacent type. These assignments were checked before dissolving borders between polygons with like labels.
- The coverage was intersected with NWI mapping and dominant wetlands system computed for each. A computer reclassification routine was executed to populate all attributes based on the photo interpreter's classification.

Buildings

Buildings were first screen-digitized to a shape file in ARCVIEW from the USGS raster base (copyright Land Info International). This provided a basis for building locations in all but heavily developed areas (municipalities, trailer parks) where individual buildings are not shown by USGS. This USGS building location coverage was plotted on the clear film base that was also used for control in 1956 and 1981 land use mapping (see above). These clear mylars were overlaid on the 1956 and 1981 photographs and buildings not present (i.e. not visible on photographs) were marked for deletion, or new buildings visible on the photographs were marked for addition. A similar process was used for 1998, with maps plotted at the 1" = 1000' scale. Building points that originated from photographs were copied forward between years. The result of these procedures is that a building present in multiple years has identical coordinates in all years. All buildings except small outbuildings were digitized. No attributes were applied to the ARC/INFO point features representing the buildings.

DESCRIPTION OF GIS COVERAGES

- All GIS coverages are in ARC/INFO 7.2.1 format. In addition to being provided as ARC/INFO coverages accessible from ARCVIEW they are present on the delivery CD as ARC/INFO export (E00) files. The CD also contains metadata for land use/land cover, building, and base feature coverages.
- The projection used for all coverages is UTM Zone 19, NAD27, meters.

Coverages Provided for each of the Three Years (yy = 56, 81, or 98)

Coverages MMByy_ALL - this is the primary coverage type of the study, containing all the attributes for land use, wetlands, and vegetation. Attributes are the same for the three years except that 1998 has enhanced information on the forest type, adding four attributes. The following descriptions of attributes does not include ARC system attributes, but these are present. The non-system attributes and code values are as follows:

ALPHA - Unique photo-interpreted code from which other codes (except WETL_SYS) were derived. For example, the letter "A" (in early phase "PEM/A") was used by the photo-interpreter to mean wild rice. This value was recoded to WET for land use, EM for land use subclass, and EM1 for WETL_CLS. Similar recodings were done for other values of ALPHA. ALPHA itself was never changed from the original interpreted value unless changed by the interpreter. Thus, it could always be checked against the acetate photo overlays on which interpretation codes were written.

LUCLASS	Land use class 3-character alphabetic
AGR	Agricultural (cropland or pasture in current or recent use)
COM	Commercial (business or commercial predominant use)
FOR	Upland Forest (predominant land use forest)
IND	Industrial (manufacturing facilities and associated land)
OW	Open Water (lake, river, or bay areas under water greater than a few inches deep at the time of photography)
RES	Residential (homes and related neighborhoods)
USS	Upland Scrub-Shrub (usually abandoned agricultural field)
UHE	Upland Herbaceous (large expanses of lawn not obviously associated with residence)

WET Wetland (general class for upland and bay wetlands other than open water)

LUSUBCLASS - Land use subclass. 4-character alphabetic. Some of the land use classes were broken into subclasses. Those that were not broken down were simply repeated in the subclass attribute. This allows the land use subclass attribute to be used as an exhaustive alternative breakdown of land use. The sub-codes, by major code are as follows:

AGR, RES, IND	no subclass breakdown, repeated primary code.
COM	either COM or one of the following alternate codes
YD	harvest yarding area in forest
GP	gravel pit
TL*	primary use transmission line

*Transmission lines were LUCLASS 'COM' and LUSUBCLASS 'TL' code only when they crossed forested land. If land under a transmission line was being used for agriculture, it was typed AGR.

WET	no subclass breakdown for uplands in 1956, 1981
AB	aquatic bed
EM	emergent vegetation
PFO	forested wetland
HT	high tide zone – unvegetated areas above high tide
ROCK	rock showing within the bay or bay area
SAND	sand flats (may be submerged)
SILT	silt (may be submerged)
PSS	palustrine scrub-shrub wetland

FOR 1998 only broken into sub-classes - other two years use FOR

1998 sub-classes

SW	softwood
MI	mixed softwood and hardwood
HW	hardwood
LG	ledge or rock outcrop in upland area

OW, USS, UHE no subclass breakdown, repeated primary code

WETL_SYS - Wetlands system. One-character alphabetic code for ecological system, under the scheme of Cowardin et al (1979). These codes were assigned by overlaying with US Fish and Wildlife National Wetlands Inventory (NWI) maps, then assigning the dominant code of the US Fish and Wildlife Service's National Wetlands Inventory maps. Thus, for example, the breaks between Riverine and Estuarine in the bay roughly match the breaks used on the NWI maps.

E	Estuarine (not subdivided into tidal and subtidal)
L	Lacustrine
P	Palustrine
R	Riverine
U	Upland

WETL_CLS. An approximation of the ecological subsystem from the Cowardin scheme, using the following codes. 3-character alphabetic.

AB	submerged vegetation
EM1	persistent emergent vegetation
FO	forested
HE	herbaceous
RS	rocky shore
SB4	streambed sand
SB5	streambed silt
SS	scrub-shrub
UB	unconsolidated bottom

VEG and VEG_DESC - Vegetation code. 1-character alphabetic code for emergent vegetation type and 20-character description with code. Codes are as follows:

A	wild rice
B	yellow water lily
C	sweet flag
D	softstem bullrush
E	river bullrush
F	pickerelweed
G	mixed emergents
H	broad-leaved cattail

FORCOV - 1998 only. Forest cover types are made up of three components, species composition, size class, and crown closure. The four-character FORCOV code is made up of the following codes for each of these components:

FORSPP (species composition)

H	Greater than 75% Hardwood
S	Greater than 75% Softwood
HS	Hardwood-dominated mixture of hardwoods and softwoods (hardwood 50-75%)
SH	Softwood-dominated mixture of hardwoods and softwoods (softwood 50-75%)

FORSIZ (a size classification roughly indicative of commercial product or seral stage)

1	Seedling	(<10' tall)
2	Sapling	(~10-30' tall)
3	Pole/Pulp	(~30-50' tall)
4	Sawtimber	(>50' tall)

FORDEN (canopy closure)

A	71-100%
B	41-70%
C	11-40%
D	0-10%

ESTUARY – "YES" if polygon is part of the area considered to be estuary, otherwise blank. This was determined by taking all emergent vegetation types bordering on the Bay.

UPL – "Yes" if polygon is part of the area considered to be upland, otherwise "NO".

