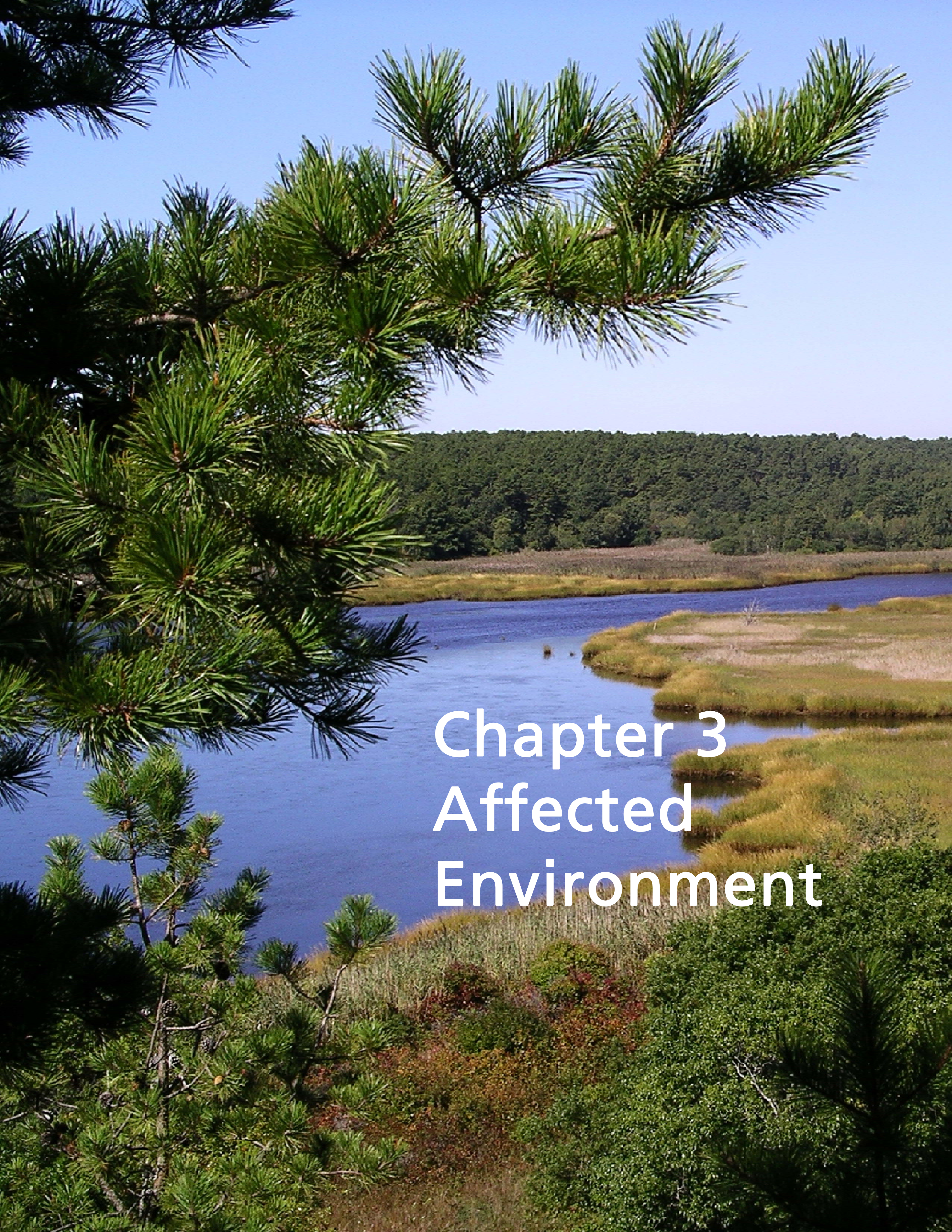


Chapter 3
Affected Environment

CHAPTER 3: AFFECTED ENVIRONMENT

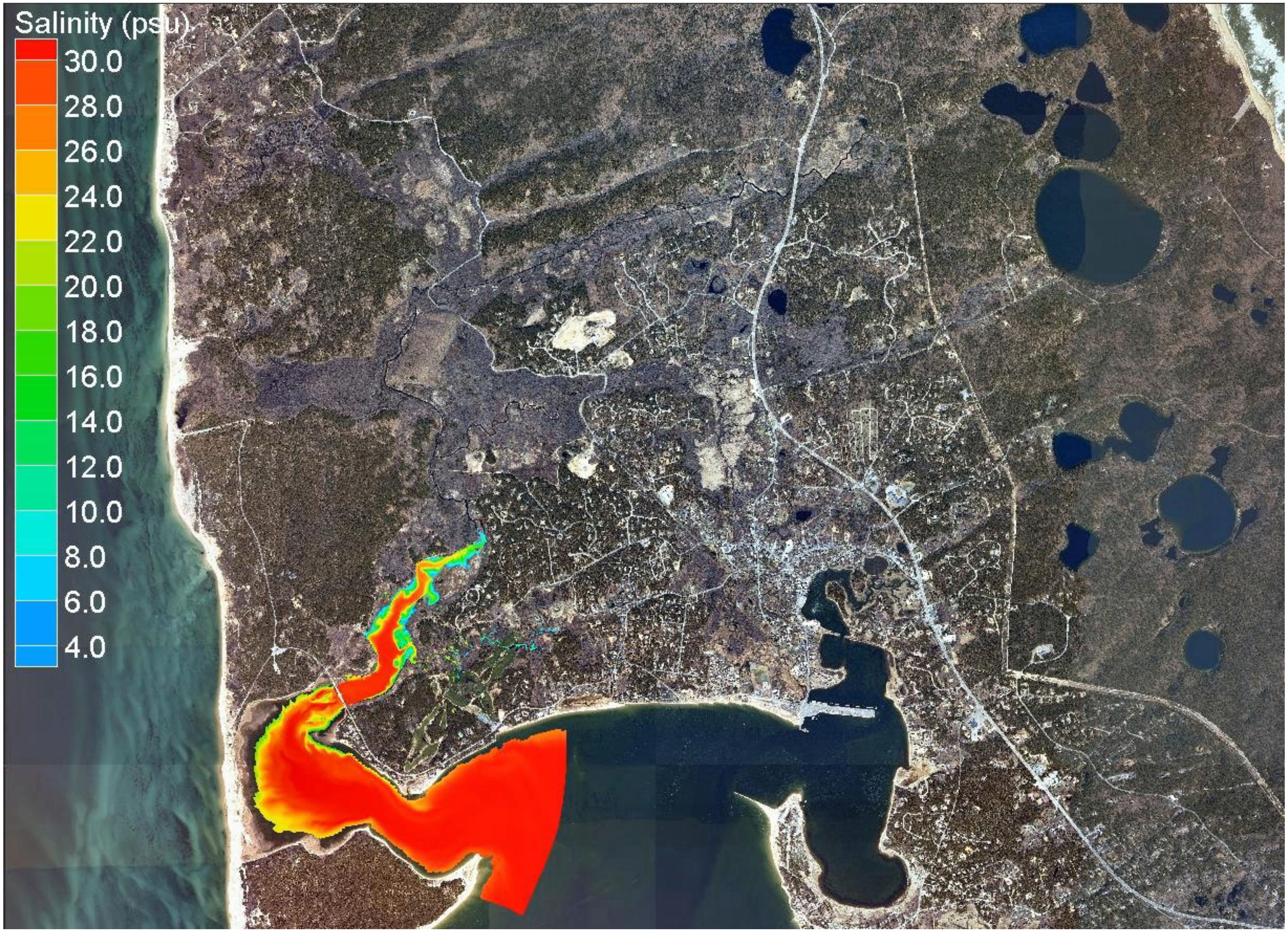
This chapter describes the existing resource conditions in the project area, and includes background on historic conditions, as appropriate. Resources affected by current and proposed management of the Herring River flood plain have been included, based on issues identified in chapter 1. The conditions described in this Affected Environment chapter serve as the baseline against which to measure changes anticipated from the proposed alternatives.

3.1 INTRODUCTION

The Herring River estuary is characteristic of Atlantic coastal estuarine environments found along the eastern United States, where freshwater from rivers, streams, and groundwater meet and mix with salt water from the ocean. These estuaries are among the most productive ecosystems on earth, creating more organic matter each year than comparably sized areas of forest, grassland, or agricultural land (USEPA 2008). The tidal, sheltered waters of estuaries also support unique communities of plants and animals, specially adapted for life at the land/sea margin. Many different habitat types are found in and around estuaries, including shallow open waters, freshwater and salt marshes, swamps, sandy beaches, mud and sand flats, rocky shores, oyster reefs, and sea grass meadows. In addition to supporting a variety of wildlife habitat, salt marsh grasses, and other wetland plants found in estuaries help to prevent erosion through streambank stabilization, provide storm surge protection, and provide vital pollution control for water draining from upland areas. During the last 200 years, 50 percent of United States coastal wetlands have been lost and even more have been substantially altered (Stedman and Dahl 2008). Along the Atlantic Coast, long-term diking and drainage efforts to control mosquito populations and for agricultural and land development have affected many coastal marshes, including the Herring River estuary. These alterations have dramatically changed the hydrologic patterns of tidal wetlands. During the last 100 years, natural estuarine functions within the Herring River estuary have been severely affected by reductions in tidal inundation and flushing. For additional information on the history of modifications to the Herring River estuary, see “Section 1.6: Background” in chapter 1.

3.2 SALINITY OF SURFACE WATERS

In Wellfleet Harbor, salinity typically ranges between 30 and 32 parts per thousand (ppt) (National Park Service (NPS) data, as presented in WHG 2009). Based on the analysis of plant remains (Orson, in Roman 1987), prior to construction of the dike in 1909, salinity penetration was extensive enough to support salt marsh cord-grass (*Spartina alterniflora*) throughout the historic flood plain. Construction of the dike has limited the upstream mean tide range to only 2.2 feet compared to 10.3 feet downstream of the dike (WHG 2012). Because of this altered hydrology, saline waters during high tide currently extend approximately 1.2 miles upstream of the dike (figure 3-1).



Note: psu = practical salinity unit; whereas ppt is parts per thousand. For the purposes of this analysis these units are used interchangeably.

Figure 3-1: Modeled Maximum Salinities for Mean High Spring Tide Under Existing Conditions

Salinity levels, along with other water and sediment quality parameters, are routinely monitored by Seashore staff. Monitoring was conducted monthly from March to October 2006 and 2010 during low tide conditions at 11 locations (figure 3-2). Monitoring took place independent of weather conditions during or prior to the sampling events. The monitored stations can be clustered into four general groups based on their site conditions:

Station 1: Unrestricted river mouth—This station was located on the harbor side of the dike and was representative of the conditions in the upper portion of Wellfleet Harbor and the unrestricted lower basin of the Herring River.

Stations 2, 3, 4, 8, 9: Tide-restricted, mid-river channels—These stations had flowing water at varying flow rates. The stations were within the zone of acid sulfate soils.

Stations 3A, 6, 10: Tide-restricted mosquito ditches—These ditches carried water only intermittently, and thus may have had standing water (which was sampled and analyzed) or could have been dry. All three stations were in ditches that drained acid sulfate soils.

Stations 5, 11: Tide-restricted, headwater channels—These stations in the headwater of the estuary had flowing water and did not receive discharge from drained acid sulfate soils.

The 2006 to 2010 Seashore monitoring data confirm that the waters within the upper estuary are consistently fresh (figure 3-3). Although these measurements were made during low tide, other observations (NPS 2007b; Portnoy and Allen 2006) document that saline water never reaches High Toss Road during normal tides. Downstream of the dike (station 1), waters at low tide were brackish to marine with monthly mean salinities of 15 to 27 ppt.

FIGURE 3-2: CAPE COD NATIONAL SEASHORE HERRING RIVER WATER QUALITY MONITORING STATIONS

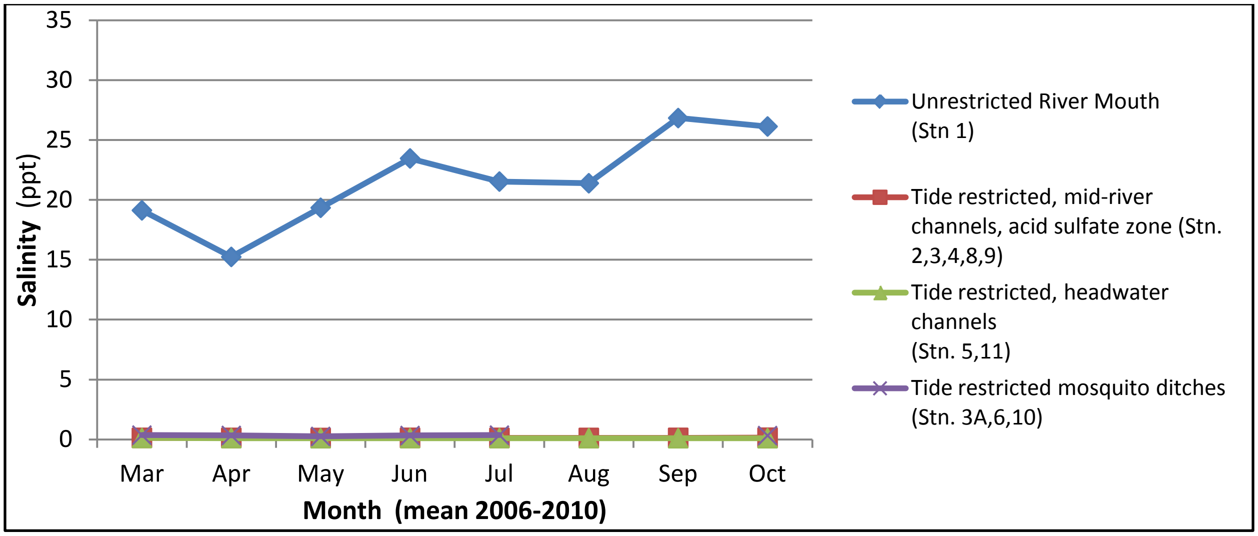


FIGURE 3-3: MONTHLY MEAN SALINITIES FOR THE HERRING RIVER AND ESTUARY AT LOW TIDE AS MONITORED BY THE CAPE COD NATIONAL SEASHORE (2006 TO 2010)

3.3 WATER AND SEDIMENT QUALITY

The Massachusetts Surface Water Quality Standards (314 CMR 4.00) have designated the Herring River as Class SA waters, the highest coastal and marine class. Class SA waters are required to have excellent habitat for fish, other aquatic life and wildlife, and primary and secondary recreation. The Herring River is also designated to be suitable for shellfish harvesting. In addition, the Herring River, and most of the Seashore, is designated by the Commonwealth as Outstanding Resource Waters [314 CMR 4.06(3)]. Outstanding Resource Waters include waters designated for protection based on their high socioeconomic, recreational, ecological, and aesthetic values. However, the Herring River estuary currently does not meet its targeted designations under the Massachusetts' regulations due to its degraded water quality conditions.

Water quality concerns have also resulted in the listing of Herring River on the 303(d) list of impaired waters under the federal Clean Water Act (CWA) (MassDEP 2011a). States are required to identify waters that do not meet requirements of their designated use. Specifically, Herring River segment MA96-07 (Herring Pond to south of High Toss Road) is impaired for metals and pH. Herring River segment MA96-33 (from south of High Toss Road to Wellfleet Harbor) is impaired for pathogens. Wellfleet Harbor (segment MA96-34) is also on the list as impaired for pathogens.

The following discussion of water and sediment quality describes the current environment as a result of historic disturbances to the Herring River estuary.

Over the last 100 years the surface water quality in the Herring River estuary has declined because of the severely restricted tidal flushing of the estuary as well as the drainage of marsh soils and sediments. Water quality and sediment quality are interrelated because chemical processes within the sediments affect the quality of the ground and surface water and vice versa. Relevant parameters discussed in more detail are dissolved oxygen, fecal coliform, pH, sulfate, metals, nutrients, and pesticides. The descriptions of current conditions are based on data from the ongoing monitoring program for the 5-year period between 2006 and 2010 (as described in section 3.2), as well as findings from other published technical studies.

3.3.1 Dissolved Oxygen

Decomposition of inorganic reduced compounds and organic matter in marsh peat contributes to high biological oxygen demand in sections of the Herring River estuary, particularly in summer. Low dissolved oxygen results from the combination of high oxygen demand (especially during periods of high water temperature) and greatly reduced tidal flushing, which would normally import copious volumes of oxygen-saturated seawater. Anoxic and near-anoxic conditions exist regularly along the mainstem of the river, particularly after heavy rains increase runoff of organic matter from the wetland (Portnoy 1991). Mean dissolved oxygen concentrations measured from 2006 to 2010 were below the regulatory limit of 6 mg/l for Class SA waters at all stations in the summer months (figure 3-4). During individual sampling events over the 5-year period, the minimum concentrations in some cases approached anoxic conditions (table 3-1). These low minimum concentrations were measured throughout the estuary upstream of the dike, with the lowest concentrations found within the mosquito ditches. Generally, dissolved oxygen concentrations in the mid-river channels as well as in the headwater channels were similar to concentrations near the dike.

Low dissolved oxygen concentrations have stressed anadromous fish species and resident aquatic fauna, and have resulted in fish kills (Portnoy 1991). In the past, low oxygen conditions in the summer compelled the NPS to control the emigration of juvenile herring to prevent complete mortality and loss of diadromous fish migration (Portnoy, Phipps, and Samora 1987), although this activity is no longer practiced. Conditions have improved since the discontinuation of annual dredging of the river for mosquito control in 1984 (HRTC 2007).

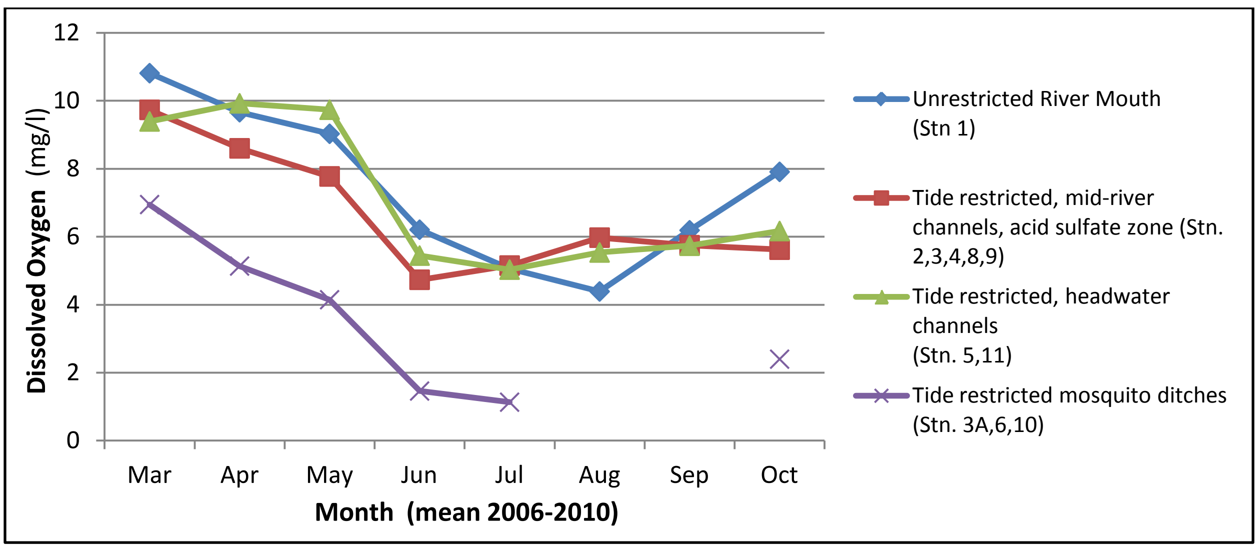


Figure 3-4: Monthly Mean Dissolved Oxygen Concentrations in the Herring River at Low Tide (2006 to 2010 Cape Cod National Seashore Monitoring Data)

TABLE 3-1: MEAN, MINIMUM, AND MAXIMUM MONTHLY DISSOLVED OXYGEN CONCENTRATIONS IN THE SURFACE WATER OF HERRING RIVER BETWEEN 2006 AND 2010 (CAPE COD NATIONAL SEASHORE MONITORING DATA)

Station	Dissolved Oxygen (monthly Mean, 2006–2010) (mg/l)*								Combined March to October Dissolved Oxygen (mg/l)				No. of ALL Samples
	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Mean	std dev	Max	Min	
River Mouth: Unrestricted													
1	10.8	9.7	9.0	6.2	5.1	4.4	6.2	7.9	7.4	2.3	11.8	2.8	31
Mid-river Channels: Tide restricted, acid sulfate zone													
2	9.8	8.9	8.4	5.6	5.7	6.5	6.3	6.7	7.2	1.6	10.9	3.0	31
3	10.1	8.9	8.0	5.4	5.1	6.0	6.3	6.2	7.0	1.8	11.2	3.0	31
4	10.1	8.8	7.7	4.5	5.1	6.6	6.6	6.4	7.0	1.9	11.4	2.6	31
8	9.8	9.1	8.9	5.6	5.6	6.3	5.5	5.9	7.1	1.8	12.6	1.1	31
9	8.9	7.4	5.9	2.6	4.3	4.6	4.1	3.0	5.1	2.2	10.6	0.6	31
Headwater Channels: Tide restricted													
5	8.4	9.4	8.5	3.7	3.1	4.8	5.7	5.8	6.2	2.4	12.0	1.9	30
11	10.4	10.4	11.0	7.2	7.0	6.3	5.8	6.5	8.1	2.1	15.1	2.7	31
Mosquito Ditches: Tide restricted													
3A	5.5	4.9	3.6	2.4	1.3	dry	dry	3.7	3.6	1.6	7.1	1.1	18
6	9.2	5.7	4.2	1.2	1.0	dry	dry	0.8	3.7	3.4	10.4	0.8	18
10	6.2	4.8	4.6	0.7	dry	dry	dry	2.7	3.8	2.1	9.3	0.4	18

* Samples were collected at low tidal conditions.

3.3.2 PH AND SULFATE

Salt marsh soils in the Herring River estuary are naturally rich in sulfur. This is because salt marsh microbes commonly use sulfate, abundant in seawater, as an oxidizing agent to decompose organic matter in anoxic marsh sediments. The process produces dissolved sulfide, a large fraction of which is sequestered as iron sulfides, particularly pyrite; this mineral is very stable under water-saturated and anaerobic conditions. However, diking and drainage of the salt marsh has allowed air to enter the normally anaerobic subsurface environment converting it to an aerobic environment in which organic matter and iron-sulfide minerals are readily oxidized. As a result, the sulfide has reacted with oxygen to form sulfuric acid which has acidified the soil to pH levels less than three. The pH of surface waters can also be lowered to pH levels of three to five when sulfuric acid contained in the soil infiltrates surface water. Acidic water can result in a loss of aquatic vegetation, as well as the killing of fish and other organisms. For example, in 1980 acidic water released into the Herring River main channel following mosquito-control ditching, accompanying sediment disturbance and aeration, and heavy rainfall resulted in a die-off of thousands of American eel (*Anguilla rostrata*) and other fish species. During this event, pH levels of less than four were recorded in the mainstem of the Herring River (Soukup and Portnoy 1986).

The regulatory standard for pH for Class SA waters is 6.5 to 8.5. Currently, the pH levels in the channels of the estuary are often lower than the regulatory standard. Portnoy and Giblin (1997a) reported that acidic sulfate soils with pH levels of less than four can be found throughout much of the Duck Harbor, Lower Pole Dike Creek, Lower Herring River, and Mill Creek sub-basins. Soukup and Portnoy (1986) reported pH levels ranging from 6.0 to 4.2 in the water of the mainstem and 3.9 to 3.3 in drainage ditches.

The 2006 to 2010 monitoring data also show that low pH levels persist in the estuary, although the absence of mosquito control ditch maintenance since 1984 has allowed some improvement. Specifically, the March to October mean pH levels in the surface water of the mid-river channels ranged from approximately 5.5 to 6.0 (figure 3-5), reaching minimum pH levels as low as 3.6 during individual sampling events (table 3-2). In the drainage ditches, the mean pH was even lower ranging from approximately 4.5 to 5.5, with minimum pH levels reaching 3.0 during individual sampling events. The mean pH levels in the headwater channels were around 6, ranging from 4.4 to 7.0 during individual sampling events. These stations are affected more by groundwater seepage from the upland and outflows from the kettle ponds. Groundwater throughout Cape Cod has pH levels of between 6 and 6.5; Frimpter and Gay (1979) measured a median pH of 6.1 in 202 wells. Due to the permeability of the sandy soils on Cape Cod, pond waters have similar pH levels as the groundwater. The average surface pH of 193 ponds sampled on Cape Cod was 6.2 with a range of 4.4 to 8.9 (Eichner et al. 2003). Ponds that are least affected by development have pH levels closer to average pH level of rain of 5.7 (Eichner 2009). These data indicate that the pH of the headwater stations reflect average conditions on Cape Cod, whereas pH levels in the mid-river section, particularly in the drainage ditches, are lowered by chemical oxidation processes.