Coverage MMBXXALL - master intersection coverage containing linking -ID numbers of the three years' primary coverages. This coverage was used in ARC/INFO to provide the cross tabulation of all years that is presented in the Excel table DATA.XLS.

Coverages MMByyROADS - modified USGS roads coverage (Source: Maine Office of GIS) within the coverage area for each year to reflect road status at the time of the photography. The only non-system attribute of this coverage is:

CLASS - Numeric, single-byte integer

1 Interstate
2 Primary
3 Secondary
4 Improved
5 Unimproved
6 Trail

Coverages MMByyCOVAREA - stereo photo coverage area within study area. An additional coverage, MMBXXCOVAREA, is provided which describes the stereo coverage area common to all three years' coverage.

Coverages MMByyBLD - a point coverage for each of the three years representing buildings. No attributes were used other than system point attributes. MMBXXBLD is a related coverage intersecting the building coverages with the MMBSECTIONS coverage so that numbers of buildings could be tabulated by section.

General Coverages (used for all three years)

Coverage MMBTWPS - Township boundaries for towns overlapping the study area (source: Maine Office of GIS). The attributes of this coverage are:

TOWN - 20 character alpha, name of Maine civil division (city, town or township).
GEOCODE - 5-character Maine code for civil division.

Coverage 24KROADS - Same as MMByyROADS except these are the same as the USGS roads, which were mapped in the mid- to late-seventies. This is used to provide context and connectivity for the roads within the study area (source: Maine Office of GIS). Attributes:

CLASS - same codes as for MMByyROADS coverages (see above).

Coverage MMB_COAST - USGS polygonal water features covering the study area (source: Maine Office of GIS). The attributes are:

RIVER - single digit integer, 0 if island, 1 if not.

Coverage MMB_RIVERS - USGS polygonal water features covering the study area (source: Maine Office of GIS). The attributes are:

ISLAND - single digit integer, 1 if island, 0 if not.

Coverage MMB_STREAMS - USGS linear water features covering the study area (source: Maine Office of GIS).

Coverage MMB_MASK - One-mile buffer on study area used to mask external water and road detail in ARCVIEW map layouts. The attribute here is INSIDE, which has a value of 100 for areas inside the one-mile buffer and 1 for areas outside.

PHOTO TIMES

The times (eastern standard time) of photography for the three dates were as follows:

1956 Photography

Flight Lines 1-8 taken on August 25 between 10:00 am and noon.
Flight Lines 9-13 taken on August 27 between 11:00 am and 1:00 pm.

1981 Photography

Taken on August 18 at a mean time of 9:00 am.

1998 Photography

Taken on August 9 at a mean time of 8:50 am. The actual flight line times were:

Line 1	9:12 to 9:13	Line 7	8:26 to 8:31
Line 2	9:08 to 9:09	Line 6	8:34 to 8:39
Line 3	9:01 to 9:05	Line 5	8:43 to 8:47
Line 4	8:52 to 8:57		

DISCUSSION OF TRENDS

While a detailed analysis of the data is beyond the scope of this report, some comment on the nature of the study's products and their appropriate uses is appropriate. The discussion below first deals with overall trends in land. Then follows a brief analysis of tide levels at the different study dates and how their influence can be factored out of the analysis of trends in the intertidal zone. Finally, some of the more significant trends in the Bay and its subsections are identified.

Land Use Changes from 1956 to 1998 Over the Entire Study Area

Increases were seen in forested land (2198 acres), residential land (1789 acres), and commercial land (331 acres). Decreases were observed in agricultural land (2413 acres) and abandoned field land or upland scrub-shrub (2497 acres). The term "abandoned field" is frequently used in this paper and on maps as a synonym for the "upland scrub-shrub" type (code USS). Table 1 summarizes the changes that have occurred from 1956 to 1998.

Table 1. Merrymeeting Bay Land Use Summary 1956-1998

	1956	1981	1998
Agriculture (AGR)	4,672	2,611	2,259
Commercial (COM)	498	913	829
Forested (FOR)	12,020	14,539	14,219
Industrial (IND)	7	27	64
Residential (RES)	747	1,547	2,537
Abandoned Field (USS)	2942	929	445
Wetland (WET)	6,363	5,954	7,315
Open Water (OW)	5,695	6,412	5,245
Total	32,945	32,945	32,945

A second set of tables (2a. and 2b) show the above categories for 1956 cross-tabulated against the same classes for later years show the types of transitions that occurred. The tables use the codes for the classes listed above. Numbers in columns represent 1956 categories and how they are reclassified in the 1981 and 1998 maps. Similarly, numbers in rows represent the 1956 origins of 1998 and 1981 classes. For example the 1998 residential class (total 2537 acres) had its origin in 1956 classes AGR (892 acres), COM (29 acres), FOR (657 acres), RES (645 acres), USS (298 acres), WET (11 acres), and OW (4 acres). (The smaller categories (COM, WET, and OW) may be discounted as probably due to the error inherent in the mapping process).

Table 2a. Land Use Change from 1956 to 1998

	Land Use 56								
Land Use 98	AGR	COM	FOR	IND	RES	USS	WET	OW	**Grand Total**
AGR	2,029	3	72		19	114	22	0	2,259
COM	97	373	239		15	99	4	3	829
FOR	1,221	79	10,437		58	2,167	201	56	14,220
IND	13	3	25	2		9	12		64
RES	892	29	657		645	298	11	4	2,537
USS	320	0	18		2	96	9	0	445
UHE	18	3	1	5		5			32
WET	80	7	500		6	143	5,458	1,122	7,316
OW	3	1	71		3	12	646	4,509	5,245
Grand Total	4,672	498	12,020	7	748	2,942	6,363	5,695	32,945

Reading the AGR column of table 2a. similarly shows 1998 types for land typed as agriculture in 1956. About 43% remained in agriculture (2029 acres), but 26% (1221 acres) became forest, 19% (892 acres) became residential, about 7% (320 acres) became abandoned field (USS), and about 2% (97 acres) was put to some commercial use. A comparison of tables 2a and 2b shows that most of the transition of agricultural land to other uses had occurred by 1981, when only about 50% of the 1956 agricultural land remained in agriculture. Other trends can be similarly analyzed using these tables.

Table 2b. Land Use Change from 1956 to 1981

	Land Use 56								
Land Use 81	AGR	COM	FOR	IND	RES	USS	WET	OW	**Grand Total**
AGR	2,329	12	101		21	115	33	0	2,611
COM	139	371	237		16	131	19	1	913
FOR	1,036	91	10,738	0	74	2,254	293	61	14,548
IND			8	7		12			27
RES	449	17	326		596	152	5	3	1,547
USS	644	5	94		30	147	8	1	929
UHE	11	0	1			1			13
WET	60	2	440		4	120	4,954	412	5,993
OW	4	1	76		6	10	1,050	5,217	6,364
Grand Total	4,672	498	12,020	7	748	2,942	6,363	5,695	32,945

Silt and Sand Changes from 1956 to 1998

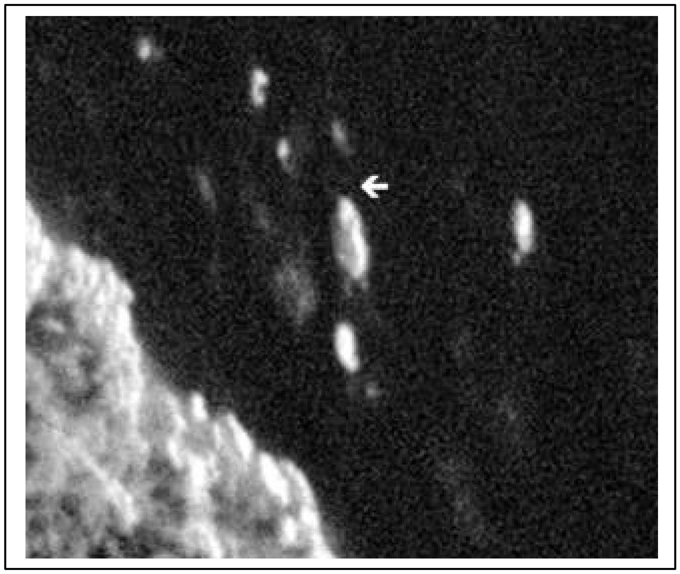
Although all aerial photographs were taken at or near low tide, there was still some variation in tide level between the three years. Before any conclusions could be drawn regarding changes in sand and silt, these differences needed to be evaluated. A close inspection was made of the photography for each year in order to determine the relative tide differences. Several spots were chosen within the bay that had highly visible rocks close to the surface of the water. At each spot, a particular rock was inspected for each year to determine relative tide heights. Figures 2 (below Chops, east side of Lines Island) and 3 (off south-west tip of Brick Island in Middle Bay) show two spots that were examined. 1998 photography proved to be the lowest tide level, followed by 1956, then 1981, which is reflected in the subtidal open water acreage (5194, 5683, and 6339 acres of open water respectively). Total acreage of the estuary is roughly the same for each year (about 10,700 acres).

Table 3. Intertidal and Subtidal Area by Year

	1956		1981		1998	
	Acres	Percent	Acres	Percent	Acres	Percent
Total Intertidal Zone	4,990	47%	4,324	41%	5,530	52%
Total Subtidal* Zone	5,683	53%	6,339	59%	5,194	48%
Total Area	10,673	100%	10,663	100%	10,724	100%

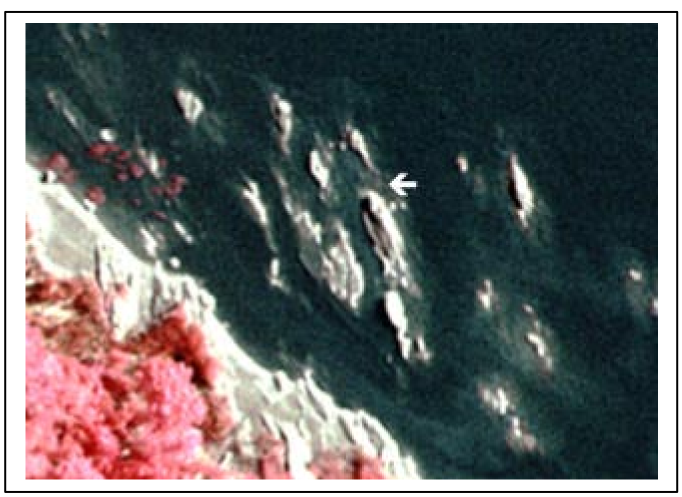
*Eliminating open water outside the estuary makes this number lower than the "land use" open water number.

Figure 2. Same rock in Chops sub-section off the east side of Lines Island used to determine relative tide levels among three time periods.