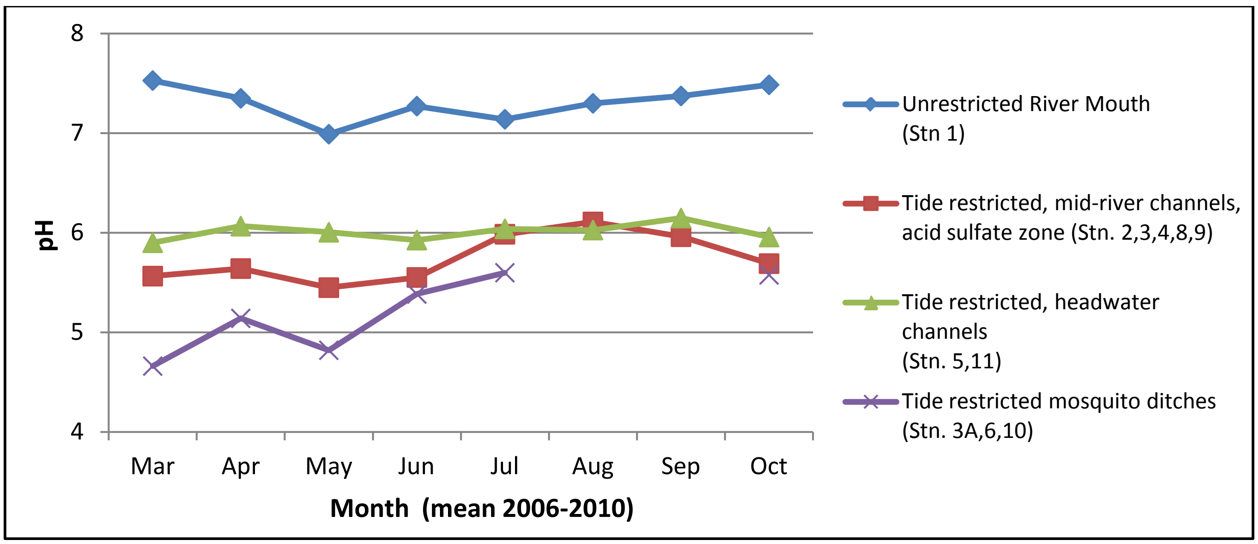


FIGURE 3-5: MONTHLY MEAN PH LEVELS IN THE HERRING RIVER AT LOW TIDE (2006 TO 2010 CAPE COD NATIONAL SEASHORE MONITORING DATA)

TABLE 3-2: MEAN, MINIMUM, AND MAXIMUM MONTHLY pH LEVELS IN THE SURFACE WATER OF HERRING RIVER (2006 TO 2010 CAPE COD NATIONAL SEASHORE MONITORING DATA)

Station	pH (monthly Mean, 2006–2010)*								Combined March to October pH Levels				No. of ALL Samples
	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Mean	std dev	Max	Min	
River Mouth: Unrestricted													
1	7.5	7.3	7.0	7.3	7.1	7.3	7.4	7.5	7.3	0.2	8.2	6.6	39
Mid-river Channels: Tide restricted, acid sulfate zone													
2	5.5	5.7	5.5	5.4	6.3	6.2	5.9	6.0	5.8	0.3	6.9	4.2	39
3	5.5	5.7	5.4	5.6	6.3	6.4	6.2	5.9	5.9	0.4	7.5	4.1	39
4	5.9	5.9	5.8	5.8	5.9	6.1	6.2	5.9	5.9	0.2	7.2	4.4	39
8	5.9	5.8	5.6	5.8	5.9	6.2	5.9	5.9	5.9	0.2	6.9	4.9	39
9	5.1	5.2	4.9	5.2	5.5	5.5	5.6	4.8	5.2	0.3	6.8	3.6	39
Headwater Channels: Tide restricted													
5	5.9	6.0	5.8	5.6	5.9	6.0	6.0	6.0	5.9	0.2	6.7	4.4	38
11	5.9	6.1	6.2	6.3	6.2	6.1	6.3	5.9	6.1	0.1	7.0	5.2	39
Mosquito Ditches: Tide restricted													
3A	3.5	3.8	3.8	4.5	4.5	dry	3.9	4.8	4.1	0.5	5.8	3.0	21
6	6.3	6.1	5.5	5.8	6.7	dry	dry	6.0	6.1	0.4	8.7	5.0	21
10	4.2	5.5	5.1	5.9	dry	dry	dry	6.0	5.3	0.7	6.7	3.3	21

* Samples were collected at low tidal conditions.

Downstream of the dike, the March to October mean pH level was 7.4 (with a range of 6.6 to 8.2), meeting the regulatory standard. These pH levels indicate that the volume of acidic water in the upper part of the estuary is small enough to be neutralized quickly once the water reaches the well-buffered tidal water of the lower estuary. For reference, the pH in Wellfleet Harbor is approximately eight (Cape Cod Extension 2011). Sulfate generated in the acid sulfate zone of the Herring River estuary does not affect receiving marine waters because this anion is naturally abundant in seawater and is neutralized by seawater cations, especially sodium and magnesium. The mean annual sulfate concentrations at the stations in the upper estuary were 0.009 mg/l at the headwater stations, 0.014 mg/l at the mid-river stations, and 0.066 mg/l in the mosquito ditches. The mean March to October sulfate concentration at the unrestricted station 1 was substantially higher at 1.3 mg/l (figure 3-6).

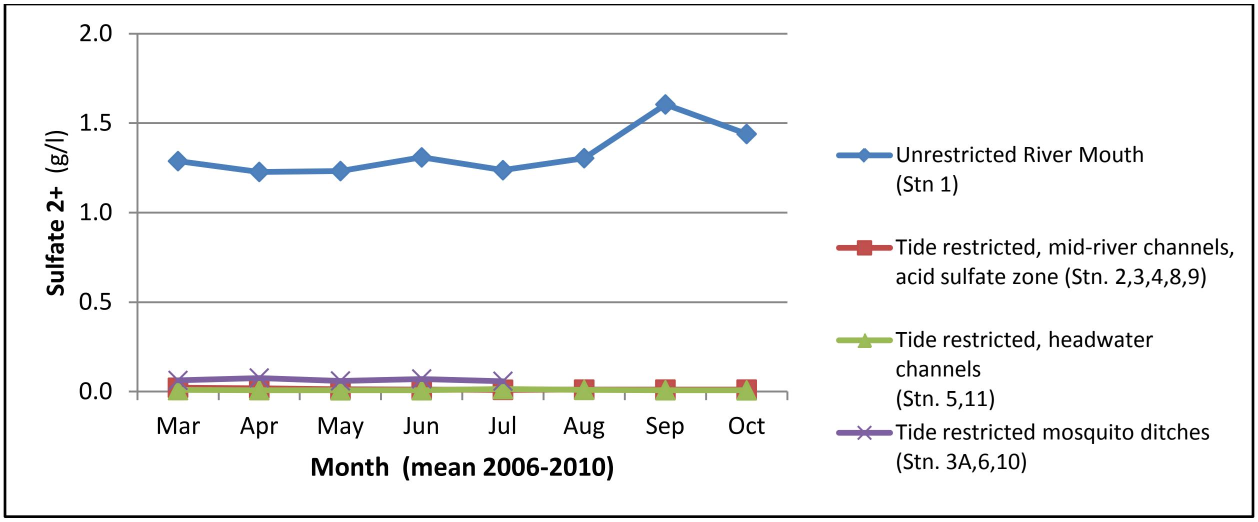


FIGURE 3-6: MONTHLY MEAN SULFATE CONCENTRATIONS IN THE HERRING RIVER AT LOW TIDE FROM 2006 TO 2010 (CAPE COD NATIONAL SEASHORE MONITORING DATA)

3.3.3 METALS

Metals in Surface Water

Low pH levels can cause leaching of metals from marsh soil, degrading water quality if they reach toxic concentrations. As stated previously, salt marsh soils naturally contain iron sulfides (particularly pyrite) that form under water-saturated and anaerobic conditions. Oxidation of the soil in dewatered marshes, such as the Herring River, releases iron, which may be present as ferrous iron (Fe^{2+}) and as ferric iron (Fe^{3+}). Total dissolved iron concentrations in surface water measured by the Seashore from 2006 to 2010 were highest at locations with the lowest flushing. Specifically in mosquito ditches, the mean March to October total iron concentration ranged from 9 mg/l to 18 mg/l (figure 3-7), with individual measurements over this 5-year period reaching 76 mg/l. Mean total iron concentrations at the mid-river channel stations were lower, ranging from 1 mg/l to 3 mg/l, but still highly variable which may have been a function of varying flow rates. At the headwater stations, the mean March to October total iron concentrations were 0.5 mg/l with much lower variability among sampling events. The mean March to October total iron concentration at the dike was 0.27 mg/l. The U.S. Environmental Protection Agency (USEPA) recommends a criterion of 1 mg/l for freshwater chronic conditions (see table 3-3 for definition). This criterion was often exceeded at the stations in the mosquito ditches and in the acid sulfate zone, but rarely at the headwater stations. There are no recommended criteria for iron in salt water (which would apply to the station downstream of the dike).

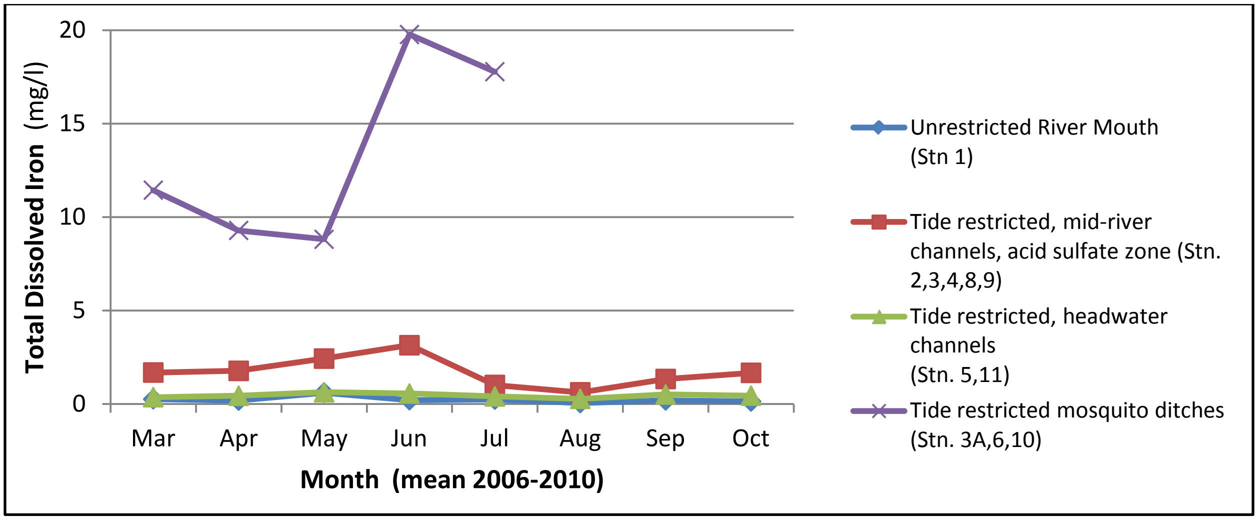


FIGURE 3-7: MONTHLY MEAN TOTAL IRON CONCENTRATIONS IN THE HERRING RIVER AT LOW TIDE FROM 2006 TO 2010 (CAPE COD NATIONAL SEASHORE MONITORING DATA)

TABLE 3-3: NATIONAL RECOMMENDED WATER QUALITY CRITERIA FOR SELECTED METALS

Metal	Freshwater		Salt Water	
	Criteria Maximum Concentration (or Acute) [a]	Criteria Continuous Concentration (or Chronic) [b]	Criteria Maximum Concentration (or Acute) [a]	Criteria Continuous Concentration (or Chronic) [b]
Aluminum (mg/l) (pH 6.5 – 9.0)	0.750 [c]	0.087 [c, d]	--	--
Arsenic (mg/l)	0.340 [e]	0.150 [e]	0.069 [e]	0.036 [e]
Iron (mg/l)	--	1.000	--	--

Source: USEPA 2009.

a "Acute criteria" corresponds to the USEPA definition of "Criteria Maximum Concentration" which was defined in 40 CFR 131.36 as the highest concentration of a pollutant to which aquatic life can be exposed for a short period of time (1-hour average) without deleterious impacts.

b "Chronic criteria" corresponds to the USEPA definition of "Criteria Continuous Concentration" which is defined in 40 CFR 131.36 as the highest concentration of a pollutant to which aquatic life can be exposed for an extended period of time (4 days) without deleterious impacts.

c This value for aluminum is expressed in terms of total recoverable metal in the water column.

d The value of 0.087 mg/l is based on a toxicity test with the striped bass in water with pH = 6.5–6.5 and hardness <10 mg/L. Data in "Aluminum Water-Effect Ratio for the 3M Plant Effluent Discharge, Middleway, West Virginia" (May 1994) indicate that aluminum is substantially less toxic at higher pH and hardness, but the impacts of pH and hardness are not well quantified at this time.

In tests with the brook trout at low pH and hardness, impacts increased with increasing concentrations of total aluminum even though the concentration of dissolved aluminum was constant, indicating that total recoverable is a more appropriate measurement than dissolved, at least when particulate aluminum is primarily aluminum hydroxide particles. In surface waters, however, the total recoverable procedure might measure aluminum associated with clay particles, which might be less toxic than aluminum associated with aluminum hydroxide.

The USEPA is aware of field data indicating that many high quality waters in the United States contain more than 0.087 mg/l of aluminum, when either total recoverable or dissolved is measured.

e Dissolved arsenic.

Acidic soils can also mobilize naturally occurring aluminum and heavy metals (such as arsenic) from the clays within the marsh soil. There are no regulatory water quality standards or USEPA guideline values for aluminum in salt water (USEPA 2009). For freshwater, the National Recommended Water Quality Criteria for total recoverable aluminum are 0.75 mg/l (acute conditions) and 0.087 mg/l (chronic conditions) (table 3-3). The USEPA noted that the value of 0.087 mg/l is based on a toxicity test in water with pH of 6.5 to 6.6 and a hardness of less than 10 mg/l; the toxicity of aluminum appears to vary with different pH and hardness conditions. Other research examined the impact of elevated aluminum concentrations on the aquatic ecosystem. For example, Driscoll et al. (1980) considered aluminum concentrations of 0.3 mg/l toxic to many fish. Baker and Schofield (1982) found that aluminum concentrations of greater than 0.1 mg/l (for white suckers) and 0.2 mg/l (for brook trout) reduced the survival and growth of larvae and postlarvae at the investigated pH levels of 4.2 to 5.6. Sparling, Lowe, and Campbell (1997) suggested that aluminum concentrations of greater than 0.1 mg/l can be harmful for many fish in mildly acidic water.

Dissolved aluminum concentrations measured by the Seashore in the Herring River estuary during 6 months in 2007 showed that only one third of the stations had dissolved aluminum concentrations above the analytical laboratory reporting limit of 0.05 mg/l (table 3-4)[1]. Of those stations that had reportable dissolved aluminum concentrations, the mean concentration was 0.25 mg/l and the highest reading was 1.2 mg/l. At station 1 near the dike, the dissolved aluminum concentration was below the laboratory reporting limit at all times. In summary, dissolved aluminum concentrations occasionally exceeded concentrations of concern at some stations.

Arsenic can cause behavioral impairments, growth reduction, appetite loss, and metabolic failure in aquatic organisms (USEPA 2011). The National Recommended Water Quality Criteria for total recoverable arsenic in freshwater are 0.34 mg/l (acute conditions) and 0.15 mg/l (chronic conditions) (table 3-4). For salt water, recommended criteria are 0.069 mg/l (acute conditions) and 0.036 mg/l (chronic conditions). In the Herring River estuary, arsenic concentrations measured in the surface waters by the Seashore in 2007 did not exceed any of these recommended criteria (table 3-4).

Other heavy metals in the surface water analyzed by the Seashore in 2007 consisted of dissolved copper, zinc, and lead. Copper and zinc concentrations were below the laboratory reporting limit at all stations during all sampling events[2]. Lead was reported at low concentrations (all well below any level of ecological concern) in 8 of the 61 samples. Most of these samples were collected downstream of the dike (station 1), indicating that there is no substantial leaching of lead from the soil in the estuary.

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[1] Laboratory reporting limits are the lowest concentrations that can be reliably quantified under routine laboratory analyses.

[2] The reporting limit for copper was 0.025 mg/l. The reporting limit for zinc was 0.2 mg/l.

TABLE 3-4: DISSOLVED ALUMINUM AND ARSENIC CONCENTRATIONS IN THE SURFACE WATERS OF HERRING RIVER IN 2007 (CAPE COD NATIONAL SEASHORE MONITORING DATA)

Station	Aluminum, Dissolved (2007) (mg/l)						Arsenic, Dissolved (2007) (mg/l)					
	Mar 26	Apr 25	May 21	Jul 18	Aug 20	Sep 17	Mar 26	Apr 25	May 21	Jul 18	Aug 20	Sep 17
River Mouth: Unrestricted												
1	--	--	--	--	--	--	0.02	0.10	0.02	0.02	0.02	--
Mid-river Channels: Tide restricted, acid sulfate zone												
2	1.2	--	--	--	--	0.18	--	--	--	--	--	--
3	--	--	--	0.12	0.2	--	--	0.01	--	--	--	--
4	--	--	--	--	--	0.15	--	--	--	--	0.01	--
8	0.06	--	--	--	0.13	--	--	--	--	--	--	--
9	0.36	--	--	0.12	--	--	0.01	--	--	--	--	--
Headwater Channels: Tide restricted												
5	0.65	--	--	--	--	--	--	--	--	--	0.01	--
11	--	0.18	--	--	--	--	--	--	--	--	--	--
Mosquito Ditches: Tide restricted												
3A	--	0.55	0.66	--	n/s	0.53	--	--	--	--	n/s	--
6	0.63	0.15	0.1	--	n/s	n/s	--	--	--	--	n/s	n/s
10	0.66	0.29	0.18	--	n/s	n/s	--	--	--	--	n/s	n/s

n/s = Not sampled due to lack of water in the channel.
Entries marked with "--" reflect measurements below the laboratory reporting limit.

Metals in Sediment

Concentrations of zinc, copper, lead, and aluminum in the Herring River estuarine soil were also low (table 3-5). Copper and zinc concentrations were below the reporting limit at all stations during Seashore monitoring in August 2007. One of the eight samples reported lead at concentrations well below National Oceanic and Atmospheric Administration (NOAA) sediment guideline concentrations. Aluminum occurs naturally in high concentrations in all soils. There are no NOAA sediment guideline values for aluminum.

Arsenic concentrations in seven out of the eight analyzed soil samples ranged from 1.7 to 17 mg/kg (table 3-5). The mean concentration of 7.7 mg/kg was below the effects range low (ERL) guideline value of 8.2 mg/kg for arsenic in marine sediments and well below the more critical effects range median (ERM) guideline value of 70 mg/kg. All values were also below the S-2 Soil Standard for Massachusetts for residential and non-residential properties of 20 mg/kg (MassDEP 2011b). Arsenic in the Herring River marsh soils likely originates from natural sources (common in New England soils) but may also be related to the wide use of lead arsenate-based pesticides for control of mosquito and gypsy moth larvae before the advent of dichlorodiphenyltrichloroethane (DDT). Arsenic is a relatively abundant element in the earth's crust; the average concentration in Massachusetts soils is 4.7 mg/kg (MassDEP 2002).

TABLE 3-5: CONCENTRATIONS OF METALS IN SOIL SAMPLES FROM THE HERRING RIVER ESTUARY ON AUGUST 20, 2007 (CAPE COD NATIONAL SEASHORE DATA)

Station	Concentrations (mg/kg)				
	Aluminum	Arsenic	Copper	Lead	Zinc
River Mouth: Unrestricted					
1	2,800	3.4	--	--	--
Mid-river Channels: Tide restricted, acid sulfate zone					
2	1,000	1.7	--	--	--
3	8,000	17.0	--	31	--
4	1,800	--	--	--	--
8	4,000	7.1	--	--	--
9	6,800	7.4	--	--	--
Headwater Channels: Tide restricted					
5	2,100	4.5	--	--	--
11	1,800	13.0	--	--	--
Mean (all stations)	**3,538**	**7.2**	--	--	--
NOAA Guideline Values (mg/kg) (Buchman 2008)					
Freshwater Sediment					
TEL	n/a	5.9	35.7	35.0	123
PEL	n/a	17.0	197.0	91.3	315
Salt Water Sediment					
ERL	--	8.2	34.0	46.7	150
ERM	--	70.0	270.0	218.0	410

Entries marked with "--" reflect measurements below the laboratory reporting limit.

TEL: Threshold Effects Level; concentration below which adverse effects are expected to occur only rarely.

PEL: Probable Effects Level; concentration above which adverse effects are frequently expected.

ERL: Effects Range Low; concentration at which toxicity is found about 10% of the time.

ERM: Effects Range Median; concentration at which toxicity is found about 50% of the time.

3.3.4 NUTRIENTS

Compared to estuaries in more developed areas, point and nonpoint-source runoff into the Herring River is small. Although there is no documentation of specific anthropogenic or natural inputs, potential sources of excessive nutrients within the Herring River watershed include agricultural activities, fertilized lawns, the Chequessett Yacht and Country Club (CYCC) golf course, the Coles Neck landfill, leaking septic systems, animal waste, and atmospheric deposition. Irrespective of the exact sources of nutrient inputs, the lack of tidal flushing has allowed nutrients to accumulate in the Herring River. In a normally functioning estuary, nutrients would be diluted and flushed out of the system with each tide cycle.

High organic matter production in salt marshes results in marsh soils that contain high concentrations of carbon and nutrients. Portnoy and Giblin (1997a) observed that the marsh soils of the Herring River estuary have retained high nitrogen and phosphorus concentrations, despite having been diked and drained for about a century. Here most inorganic nitrogen, the form used by plants and algae and most likely to cause eutrophication, is in the form of ammonium adsorbed to silt and clay particles. Experiments have shown that reflooding of these sediments with seawater will cause this ammonium-nitrogen to be released into receiving waters, at least over the short term (months) (Portnoy and Giblin 1997b). For this reason ammonium-nitrogen is of special concern in the Herring River and is a focus of ongoing nutrient monitoring. The highest ammonium concentrations were observed in the most acidic surface water samples (i.e., within the mosquito ditches) by the 2006 to 2010 Seashore monitoring program (figure 3-8).

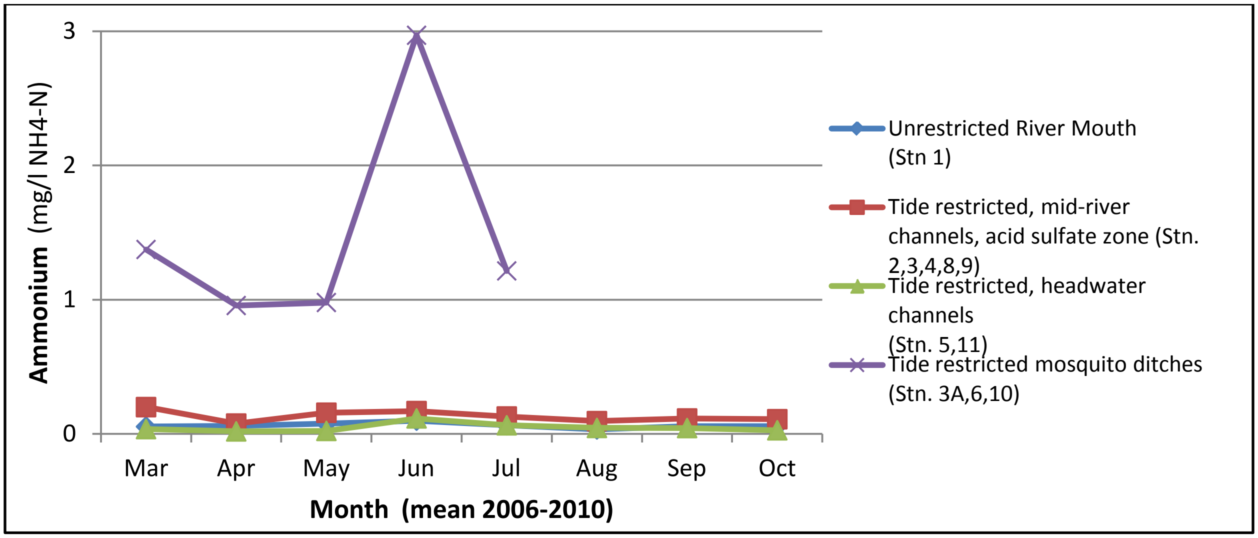


FIGURE 3-8: MONTHLY MEAN AMMONIUM CONCENTRATIONS IN THE HERRING RIVER AT LOW TIDE (2006 TO 2010 CAPE COD NATIONAL SEASHORE MONITORING DATA)

Phosphate levels are probably associated with the abundant iron and aluminum oxides remaining in the drained and aerobic marsh soils (figure 3-9). Tidal restoration is expected to cause a modest release of this chemically bound phosphorus through the dissolution of these minerals once the presently drained marsh peat again becomes waterlogged and anaerobic (Portnoy and Giblin 1997b). Phosphorus concentrations in the tide-restricted mid-river section and in the ditches are elevated reaching hypertrophic levels of greater than 0.1 mg/l. These concentrations are likely in part related to limited flows at these locations.