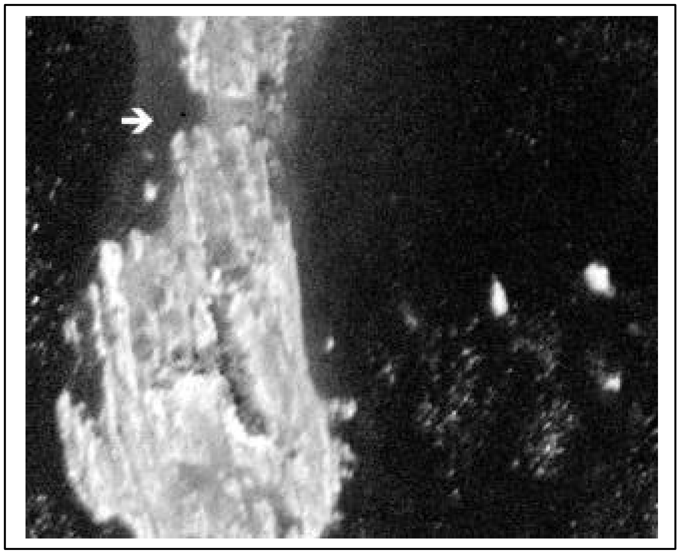
1956
Medium Tide Level

1981
Higher Tide Level

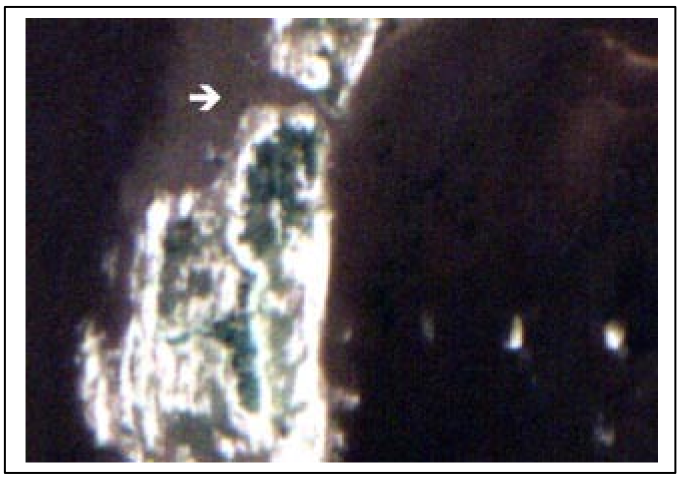


1998
Lower Tide Level

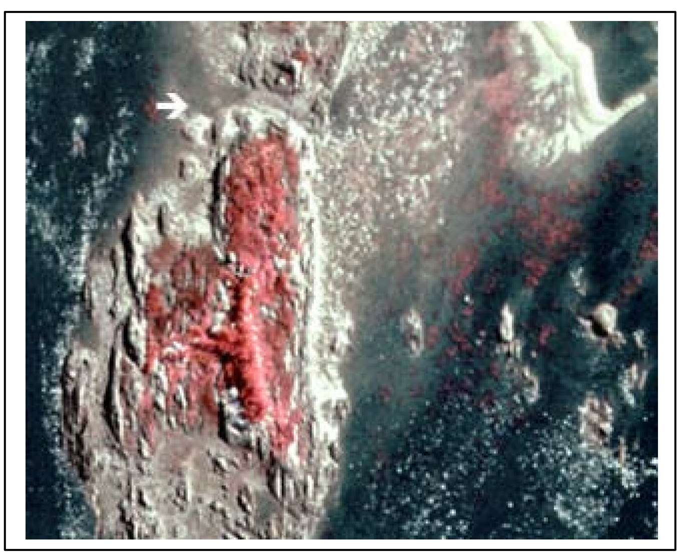
Figure 3. Same rock in Middle Bay sub-section near southwest tip of Brick Island used to determine relative tide levels among three time periods.



1956
Medium Tide Level



1981
Higher Tide Level



1998
Lower Tide Level

In silt and sand areas, the water line is very difficult to discern, but there is usually a clear break at the edge of the silt or sand where deeper water appears to begin. Silt and sand were therefore interpreted when they could be distinguished even if submerged. A review of the classification was conducted after all areas were interpreted to check for consistency in interpretation of sand and silt. As a result of the review, the photo interpreter felt the depth of water and therefore the amount of submerged silt and sand were relatively consistent from year to year. That is, about the same amount of underwater silt and sand is interpreted in each case.

Although based on total acreage, the entire bay saw an increase (1338 acres) of silt and sand from 1956 to 1998, i.e. More sand and silt was identified in the 1998 interpretation due to the lower water level. To correct for the difference in acres of sand and silt due to water level, the decrease in open water within the estuary from 1956 to 1998 was calculated. There was a decrease of 489 acres in open water. Correcting for this difference, silt and sand increased by about 850 acres between 1956 and 1998. (The same trend was observed by K.H. Anderson in 1982 who noted a 646 acre increase in silt and sand between 1956 and 1981.) Figure 4 shows that total silt, sand, and water were roughly equal between 1981 and 1998, but greater than in 1956.

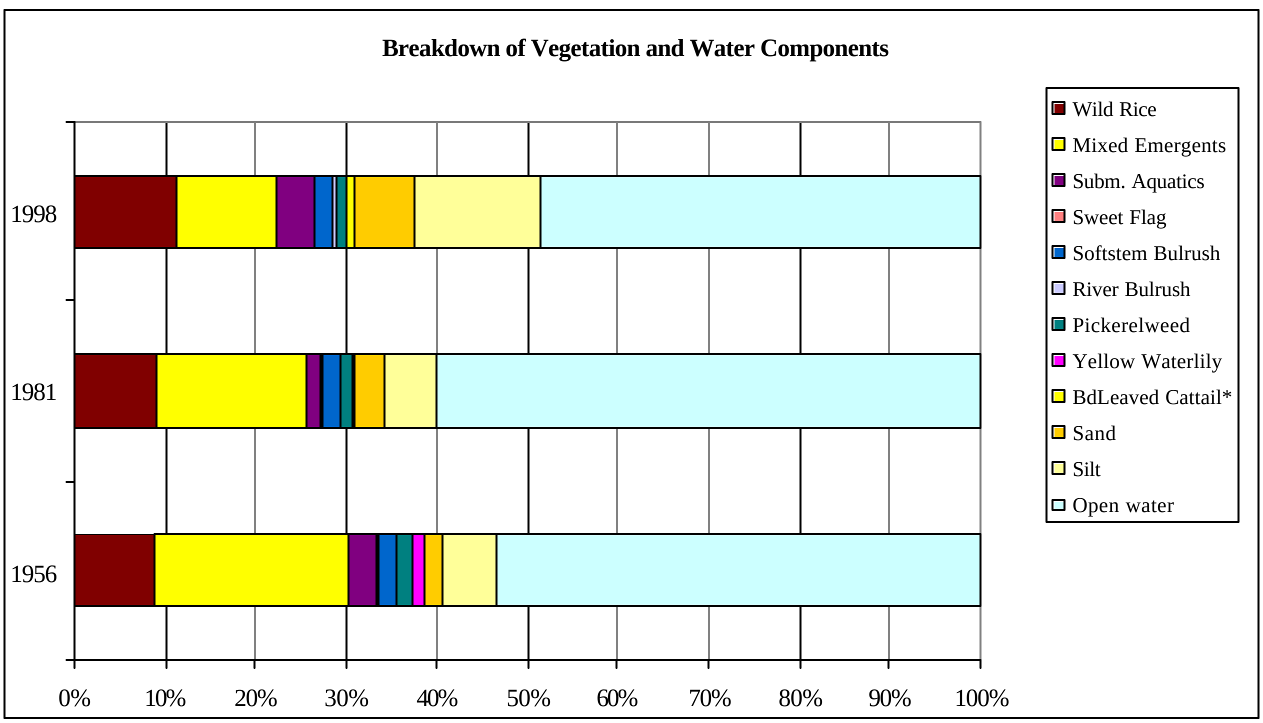


Figure 4. Breakdown of Vegetation and Water Components

Vegetation Changes from 1956 to 1998 Over the Entire Bay

Vegetation changes are reported in acres as well as a percent of change within each class, calculated as (1998acres-1956acres)/1956acres*100. Major increases for individual vegetation classes were seen in wild rice (283 acres or 30% increase) and submerged aquatics (102 acres or 30%). There was a major decrease in mixed emergent vegetation (-1117 acres or 49% decrease) possibly attributed to the dominance of wild rice at the time of photography in 1998, which decreased the mixed class. There was also a decrease in yellow waterlily (-101 acres or 84% decrease) and pickerelweed (-65 acres or 37% decrease).