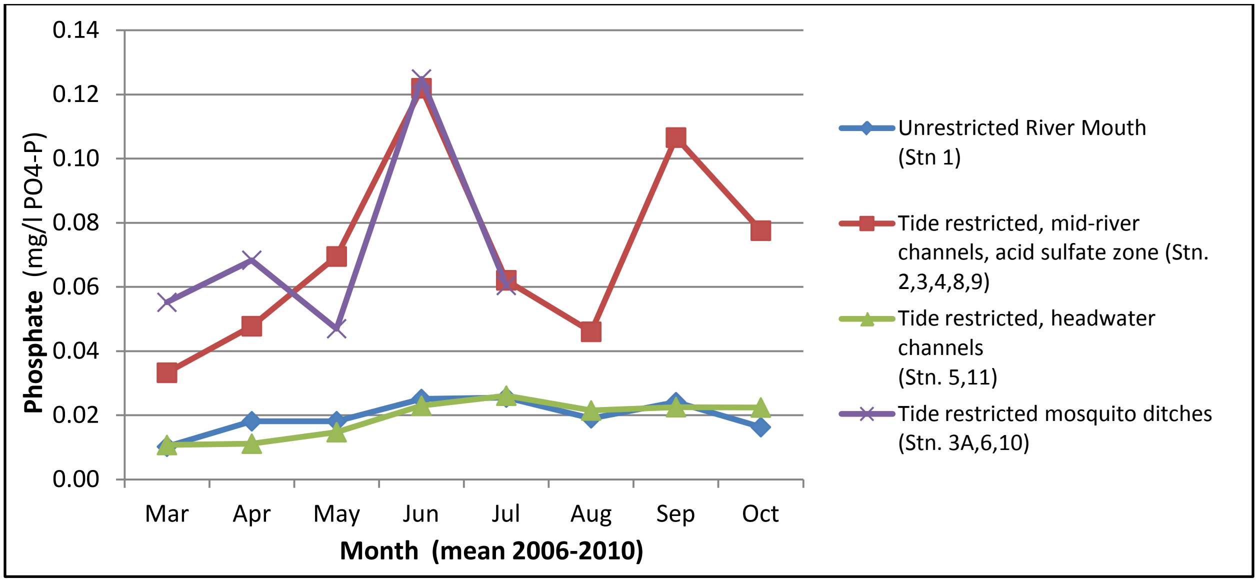


FIGURE 3-9: MONTHLY MEAN PHOSPHATE CONCENTRATIONS IN THE HERRING RIVER AT LOW TIDE (2006 TO 2010 CAPE COD NATIONAL SEASHORE MONITORING DATA)

3.3.5 PESTICIDES AND OTHER ORGANIC COMPOUNDS

Pesticides were used for mosquito control in the marsh in the past (Soukup and Portnoy 1986). Another potential source for pesticides could have been the CYCC golf course. The use of the pesticide DDT for agricultural purposes started in the United States in the 1940s and was banned in 1972; dieldrin (a common insecticide used from the 1950s to 1970s) was banned in 1985 (USEPA 2012). Pesticide concentrations (DDT, dieldrin) measured in the Herring River sediments downstream of the dike in 1969 (Curley et al. 1972) were found to be elevated for both compounds, exceeding NOAA ERM guideline values (Buchman 2008). However, samples analyzed for organics (including pesticides) from the Wellfleet Harbor by Hyland and Costa (1995) did not exceed NOAA guideline values. Quinn et al. (2001) analyzed the upper 2 cm of the marsh sediments at four stations upstream and downstream of the Chequessett Neck Road Dike for polychlorinated biphenyls (PCBs), DDT, total petroleum hydrocarbons (TPH), and polycyclic aromatic hydrocarbons (PAHs). PAHs were found to be below the NOAA ERL guideline values, whereas PCBs and DDT were found to be above the ERL value but below the ERM value. Additional samples will be collected in channels of the Herring River estuary and analyzed prior to the completion of the final Herring River Restoration Environmental Impact Statement / Environmental Impact Report (EIS/EIR).

In 2007, the Seashore analyzed eight surface water samples for pesticides throughout the estuary (see figure 3-2, stations 1, 2, 3, 4, 5, 8, 9, 11). All samples tested below the analytical reporting limit (Cape Cod National Seashore, unpublished data).

3.3.6 FECAL COLIFORM

The Herring River is listed as impaired for fecal coliform in a 0.39 square mile area between Griffin Island and Wellfleet Harbor (MassDEP et al. 2009). In 2005, fecal coliform concentrations in Herring River at nine stations between High Toss Road and Egg Island were found to be elevated, reaching up to 1,000 colonies per 100 ml during the outgoing tide (figure 3-10; Portnoy and Allen 2006). For reference, shellfish harvesting is prohibited if the coliform concentrations exceed 14 colonies per 100 ml. During incoming tide on September 20, the concentrations at the most seaward stations 8, 9, and 10 were below this regulatory level reflecting the inflow of water from Wellfleet Harbor; higher fecal coliform concentrations existed further upstream (stations 5, 6, and 7), reflecting the lower tidal flushing rates. At stations 1 to 4, fecal coliform concentrations were similar during high and low tides. High fecal coliform concentrations have kept the Herring River downstream of the dike permanently closed for shellfishing in some parts and only conditionally approved in other parts (see section 3.10, figure 3-22).

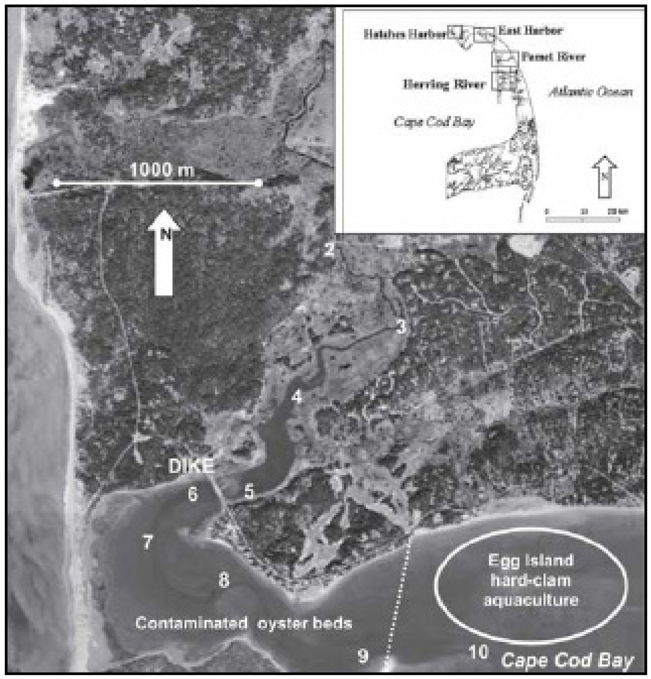


FIGURE 3-10: SAMPLING STATIONS FOR FECAL COLIFORM ANALYSES IN THE SURFACE WATERS OF THE HERRING RIVER IN 2005

Fecal coliform bacteria are found only in the fecal waste of warm-blooded organisms. Given the small number of houses (all of which have septic systems) within the watershed, the likelihood of fecal coliform bacteria from human sources is low. Therefore, fecal coliform bacteria probably originate from wildlife in the estuary and watershed (although confirmatory data do not exist). Over seven dry-weather sampling events, fecal coliform concentrations measured by Portnoy and Allen (2006) were highest in the tidal waters just upstream and seaward of the Chequessett Neck Road Dike (figure 3-11). However, peak fecal concentrations were measured after Tropical Storm Ophelia throughout the entire Herring River estuary, including the upper estuary. In fact, concentrations were higher by a factor of 2 to 4 over mean concentrations measured during the dry weather events, suggesting that runoff from the 3.5-inch rainstorm may have washed bacteria from wildlife sources in the marsh and surrounding watershed into the estuarine waters. Concentrations measured after the storm at stations near the dike were approximately 800 colonies per 100 ml.

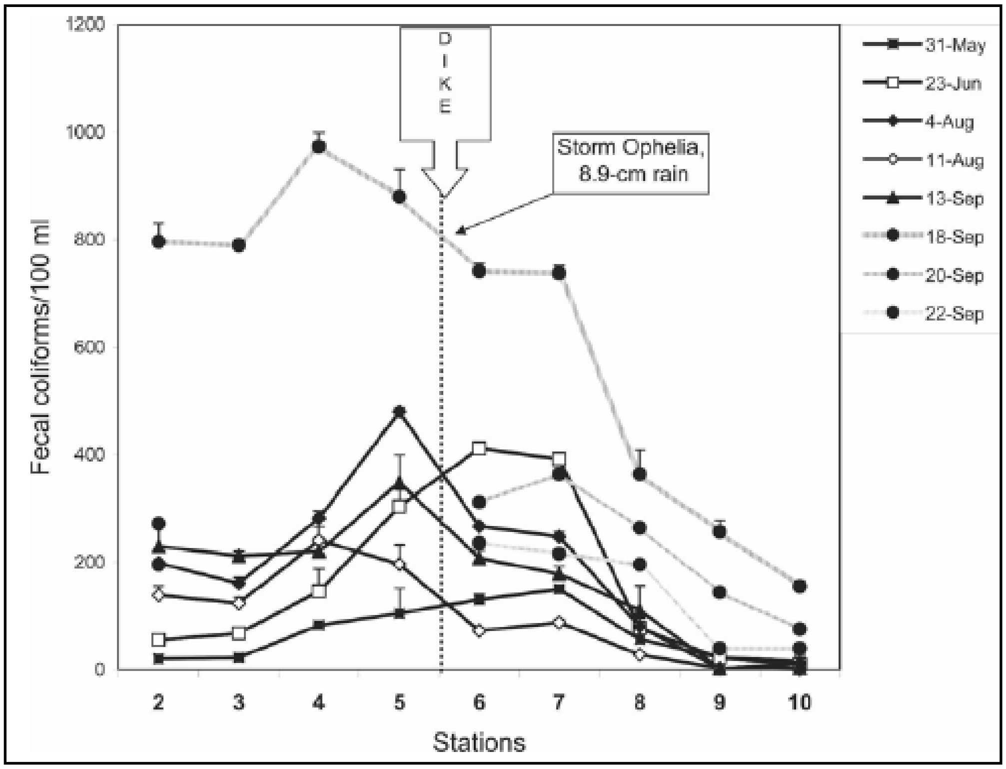


FIGURE 3-11: FECAL COLIFORM CONCENTRATIONS IN THE HERRING RIVER ESTUARY AT LOW TIDE

3.4 SEDIMENT TRANSPORT AND SOILS

The basic geomorphology surrounding the Herring River has been primarily determined by relatively recent glacial processes, which ended about 15,000 years before present. Landforms are generally comprised of post-glacial outwash plain deposits (fine to coarse gravelly sand, variably sized pebbles, stones, and boulders). Fluctuating sea levels associated with glacial retreat caused deposition of marine sands, silts, and clays (Oldale 1969). As sea level change slowed about 4,000 years ago, organic accumulation began to form peat, which provided the base for salt marshes to develop. Material derived from decaying salt marsh plants, diurnal tidal exchange, and coastal storm surges was crucial for maintaining salt marsh elevations as the sea level increased; the material eventually accumulated to a thickness of about ten feet (Roman 1987, Appendix 1). When the Herring River was diked more than 100 years ago, these processes were interrupted and both the salt marsh and the underlying peat began to subside.

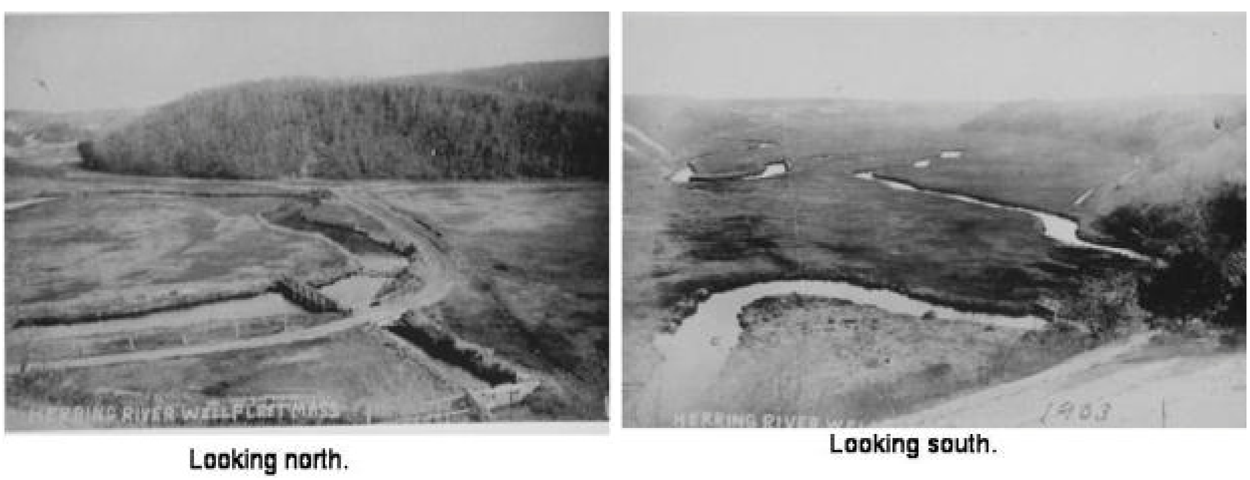
The ecological functions of the Herring River estuary are dependent on and linked to the river's proximity and connections to Cape Cod Bay and Wellfleet Harbor. Historically, a direct hydrologic connection to the bay existed at Duck Harbor in addition to the existing connection to the harbor at Chequessett Neck (now diked). The Duck Harbor inlet augmented tidal exchange into the upper reaches of Bound Brook and the Herring River, but mapping by the U.S. Coastal Survey (later, the U.S. Geological Survey) beginning in the 1840s shows the Duck Harbor channel naturally migrating southward and closing. Although the exact year of closure is unclear, by the time the Chequessett Neck Road Dike was constructed, the Duck Harbor channel was completely filled in.

Southward longshore drift along Cape Cod Bay also created Ryder Beach, Duck Harbor Beach, and Jeremy Point and the dunes which eventually connected Bound Brook Island, Griffin Island, and Great Island. The stretch of sand connecting Griffin and Great Islands, called a “tombolo” in geologic terms, is locally known as “the Gut.” The Gut formed long before the Herring River was diked and was not affected after the dike was constructed. The Gut is kept stabilized by the abundant sand supplied from erosion of the beach and dunes. For this reason, the Herring River flows into Wellfleet Harbor rather than directly into Cape Cod Bay through the Gut barrier beach (Dougherty 2004).

There are two sediment-related issues relevant for this restoration project. First, opening the dike would mobilize sediment that has accumulated within the existing channels as a natural tidal channel system begins to re-establish itself. Second, changes in the tidal water surface elevation in the estuary along with subsidence of the marsh surface during the last 100 years need to be considered to assure successful transition back to a salt marsh with healthy vegetation. Potential sediment impacts to commercial shellfish resources downstream of the dike in Wellfleet Harbor are discussed in “Section 4-10: Impacts on Socioeconomics.”

3.4.1 TIDAL CHANNELS

Tidal wetlands generally have channel systems with dimensions that are proportional to the volume of water passing through them with each tidal cycle (Friedrichs and Perry 2001). Because the volume of water flowing through the estuary was greatly reduced by the construction of the Chequessett Neck Road Dike, the tidal channel system in the Herring River estuary that existed prior to the construction of the dike (figure 3-12) has completely or partially filled with sediment. In addition, the river was straightened in some areas in an effort to improve drainage of the marsh, cutting off meanders from High Toss Road to the present Route 6. Organic and inorganic sediment from estuarine and upland sources has filled these channels to varying degrees.



As seen from Old County Road, looking north and south; the photographs provide an understanding of the channel dimensions that existed prior to the construction of the dike. (Source: Friends of the Herring River 2012.)

FIGURE 3-12: PHOTOGRAPHS OF HERRING RIVER ESTUARY FROM YEAR 1903

Other existing depositional features that likely will be affected by a change in hydrology from the restoration alternatives include the flood-tidal shoal that has formed just upstream and the smaller ebb-tidal shoal has formed just downstream of the Chequessett Neck Road Dike. Sediments in the shoals consist predominantly of sand (Harvey 2010). The net sediment transport under existing conditions is upriver as reflected in the larger flood-tidal shoal, but the extent of transport of sediment further upstream is limited because of low flow velocities and the attenuation of tidal flow, even during storm surges (Spaulding and Grilli 2001, WHG 2010 and 2011a). The flow is sufficient to move the predominantly coarse sediment only in the vicinity of the dike.

Sediment transport analyses of the existing system (see appendix B) found that normal tidal flow velocities are sufficient to initiate sediment movement, but only in the vicinity of the dike. The study confirmed that the system is flood-dominant; meaning that net transport of sediment is into the Herring River. This flood-dominant process is the result of the greater flow velocities created by the existing culverts and tide gates at the Herring River Dike, which confines the cross-section to one 6-foot wide culvert during flood tides as compared to the lower velocities created by the three 6-foot wide culverts during ebb tides. The dike has also caused a substantial reduction in flow velocity during flood tides in the area immediately downstream of the dike (as compared to pre-dike conditions), which likely has resulted in settling and deposition of suspended sediment during the slack flood tide in this area.

3.4.2 MARSH SURFACE ELEVATIONS

Tidal restrictions adversely affect the process of sediment deposition on salt marshes. Coastal marsh elevations must increase at a pace equal to or greater than the rate of sea level rise to persist and to promote the growth of salt marsh grasses. An increase in marsh elevation depends on several processes, including net transport of sediment into an estuary and its deposition onto the marsh, the growth and accumulation of organic matter on the marsh surface, and accumulation of belowground peat.

In the Herring River estuary, the 1909 dike construction greatly reduced the upstream transport of inorganic sediment from reaching the salt marshes within the basin. Additionally, marsh drainage has increased the rate of organic peat decomposition by aerating and drying the sediment and has caused soil pore spaces to collapse and marsh elevations to subside. Much of the marsh surface upstream of the dike is currently at elevations between 1 to 3 feet (figure 3-13). These elevations are up to 3 feet (90 cm) lower than the marsh surface downstream of the dike relative to modern mean sea level. Approximately 2.3 feet (70 cm) of this difference is directly due to subsidence from pore-space collapse and peat decomposition; the remaining 20 cm are a result of an increase in marsh elevation downstream of the dike due to accretion in Wellfleet Harbor caused by sea level rise. Therefore, much of the former salt marsh surface is approximately 1 to 3 feet lower than the mean high water elevation of 4.8 feet in Wellfleet Harbor (Portnoy and Giblin 1997a) (figure 1-2 and figure 3-14).

Ultimately, to restore a healthy salt marsh, surface elevations need to increase in response to the restored tide levels and to sea-level rise. With restoration of tidal flows, the drained peat would be resaturated and may expand slightly, peat accumulation will increase with growth of marsh vegetation, subsidence would be reduced, and sediment delivery to the marsh would be enhanced, all contributing to an increase in marsh elevation that is necessary to sustain a restored marsh ecosystem.

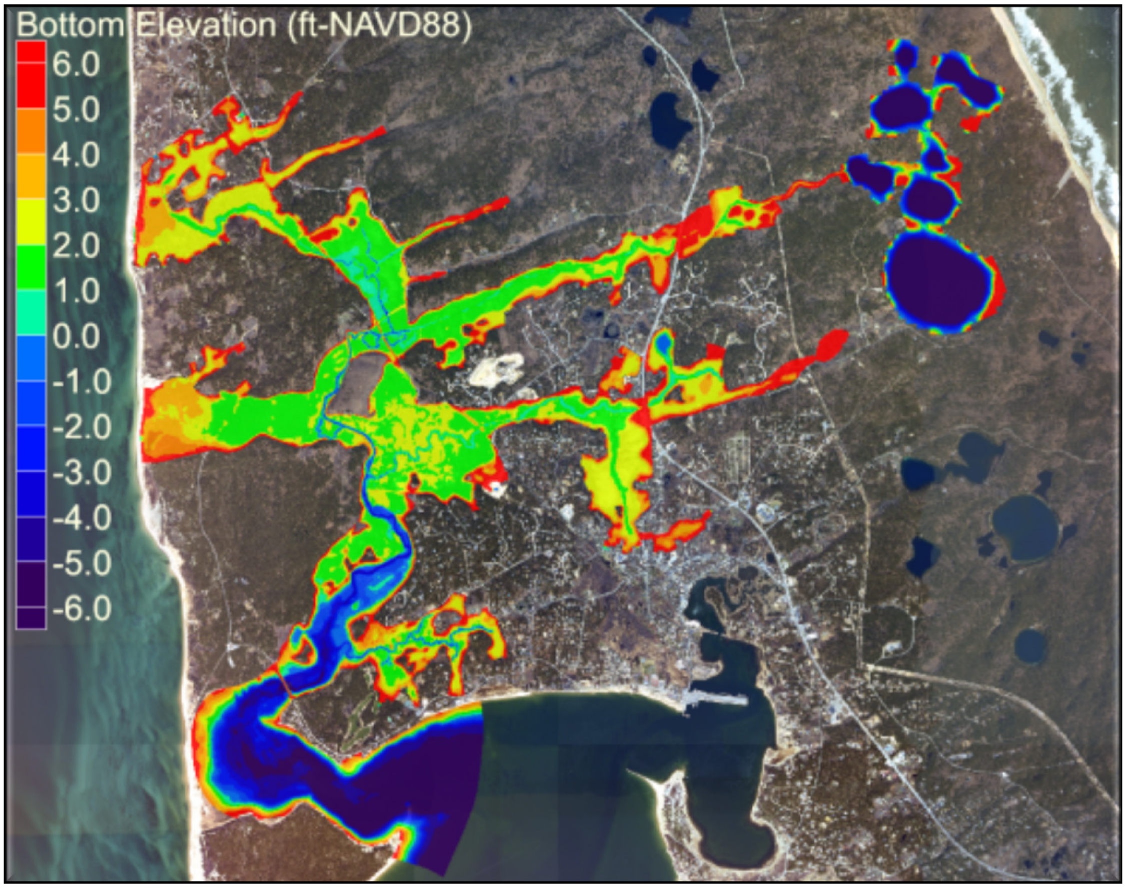
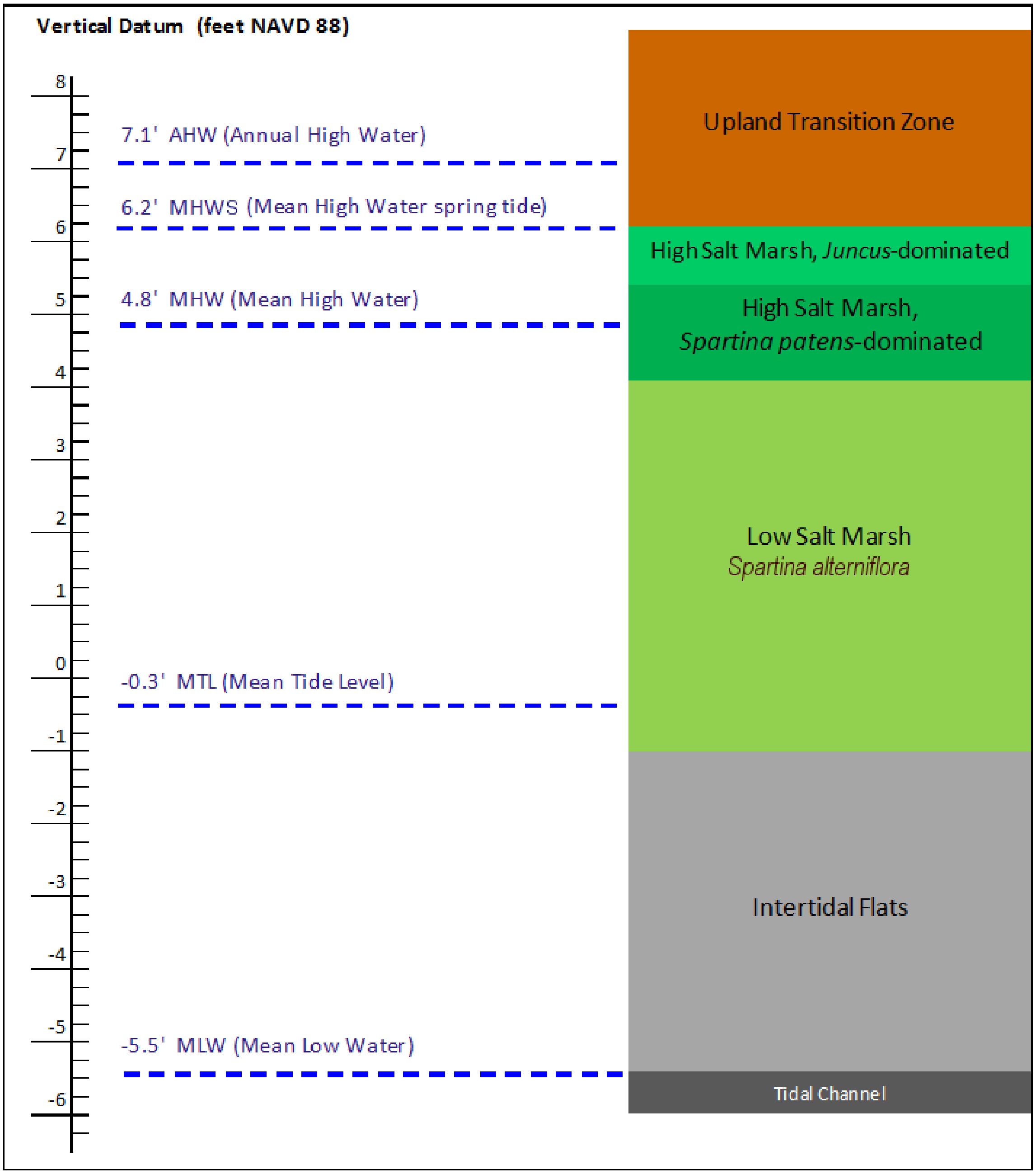


FIGURE 3-13: TOPOGRAPHY OF THE HERRING RIVER ESTUARY, BASED ON PHOTOGRAMMETRIC DATA



Note: All elevations presented in this EIS/EIR are based on the North American Vertical Datum of 1988 (NAVD88). NAVD88 replaced National Geodetic Vertical Datum of 1929 (NGVD 29) as a result of greater accuracy and the ability to account for differences in gravitational forces in different areas based on satellite systems. NAVD88 is 0.86 feet lower in elevation than NGVD 29.

FIGURE 3-14: IDEALIZED RELATIONSHIP BETWEEN SALT MARSH PLANT ZONATION AND MODEL DERIVED TIDAL ELEVATIONS FOR WELLFLEET HARBOR

3.4.3 SOILS

Approximately 80 percent of the Herring River flood plain is comprised of hydric soils, as determined by the U.S. Department of Agriculture Natural Resources Conservation Service (NRCS) (figure 3-15). Typically, hydric soils include those developed under sufficiently wet conditions to support wetland vegetation. The following map unit descriptions are excerpted from the *Soil Survey of Barnstable County, Massachusetts* (Fletcher 1993). Soil types within the Lower Herring River sub-basin are generally equally distributed among subaqueous open water (22 percent), Freetown and Swansea mucks (22 percent), Maybid Variant silty clay loam (29 percent), and Carver coarse sand (23 percent). Freetown and Swansea mucks are very deep, level, very poorly drained soils found on outwash plains and moraines and in areas of glacial lake deposits. They are in depressions and in areas adjacent to streams, ponds, and lakes. Maybid Variant silty clay loam is a very deep, level, poorly drained soil found in low areas along the Herring River. This soil is formed in tidal marsh deposits that are no longer subject to tidal flooding and have been drained of salt water. Carver coarse sand is a very deep, gently sloping, excessively drained upland soil found in broad areas and on the tops of knobs on outwash plains.

Soils within the Mill Creek sub-basin are primarily comprised of Maybid silt loam (70 percent) with lesser amounts of Carver coarse sand (30 percent). Maybid silt loam is a very deep, nearly level, very poorly drained soil found in depressions, at the base of swales, and in low areas bordering ponds, streams, and swamps. The soil is formed in areas of glacial lake deposits. Soils within the Middle Herring River sub-basin are primarily comprised of Maybid Variant silty clay loam (79 percent) with lesser amounts of Freetown and Swansea mucks (11 percent) and Carver coarse sand (10 percent). Soils within the Pole Dike Creek sub-basin are primarily comprised of Freetown and Swansea mucks (83 percent) and Carver coarse sand (7 percent). Soils within the Duck Harbor sub-basin are generally equally distributed among Maybid Variant silty clay loam (43 percent), Pipestone loamy coarse sand (36 percent) and Carver coarse sand (20 percent). Pipestone loamy coarse sand is a very deep, nearly level, poorly drained soil found in depressions, at the base of swales, and in low areas bordering streams, ponds, and swamps. It is on outwash plains and in areas of glacial lake deposits. Soils within the Bound Brook sub-basin are primarily comprised of Freetown and Swansea mucks (73 percent) and with lesser amounts of Carver coarse sand (19 percent). Soils within the Upper Herring River sub-basin are primarily comprised of Freetown and Swansea mucks (72 percent) and with lesser amounts of Carver coarse sand (18 percent).

Three of the soil types are relevant for the Herring River project:

1. Carver coarse sand is an upland soil that surrounds most of the flood plain at higher elevations, such as Merrick Island. Its presence helps locate the upland/hydric soil boundary.
2. Maybid Variant silty clay loam is a hydric soil that it is formed in tidal marsh deposits that are no longer subject to tidal flooding and have been drained of salt water. Its presence illustrates that soils of the flood plain have been changed by the tidal restriction caused by the Chequessett Neck Dike, the Duck Harbor, and Bound Brook natural closures and marsh drainage. Since those hydrologic modifications have also changed the vegetation over time, upland plant types can be found in some parts of the flood plain growing on hydric soils.
3. Ipswich, Pawcatuck, and Matunuck peats occupy an area of salt marsh just south of the main dike at the mouth of the river. It is the typical soil complex found in unrestricted salt marshes.

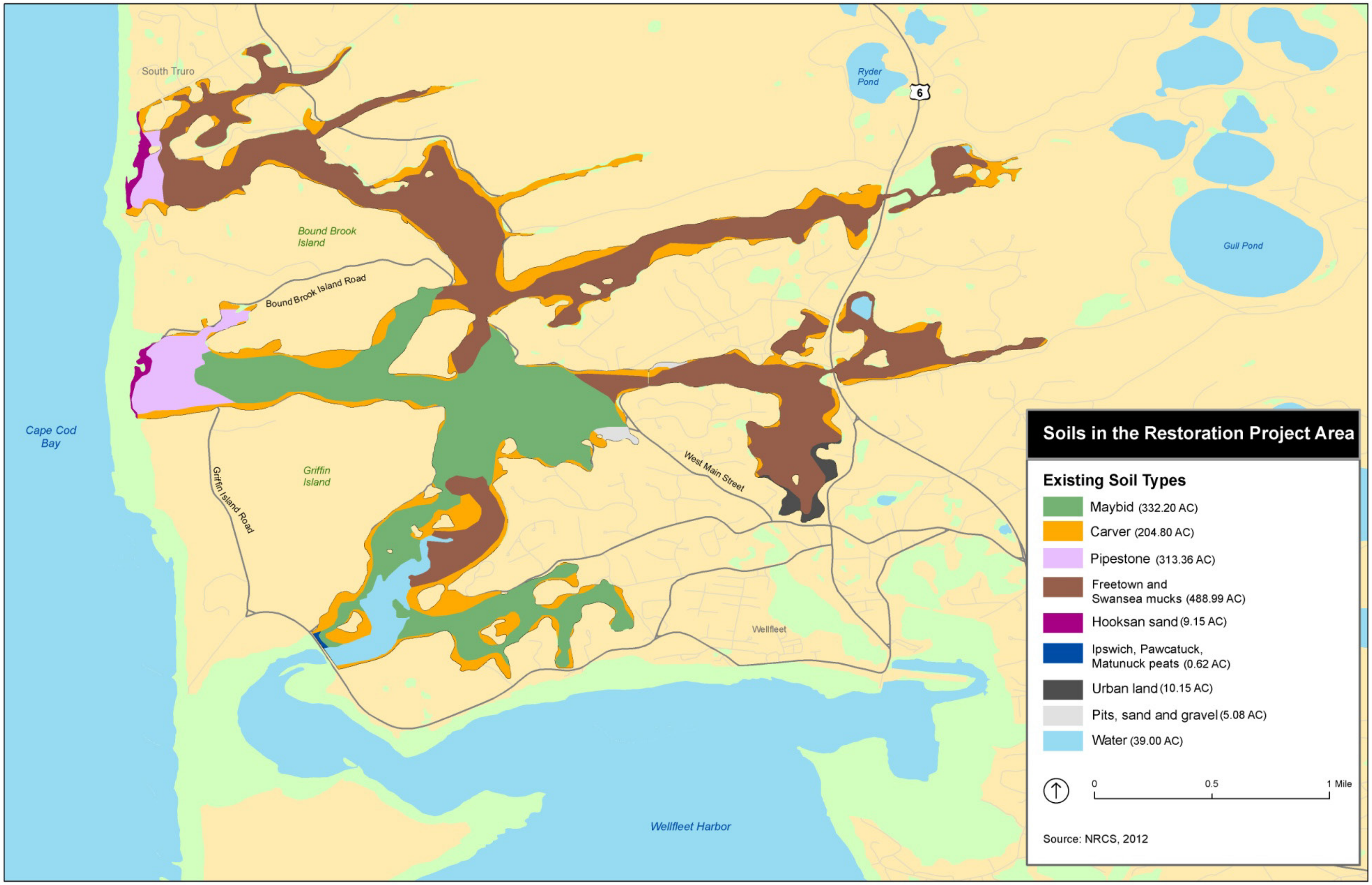


FIGURE 3-15: EXISTING SOILS IN THE HERRING RIVER FLOOD PLAIN

3.5 WETLAND HABITATS AND VEGETATION

Wetland habitats and vegetation coverage within the Herring River flood plain have changed as Wellfleet Harbor developed into its current geological configuration and European settlers began to change the habitat conditions in the region. Over time longshore sediment transport created barrier beaches connecting Bound Brook Island and Griffin Island (Chamberlain 1964 in Snow 1975). Analysis of peat cores shows that salt marsh vegetation within the Herring River flood plain once extended east of present day Route 6 during the early formation of the marsh complex. However, much of the estuary shifted toward less salt tolerant vegetation with the natural closure of the Bound Brook and Duck Harbor tidal channels and reduction in tidal exchange (Orson and Roman 1987 in Roman 1987). Anthropogenic reductions in tidal exchange resulted from the construction of early roads across the flood plain and construction of the railroad to Provincetown in 1869. Following its construction, a large portion of the marsh upstream of the railroad embankment was separated from tidal impacts (Snow 1975). Further dramatic changes in vegetation resulted from the construction of the Chequessett Neck Road Dike in 1909, drastically reducing tidal flow at the mouth of the Herring River. Subsequent widespread ditching and straightening of the meandering creeks effectively drained most of remaining salt marshes. Based on an examination of historic aerial photography, Portnoy, Roman, and Soukup (1987) found brackish to fresh herbaceous marsh still persisted into the 1930s, but was largely replaced with woody species by 1977.

A summary of current wetland habitats and vegetation within the Herring River flood plain is based on vegetation mapping completed by the Seashore (figure 3-16). Color-infrared aerial photographs from 2000 were interpreted and assigned vegetation types from a broad classification system of New England plant communities (Sneddon 2004). Based in part on field observations in 2007, the classification was modified by the Seashore to include several unexpected assemblages of opportunistic upland species within drained portions of the flood plain where wetland communities would have been expected to appear (HRTC 2007). The Seashore mapping included 11 vegetation cover classes within the Herring River flood plain, as well as open water and developed lands. To further simplify the existing vegetation descriptions for this draft EIS/EIR, the various shrub and forested vegetation communities were consolidated into shrublands and woodlands. In addition, dune grassland and heathland grassland were consolidated into dune/heathlands and freshwater marsh and old field herbaceous were consolidated into freshwater marsh/meadow. The consolidation of the original 11 vegetation cover types into six classes is summarized in table 3-6. The aerial coverage of various consolidated cover types within the project area by sub-basin is provided in table 3-7.

Typical vegetation is described in the following narrative. Where available, species occurrence is augmented by unpublished Seashore vegetation data collected in 2008 along 15 permanent transects established within the Herring River flood plain (8 within the Lower Herring River sub-basin, 4 within the Middle Herring River sub-basin and 3 within the Pole Dike Creek sub-basin, table 3-8). Table 3-8 lists representative species documented within each cover class and includes several species occurrences which are atypical for the listed vegetation type. These anomalies are attributed to the highly disturbed nature of the Herring River flood plain and the broad scale of cover type mapping which likely included transitional areas between various cover types.

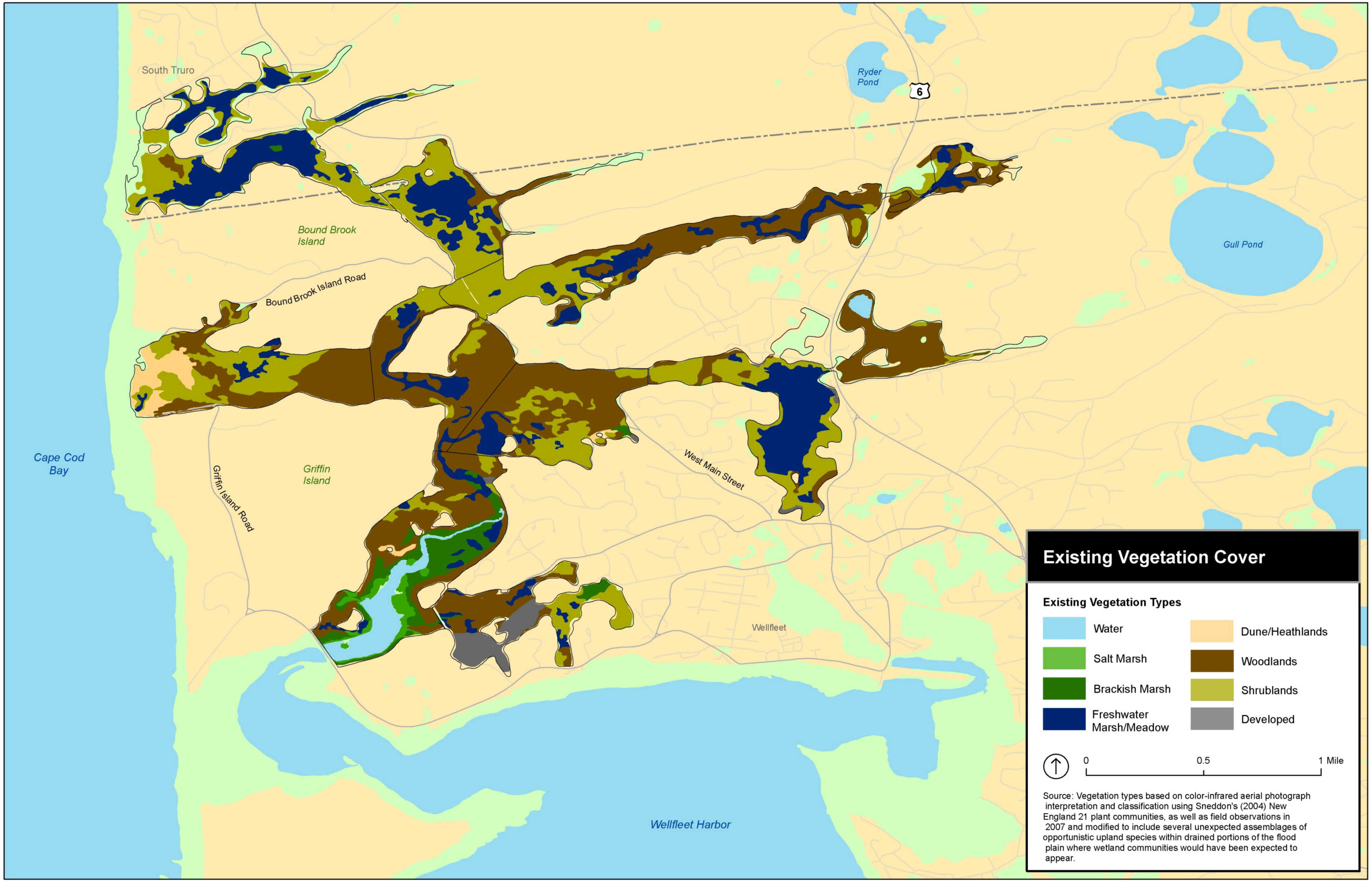


FIGURE 3-16: EXISTING VEGETATION COVER IN THE HERRING RIVER FLOOD PLAIN

TABLE 3-6: VEGETATION COVER TYPE CATEGORIES

Consolidated Cover Types	Original Seashore Mapping Cover Types
Water	Water
Salt Marsh	Salt Marsh
Brackish Marsh	Brackish Marsh
Freshwater Marsh/Meadow	Freshwater Marsh Old Field Herbaceous
Shrublands	Dry Shrubland Wet Shrub
Woodlands	Dry Deciduous Forest Dry Deciduous Woodland Pine Woodland Wet Deciduous Forest
Dune/Heathlands	Dune Grasslands Heathland Grasslands
Developed	Developed

TABLE 3-7: EXISTING VEGETATION COVER TYPES IN ACRES WITHIN HERRING RIVER FLOOD PLAIN

Herring River Sub-basin	Water	Salt Marsh	Brackish Marsh	Freshwater Marsh/ Meadow	Shrub lands	Wood lands	Dune/ Heathlands	Developed	Total Area
Bound Brook			1	94	89	12			196
Duck Harbor				6	47	57	18		128
Lower Herring River	29	13	37	11	7	62	2	1	162
Middle Herring River				16	12	61		0	89
Mill Creek			3	6	17	25		20	71
Pole Dike Creek	3		1	60	78	116	1	3	262
Upper Herring River				29	49	69			147
Total Area	**32**	**13**	**42**	**222**	**299**	**402**	**21**	**24**	**1055**

Source: Cape Cod Vegetation Map (HRTC 2007). To simplify the existing vegetation descriptions several vegetation cover types were consolidated (see table 3-6).

TABLE 3-8: SPECIES OCCURRENCE ALONG PERMANENT VEGETATION TRANSECTS WITHIN HERRING RIVER FLOOD PLAIN BY COVER TYPE

Salt Marsh	Brackish Marsh	Freshwater Marsh/Meadow	Shrublands	Woodlands
Ascophyllum nodosum (rockweed) *Convolvulus sepium* (false bindweed) *Fucus vesiculosus var. spiralis* (bladderwrack) *Phragmites australis* (common reed) *Populus grandidentata* (bigtooth aspen) *Rubus hispidus* (swamp dewberry) *Spartina alterniflora* (smooth cordgrass) *Toxicodendron radicans* (poison ivy) *Viburnum recognitum* (arrowwood)	*Aster novi-belgii* (New York Aster) *Calamagrostis canadensis* (bluejoint) *Cladophora sp.*(clado) *Convolvulus sepium* (false bindweed) *Morella pensylvanica* (northern bayberry) *Phragmites australis* (common reed) *Rosa palustris* (swamp rose) *Rubus hispidus* (swamp dewberry) *Salicornia maritima* (grasswort) *Spartina alterniflora* (smooth cordgrass) *Spiraea tomentosa* (steeplebush) *Thelypteris palustris* (eastern marsh fern) *Toxicodendron radicans* (poison ivy) *Viburnum recognitum* (arrowwood)	*Agrostis alba* (creeping bentgrass) *Bidens connata* (purplestem beggertick) *Decodon verticillatus* (swamp loosestrife) *Holcus lanatus* (common velvetgrass) *Lysimachia terrestris* (loosestrife) *Phalaris arundinacea* (reed canary grass) *Phragmites australis* (common reed) *Polygonum hydropiper* (marshpepper knotweed) *Rosa palustris* (swamp rose) *Rubus hispidus* (swamp dewberry) *Smilax rotundifolia* (greenbriar) *Solidago rugosa* (wrinkleleaf goldenrod) *Spirea alba* (white meadowsweet) *Spirea tomentosa* (steeplebush) *Toxicodendron radicans* (poison ivy) *Typha angustifolia* (narrowleaf cattail)	*Calamagrostis canadensis* (bluejoint) *Decodon verticillatus* (swamp loosestrife) *Euthamia tenuifolia* (slender goldentop) *Galium trifidum* (threepetal bedstraw) *Holcus lanatus* (common velvetgrass) *Ilex sp.* (holly) *Juncus effusus* (common rush) *Lysimachia terrestris* (loosestrife) *Morella pensylvanica* (northern bayberry) *Phalaris arundinacea* (reed canarygrass) *Rosa palustris* (swamp rose) *Rubus hispidus* (swamp dewberry) *Rubus occidentalis* (black raspberry) *Rumex acetosella* (common sheep sorell) *Solidago rugosa* (wrinkleleaf goldenrod) *Sparganium eurycarpum* (broadfruit burreed) *Spirea alba* (white meadowsweet) *Spiraea tomentosa* (steeplebush) *Toxicodendron radicans* (poison ivy) *Typha angustifolia* (narrowleaf cattail)	*Agrostis sp.* (bentgrass) *Convolvulus sepium* (false bindweed) *Euthamia tenuifolia* (slender goldentop) *Holcus lanatus* (common velvetgrass) *Onoclea sensibilis* (sensitive fern) *Phragmites australis* (common reed) *Populus tremuloides* (quaking aspen) *Prunus serotina* (black cherry) *Quercus velutina* (black oak) *Rosa palustris* (swamp rose) *Rubus hispidus* (swamp dewberry) *Rubus occidentalis* (black raspberry) *Solanum dulcarama* (bittersweet) *Solidago rugosa* (wrinkleleaf goldenrod) *Sphagnum sp.* (sphagnum moss) *Spirea alba* (white meadowsweet) *Thelypteris palustris* (eastern marsh fern) *Toxicodendron radicans* (poison ivy) *Viburnum recognitum* (arrowwood)

Source: Cape Cod National Seashore 2008 unpublished data.

3.5.1 SUB-TIDAL HABITAT

The Seashore vegetation map identifies 29 acres of open water within the Lower Herring River sub-basin which represents the impounded brackish condition immediately upstream of the Chequessett Neck Road Dike (table 3-7). This area of open water currently supports an extensive bed of submerged aquatic vegetation comprised of widgeon grass (Portnoy, Phipps, and Samora 1987; Snow 1975). An additional 3 acres of open water occur within the Upper Pole Dike Creek sub-basin east of Route 6. Watercress (*Rorippa nasturtium-aquaticum*) is a non-native, common freshwater submerged aquatic plant and is found within non-tidal portions of the Herring River (see "Section 3.5.9: Invasive Plants").

3.5.2 SALT MARSH

As a result of natural and human-induced events, the previously extensive areas of salt marsh within the approximately 1,000-acre flood plain have nearly all developed into freshwater herbaceous and wooded habitats. Currently only 13 acres of salt marsh persist upstream of the dike within the Lower Herring River sub-basin (table 3-7). This area of salt marsh occupies a relatively narrow band between open water and brackish marsh dominated by common reed (*Phragmites australis*). In New England, salt marshes support salt-tolerant vegetation such as smooth cordgrass (*Spartina alterniflora*), salt marsh hay (*Spartina patens*), glasswort (*Salacornia virginica*), spikegrass (*Distichlis spicata*), black grass (*Juncus gerardii*), marsh elder (*Iva frutescens*), and groundsel bush (*Baccharis halimifolia*) (Niering and Warren 1980; Tiner 1987). Species occurrence in plots within salt marsh zones along permanent transects is found in table 3-8.

Within Herring River, Snow (1975) reported increases in smooth cordgrass and salt marsh hay fringing the river in response to the gradual deterioration of the original 1909 tide gates prior to their replacement in 1975. In subsequent surveys (Gaskell 1978; Valiela et al. 1983), a trend toward increased coverage of smooth cordgrass was reported, although no area estimates were provided. Portnoy, Roman, and Soukup (1987) reported an increase from zero to 7.4 acres of *Spartina*-dominated marsh between 1960 and 1977, reflecting the response of the vegetation community to increased salinity during the period when the tide gates were in disrepair.

3.5.3 BRACKISH MARSH

Forty-two acres of brackish marsh occurs within the project area, mostly within the Lower Herring River sub-basin (table 3-7). The remaining smaller areas lie within the Mill Creek, Bound Brook, and Pole Dike Creek sub-basins. In the Herring River, brackish marsh consists of nearly monotypic dense stands of common reed (*Phragmites australis*) with common three-square (*Schoenoplectus pungens*) a common associate. Common reed, a non-native invasive plant, is frequently found within tidally restricted marshes and tends to displace valuable native salt marsh and brackish plant communities. Species occurrence in plots within brackish marsh zones along permanent transects is found in table 3-8.

Valiela et al. (1983) reported that a majority of the marsh downstream of High Toss Road, formerly occupied by cattail (*Typha* spp.) had been colonized in 1974 by common reed in response to the deteriorated tide gates. This trend has likely continued to the present as common reed is more salt-tolerant than cattail and other freshwater wetland plants.