Overall, the data show a change toward greater quantities of wild rice in 1998. It appears there may be a reciprocal relationship between wild rice and mixed emergents. When wild rice is an important component of a marsh stand and growing vigorously, it may easily achieve the 70% of cover needed to call the stand wild rice. When it does not have as good a season, the same area might well fall into the mixed emergent or other class. But in 1998, the wild rice dominance was clear where it was the interpreted species.

Although there was an increase in wild rice, there was a decrease (-786-acre or 23.6%) in emergent vegetation throughout the estuary. This difference had already occurred by 1981, with no reduction in emergent vegetation between 1981 and 1998. (The 1956 to 1981 reduction is corroborated by Anderson (1982), who noted a 650-acre decline in total vegetation in the Bay between 1956 and 1981). See Table 4 for a summary of estuarine cover composition change. For composition breakdown, see Figure 4.

Table 4. Intertidal Zone Composition Change

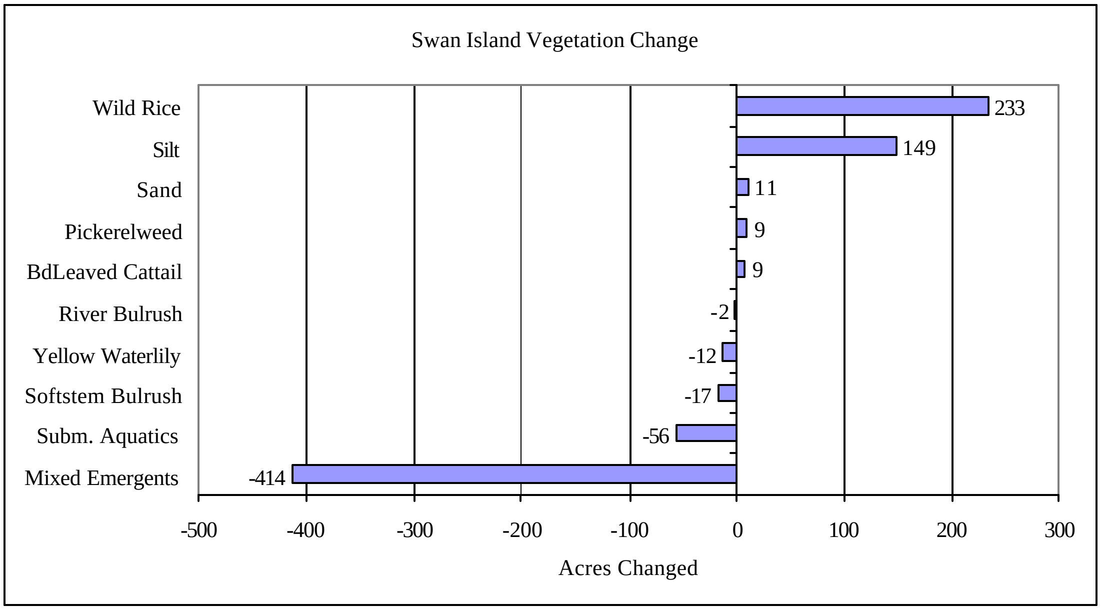
	Composition Change			Percent change		
	1956 Acres	1981 Acres	1998 Acres	1956 to 1981	1981 to 1998	1956 to 1998
Wild Rice	933	959	1,216	3%	27%	30%
Mixed Emergents	2,278	1,770	1,161	-22%	-34%	-49%
Subm. Aquatics	336	178	438	-47%	146%	30%
Sweet Flag	8	4	3	*	*	*
Softstem Bulrush	221	206	233	-7%	13%	5%
River Bulrush	13	9	28	*	*	*
Pickerelweed	178	124	113	-30%	-9%	-37%
Yellow Waterlily	121	50	20	-59%	-60%	-84%
BdLeaved Cattail	4	7	95	*	*	*
Total Vegetation	4,092	3,306	3,306	-19%	0%	-19%
High Tide Zone	52	7	44	*	*	*
Rock	8	30	4	*	*	*
Sand	221	346	695	57%	101%	215%
Silt	617	635	1,481	3%	133%	140%

* No change (absolute size of the category too small to conclude relative change)

Vegetation Changes from 1956 to 1998 by Sub-Section

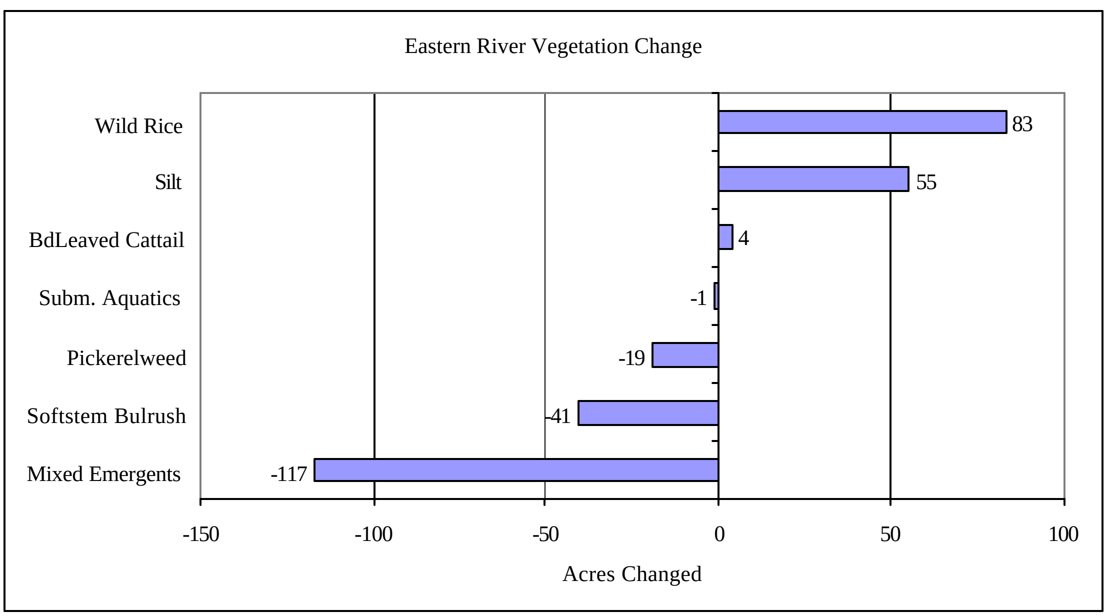
Swan Island

There were major increases in wild rice (233 acres), and silt (149 acres) in the Swan Island sub-section. Mixed emergent vegetation decreased (-414 acres), as well as submerged aquatics (-56 acres), softstem bulrush (-17 acres) and yellow waterlily (-12 acres). There was an overall decrease (-194 acres) of emergent vegetation.