3.5.4 FRESHWATER MARSH/MEADOW

There are 222 acres of freshwater marsh/meadow occurring within the project area, representing the third most common cover type (table 3-7). This composite cover type is typically limited to banks of the river within the Lower, Middle, and Upper Herring River sub-basins. More extensive areas of freshwater marsh/meadow occupy the Bound Brook sub-basin (94 acres) and Pole Dike Creek sub-basins (60 acres). Freshwater marsh habitats within the project area are typically dominated by narrowleaf cattail (*Typha angustifolia*) with the following common associates: wool grass (*Scirpus cyperinus*), bluejoint (*Calamagrostis canadensis*), rushes (*Juncus* spp.), and American bur-reed (*Sparganium americana*). Narrowleaf cattail is somewhat tolerant of saline environments (Grace and Wetzel 1982) and is considered an early to mid-seral species and is known to replace cordgrasses (*Spartina* spp.) in diked or tidally restricted coastal wetlands (Barrett and Niering 1993).

Common species within the old field herbaceous cover type include little bluestem (*Schizchyrium scoparium*), wavy hairgrass (*Descahmpsia flexuosa*), common velvetgrass (*Holcus lanatus*) and red fescue (*Festuca rubra*). Of the 222 acres of freshwater marsh/meadow, 20 acres are identified as old field herbaceous. Because much of the vegetation data collected by the Seashore from plots within old field herbaceous zones along permanent transects is typical of wet meadow species (table 3-8), the two wetland freshwater herbaceous cover types were combined for this analysis.

Water-willow or swamp loosestrife (*Decodon verticillatus*) (a larval host plant for a State-listed moth, water-willow stem borer [*Papaipema sulphurata*]), is a common component of the flora along the banks of Herring River, Bound Brook, and Pole Dike Creek (Mello 2006). The majority of these occurrences were within freshwater marsh with the remaining areas found within shrublands.

3.5.5 SHRUBLANDS

There are 299 acres of shrubland habitat in the project area, representing the second most common cover type (table 3-7). Shrublands comprise large portions of the Bound Brook, Duck Harbor, Mill Creek, Pole Dike Creek and Upper Herring River sub-basins. Extensive areas of wet shrublands have encroached into former brackish and freshwater herbaceous marsh as a result of the effective drainage of the flood plain (Portnoy, Roman, and Soukup 1987). Nearly all the composite shrubland habitat is comprised of wet shrubland with just 2 percent mapped as dry shrubland. Common woody species within this cover type include highbush blueberry (*Vaccinium corymbosum*), sweet pepperbush (*Clethra alnifolia*), swamp azalea (*Rhododendron viscosum*), water-willow, buttonbush (*Cephalanthus occidentalis*), alder (*Alnus* spp.), and leatherleaf (*Chamaedaphne calyculata*). Common woody species within the dry shrubland habitat include northern bayberry (*Morella pensylvanica*), black oak saplings (*Quercus velutina*), and shadbush (*Amelanchier* spp.). Species occurrence in plots within shrubland zones along permanent transects is presented in table 3-8.

3.5.6 WOODLANDS

Woodland habitat within the Herring River flood plain represents a consolidation of several forested cover types (including dry deciduous woodland, wet deciduous forest, dry deciduous forest, and pine woodland) A total of 402 acres of woodland habitat currently occurs in the project area and represents the most common cover type for the entire project area as well as within each of the sub-basins except Bound Brook (table 3-7). The dry deciduous woodland cover type comprises the majority (242 acres) of the total woodland habitat. This common cover type was included to account for unexpected vegetation assemblages of species due to the effective drainage within areas where wetland communities would be expected to occur. The overstory of this cover type is dominated by black cherry (*Prunus serotina*) with shadbush and northern arrowwood (*Viburnum recognitum*) found as common shrubs in the understory. This vegetation cover type is common within the Lower Herring River, Middle Herring River / Lower Pole Dike Creek, and Duck Harbor sub-basins where black cherry can be found along with an understory of old field species, including goldenrod (*Solidago* sp.), Canadian lettuce (*Lactuca canadensis*), common velvetgrass (*Holcus lanatus*), and Alleghany blackberry (*Rubus allegheniensis*) (HRTC 2007). Species occurrence in plots within woodland zones along permanent transects is presented in table 3-8.

The wet deciduous forest cover type comprises 124 acres of the 402 acres of woodland habitat. The overstory of the wet deciduous forest is dominated by red maple (*Acer rubrum*) with sweet pepperbush and swamp azalea found as common shrubs in the understory. The pine woodland cover type comprises 29 acres of the total woodland habitat. Common species within the pine woodland include pitch pine (*Pinus rigida*), black huckleberry (*Gaylussacia baccatta*), lowbush blueberry (*Vaccinium angustifolium*), and wavy hairgrass (*Deschampsia flexuosa*). The dry deciduous woodland cover type comprises only 7 acres of the total woodland habitat with an overstory comprised of black oak, white oak (*Quercus alba*) American beech (*Fagus grandifolia*), and black locust (*Robinia pseudoacacia*).

3.5.7 DUNE/HEATHLANDS

Within the limits of the project area, coastal dune/heathland habitats are confined to the western extent of the Duck Harbor and Bound Brook sub-basins where they join the interior of the barrier beach system along Cape Cod Bay (figure 3-16). The combined area of dune and heathland grasslands is 21 acres (table 3-7). Common species within the dune grassland type include American beachgrass (*Ammophila breviligulata*) and wavy hairgrass. Common species within the heathland grassland type include bearberry (*Arctostaphylos uva-ursi*), northern bayberry (*Morella pensylvanica*), lowbush blueberry (*Vaccinium angustifolium*), goldenheather (*Hudsonia ericoides*), woolly beachheather (*H. tomentosa*), and broom crowberry (*Corema conradii*).

3.5.8 DEVELOPED

Twenty-four acres of land area within the project area is identified as developed (table 3-7). Due to the broad nature of the cover type mapping, developed lands include areas of managed landscapes associated with recreational, residential, and commercial development. Existing roadways within the project limits were too narrow to effectively map as developed lands at this broad scale. The majority of the total developed area (20 acres) is the low-lying portions of the CYCC golf course. The remainder consists of smaller developed lands within the Pole Dike Creek and Lower Herring River sub-basins.

3.5.9 INVASIVE PLANTS

Invasive plants are generally considered non-native species which cause economic or environmental harm by developing self-sustaining populations and become dominant and/or disruptive to those systems (Massachusetts Invasive Plant Advisory Group 2005). The Invasive Plant Atlas of New England (Mehrhoff et al. 2003) and the Massachusetts Invasive Plant Advisory Group maintain listings of non-native or exotic plants considered invasive. Exotic plants can cause a variety of problems including loss of habitat for native plant and wildlife species, reductions in biodiversity, and changes to natural ecological processes such as plant community succession, nutrient cycling, and the hydrologic regime (Martin and Hanley 2001). Martin and Hanley (2001) conducted a Seashore wide survey to establish a baseline of abundance and distribution of exotic plant species in preparation for the development of exotic vegetation management plans and implementation of control treatments. The flora of the Seashore is composed of about 830 species of plants, of which approximately 25 percent (211 species) are non-native to the outer Cape (Martin and Hanley 2001). During this study, the following exotic species were identified within the Herring River flood plain: Japanese barberry (*Berberis thunbergii*), spotted knapweed (*Centaurea biebersteinii*), Oriental bittersweet (*Celastrus orbiculata*), common velvet grass (*Holcus lanatus*), Japanese honeysuckle (*Lonicera japonica*), Morrow's honeysuckle (*Lonicera morrowii*), common reed, white poplar (*Populus alba*), multiflora rose (*Rosa multiflora*), water-cress, and black locust (*Robinia pseudo-acacia*). Watercress is a common freshwater aquatic plant found within non-tidal portions of the Herring River that is growing so densely in the waterway that it has become an obstacle to migrating riving herring (Hughes, pers. comm. 2011). All of the non-native species listed above except common velvet grass and white poplar are considered to be invasive (Massachusetts Invasive Plant Advisory Group 2005).

Additional invasive plant species documented along permanently established vegetation monitoring transects within the Herring River flood plain include Russian olive (*Elaeagus angustifolia*) and reed canary grass (*Phalaris arundinacaea*) (Smith 2007). These invasive species and others found in the area, including cheatgrass (*Bromus tectorum*), and curly dock (*Rumex crispus*), could be eliminated or greatly reduced through tidal restoration and the introduction of saline waters (Smith 2005). Narrow-leaf cat-tail (*Typha angustifolia*), the dominant plant within freshwater marshes in the Herring River flood plain, has become naturalized throughout most of eastern North America, but is probably not native to New England (Shih and Finkelstein 2008).

Wetland restoration projects often are designed to control common reed, as the expansive monotypic stands tend to displace valuable native coastal wetland plant communities, primarily salt marsh. Saltonstall (2002) documented the presence of numerous genetic strains of common reed throughout the world, including native and non-native types inhabiting New England. The native type is now classified as the sub-species *Phragmites australis* ssp. *americanus* (Saltonstall et al. 2004). This sub-species was historically a common, non-invasive component of New England wetland plant communities. But once the invasive type was introduced from Europe, it spread rapidly and generally replaced the native type, which is now rare compared to the massive stands of non-native common reed found in many locations. Within the Herring River flood plain, no known native populations are thought to exist (Smith 2011). As previously discussed, common reed is found primarily within the Lower Herring River sub-basin where it has formed an expansive monotypic stand and displaced valuable native coastal wetland plant communities. The control of existing stands and the future spread of this invasive species is an important component of the Herring River project. Another common invasive plant in freshwater wetland habitats is purple loosestrife (*Lythrum salicaria*). This species has not been recorded within the limits of the restoration project, but it has been identified on the shore of Higgins Pond further upstream in the watershed (Martin and Hanley 2001).

3.6 AQUATIC SPECIES

The mixing of fresh and salt water in estuaries creates a brackish transition zone where salinity can range from 0.5 ppt to 30 ppt. Estuarine salinity levels are generally highest near the mouth of the river where the ocean water enters, and lowest upstream where fresh water flows in. However, salinity levels throughout an estuary can change daily depending on tides, weather, or other factors (NOAA 2008). To survive in these conditions, species living in estuaries must respond quickly to the drastic changes in salinity.

Stenohaline species can tolerate a narrow range of salinity, and are typically freshwater specific or salt water specific. Euryhaline species can tolerate a wide range of salinities, such as those encountered in the brackish, shifting waters of an estuary. Because of the special features (physical and behavioral) and energy required to adapt to the constantly changing salinities in an estuary, there are far fewer euryhaline species than stenohaline species (NOAA 2008). Despite this, estuaries rank along with tropical rainforests and coral reefs as the most productive ecosystems in the world, more productive than the rivers and ocean influencing them (NOAA 2008).

The following sections summarize inventories and wildlife observations describing the aquatic fauna existing within the Herring River estuary, and where appropriate, the receiving waters of Wellfleet Harbor. In general, the estuary downstream of the Chequessett Neck Road Dike is characterized by estuarine species that are dependent on marine conditions, while the abrupt change in salinity and tidal flushing in the Lower Herring River basin between the dike and High Toss Road results in a dramatic change in species richness and abundance, with species more tolerant of lower salinities becoming most dominant. Upstream of High Toss Road only freshwater or anadromous/catadromous species are found.

3.6.1 ESTUARINE FISH

Estuaries provide spawning, nursery, and feeding grounds for many young and adult fish and shellfish species (see “Section 3.6.4: Shellfish” for a more detailed discussion). Some fish species (generally smaller fish) spend their entire lives in estuaries, while other larger species migrate short or long distances into or out of estuaries. Prior to construction of the Chequessett Neck Road Dike, the expansive Herring River provided important habitat for a number fish and macroinvertebrate species.

Within Herring River, upstream and downstream of the Chequessett Neck Road Dike, several surveys of fish species have been conducted by Gwilliam (2005 unpublished data), Raposa (1998 to 1999 unpublished data), and Marteinsdottir (as cited in Roman 1987). Curly et al. (1972) also conducted a survey downstream of the dike in 1968 to 1969 as part of a study of the marine resources in Wellfleet Harbor. The Gwilliam, Raposa, and Marteinsdottir studies surveyed areas both downstream and upstream of the dike. Gwilliam surveyed the entire length of the mainstem of Herring River upstream of the dike; while the upstream portions of the Raposa and Marteinsdottir surveys were confined to the area between the dike and High Toss Road. The 2005 (Gwilliam) and 1998–1999 (Raposa) surveys were conducted using a 1-m^2 throw trap, while the earlier surveys were conducted using seines. In addition to using a seine to sample the Herring River downstream of the dike and two other intertidal locations in Wellfleet Harbor, Curly et al. (1972) surveyed the deeper portions of the harbor with an otter trawl. Table 3-9 presents a summary of the finfish species caught during these surveys and their relative abundance. Differences in abundance between the two older surveys (Curley et al. and Marteinsdottir) and the more recent surveys (Raposa and Gwilliam) are due in large part to the sampling gear used and specific locations sampled. Table 3-10 provides estimates of species density (number of individuals per m^2) that were derived from the 2005 and 1998 surveys that used the 1-m^2 throw traps (Roman and James-Pirri 2011).

TABLE 3-9: FINFISH SPECIES AND SURVEY ABUNDANCE IN HERRING RIVER AND WELLFLEET HARBOR

Common Name	Scientific Name	1968–1969 [a,e]			1984 [b,e]			1998–1999 [c,f]			2005 [d,f]		
		Up stream Dike [g]	Down stream Dike	Wellfleet Harbor	Up stream Dike	Down stream Dike	Wellfleet Harbor [g]	Up stream Dike	Down stream Dike	Wellfleet Harbor [g]	Up stream Dike	Down stream Dike	Wellfleet Harbor [g]
Alewife	*Alosa pseudoharengus*	-	common	rare	occasional	common	-	rare	rare	-	absent	absent	-
American eel	*Anguilla rostrata*	-	absent	absent	rare	rare	-	occasional	rare	-	occasional	rare	-
Atlantic herring	*Clupea harengus*	-	absent	absent	absent	absent	-	absent	rare	-	absent	absent	-
Atlantic mackerel	*Scomber scombrus*	-	absent	absent	absent	rare	-	absent	absent	-	absent	absent	-
Atlantic menhaden	*Brevoortia tyrannus*	-	occasional	occasional	common	abundant	-	absent	occasional	-	abundant	occasional	-
Atlantic silverside	*Menidia menidia*	-	abundant	abundant	occasional	abundant	-	occasional	occasional	-	rare	rare	-
Atlantic tomcod	*Mircrogadus tomcod*	-	absent	rare	absent	absent	-	absent	absent	-	absent	absent	-
Blueback herring	*Alosa aestivalis*	-	rare	absent	rare	abundant	-	absent	absent	-	absent	absent	-
Blue fish	*Pomatomus saltatrix*	-	absent	rare	-	occasional	-	absent	absent	-	absent	absent	-
Chain pickerel	*Esox niger*	-	absent	absent	rare	absent	-	absent	absent	-	absent	absent	-
Cunner	*Tautogolabrus adspersus*	-	absent	rare	common	absent	-	absent	absent	-	absent	absent	-
Eastern shiner species	*Notropis* species	-	absent	absent	absent	absent	-	rare	absent	-	absent	absent	-
Four-spine stickleback	*Apeltis quadracus*	-	rare	absent	absent	occasional	-	common	absent	-	common	absent	-
Golden shiner	*Notemigonus chrysoleucas*	-	absent	absent	rare	absent	-	absent	absent	-	absent	absent	-
Goosefish	*Lophius americanus*	-	absent	rare	absent	absent	-	absent	absent	-	absent	absent	-
absent Grubby	*Myoxocephalus aenaeus*	-	-	rare	absent	absent	-	absent	absent	-	absent	absent	-
Hickory shad	*Notemigonus chrysoleucas*	-	absent	absent	absent	occasional	-	absent	absent	-	absent	absent	-
Hogchoker	*Trinectes maculates*	-	absent	absent	absent	absent	-	rare	absent	-	rare	absent	-
Inland silverside	*Menidia beryllina*	-	absent	absent	absent	absent	-	occasional	absent	-	absent	absent	-
Little skate	*Raja erinacea*	-	absent	rare	absent	absent	-	absent	absent	-	absent	absent	-
Lumpfish	*Cycolpterus lumpus*	-	absent	rare	absent	absent	-	absent	absent	-	absent	absent	-

Common Name	Scientific Name	1968–1969 [a,e]			1984 [b,e]			1998–1999 [c,f]			2005 [d,f]		
		Up stream Dike [g]	Down stream Dike	Wellfleet Harbor	Up stream Dike	Down stream Dike	Wellfleet Harbor [g]	Up stream Dike	Down stream Dike	Wellfleet Harbor [g]	Up stream Dike	Down stream Dike	Wellfleet Harbor [g]
Mummichog	*Fundulus heteroclitus*	-	common	common	common	abundant	-	common	abundant	-	common	abundant	-
Northern kingfish	*Menticirrhus saxatilus*	-	occasional	rare	absent	absent	-	absent	absent	-	absent	absent	-
Northern pipefish	*Syngnathus fuscus*	-	rare	rare	rare	rare	-	rare	rare	-	rare	rare	-
absent Northern puffer	*Maculates*	-	-	rare	absent	absent	-	absent	absent	-	absent	absent	-
Northern searobin	*Prionotus carolinus*	-	-	rare	absent	absent	-	absent	absent	-	absent	absent	-
Sheepshead minnow	*Cyprinodon variegates*	-	absent	absent	absent	absent	-	absent	absent	-	rare	absent	-
absent Smooth dogfish	*Mustelus canis*	-	-	rare	absent	absent	-	absent	absent	-	absent	absent	-
Striped killifish	*Fundulus majalis*	-	abundant	abundant	occasional	abundant	-	rare	rare	-	common	occasional	-
absent Striped searobin	*Prionotusevolans*	-	-	rare	absent	absent	-	absent	absent	-	absent	absent	-
Sunfish species	*Lepomis* species	-	absent	absent	rare	absent	-	rare	absent	-	absent	absent	-
Tautog	*Tautoga onitis*	-	rare	rare	absent	absent	-	absent	absent	-	absent	absent	-
Three-spine stickleback	*Gasterosteus aculeatus*	-	rare	rare	absent	absent	-	absent	absent	-	absent	absent	-
Tidewater silverside	*Menidia berilyna*	-	occasional	absent	rare	absent	-	absent	absent	-	absent	absent	-
White perch	*Morone Americana*	-	absent	absent	rare	rare	-	absent	absent	-	absent	absent	-
Windowpane flounder	*Scophthalmus aquosus*	-	absent	rare	absent	absent	-	absent	absent	-	absent	absent	-
Winter flounder	*Pseudopleuronectus americanus*	-	occasional	occasional	rare	rare	-	absent	absent	-	absent	rare	-

a Curley et al. 1972

b Roman 1987

c Raposa 1998-1999 unpublished data

d Gwilliam 2005 unpublished data

e absent = not observed; rare = density (number per m2) < 0.1; occasional = density between 0.1 and 1.0; common = density between 1.0 and 5.0; abundant = density > 5.0

f absent = not observed; rare = number of individuals per seine haul < 1.0; occasional = number of individuals per seine haul between 1.0 and 10.0; common = number of individuals per seine haul between 10.0 and 50.0; abundant = number of individuals per seine haul > 50

g Area not surveyed

TABLE 3-10: ESTIMATES OF FINFISH DENSITY IN HERRING RIVER DERIVED FROM RAPOSA (1998) AND GWILLIAM (2005) SURVEYS

Common Name	Scientific Name	1998 [a,b] Density (number/m^2)[d]		2005 [c] Density (number/m^2)[d]	
		Upstream of Dike	Downstream of Dike	Upstream of Dike	Downstream of Dike
Alewife	*Alosa pseudoharengus*	0.05	0.03	-	-
American eel	*Anguilla rostrata*	0.59	0.03	0.29	0.03
Atlantic menhaden	*Brevoortia tyrannus*	-	0.15	5.50	0.25
Atlantic silverside	*Menidia menidia*	0.10	0.15	0.09	0.20
Eastern shiner species	*Notropis* species	0.01	-	-	-
Four-spine stickleback	*Apeltis quadracus*	2.18	-	1.65	-
Hogchoker	*Trinectes maculates*	0.03	-	0.03	-
Inland silverside	*Menidia beryllina*	0.14	-	-	-
Mummichog	*Fundulus heteroclitus*	3.24	7.33	1.12	8.43
Northern pipefish	*Syngnathus fuscus*	0.01	0.03	0.06	0.03
Sheepshead minnow	*Cyprinodon variegates*	-	-	0.09	-
Striped killifish	*Fundulus majalis*	0.04	1.00	0.06	0.95
Sunfish species	*Lepomis* species	0.01	-	-	-
Winter flounder	*Pseudopleuronectus americanus*	-	-	-	0.03
	Total Fish Density	**6.39**	**8.73**	**8.79**	**9.90**

a Raposa 1999 unpublished data as reported in Roman and James-Pirri 2011.

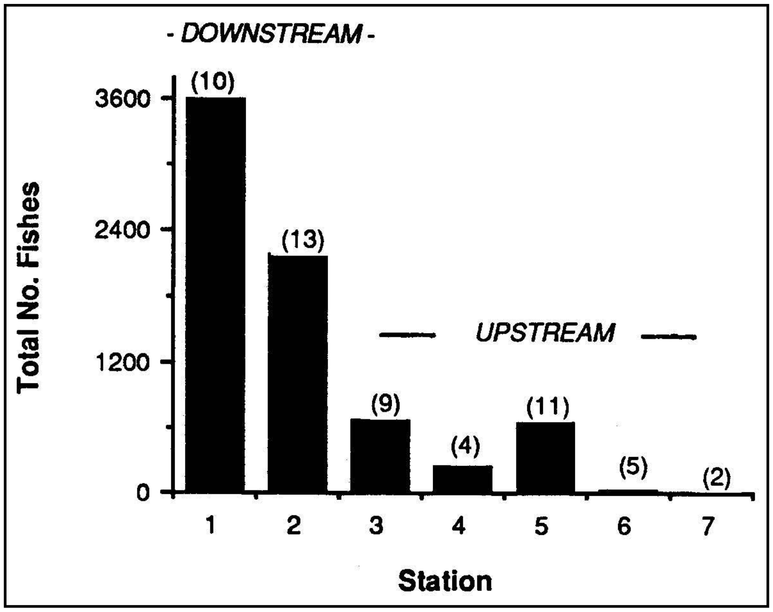
b Only includes August through October data to be comparable to Gwilliam data.

c Gwilliam 2005 unpublished data as reported in Roman and James-Pirri 2011.

d Densities derived from catch per unit effort (i.e., number of individuals caught in each 1 m2 throw trap sample).

In the more recent unpublished Raposa and Gwilliam surveys, a total of 14 species of fish were identified. Of the non-migratory estuarine species, mummichog (or common killifish) and four-spine stickleback were the dominant species upstream of the dike, while mummichog was the dominant species downstream of the dike (tables 3-9 and 3-10). In the 1998–1999 Raposa survey, the catadromous American eel was also an abundant species upstream of the dike. This species was most numerous during the May sampling (Raposa unpublished data), presumably during its spring migration upstream. The Atlantic menhaden was also found to be abundant upstream of the dike in 2005.

The Raposa and Gwilliam surveys also show that the relative abundance of non-migratory estuarine species such as mummichogs, striped killifish, and Atlantic silversides is greater downstream of the dike than upstream of the dike. This was consistent with the 1984 survey (Roman 1987) that showed that while the fish assemblage in the brackish waters immediately upstream of the dike was similar to that of downstream of the dike, the abundance of individuals was greatly reduced (table 3-9 and figure 3-17).



Source: Roman 1987.
Note: Number in parentheses is the number of species caught.

FIGURE 3-17: TOTAL NUMBER OF INDIVIDUALS AND SPECIES COLLECTED AT EACH SAMPLING STATION, 1984 SURVEY

Mummichogs use the high intertidal marsh as a nursery area, depending on it for spawning and survival of juveniles (Kneib 1984). Kneib (1993) also found that when high and low marshes had equal hydroperiods, growth rates and survival of mummichog larvae were greater in the high marsh, presumably due to the greater availability of preferred invertebrate prey. Striped killifish and Atlantic silversides prefer higher salinities, and, as indicated in tables 3-9 and 3-10, are more abundant downstream of the Chequessett Neck Road Dike when compared to upstream of the dike. Mummichogs, striped killifish, and Atlantic silversides are important in salt marsh food chains because of their distribution and abundance, and they are major prey for wading birds (e.g., herons and egrets), aerial searching birds (e.g., least and common terns) and many predatory fishes such as striped bass and blue fish (Abraham 1985). As such, they are also an important link in the transfer of organic material/energy within and out of salt marsh ecosystems (Abraham 1985; Kneib and Stiven 1978).

In the more recent surveys, fish with an affinity for fresh water and lower salinity waters (eastern shiner species, sunfish species, inland silverside and hogchoker) were found exclusively upstream of the dike. In 1984, the freshwater portion of the river exhibited the poorest habitat conditions in terms of number of species as well as abundance, as only three freshwater species, chain pickerel (*Esox niger*), pumpkinseed (*Lepomis gibbosus*), and golden shiner (*Notemigonus chrysoleucas*), represented by seven individuals were caught. In general, the freshwater fish fauna at Cape Cod is recognized as being depauperate (Roman 1987).

Wellfleet Harbor is an open embayment entering Cape Cod Bay and is the receiving waters for Herring River, which provides the only appreciable amount of freshwater into the harbor (Curley et al. 1972). The harbor serves as a nursery area for juveniles of many sport and commercial finfish, with Atlantic menhaden being by far the most abundant, numbering in the tens of thousands in the summer months (Curley et al. 1972; Town of Wellfleet 1995). Juveniles of other species found using the area as a nursery include winter flounder, windowpane flounder, northern kingfish, tautog, bluefish, and mackerel. Locally abundant forage species include Atlantic silverside, four-spine stickleback, common killifish, striped killifish, tidewater silverside, alewife, blueback herring, and white perch (Curley et al. 1972). These fish form the forage base for larger transitory fish visiting the area such as striped bass, bluefish, and Atlantic mackerel. For a more detailed discussion on migratory fish visiting the area see "Section 3.6.3: Anadromous and Catadromous Fish."

3.6.2 MACROINVERTEBRATES

In 2005 macroinvertebrates were sampled downstream and upstream of the Chequessett Neck Road Dike (Johnson 2005 unpublished data). Eleven species were collected from the Herring River downstream of the dike with the gastropod, Eastern mud snail (*Ilyanassa obsolete*) being the most dominant (Johnson 2005 unpublished data). Though uncommon, other gastropods identified included, the spiny slipper snail (*Crepidula aculeata*), Atlantic oyster drill (*Urosalpinx cinerea*), common periwinkle (*Littorina littorea*), greedy dovesnail (*Anachis avara*). The bivalves that were commonly found downstream of the dike included the quahog (*Mercenaria mercenaria*), eastern oyster (*Crassostrea virginica*), with lesser numbers of soft shell clam (*Mya arenaria*), razor clam (*Ensis americanus*), Baltic clam (*Macoma balthica*), and blood ark (*Anadara ovalis*). In the sub-tidal areas of the Herring River between the Chequessett Neck Road Dike and High Toss Road only two species were found, eastern mud snail and quahog, although the quahog was rare with only three specimens collected (Johnson 2005 unpublished data).

In 2004, Lassiter (2004 unpublished data) sampled macroinvertebrates at three locations, (1) immediately upstream of the Chequessett Neck Road Dike, (2) just downstream of High Toss Road and, (3) immediately downstream of Bound Brook Island Road. Species collected included nudibranchs, polychaete worms, oligochaetes, insects, amphipods, gastropods, isopods, green crab (*Carcinus maenas*), and quahog immediately upstream of the dike. Both the number of species and number of individuals were greatest immediately upstream of the dike and lowest in the upper portions of the system just downstream of Bound Brook Island Road (table 3-11).

TABLE 3-11: SPECIES RICHNESS AND RELATIVE ABUNDANCE OF MACROINVERTEBRATES IN THE HERRING RIVER UPSTREAM OF THE DIKE IN 2004

Location	Number of Species	Number of Individuals
Upstream of dike	23	391
High Toss Road	7	36
Bound Brook Island Road	4	14

Source: Lassiter 2004 unpublished data.

Raposa and Gwilliam also captured macroinvertebrates during their surveys in 1998 and 2005. Grass shrimp (*Palaemonetes* sp.) strongly dominated both sample years upstream and downstream of the dike, although in 2005 there was also a moderately high density of the longwrist hermit crab (*Pagurus longicarpus*) downstream of the dike (Raposa 1998 unpublished data and Gwilliam 2005 unpublished data as reported in Roman and James-Pirri 2011) (table 3-12).

TABLE 3-12: ESTIMATES OF CRUSTACEAN DENSITY IN HERRING RIVER DERIVED FROM RAPOSA (1998) AND GWILLIAM (2005) SURVEYS

Common Name	Scientific Name	1998 [a,b] Density (number/m²) [d] Upstream Dike	1998 [a,b] Density (number/m²) [d] Downstream Dike	2005 [c] Density (number/m²) [d] Upstream Dike	2005 [c] Density (number/m²) [d] Downstream Dike
American horseshoe crab	*Limulus polyphemus*	0.01	-	0.06	-
Atlantic mud crab	*Panopeus herbstii*	-	-	0.03	0.55
Atlantic sand fiddler	*Uca pugilator*	-	0.03	-	-
Crab (unidentified)	Unknown crab	-	-	-	0.05
Crayfish (unidentified)	Unknown crayfish	-	0.03	-	-
Grass shrimp species	*Palaemonetes* sp.	42.31	39.58	154.12	39.98
Grassflat crab species	*Neopanope* sp.	0.01	-	-	-
Green crab	*Carcinus maenas*	0.58	1.35	0.03	0.08
Lady crab	*Ovalipes ocellatus*	-	-	-	0.03
Longwrist hermit crab	*Pagurus longicarpus*	0.06	1.73	-	15.43
Say mud crab	*Dyspanopeus sayi*	-	-	0.41	0.85
Sevenspine bay shrimp	*Crangon septemspinosa*	0.80	2.03	1.09	1.60
	Total Density	**43.787**	**155.76**	**44.70**	**58.55**

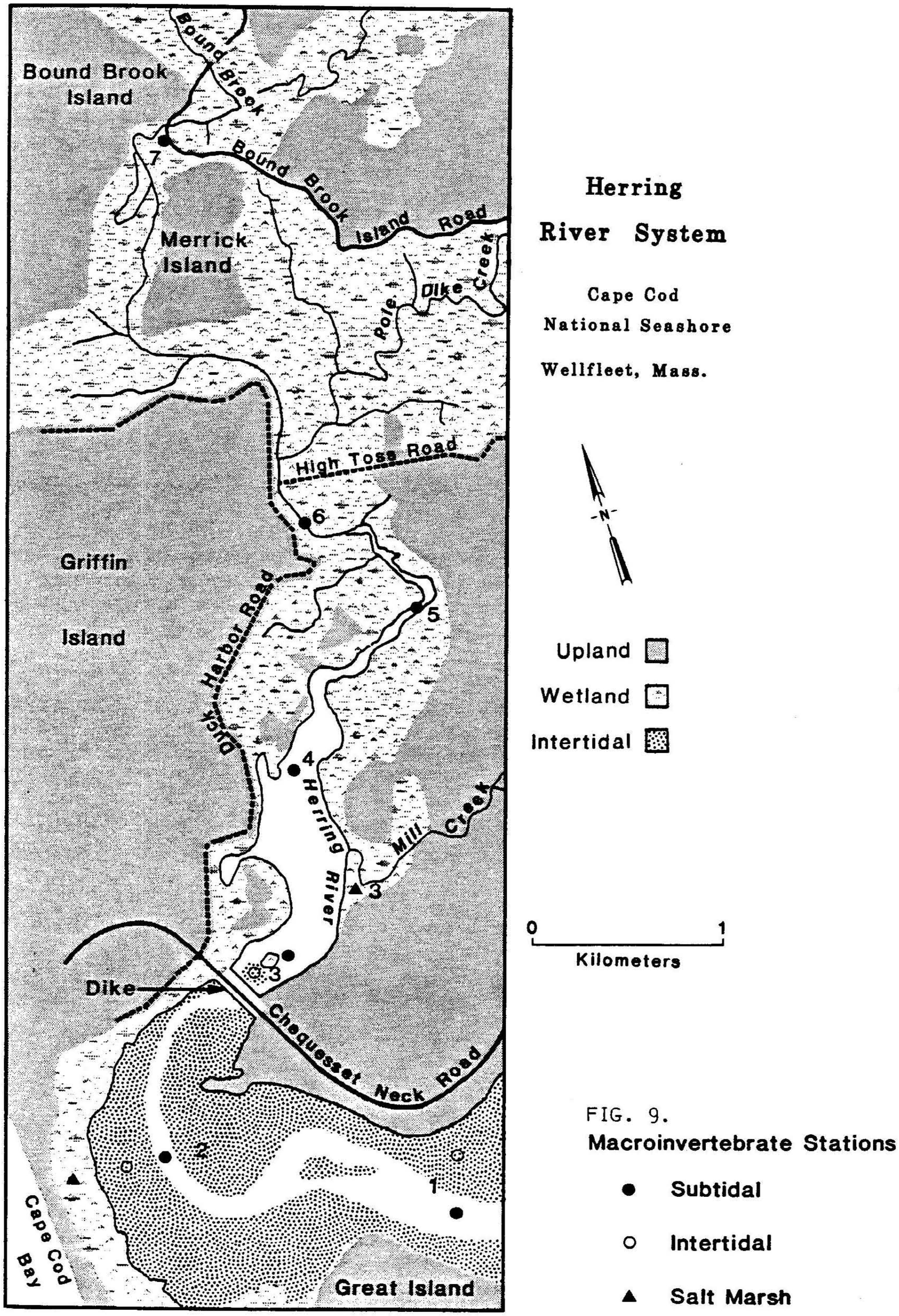
a Raposa 1998 unpublished data as reported in Roman and James-Pirri 2011.

b Only includes August through October data to be comparable to Gwilliam data.

c Gwilliam 2005 unpublished data as reported in Roman and James-Pirri 2011.

d Densities derived from catch per unit effort (i.e., number of individuals caught in each 1 m^2 throw trap sample).

In 1984 macroinvertebrates were sampled (Roman 1987) at seven locations in the sub-tidal, intertidal, and freshwater marsh habitats of the Herring River estuary (figure 3-18). Sixty-five species were collected from the estuarine portion of the river and the adjacent tidal marsh (stations 1–5), whereas 22 species were found in the freshwater portion of the system (stations 6–8). Species collected included bivalves (e.g., quahogs, razor clams (*Ensis directus*) and eastern oyster), decapod crustaceans (e.g., green crab), hermit crab (*Pagurus longicarpus*), and grass shrimp (*Palaemonetes* spp.), gastropods (e.g., Eastern mud snail and common periwinkle), amphipods, marine worms, leeches and others. For a complete list of the species, see Roman 1987. Species richness of intertidal and sub-tidal macroinvertebrates was moderate in the freshwater portion of the river, low in less saline areas, and high near the mouth of the river. Table 3-13 summarizes the relative abundance of the major estuarine macroinvertebrate species upstream of the Chequessett Neck Road Dike based on the sampling conducted in 1984 (Roman 1987). For a more detailed discussion of shellfish resources see “Section 3.6.4: Shellfish.”



Source: Roman 1987.

FIGURE 3-18: MACROINVERTEBRATE SAMPLING STATIONS, 1984 SURVEY

TABLE 3-13: RELATIVE ABUNDANCE OF MAJOR ESTUARINE MACROINVERTEBRATES IN HERRING RIVER UPSTREAM OF THE DIKE AS REPORTED IN ROMAN (1987)

Organism	Occurrence in Herring River Upstream of the Dike
Oyster (*Crassostrea virginica*)	Rare
Hard clam (*Mercenaria mercenaria*)	Absent
Freshwater species • Isopod (Asellus sp.) • Freshwater shrimp (*Gammarus fasciatus*)	Common far upstream
Estuarine endemic species • Spionid worm (*Scolecolepides viridis*)	Abundant
Euryhaline species • Isopod (*Edotea triloba*) • Polychaete (*Eteone heteropoda*) • Capitellid worm (*Heteromastus filiformis*) • Spionid worm (*Streblospio benedicti*)	Common
Stenohaline species • Blood worm (*Glycera dibranchiate*) • Polychaete (*Spiochaetopterus oculatus*)	Absent
Grass Shrimp (*Palaemonetes pugio*)	Common
Grass Shrimp (*Palaemonetes vulgaris*)	Absent
Green crab (*Carcinus maenas*)	Absent
Lady crab (*Ovalipes ocellatus*)	Absent

Source: Roman 1987.

3.6.3 ANADROMOUS AND CATADROMOUS FISH

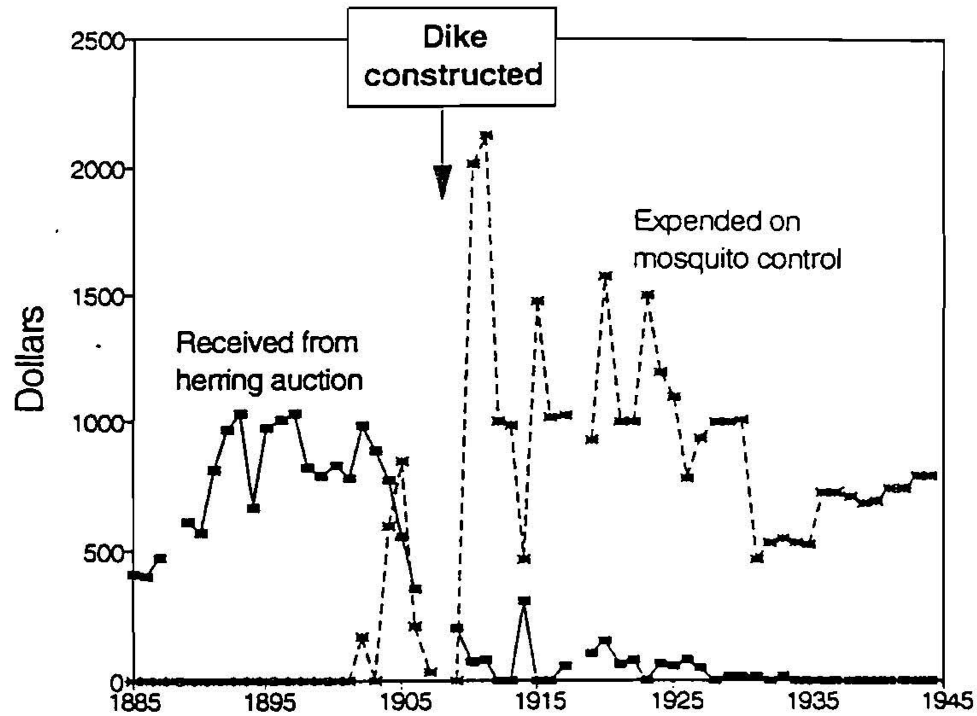
Five anadromous species (alewife, blueback herring, hickory shad, white perch, and striped bass), along with one catadromous species (American eel) are found in the Herring River.

Alewives and blueback herring (collectively referred to as river herring) migrate into freshwater from the ocean in early spring to spawn. Alewives typically spawn in coastal ponds and blueback herring typically spawn in rivers and streams. Adults of both species migrate rapidly downstream after spawning, with a total spawning time of approximately five days for a single migrating group (Fay, Neves, and Pardue 1983). Although supporting data are sparse, river herring are highly tolerant of salinity changes, either gradual or abrupt (Fay, Neves, and Pardue 1983).

Juvenile river herring remain in freshwater systems for three to seven months prior to migrating to the ocean between June and November, often exhibiting pulses of early and late migrations (Iafrate and Oliveira 2008). The emigrations of juveniles appear to be affected by abiotic (precipitation, water temperature, lunar phase) and biotic (size, age, hatch date, food availability) factors (Fay, Neves, and Pardue 1983; Iafrate and Oliveira 2008). In the Herring River estuary the three headwater ponds (Herring, Higgins, and Gull Ponds) provide approximately 156 acres of alewife spawning habitat (figure 3-19).

Historically, the sources of the Herring River were Herring Pond (18.5 acres) and Higgins Pond (33.5 acres), but in 1893 a channel was cut between Higgins Pond and Gull Pond, increasing the spawning area by 104 acres (Curley et al. 1972). In the 1880s, alewives (and presumably blueback herring) were abundant in Wellfleet Harbor and supported a profitable fishery in the Herring River prior to the construction of the Chequessett Neck Road Dike (Curley et al. 1972, figure 3-20 from; Portnoy and Reynolds 1997). Historic Board of Selectman records indicate the annual river herring harvest to be about 200,000 to 240,000 fish (Town of Wellfleet 1889 and 1890). Because these were numbers of fish caught, the actual size of river herring run was much larger. As shown in figure 3-20 and described by Belding (1920), there was a large decline in river herring population in the early 1900s and the value of the fishery plummeted. The decline in the fishery was attributed to exploitation resulting from annual leases (Belding 1920) and construction of the Chequessett Neck Road Dike limiting the number of adults reaching their spawning grounds (Curley et al. 1972). In 1920, Belding (1920) indicated that partial obstruction affecting the migration of river herring included the abundant growth of wild rice (*Zizania aquatic*), the passageway under Old King's Highway, and the dike.

FIGURE 3-19: HERRING RIVER ANADROMOUS FISH RUN



Source: Portnoy and Reynolds 1997.

FIGURE 3-20: VALUE OF THE HERRING RIVER HERRING FISHERY, 1885–1945

In more recent years, low summertime dissolved oxygen levels in the upper river system, likely exacerbated by the restriction of seawater flow and flushing rate caused by the dike, resulted in large fish kills of emigrating juvenile river herring. Beginning in 1983, the NPS documented total stream anoxia lasting 10 to 17 days accompanied by massive die-offs of emigrating juvenile river herring. The number of fish killed in 1985 was estimated at 19,000 individuals, likely representing a major depression in the ultimate future annual recruitment from this year class (Portnoy, Roman, and Soukup 1987). Because of the massive die-offs, the NPS constructed a fish gate at the outlet of Herring Pond to permit the blockage of out-migrating juvenile river herring during periods of low dissolved oxygen (Portnoy, Roman, and Soukup 1987). This practice no longer occurs. In addition to low dissolved oxygen, non-native watercress (*Rorippa nasturtium-aquaticum*) and other submerged and emergent plant species just downstream of the Herring Pond outlet have grown dense enough in the waterway to become an obstacle to migrating riving herring. To help alleviate this problem, the Town of Wellfleet's Herring Warden spends approximately 100 to 150 hours annually clearing a path through the vegetation for the herring to pass (Hughes, pers. comm. 2011).

In 2009 the Association to Preserve Cape Cod began a volunteer monitoring program to estimate the size of the herring run in Herring River from April 1 through June 1. Based on daytime counts from 7 a.m. to 7 p.m. the estimated river herring run (using the MA Division of Marine Fisheries' Visual Counts Software) was 17,035 in 2009, 12,523 in 2010, and 7,740 in 2011 (APCC 2011). River herring mature and begin to return to spawn after three years (Fay, Neves, and Pardue 1983); with only three years of data, it is difficult to interpret the decrease from 2009 to 2011 as an ongoing trend because of inter-annual variations that could be occurring. Many outside factors such as increases in predators (e.g., striped bass) or offshore fishing can impact populations. However, regionally throughout the Atlantic coast, river herring populations have experienced substantial declines to the point where in 2006 NOAA listed the alewife and the blueback herring as species of concern (NOAA 2006), and currently NOAA is considering listing them as threatened under the Endangered Species Act (NOAA 2011).

White perch, hickory shad, and striped bass are other anadromous fish that have been collected or observed at the mouth of the Herring River; however, because they are capable of avoiding the various sampling gears used, they are likely more common than surveys indicate (Curley et al. 1972; Roman 1987).

White perch, a commercially important and popular game fish, inhabit estuaries and freshwater systems from South Carolina north to the Canadian Maritimes. Marine populations migrate into estuaries and spawn in waters with salinities generally less than 4.2 ppt from May through July (Stanley and Danie 1983). Juveniles generally use the estuarine waters as a nursery site, staying in these areas for up to one year (Stanley and Danie 1983). Within Herring River, white perch can be found in abundance and use the upper main river stem and ponds as spawning sites (HRTC 2007).

Historically, hickory shad have been an important commercial fish; however, over the past 50 years their abundance has declined. Similar to river herring, hickory shad spend the majority of their adult life at sea, only entering freshwater in the spring to spawn. They spawn in rivers and tributaries along the Atlantic coast from the Bay of Fundy, Canada to Florida (ASMFC n.d.). Adults return to the sea after spawning, but most juveniles migrate from their nursery areas to the sea in early to late summer (ASMFC n.d.). Though, no adult or juvenile fish were caught during the 1984 sampling surveys, schools of hickory shad were observed at the dike on the downstream side in September (Roman 1987).

Striped bass, an important commercial and recreational fish, is another anadromous species not captured during either the 1984 or 1972 sampling surveys. However, they are common in Wellfleet Harbor and in Herring River immediately downstream of the Chequessett Neck Road Dike, where they are sought after and caught by sport fisherman (Curley et al. 1972; Roman 1987). In Massachusetts, stripers are most common in spring and fall as transients. Spawning takes place from the spring to early summer, with the greatest activity when the water warms to about 65°F (MA DMF n.d.). Striped bass feed on a variety of macroinvertebrates and forage fish, many of which are common in Wellfleet Harbor and Herring River.

In addition to anadromous fish, the American eel, a catadromous species, is found in the Herring River. Eels spend most of their lives in rivers and freshwater ponds and migrate to sea to spawn. Young eels ("elvers") enter the river on their way to the ponds in April and May, and the adults migrate to the sea in June. Though counts of migrating eels do not take place in Herring River, in 2009 107 elvers were observed migrating into Herring Pond as part of the Association to Preserve Cape Cod and Friends of Herring River volunteer river herring counts (APCC 2011). Additionally, in the fall of 1980, several thousand eels of all sizes were killed as a result of low pH, high sulfate, and high aluminum concentrations in the surface waters in the upper reaches of the river (Portnoy, Roman, and Soukup 1987).

Brook trout (*Salvelinus fontinalis*) are the only trout native to much of the eastern United States, and although not currently found in Herring River, the "salter" variety of brook trout likely occurred historically in the Herring River (Hurley, pers. comm. 2011). Brook trout require cold (below 75°F), clean, and well oxygenated waters to survive (Smith 1985; EBTJV 2006). Salter brook trout are anadromous, spawning in the fall and moving downstream to salt water in November where they overwinter. Salters begin to move upstream in early spring and found in brackish or fresh water by mid-May.

Salter brook trout were historically an important native game fish of southeastern Massachusetts and during the 1800s Cape Cod was a favorite fishing destination (Hurley, pers. comm. 2007). Unfortunately, during the past couple hundred years, salter brook trout populations in Massachusetts have been in decline, largely due to pressures from urbanization and habitat fragmentation from the building of dams.

Although little population data exists for salter brook trout from Boston south to Cape Cod (EBTJV 2006; Hurley, pers. comm. 2007), restoration efforts in southeastern Massachusetts, such as Red Brook in Wareham, Massachusetts and Childs River in Mashpee, Massachusetts on Cape Cod have been successful. Other restoration efforts include the Coonamessett River in Falmouth, the Quashnet River, and potentially Marston Mills River on Cape Cod as well. Additionally, the Seashore is working with Trout Unlimited, Massachusetts Division of Fish and Game, and the U.S. Fish and Wildlife Service (USFWS) to potentially restore brook trout to Fresh Brook and other habitats in Wellfleet, and would likely extend this effort to Herring River as part of the restoration project (Hurley, pers. comm. 2011).

3.6.4 SHELLFISH

Oysters, quahogs, and softshell clams (*Mya arenaria*) constitute the most common shellfish in Wellfleet Harbor and Herring River, at least downstream of the dike, with oyster and quahog being the two most abundant and economically important species (see "Section 3.10: Socioeconomics" for detailed information on the commercial and recreational aspect of shellfishing in the Town of Wellfleet).

Oysters are filter feeders and prefer habitats in shallow estuarine waters including flats, offshore bars, and oyster reefs, and require hard substrate for their larvae to settle on (Sellers and Stanley 1984). They are usually restricted to waters with salinities between 5 ppt and 30 ppt, with an optimum salinity range of 10 ppt to 28 ppt (Sellers and Stanley 1984). Salinities above 7.5 ppt are required for spawning (Sellers and Stanley 1984). They are generally not found north of Cape Cod due to cool water temperatures (Curley et al. 1972; Sellers and Stanley 1984). Oysters spawn at water temperatures above 70°F, generally from early July through August in Wellfleet Harbor (Town of Wellfleet 1995). Sperm and eggs are synchronously released into the water column where fertilization takes place. The fertilized egg rapidly develops into a microscopic swimming larva and after 24 to 48 hours develops into a feeding form known as a veliger. After feeding on algae for 12 to 20 days, it develops a foot, becomes a pediveliger and settles to the bottom where it crawls along until it finds a location where it will cement itself to a suitable substrate by means of a limey secretion. It then becomes a tiny oyster known as spat. Spat grow rapidly to become juvenile oysters. Growth to harvestable size depends on water temperature, oxygen concentration, and quantity of food.