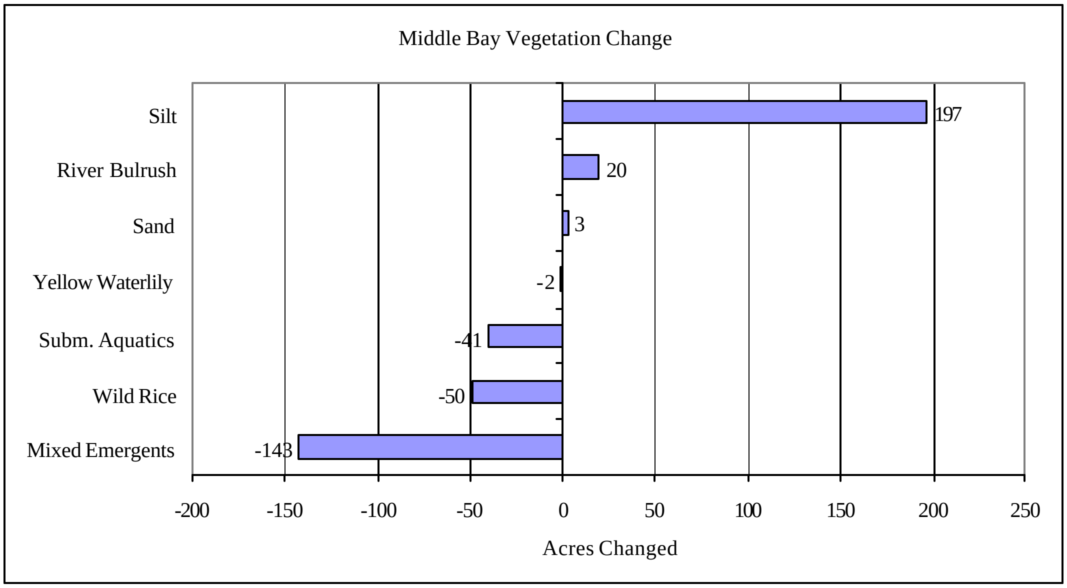
Eastern River

This subsection saw an increase in wild rice (83 acres) and silt (55 acres). The mixed emergent vegetation decreased (-117 acres), as well as softstem bulrush (-41 acres) and pickerelweed (-19 acres). There was an overall decrease of emergent vegetation (-90.5 acres).



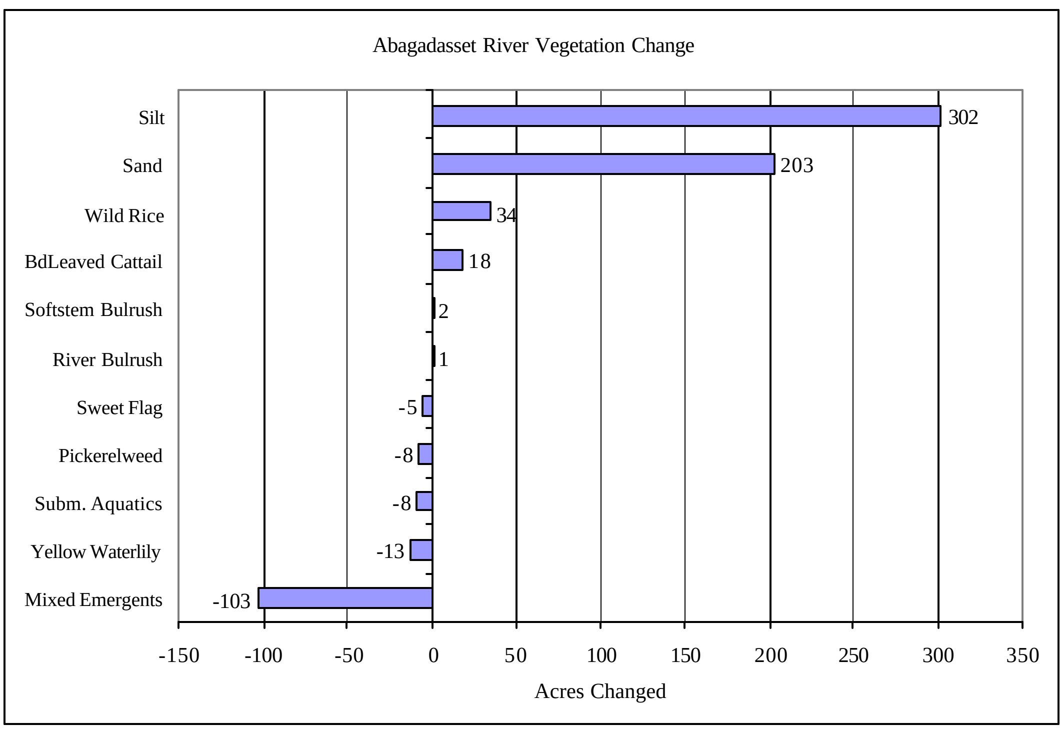
Middle Bay

The only large-scale increase in this subsection was silt (197 acres). Major decreases were observed for mixed emergent vegetation (-143 acres), wild rice (-50 acres), and submerged aquatic vegetation (-41 acres). There was an overall decrease of emergent vegetation (-175 acres).