In 1969, Curley et al. (1972) sampled four areas downstream of the dike for oysters and found densities ranging from 0.1 to 7.8 per square yard for "legals" and 7.3 to 74 per square yard for "sub-legals." The current legal size for oysters in Massachusetts is 3 inches (7.5 cm, MA DMF 2011). They also reported that the Herring River (downstream of the dike) was one of the best spawning and setting areas for oysters in the Wellfleet Harbor area. In 1978, seed-size oysters averaging 2 inches long were found attached to rocks on the upstream face of the dike and scattered throughout the river to a point approximately 100 yards upstream of the dike (Gaskell 1978). During the 1984 survey (Roman 1987) oysters were found in densities of approximately 25 per square yard in the intertidal areas of the river downstream of the dike, but few were found upstream. Various factors limit the propagation and survival of oysters in Wellfleet Harbor, one of which is the lack of clean, hard bottom or substrate for oyster larvae to settle on. However, to provide suitable substrate, the town has been laying down cultch (empty oyster, clam, and scallop shells used as substrate) for larval settlement (Town of Wellfleet 1995; Koch, pers. comm. 2011a). Cultch is typically laid down beginning the second week of June and completed by July 1 to coincide with when the larvae settle out as spat, typically in mid-July. If cultch is laid out too soon, they can develop a coating of slimy algae which can hamper the ability of spat to attach to the cultch (Town of Wellfleet 2007). Cultch is typically placed at the mouth of Herring River; in Duck Creek, Chipman's Cove, and Blackfish Creek; south of Great Island; and along Indian Neck (Koch, pers. comm. 2011b).

The quahog (i.e., hard clam) can be found in intertidal and sub-tidal areas and is most abundant from Massachusetts to Virginia, though it ranges from the Gulf of St. Lawrence to Texas (Stanley and DeWitt 1983). Though they are found in substrates ranging from pure mud to coarse sand, optimum quahog production is generally reported from sandy mud to muddy sand sediments in areas with a 15 ppt to 35 ppt salinity range (Roman 1987; Stanley and DeWitt 1983). Spawning takes place at temperatures above 70°F; growth requires temperatures above 46°F. With suitable sediment, salinity, favorable temperatures for both growth (April through October) and spawning (July and August), and 10-foot tides moving large volumes of water through the area providing sufficient food, oxygen and waste removal, Wellfleet Harbor exhibits some of the highest quahog growth rates in the state of Massachusetts (Town of Wellfleet 1995). In 1969, Curley et al. (1972) reported average densities of less than 1 per square yard, but several areas throughout Wellfleet Harbor, including Herring River downstream of the Chequessett Neck Road Dike had densities of up to 8 per square yard. In 1984 (Roman 1987), the one station where a quantitative estimate was made downstream of the dike had quahog densities of 1 per square yard. Roman (1987) did not find quahogs upstream of the dike, possibly because existing salinities were too low to allow them to establish a population.

Within its range, the softshell clam is most abundant in the intertidal regions of the New England coast and sub-tidally in Chesapeake Bay. Optimum salinities are 10 ppt to 33 ppt and fine sediments are preferred over coarse sediments, although softshell clams can be found in soft muds, sands, compact clays, coarse gravel, and between stones (Newell and Hidu 1986). Curley et al. (1972) found in softshell clams in various areas of Wellfleet Harbor and seed clams (average size of 1 inch) have been found just upstream of the Chequessett Neck Road Dike in 1978 at densities of 4 per square foot in a narrow band on the east shore of the small tidal island in the middle of the river (Gaskell 1978). However, no softshell clams were found in Herring River upstream of the dike during the 1984 survey (Roman 1987). Softshell clams are currently harvested in Wellfleet Harbor at various locations. Other shellfish species found in the Herring River estuary include razor clams, blue mussels (*Mytilus edulis*), surf clams (*Spisula solidissima*), and bay scallops (*Argopecten irradians*) all of which are found downstream of the Chequessett Neck Road Dike (Town of Wellfleet 1995). Bay scallops are occasionally important commercially, but occur erratically in Wellfleet Harbor. According to Curley et al. (1972) their numbers are limited by the harbor's 10-foot tide range, which exposes large areas of flats in the winter, which can adversely affect survival (Curley et al. 1972).

3.7 STATE-LISTED RARE, THREATENED, AND ENDANGERED SPECIES

NPS policies (e.g., NPS *Management Policies 2006* and Director's Order 12) and the Massachusetts Endangered Species Act (MESA) (M.G.L c.131A and regulations 321 CMR 10.00) require examination of impacts on state-listed threatened and endangered species and species of special concern. Massachusetts Division of Fish and Wildlife, Natural Heritage Endangered Species Program (NHESP) oversees listing of state species and administering MESA. Species listed as endangered or threatened by the state are defined in the same way as federally endangered and threatened species. Currently, six state-listed wildlife species occur within the Herring River project area: three birds, American bittern (*Botaurus lentiginosus*), least bittern (*Ixobrychus exilis*), and northern harrier (*Circus cyaneus*); two reptiles, diamondback terrapin (*Malaclemys terrapin*) and eastern box turtle (*Terrapene c. carolina*); and one invertebrate, water-willow stem borer (*Papaipema sulphurata*). The following sections describe these protected species and their current status within the Herring River.

3.7.1 AMERICAN BITTERN (*BOTAURUS LENTIGINOSUS*) – ENDANGERED

The American bittern is a medium-sized bird that spends the majority of its time hidden among marshland vegetation. It prefers wetlands dominated by tall, emergent vegetation such as cattails, bulrushes, sedges, and grasses, but may also occur in brackish wetlands (NHESP n.d.). Within these habitats the American bittern frequents vegetation fringes and shorelines (Gibbs et al. 2009a). The American bittern forages in marshes, meadows, and along edges of shallow ponds. Preferred foods include frogs, small snakes and eels, crayfish, fish, salamanders, and occasionally mice and grasshoppers caught in open fields (NHESP n.d.).

Bitterns typically nest in marshes, but may also nest in grassy upland fields adjacent to wetlands. Nests are about a foot (30 centimeters) in diameter, made up of dead reeds, cattails, grasses, and sedges; nests located on the ground in dense vegetation or on a platform about a foot above the water. One clutch of three to five eggs is laid per year (NHESP n.d.). The breeding range of the American bittern extends from Newfoundland west to Manitoba and British Columbia; south to Maryland; and west through Oklahoma and Kansas to southern California. American bitterns return from their wintering habitat to Massachusetts marshes in April (Gibbs et al. 2009a).

The entire life cycle of the bittern is dependent on wetlands, so availability of suitable wetland breeding habitat within its range likely determines gross abundance of this species (Gibbs et al. 2009a). Population trends in Massachusetts are not known although the global population is thought to be declining (NHESP n.d.). Loss of wetland habitat is the major cause of decline, starting as early as the 1890s in some states, including Massachusetts. Over half the original wetlands in the United States have already been destroyed; inland, freshwater wetlands, the nesting and wintering areas of American bitterns are among the most threatened habitats. Other causes of population declines are human disturbance and pesticides/contaminants (Gibbs et al. 2009a).

Although call-playback survey results indicate the presence of American bitterns (Erwin, Conway, and Hadden 2002), there is no documentation of nesting activity of this species within the Herring River project area.

3.7.2 LEAST BITTERN (*IXOBRYCHUS EXILIS*) – ENDANGERED

The least bittern is the smallest member of the heron family, weighing on average 2.8 ounces (80 grams), and among the most inconspicuous of North American marsh birds. Suitable habitats include fresh and brackish water marshes with tall, dense emergent vegetation and clumps of woody plants over deep water (Gibbs et al. 2009b). Massachusetts NHESP occurrence records describe habitat as primarily cattails and open water (NHESP n.d.). Least bitterns forage by stalking along the openwater side of emergent vegetation, grasping clumps of plants with their long toes and curved claws. They are also known to build small foraging platforms at feeding sites, catching fast-moving prey (mainly small fish and insects) (Gibbs et al. 2009b).

The least bittern nest is an elevated platform with an overhead canopy, built of emergent aquatic vegetation and sticks. A clutch of four to five eggs is laid over a six-day period every year. A second attempt at breeding may occur if the first attempt fails. Least bitterns breed from southeastern Canada through the eastern and central United States to Mexico and Costa Rica. They typically arrive at nesting areas in Massachusetts by mid- to late-May; eggs and fledglings have been observed in the state throughout June (NHESP n.d.).

When encountered, least bitterns typically burrow through dense vegetation, fly away weakly over marsh vegetation, or stand still with their bill pointed upward, feathers compressed, and eyes directed forward (Gibbs et al. 2009b).

Although call-playback survey results indicate the presence of least bitterns (Erwin, Conway, and Hadden 2002), there is no documentation of nesting activity of this species within the Herring River project area.

3.7.3 NORTHERN HARRIER (*CIRCUS CYANEUS*) – THREATENED

The northern harrier, sometimes referred to as the marsh hawk, is a slim, long-legged, long-tailed accipiter. Harriers establish nesting and feeding territories in wet meadows, grasslands, and coastal and inland marshes. Harriers construct their nests from grasses, weeds, and other emergent aquatic and upland vegetative material. Nests are typically on the ground among bushes and other low vegetation. Sometimes the nests are built over shallow water on raised mounds of sticks. Egg incubation occurs in the spring (April). Harriers prey on a variety of small animals, including rodents, rabbits, and other small mammals, small birds, insects, amphibians, reptiles, and carrion. In Massachusetts, meadow voles (*Microtus pennsylvanicus*) constitute an important component of the harrier's diet; there is a direct correlation between the breeding success of northern harriers and the number of voles found in their territory (NHESP n.d.).

Harriers are uncommon summer residents or migrants in Massachusetts, although they once were much more abundant in the state. The harrier was once a common breeder throughout Massachusetts from the mid-1800s to the early 1900s. Today, almost all of the breeding harriers in the state are confined to the offshore islands, Cape Cod, and Plum Island in the northeast corner of the state. Most harriers in the state that do not migrate south spend the winter in coastal marshes on Cape Cod and the offshore islands. Some northern harriers that breed in areas north of Massachusetts may also spend the winter on the offshore islands and along the coast (NHESP n.d.).

Results from field surveys conducted from 2004 through 2006 indicate the harrier breeding population at the Seashore in 2004 consisted of 10 nesting pairs, which was likely the largest breeding population anywhere on the Massachusetts mainland and, therefore, of statewide conservation significance. The 2005 population was smaller, comprising five nesting pairs plus four other pairs that mated and established a breeding territory early in the season but did not progress to nesting (Bowen 2006). The 2006 population was slightly larger and consisted of seven nesting pairs (Byrne 2007). Two of the seven nests were successful and produced five fledglings. Two nesting sites documented within the vicinity of the Herring River project at the Ryder Hollow and Bound Brook areas in all three survey years may be affected by the proposed project. Both sites were in freshwater marshes dominated by cattail. Although no formal, systematic nesting survey has been conducted since 2006, anecdotal observations of adult harriers have been made since then during the nesting season near documented nesting sites. Thus there is no reason to assume that northern harriers have not continued to nest in the Bound Brook sub-basin (Cook, pers. comm. 2011).

Cattail marshes are considered the single most important harrier nesting habitat at the Seashore, accounting for 50 percent of all nest sites. Other nests on Cape Cod have been found in outwash scrub oak barrens (Bowen 2006). The most substantial factor in the northern harrier decline has been destruction of suitable habitat by reforestation of agricultural land and destruction of coastal and freshwater wetlands. In coastal areas, human disturbance may cause some harriers to abandon their nests. Other factors such as prey abundance, prolonged periods of rain (which may destroy nests and eggs), and predation on eggs and nestlings can also affect their success (NHESP n.d.).

3.7.4 Diamondback Terrapin (*Malaclemys terrapin*) – Threatened

The diamondback terrapin, a marine turtle, uses brackish marsh habitats for foraging and sandy shoreline habitats for nesting. The brackish marshes along the periphery of Wellfleet Harbor support the northernmost population on the East Coast, although individuals have been found in Provincetown.

Terrapins are strong, fast swimmers and feed primarily on snails, mussels, and crabs. They live most of their lives in the marsh and are the only emydid turtle capable of surviving in a high salinity environment without accessing a freshwater source. Terrapins hibernate in the mud of tidal creeks and mate in the calm waters of the salt marsh in mid-spring. Females nest on land, usually among the dunes and open habitats adjacent to the marsh, often within the Seashore (Cook 2008a).

Terrapin populations were decimated in the 19th century by overharvesting for food. They recovered by the mid-20th century, but now face renewed pressures from loss or degradation of nesting habitats to development, increased nest predation by raccoons and skunks, and increased adult mortality from road kills (Cook 2008b).

3.7.5 Eastern Box Turtle (*Terrapene c. carolina*) – Species of Special Concern

Eastern box turtles are relatively common terrestrial reptiles on Cape Cod that use dry and moist woodland and freshwater marsh habitats. The box turtle shifts habitats seasonally to avoid excessive heat or cold. They frequent the edges of wetlands, especially during dry summer periods when they move into fresh surface water for hydration.

Pine barrens and oak thickets present in areas adjacent to the Herring River estuary are optimal habitat types for this species. Upland habitats that support communities of bearberry (*Arctostaphylos uva-ursi*), lowbush blueberry (*Vaccinium angustifolium*), and bracken fern (*Pteridium aquilinum*), common upland plant species adjacent to the estuary, are also preferred habitat (Erb 2011). The turtles feed on a broad range of foods including insects, worms, slugs, fruit, mushrooms, vegetation, and carrion provided by the upland habitats.

Box turtles are in decline throughout much of their range in the eastern United States. They are extremely long lived, slow to mature, and have relatively few offspring per year. These characteristics, along with habitat degradation, road kill frequency, and pet collection, make the box turtle a species particularly susceptible to human-induced pressures. The Seashore, however, with its fairly intact, unfragmented landscape, likely provides some of the best remaining box turtle habitat in New England and they are frequently encountered in and adjacent to the Herring River project area (R. Cook, pers. comm. 2011).

3.7.6 Water-Willow Stem Borer (*Papaipema sulphurata*) – Threatened

The water-willow stem borer is a globally rare, nocturnal moth found only on the coastal plain of southeastern Massachusetts and Cape Cod. Water-willow stem borer larvae feed almost exclusively on water-willow (*Decodon verticillatus*), a freshwater wetland plant widely distributed throughout New England. Typically, water-willow grows in the shallowest portions of vernal ponds, in seasonally flooded freshwater swamps, and along upland edges of streams, ponds, and other permanent bodies of water. On outer Cape Cod, water-willow has become established in formerly tidal river systems where diking has created and maintained freshwater conditions.

Numerous stands of water-willow support the stem borer along the margins of the Herring River and its tributaries. During a survey performed in 2006, 89 larval host plant patches were located within the Herring River flood plain and 80 records of stem borer use were recorded. *D. verticillatus* patches were mapped as 172 discrete stands occurring along approximately 41,000 linear feet of streambank habitat. An additional 29 stem borer records were found within 17 host plant patches at Salt Meadow within the East Harbor system in Truro (Mello 2006). Casual observations by Seashore scientists made since the 2006 survey indicate that *D. verticillatus* also occurs along the edges of a majority of vernal pools and ponds throughout the Seashore (R. Cook, unpublished NPS data, 2012).

3.8 TERRESTRIAL WILDLIFE

Over 450 species of amphibians, reptiles, fish, birds, and mammals depend on the diversity of upland, wetland, and coastal ecosystems found in the Seashore and nearby environs. Depending on the species, the Seashore may provide habitat year round, or only during nesting season, migration, or winter. Seashore wildlife includes marine mammals and turtles; the familiar gulls, terns, and waterbirds of beaches and salt marshes; and a great variety of animals that inhabit Seashore woodlands, heathlands, grasslands, swamps, marshes, and vernal ponds (NPS 2011e).

3.8.1 BIRDS

The Seashore provides a wide diversity of freshwater, marine, and upland habitats for the roughly 370 species of birds. About 80 of these nest here during the spring and summer months, with the remainder using the Seashore for migratory stopovers or to overwinter. The Seashore contains prime habitat for a multitude of species including many that migrate along the Atlantic Flyway. A list of species observed within the project area is presented in appendix E.

Freshwater Marsh Birds and Upland Birds

The birds of the Wellfleet area were surveyed in 2000, as part of a survey of grassland birds (Kearney and Cook 2001). Species recorded at Wellfleet during the breeding season (June) and presumed to breed there or nearby and forage there include the following: northern flicker (*Colaptes auratus*), mourning dove (*Zenaida macroura*), eastern phoebe (*Sayornis phoebe*), eastern kingbird (*Tyrannus tyrannus*), brown thrasher (*Toxostoma rufum*), northern mockingbird (*Mimus polyglottos*), black-capped chickadee (*Poecile atricapillus*), prairie warbler (*Dendroica discolor*), red-winged blackbird (*Agelaius phoeniceus*), brown-headed cowbird (*Molothrus ater*), rufous-sided towhee (*Pipilo* spp.), American goldfinch (*Carduelis tristis*), song sparrow (*Meospiza melodia*), chipping sparrow (*Spizella passerina*), field sparrow (*Spizella pusilla*), and vesper sparrow (*Pooecetes gramineus*). Many of these species are generalists and live near freshwater habitats, but may also forage and rest near brackish water.

Species common to shrub thickets and freshwater habitat likely have increased in the Herring River flood plain as conditions changed due to the tidal restriction. These include red-winged blackbirds (*Agelaius phoeniceus*), song sparrows (*Melospiza melodia*), prairie warblers (*Dendroica discolor*), common yellowthroats (*Geothlypis trichas*), eastern towhees (*Pipilo erythrophthalmus*), and grey catbirds (*Dumetella carolinensis*). Many of these species are abundant nesters elsewhere on Cape Cod and southeastern Massachusetts (Veit and Peterson 1993).

Marsh birds were inventoried at the Seashore during a 1999 and 2000 auditory and visual detection survey. Seven species were identified; sora (*Porzana carolina*), pied-billed grebe (*Podilymbus podiceps*), Virginia rail (*Rallus limicola*), American coot (*Fulica Americana*), king rail (*Rallus elegans*), American bittern, and least bittern. As described in "Section 3.7: State-listed Rare, Threatened, and Endangered Species," the American bittern and least bittern are listed as endangered under Massachusetts Environmental Policy Act (MEPA). Within the entire survey area, the most commonly detected freshwater marsh birds were sora, pied-billed grebe, and Virginia rail. Sora and Virginia rail were the only species detected within the Herring River flood plain. Both were only detected auditorially, outside of the breeding season (Erwin, Conway, and Hadden 2002).

Salt Marsh Birds

Many birds use salt marsh habitats for breeding, foraging, and roosting, including several species of waterfowl, raptors, wading birds, shorebirds, and songbirds. Seasonal use of intertidal and salt marsh habitat also varies, with some species using the salt marsh for breeding and others during migration or the wintering period. Because freshwater habitats now dominate the once salt water marsh, many species of birds found in the Herring River likely are different today when compared to what existed prior to the construction of the Chequessett Neck Road Dike.

Much of the change in bird occurrence and use likely has been the result in the change of a system dominated by intertidal flats and cordgrass (*Spartina* spp.) to one currently dominated by freshwater (cattail and common reed) and mixed upland vegetation. Concurrent with these changes has been the resulting poor water quality conditions in the Herring River (e.g., acidification and oxygen depletions) and the limited tidal range that has adversely affected forage fish populations important seasonal food resources for many birds (HRTC 2007).

Several high-priority tidal creek and saltmarsh-dependent species such as saltmarsh sharp-tailed sparrows (*Ammodramus caudacutus*), willets (*Catoptrophorus semipalmatus*), American black ducks (*Anas rubripes*), common and roseate terns (*Sterna hirundo* and *S. dougallii*), and several species of shorebirds and wading birds (USFWS 2006) commonly use nesting (*Spartina* dominated habitat) and/or foraging opportunities (primarily estuarine fish) in salt marshes adjacent to the Herring River. Other species, including but not limited to, osprey (*Pandion haliaetus*), and belted kingfisher (*Ceryle alcyon*) also forage in nearby salt marshes.

3.8.2 MAMMALS

Small mammals, such as mice, voles, and shrews are very abundant in marsh grasses around Herring River. Small mammals are an important component of Seashore fauna. In addition to their direct contribution to species richness, they play a major role in trophic dynamics, consuming plant material and invertebrates, and in turn serving as prey items for snakes, raptorial birds, and small to mid-sized carnivorous mammals.

The most common group of mammals found in coastal marsh habitats in the New England region are rodents, such as the meadow vole, which are an important prey species for northern harriers and other raptors (see "Section 3.7.3: Northern Harrier (*Circus cyaneus*) – Threatened"). Other common mammals of coastal marshes include red fox (*Vulpes vulpes*), opossum (*Didelphis virginiana*), chipmunk (*Tamias* spp.), and muskrat (*Ondatra zibethicus*) (Smith 1997).

In 2000 and 2001, small mammals were inventoried at the Seashore to determine their occurrence, abundance, and preferred habitats (Cook, Boland, and Dolbeare 2006). Sites in heathland, freshwater marsh, grassland, oak forest, and pine forest were sampled using live traps. A total of

1,829 individuals representing 11 species were captured. Two species of rodents, the white-footed mouse (*Peromyscus leucopus*) and the meadow vole, accounted for 59 percent of all individuals caught. Collectively, rodents made up 83.5 percent of the total. Small mammals were most abundant in woodland and wetland habitats, with decreasing numbers in grasslands, pine forests, and heathlands (Cook, Boland, and Dolbeare 2006).

The three most common species documented in sites near the Herring River were white-footed mouse, meadow vole, and the meadow jumping mouse (*Zapus hudsoniu*). Although species composition of small mammal communities at the Seashore are essentially the same as those found elsewhere on Cape Cod, relative abundance of species differs (Adler 1988). Compared to other sites studied in the Cape Cod region, masked shrew and meadow jumping mouse were more abundant, and short-tailed shrew and red-backed vole were less abundant at the Seashore. Regardless of whether they are considered a generalist or a specialist with regard to habitat structure, the occurrence and abundance of prevalent species appears related to site moisture (Smith 1997).

Larger mammals, such as coyotes (*Canis latrans*), river otters (*Lutra canadensis*), raccoons (*Procyon lotor*), and white-tailed deer (*Odocoileus virginianus borealis*) also use the freshwater habitats within Herring River flood plain. Within the Seashore, red fox and other carnivores prey upon nests of colonial waterbirds and shorebirds. Because small mammals serve as a food source for these predators, variation in their abundance may affect predation pressure on these birds (Cook, Boland, and Dolbeare 2006).

3.8.3 REPTILES AND AMPHIBIANS

The Seashore is an important area for reptiles and amphibians. In addition to its importance to the five species of migratory marine turtles foraging the offshore waters of Cape Cod, there are 23 species of reptiles and amphibians living their entire life at the Seashore within the Herring River project vicinity (table 3-14). Many of these species are important in the functioning of park ecosystems, consuming large quantities of small prey items, such as insects, and serving as prey for larger species of wildlife (Cook 2008a).

Turtles comprise a familiar group of vertebrates occupying a broad range of habitats and ecological functions. The Seashore supports populations of six species of nonmarine turtles, occupying terrestrial, freshwater, and estuarine habitats. In addition to the diamondback terrapin and eastern box turtle (discussed in "Section 3.7: State-listed Rare, Threatened, and Endangered Species"), these include presently common and/or widespread species such as the freshwater painted turtle (*Chrysemys picta*); snapping turtle (*Chelydra serpentina*); the less common musk turtle (*Sternotherus odoratus*); and spotted turtle (*Clemmys guttata*) (Cook 2008a).

Other species of reptiles and amphibians including the green frog (*Rana clamitans melanota*), Fowler's toad (*Bufo woodhousii fowleri*), eastern spadefoot toad (*Scaphiopus holbrooki*), eastern garter snake (*Thamnophis s. sirtalis*), and northern water snake (*Nerodia s. sipedon*) use coastal marsh habitats similar to those found at the Herring River and Wellfleet Harbor estuary. The four-toed salamander (*Hemidactylium scutatum*) has also been documented in or adjacent to wetlands associated with the Herring River (Cook, Portnoy, Murphy et al. 2006).