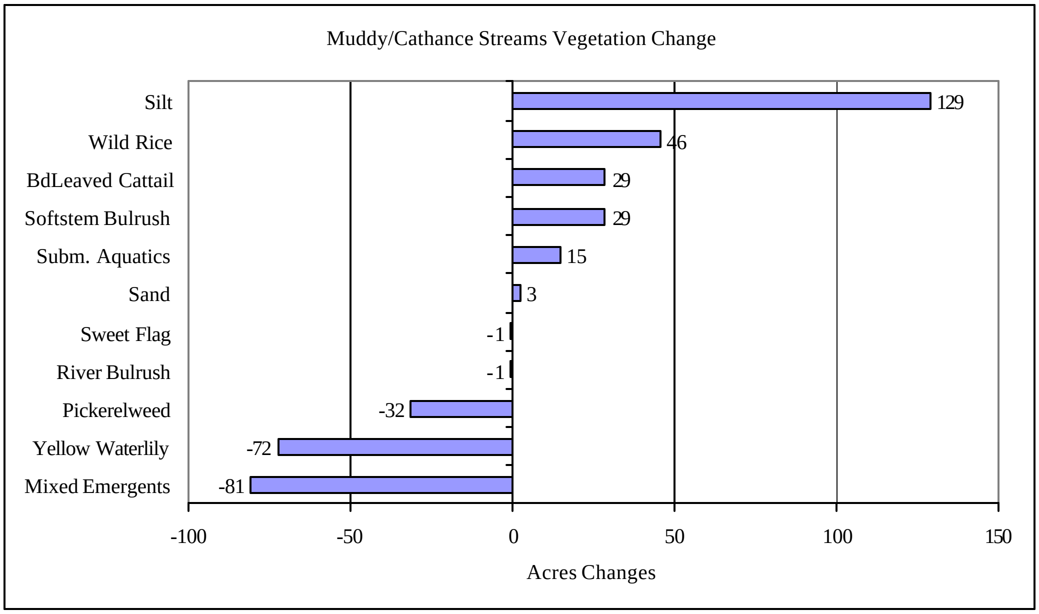
Abagadasset River

This sub-section saw the largest increase in silt (302 acres) and sands (203 acres). There was an increase in wild rice (34 acres) and broad-leaved cattail (18 acres). Decreases were observed in mixed emergent vegetation (-103 acres), yellow waterlily (-13 acres), submerged aquatic vegetation (-8 acres). There was a decrease in emergent vegetation (-72 acre).



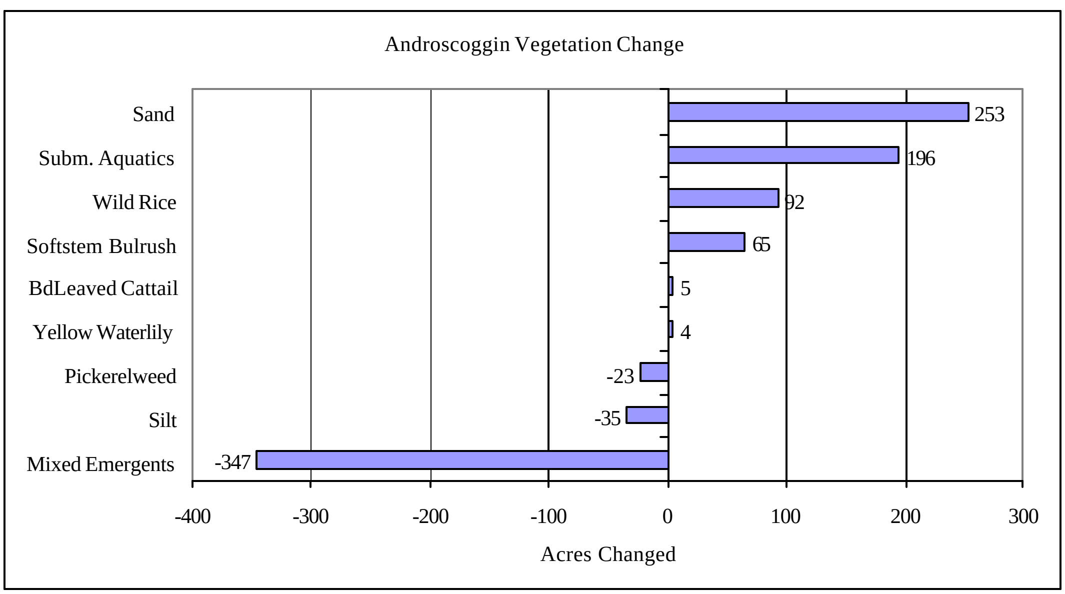
Muddy and Cathance Streams

Silt increased (129 acres) in this sub-section. Other increases were observed in wild rice (46 acres), broad-leaved cattail (29 acres), softstem bulrush (29 acres), and submerged aquatic vegetation (15 acres). Mixed emergent vegetation decreased (-81 acres), as well as yellow waterlily (-72 acres), and pickerelweed (-32 acres). There was an overall decrease of emergent vegetation (-83 acres).



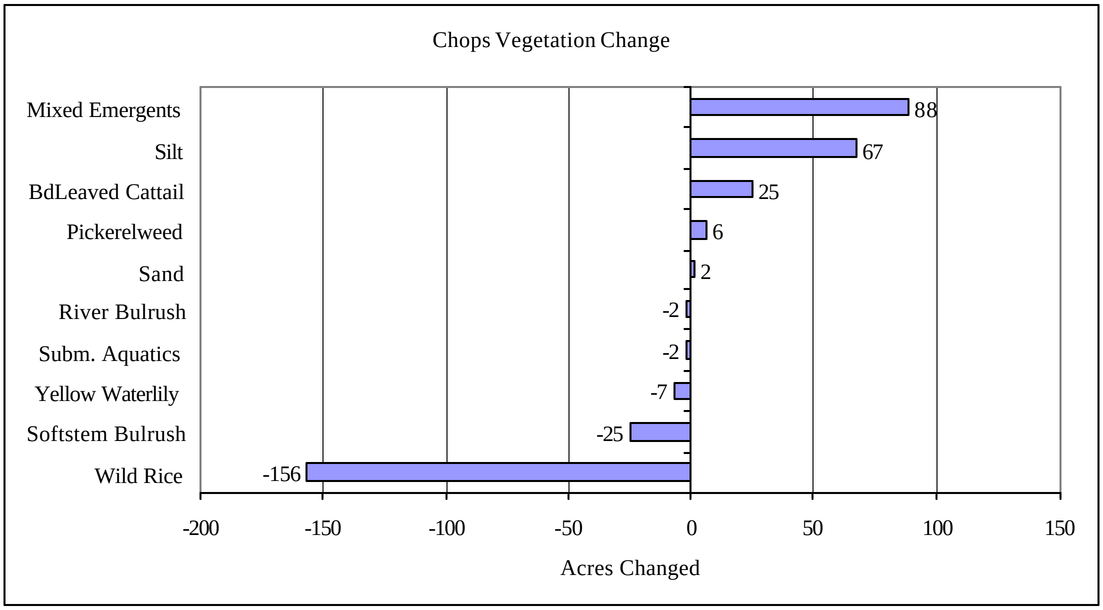
Androscoggin

This sub-section saw the largest increase in sand (253 acres), and submerged aquatic vegetation (196 acres). Increases were also observed in wild rice (92 acres) and softstem bulrush by 65 acres. Decreases were observed in mixed emergent vegetation (-347 acres), silt (-35 acres) and pickerelweed (-23 acres). There was a decrease in emergent vegetation (-202 acres).



Chops

Increases in mixed emergent vegetation (88 acres), silt (67 acres), and broad-leaved cattail (25 acres). There were decreases in wild rice (-156 acres), softstem bulrush (-25 acres), and yellow waterlily (-7 acres). There was a decrease in emergent vegetation (-71 acres).



Buildings

The digitized buildings were tallied for the study area, and by sub-section. The numbers of buildings increased by 235 over the whole study area, from 1956 to 1981, and increased another 1283 from 1981-1998. When divided by sub-section, several areas decreased in number of buildings from 1956 to 1981. This may be attributed to the decline of agricultural buildings, which were then replaced by residential building after 1981. See Table 5 and Figure 5 for a summary of sub-section changes.

Table 5. Numbers of Buildings in Study Area by Section and Year

Section	1956	1981	1998
Swan Island	577	563	693
Eastern River	104	100	162
Abagadasset R.	55	50	90
Middle Bay	44	35	41
Muddy/Cathance	105	110	189
Chops	254	245	375
Androscoggin R.	715	986	1822
Total	1854	2089	3372

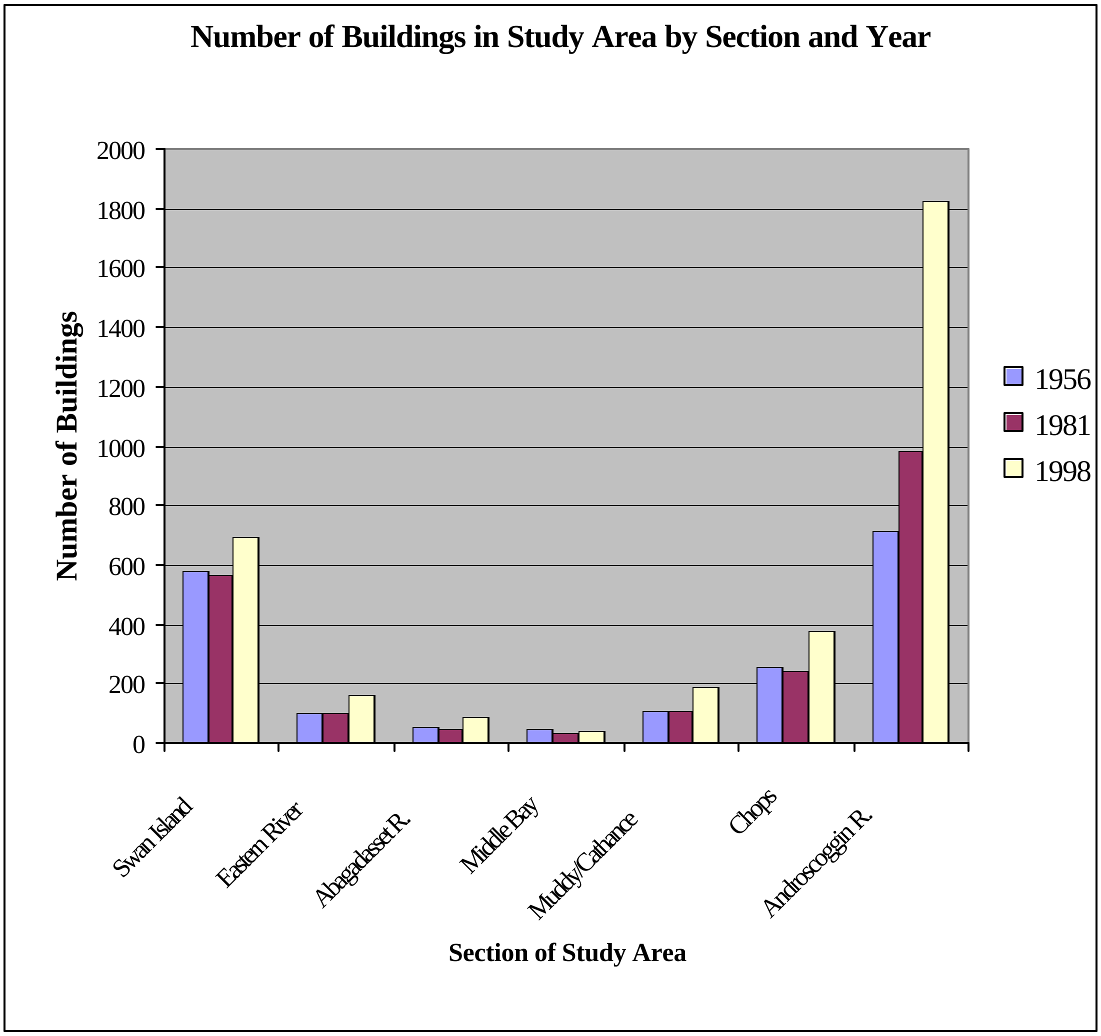


Figure 5. Number of Buildings in Study Area

SUMMARY

A Geographic Information System was used to replicate 1956 and 1981 analyses of Merrymeeting Bay wetlands, and extend them 17 years, to 1998. Upland areas for a half-mile buffer surrounding the bay were included. The methods used allow detailed cross-tabulation of conditions between years, showing not only differences in land use and vegetation, but also where those changes occurred.

Trends noted within the Bay in the 1956-1981 interval corroborated the findings of earlier studies: there was an increase in silt/sand and a decrease in emergent vegetation. Between 1981 and 1998 this trend appeared to have stabilized, with no significant increase in silt/sand. Total emergent vegetation remained stable, although there was a shift among species, with wild rice showing an increase. It is difficult to conclude from the data of this study alone, however, whether the dominance of wild rice is a long-term or short-term effect of favorable conditions, since wild rice is an annual.

In upland areas, the land use and buildings data clearly reflect the significant increase in human population and corresponding decreases in other land use types, notably agriculture. About half of the 1956 agricultural acreage transitioned to forest or a developed condition by 1998. The number of buildings in the study area more than tripled between 1956 and 1998.

The digital information resulting from this study will provide a good base for future analyses, as long term trends in the bay continue to be examined.

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