TABLE 3-14: REPTILES AND AMPHIBIANS OF CAPE COD NATIONAL SEASHORE AND ADJACENT TOWNS, BASED ON RECENT RECORDS (1980 THROUGH SEPTEMBER 2008)

Species	Eastham	Wellfleet	Truro	Provincetown
Spotted salamander	X*	X*	X*	
Red-spotted newt	X*			
Redback salamander	X*	X*	X*	X*
Four-toed salamander	X*	X*	X*	
Eastern spadefoot toad (MA T)	X*	X*	X*	X*
Fowler's toad	X*	X*	X*	X*
Spring peeper	X*	X*	X*	X*
Grey treefrog	X*			X*
Bullfrog	X*	X*	X*	X*
Green frog	X*	X*	X*	X*
Wood frog	X*	X*		
Pickerel frog	X	X*	X*	
Leatherback turtle (marine)	X	X	X	X
Green turtle (marine)	X	X	X	X
Loggerhead (marine)	X	X	X	X
Hawksbill turtle (marine)	X	X	X	X
Kemp's ridley turtle (marine)	X	X	X	X
Snapping turtle	X*	X*	X*	X*
Musk turtle	X*	X*	X*	
Painted turtle	X*	X*	X*	X*
Spotted turtle	X*	X*	X*	X*
Diamondback terrapin (MA T)	X	X*	X	X*
Eastern box turtle (MA SC)	X*	X*	X*	X*
Eastern garter snake	X*	X*	X*	X*
Eastern ribbon snake	X*	X*	X*	X*
Northern water snake		X*	X*	
Northern ringneck snake	X*	X*	X*	X*
Black racer	X*	X*	X*	X*
Eastern hognose snake	X	X*	X*	X
Eastern milk snake		X*	X*	X*

Source: Cook 2008a.

MA SC and MA T denote Massachusetts special concern and threatened species, respectively.

*Species with documented presence inside Cape Cod National Seashore.

A long-term monitoring effort of pond breeding amphibians was initiated in 2003 as a component of freshwater wetland monitoring in the Seashore (Cook, Schult, Goodstine et al. 2006). Occurrence and abundance of vernal pond breeding species spotted salamander (*Ambystoma maculatum*) and wood frog (*Rana sylvatica*) are currently monitored through egg mass counts. Occurrence and relative abundance of the breeding anuran community park wide is also monitored. Five monitoring sites are within the Herring River project area, near Bound Brook Island Road, and Pamet Point Road. Of those sites, spotted salamander egg masses were present during the 2003 to 2005 surveys, but wood frogs were not present at any site location during the surveys. Additional monitoring of these species is necessary to better characterize the important role amphibians play in wetland habitats, and how global, regional, and local factors alter the abundance, distribution, and structure of their communities.

3.9 CULTURAL RESOURCES

The NPS has a unique stewardship role for cultural resources, reflected in regulation and policy. NPS categorizes cultural resources as archeological resources, cultural landscapes, historic districts and structures, museum objects, and ethnographic resources. For this draft EIS/EIR, the categories of archeological resources and historic structures were retained for analysis.

3.9.1 GUIDING REGULATIONS AND POLICIES

Federal actions that have the potential to affect cultural resources are subject to a variety of laws. The National Historic Preservation Act (NHPA) (1966, as amended) is the principal legislative authority for managing cultural resources associated with NPS projects. Generally, Section 106 of the act requires all federal agencies to consider the effects of their actions on cultural resources listed on or determined eligible for listing in the National Register. Such resources are termed historic properties. Agreement on how to mitigate effects to historic properties is reached through consultation with the State Historic Preservation Officer (SHPO); the Tribal Historic Preservation Officer (THPO), if applicable; and the Advisory Council on Historic Preservation, as necessary. In addition, federal agencies must minimize harm to historic properties that would be adversely affected by a federal undertaking. Section 110 of the act requires federal agencies to establish preservation programs for the identification, evaluation, and nomination of historic properties to the National Register.

The NHPA established the National Register, the official list of the nation’s historic places worthy of preservation. Administered by the NPS, the National Register is part of a national program to coordinate and support public and private efforts to identify, evaluate, and protect America’s historic and archeological resources. The criteria applied to evaluate properties are contained in 36 CFR 60.4. The quality of significance in American history, architecture, archeology, engineering, and culture is present in districts, sites, buildings, structures, and objects that possess integrity of location, design, setting, materials, workmanship, feeling, and/or association, and that are associated with events that have made a significant contribution to the broad patterns of our history; or

- that are associated with the lives of persons significant in our past; or
- that embody the distinctive characteristics of a type, period, or method of construction, or that represent the work of a master, or that possess high artistic values, or that represent a significant and distinguishable entity whose components may lack individual distinction; or
- that have yielded or may be likely to yield, information important in prehistory or history.

Cultural resources that meet the eligibility criteria for listing in the National Register are considered “significant” resources and must be taken into consideration during the planning of federal projects.

Other important laws or Executive Orders designed to protect cultural resources include, but are not limited to:

- NPS Organic Act—to conserve the natural and historic objects within parks unimpaired for the enjoyment of future generations;
- American Indian Religious Freedom Act—to protect and preserve for American Indians access to sites, use and possession of sacred objects, and the freedom to worship through ceremonials and traditional rites;
- Archeological Resources Protection Act—to secure, for the present and future benefit of the American people, the protection of archeological resources and sites that are on public lands and Indian Lands;
- National Environmental Policy Act (NEPA)—to preserve important historic, cultural, and natural aspects of our national heritage
- Executive Order 11593 (Protection and Enhancement of the Cultural Environment)—to provide leadership in preserving, restoring, and maintaining the historic and cultural environment of the Nation; and
- Executive Order 13007 (Indian Sacred Sites)—to accommodate access to and ceremonial use of Indian sacred sites by Indian religious practitioners and avoid adversely affecting the physical integrity of such sacred sites.

Through legislation and the Executive Orders listed above, the NPS is charged with the protection and management of cultural resources in its custody. This is further implemented through Director's Order 28: Cultural Resource Management, NPS *Management Policies 2006* (NPS 2006), and the 2008 "Programmatic Agreement among the National Park Service (U.S. Department of the Interior), the Advisory Council on Historic Preservation, and the National Conference of SHPOs for Compliance with Section 106 of the National Historic Preservation Act" (NPS 2008). These documents charge NPS managers with avoiding, or minimizing to the greatest degree practicable, adverse impacts on park resources and values. Although the NPS has the discretion to allow certain impacts in parks, that discretion is limited by the statutory requirement that park resources and values remain unimpaired, unless a specific law directly provides otherwise.

Council on Environmental Quality (CEQ) regulations and NPS Director's Order 12 also call for a discussion of the appropriateness of mitigation, as well as an analysis of how effective the mitigation would be in reducing the intensity of a potential impact (e.g., reducing the intensity of an impact from major to moderate or minor). Any resultant reduction in the intensity of an impact due to mitigation, however, is an estimate of the effectiveness of mitigation under NEPA only. Cultural resources are non-renewable resources, and adverse effects generally consume, diminish, or destroy the original historic materials or form, resulting in a loss in the integrity of the resource that can never be recovered.

3.9.2 Archeological Resources

Archeological resources consist of "any material or physical evidence of past human life or activities which are of archeological interest, including the record of the effects of human activities on the environment" (NPS 2006). Archeological resources in the project area have been assessed with combination of archival research, site file research, and walkover surveys. These were used to document known archeological resources within the Herring River restoration area and to identify areas where unknown archeological resources may exist. This information, in combination with predictive models developed for archeological resources elsewhere in the region, was then used to plot areas of archeological sensitivity within the area of potential effect (APE), which is the geographic area in which an undertaking may cause changes in the character or use of historic properties, as defined under Section 106 of the NHPA (36 CFR 800, as amended). For this project, the APE is defined as areas in the estuary below the 10-foot contour elevation, and certain upland areas where project impacts may occur, such as areas around CYCC, the Chequessett Neck Road Dike, and several low-lying roads including High Toss Road, Bound Brook Island Road, and Pole Dike Road. This APE was investigated by the Public Archaeology Laboratory in 2011 to identify areas where significant historic resources might be found (Herbster and Heitert 2011). However, significant archaeological resources have yet to be identified pending final project design, and steps to identify, evaluate, and mitigate any adverse effects to significant properties are currently being developed in a Programmatic Agreement (PA) among the consulting parties.

Archeologists have documented 12,000 years of pre-contact Native American occupation of the New England region, and oral tradition of some contemporary tribes recount a 50,000-year cultural legacy (Herbster and Heitert 2011). The earliest archeologically documented peoples to inhabit the area are called Paleoindians by archeologists and are generally thought to have occupied Cape Cod between 10,000 and 12,000 years ago. Sites containing evidence from a number of time periods (i.e., multicomponent sites) have been identified in the Herring River basin in Harwich, and possible evidence of Paleoindian occupation has been recovered from some of these sites (Herbster and Heitert 2011:30). To date, no evidence of Paleoindian occupation has been found in the APE.

The subsequent Archaic period dates to between 3,000 and 10,000 years ago and is characterized by the frequent movement of small bands of people across the landscape to exploit a wide diversity of seasonal plant and animal resources. The toolkit of Archaic peoples was more diversified than in the prior Paleoindian period, and included a wide variety of stemmed and notched projectile points as well as groundstone tools such as axes, gouges, and grooved adzes. Beginning in the Middle Archaic period (circa 7,500 years ago), there is evidence that anadromous fish became a dietary staple, and brackish estuary heads are the locations of many sites dating to this period. By the end of the Archaic Period (circa 3,000 years ago), archeological sites are found in all types of environmental settings. Several sites in and around the APE contain evidence of Archaic occupation, in addition to a number of small lithic scatters of which many are likely Archaic in age.

The Woodland Period, dating between 3,000 and 500 years ago is signaled by the introduction of ceramic technology. There is an increase in the exploitation of shellfish, and evidence of Woodland period occupation is best represented by large accumulations of shell (middens). Archeological sites containing shell and pottery have been found along the Herring River in the vicinity of the APE. There are 25 known pre-contact sites within or adjacent to the APE. These sites include 15 sites documented by NPS staff during systematic surveys, and 10 sites indentified by amateurs (table 3-15). Pre-contact sites are generally small resource procurement and processing areas, especially shellfish gathering and middens (shell piles). Sites at higher elevations are generally lithic (chipped stone tools and debris) concentrations. Some include fire-cracked rock suggesting hearths (Herbster and Heitert 2011).

It is assumed that other unsurveyed sub-basins in the project area may contain pre-contact period archeological sites. Based on proximity to fresh or salt water, well-drained soils, level topography, known site locations, and degree of disturbance, an archeological sensitivity map has been developed for pre-contact archeological resources (Herbster and Heitert 2011:59-60). High and moderate sensitivity areas where pre-contact resources may be expected to occur have been identified within the APE, and consist primarily of flood plain margins along the edges of the APE. In addition, upland areas that could potentially be affected by the project have also been identified as sensitive for pre-contact archeological resources.

TABLE 3-15: KNOWN PRE-CONTACT SITES WITHIN OR ADJACENT TO THE AREA OF POTENTIAL EFFECT

Number	Study Area Location	Cultural Materials	Site Size/Type	Method of Identification
1	Herring River-Upper Basin	Unknown	Unknown	Amateur Find
2		Low density chipping debris; Fire-cracked rock	100 sq meters Lithic scatter	NPS Survey
3		Low density chipping debris; Fire-cracked rock	200 sq meters Lithic Scatter	NPS Survey
4		Single flake; whiteware	0.5 sq meters Find Spot	NPS Survey
5		Low density chipping debris; Quartz biface; Fire-cracked rock	700 sq meters Lithic Scatter	NPS Survey
6		Chipping debris	1,200 sq meters Lithic scatter	Amateur Find
7		High density debris; Shell; Projectile points; Pottery; Charcoal; Fire-cracked rock	12,500 sq meters Large site	NPS Survey
8		Chipping debris	Unknown	NPS Surface Find
9	Griffin Island	Shell	Unknown Shell middens	Amateur Find
10		Shell; Hammerstone	2 finds, 100-m apart Lithic scatter	NPS Survey
11		Chipping debris; Fire-cracked rock	400 sq meters	NPS Surface Find
12		Low density chipping debris; Biface; Fire-cracked rock	900 sq m Lithic scatter	NPS Survey
13		Shell; Pottery; Chipping debris; Hammerstone; Possible feature	Unknown Shell midden	Amateur Find/NPS Survey
14		Shell; Pottery; Chipping debris	Unknown	NPS Survey
15		Single flake	Unknown Find spot	NPS Survey
16		Low density chipping debris	Unknown	NPS Survey
17		Low density chipping debris; Shell	125 sq meters	NPS Survey
18		Hammerstone; Quartz core	Unknown	NPS Survey
19	Bound Brook Island	Unknown	Unknown	Amateur Find
20		Single flake	0.5 sq meters Find Spot	CRM Survey
21	Pole Dike Creek	Unknown	Unknown Shell midden	Amateur Find
22		250 projectile points; 8 gouges; 20 plummets; 2 pestles; 30 choppers or hoes; Hammerstones; Red paint-indicative of possible burials	Unknown Habitation site	Amateur Find
23		Unknown	Unknown	Amateur Find
24	Mill Creek	Unknown	Unknown Shell midden	Amateur Find
25		Unknown	Unknown	Amateur Find

Contact and post-contact period sites date to after AD 1500, the entry period of Euro-Americans to the northeast coast of the United States. Native American contact period sites are characterized by shell middens and family farmsteads along coastal estuarine areas (LBG 2007). The population center of the Mashpee Wampanoag people was centered near Truro (LBG 2007). Ethnohistoric accounts document a well-established system of Native American trails on the Cape. A trail may have passed close to the project area along West Road, Route 6, and Chequessett Neck Road in Wellfleet (Herbster and Heitert 2011).

The year 1644 marks the beginning of permanent European settlement of the Lower Cape, when a tract of land that stretched from Pleasant Bay to Truro was purchased from the Nauset Indians by the Plymouth Colony. Within two decades, the southern portion of the patent, called Eastham, was no longer arable due to erosion from deforestation and agriculture, and settlers began moving north into what is now the Town of Wellfleet. The first meeting house was established at Chequessett Neck in 1712, and in 1723, the community was renamed the North Precinct or Billingsgate Parish. The parish was linked to the south by the King's Highway, constructed in 1720, and the first wharf was built on Griffin Island around this time (Herbster and Heitert 2011:35-36).

The North Precinct was incorporated as Wellfleet in 1763, and the primary industries of whaling, oystering, and fishing were the focus of commercial development in the area, including a whale-oil rendering try works located near Bound Brook Island Road. Limited agriculture was an aspect of the eighteenth-century economy of the town, as was the ship building industry in Duck Harbor. To support the booming mackerel and alewife fisheries, nearly 40 saltworks were built along the Herring River and its tributaries by 1837. These saltworks consisted of buildings and associated windmills, which were used to bring seawater up into evaporation vats. Diseased oyster beds were reseeded with oysters from the Chesapeake Bay, rejuvenating the industry, but agriculture continued to diminish in importance throughout the nineteenth century. One agricultural practice which continued throughout the nineteenth century was salt marsh haying, with over 300 tons of hay produced annually (Herbster and Heitert 2011:36-43).

The fishing industry, which served as the cornerstone of the economy through the eighteenth and early nineteenth centuries, began to decline after 1850. Siltation had begun to restrict the harbors, especially Duck Harbor, and the construction of the Cape Cod railroad causeway across the harbor in 1870 left it closed off from the sea. The construction of dikes and causeways for the railroad impounded marshes and restricted fish migrations, and by the end of the nineteenth century, communities on Bound Brook and Griffin islands once supported by the fishing industry had all but disappeared (Herbster and Heitert 2011:43).

However, construction of the Cape Cod Railroad led to a rise in tourism, and the local economy rebounded with the construction of resorts, hotels, and restaurants; local fishing and farming also rebounded to provide seafood and produce to growing numbers of summer visitors. Weir fishing became established in the 1870s, and by the end of the century, the herring runs throughout the Herring River estuary were some of the most productive in the state. One weir and an associated fish house may be located within or adjacent to the APE near the Atwood-Higgins property. Oyster shellfishing also flourished at this time, in part due to the proximity of reliable rail transportation to get the oysters to markets (Herbster and Heitert 2011:43-46).

By the beginning of the twentieth century, concerns that mosquitoes were affecting the tourism industry led to widespread ditching and diking of the low-lying flood plains and salt marshes. Unlike earlier dikes, these new structures prevented tidal exchange throughout much of the estuary; this tidal flushing was needed to maintain salt marsh hay crops and allow seasonal fish runs. Diking and ditching did allow for the construction of homes and resorts along the flood plain, including the

CYCC, and the primacy of a tourism-based economy was firmly established. Throughout the twentieth century, roads were built or improved to handle the ever-increasing amount of automotive traffic bringing seasonal residents and visitors to the area (Herbster and Heitert 2011:47-48).

Eight post-contact period Euro-American sites have been recorded in the project area (table 3-16). All of the recorded sites relate to residential settlement. They include cemeteries, eighteenth and nineteenth century cellar holes with associated artifact scatters, and eighteenth - and nineteenth-century trash middens (Herbster and Heitert 2011).

TABLE 3-16: POST-CONTACT PERIOD EURO-AMERICAN SITES

Number	Study Area Location	Cultural Materials	Site Size/Type	Method of Identification
1	Herring River-Upper Basin	Cellar hole; Shell; Ceramics; Charcoal; Glass; Brick; Mortar	925 sq meters Residential	NPS Survey
2		Metal; Nails	100 sq meters Historic scatter	NPS Survey
3		Ceramics; Shell; Building materials	5,000 sq meters refuse Dump	NPS Survey
4	Griffin Island	Ceramics; Brick; Glass	500 sq meters Historic Trash Deposit	NPS Survey
5	Bound Brook Island	2 standing gravestones w/ 3 names	Mortuary	Amateur Find/CRM Survey
6		Unknown	Residential	Amateur Find
7		Cellar hole; Shell; Metal; Glass; Ceramics; Leather; Coal	700 sq meters Residential/Agrarian	NPS Survey
8		Cellar hole; Glass; Ceramics; Building Materials	2,500 sq meters Residential/Agrarian	NPS Survey

Based on historical references and limited above-ground evidence in walkover surveys, other likely types of post-contact Euro-American archeological resources that may potentially be found in the APE include wharves and docks; tidal mills and windmills; saltworks and try works; fishing stations and weirs; and foot paths, cart paths, and portions of the Cape Cod/Old Colony Railroad. Several historical sources refer to wharves or docks on Griffin and Bound Brook Island, but the on-the-ground locations have not been identified. With the arrival of the Cape Cod Railroad in 1870, water transportation diminished and there was little need to build or maintain these features. Mills and windmills appear on several historic maps, but none have been identified through archival research within the APE. If present, these features would likely be associated with a saltworks. Nineteenth century saltworks appear in the APE on Griffin and Bound Brook islands. The Bound Brook Island works also reportedly supported a try works (where whale oil was rendered from whale carcasses). The walkover survey of these saltworks did not identify above-ground features, with the possible exception of an earthen berm on Bound Brook Island. Archeological remains associated with saltworks could include wood from evaporation vats, barrel staves, or pipes; nails and screws; iron tool parts, such as shovels, rakes, poles, and barrel hoops; relict posts used to support vats; collapsed decking; and stone foundation elements associated with storage sheds. Tryworks could include iron tool parts such as kettles, hooks, and knives; burned bricks; heavily oxidized ground surfaces; stone foundations of storage sheds; and possibly whale remains. Areas of high and moderate sensitivity for post-contact archeological resources were identified during the Phase IA archeological survey and are present in the APE (Herbster and Heitert 2011:61-62). Site identification and evaluation of eligibility for the National Register of Historic Places (National Register).

3.9.3 HISTORIC STRUCTURES

The NPS defines historic structures as "a constructed work, usually immovable by nature or design, consciously created to serve some human activity." Examples are buildings, monuments, dams, roads, railroad tracks, canals, millraces, bridges, tunnels, locomotives, nautical vessels, stockades, forts, earthworks, ruins, fences, and outdoor sculpture (NPS 2006). Although there are no historic structures listed in the National Register in the Herring River estuary, a dike apparently spanned Mill Creek near the confluence with the Herring River. This dike was part of a historical tidal gristmill operation (Herbster and Heitert 2011). The Colonial period Atwood-Higgins House, listed on the National Register in 1976, and other buildings associated with the house lie within 100 meters (328 feet) of the APE of the restoration project near the confluence of Bound Brook and the Herring River on the eastern tip of Bound Brook Island (NPS pers. comm. 2011a; Herbster and Heitert 2011). Recent work has defined an Atwood-Higgins Historic District, which has been nominated for the National Register. The district as it is currently defined extends into or adjacent to the APE, although no significant resources in the district are within or immediately adjacent to the APE (Burke pers. comm. 2011a). Other historic structures may be identified and evaluated as the extent of project effects are finalized; steps necessary to identify and evaluate historic structures in the APE will be defined in the PA which is currently under development.

The Old Colony Railroad easement was constructed in 1870 and was incorporated into the Cape Cod Railroad in 1872. The railroad easement crosses the estuary from the west side of Bound Brook Island to the Town of Wellfleet. Along the railroad easement can be found the raised rail bed, tracks/ties, bridge abutments, and stone culverts (Herbster and Heitert 2011). A trestle also crosses Herring River northeast of the Bound Brook Island Bridge. Although these features can be classified as historic structures, the portions of the Cape Cod/Old Colony Railroad within the APE are considered archeological resources for the purposes of identification and evaluation.

The NPS maintains a List of Classified Structures (LCS). These structures are either listed in or eligible for the National Register or are to be treated as cultural resources even though they do not meet all National Register requirements. The LCS for the Seashore includes 72 structures such as stone walls, outhouses, shacks, and life-saving stations (NPS 2011d). None of the LCS structures are in the immediate project area.

3.10 SOCIOECONOMICS

The restoration of the Herring River estuary has several implications for local communities, homeowners, industries, and the local economy. First, changes to Herring River water quality and sediment transport could affect the Wellfleet Harbor shellfishery, most likely by allowing currently closed areas to open and by mobilizing sediment in areas immediately upstream and downstream of the Chequessett Neck Road Dike. Second, the estuary contains a number of low-lying roads and private properties that would be affected by higher tide levels if measures are not taken to protect them. Third, changes to the physical appearance and environmental conditions of the estuary would affect viewscapes and recreational opportunities in the estuary, possibly changing property values. Finally, construction activities associated with the project are expected to have a positive economic impact, although only general estimates about increased job opportunities can be made at this time.

3.10.1 NUISANCE MOSQUITOES

The human concern about biting mosquitoes has been a long-standing issue in the Herring River. Even the hardy Henry David Thoreau complained about the mosquitoes he encountered on the outer Cape during his famous walk in 1849 (Thoreau 1865, as cited in Cumbler, in press). By the beginning of the 20th century, as Wellfleet was evolving into a seasonal enclave for summer visitors, town leaders expressed concerns about mosquitoes and their potential for driving tourists away. One prominent citizen, Lorenzo Dow Baker, a wealthy former ship captain and the so-called "Banana King," owned the Chequessett Inn, a hotel built on a pier over Wellfleet Harbor. After several very wet years with high populations of mosquitoes, Baker led a group of town officials who petitioned the Massachusetts legislature for authorization to fund and construct a dike at the mouth of the Herring River (Cumbler, in press). According to an engineering study commissioned by the Town, "…the first and main object sought is to exterminate the mosquito pest…to transform the unsightly swamps…into clean and healthy areas, which will add to, instead of detract from, the beautiful landscape with which nature has richly endowed this locality" (Whitman and Howard 1906).

Although the Chequessett Neck Road Dike was built for this expressed purpose several years later in 1909, its effectiveness for mosquito control was marginal and the town was forced to continue and expand other mosquito control practices for several decades. This included oiling the marshes, channelizing the river, and creating grid ditches to drain freshwater. Much of this labor-intensive work was completed during the 1930s as the Works Progress Administration put thousands of men to work draining salt marshes all over the East Coast.

Although the practice of deliberately draining salt marshes for mosquito control diminished by the 1960s, on Cape Cod, the Cape Cod Mosquito Control Project (CCMCP) continues to maintain salt marsh channels and ditches in an effort to drain freshwater and eliminate standing pools of water, which are prime mosquito breeding areas. In 1980, one of several massive die-offs of American eels (*Anguilla rostrata*) and other fish species occurred. After NPS researchers documented that fish kills in the Herring River were linked to low dissolved oxygen and re-suspension of highly acidic sediment caused by mosquito ditch maintenance in the tidally restricted system (see section 3.3.2 and refer to Soukup and Portnoy 1986), CCMCP discontinued mosquito ditch maintenance in the Herring River flood plain. However, ditches are still maintained outside the Seashore boundary in the Mill Creek, Upper Pole Dike Creek, and Upper Bound Brook sub-basins.

Despite decades of work and large public expenditures to eliminate them, the Herring River remains a major breeding area for nuisance mosquitoes. Dense vegetation, lack of tidal flushing and substantial freshwater flows, subsided marsh surfaces, and prior disturbances to the flood plain create extensive stagnant water breeding areas. In sampling conducted by the Seashore and CCMCP, the dominant mosquito species caught in the Wellfleet area, *Ochlerotatus cantator,* breeds in fresh to brackish water. Its larvae can tolerate the acidified waters that keep its predators—fish species that eat mosquito larvae—at bay. Species that are generally linked to human diseases, such as *Culex pipiens*—the primary vector for West Nile Virus in Massachusetts—are not abundant in the Herring River flood plain. In addition, *Culiseta melanura*, the primary vector of Eastern Equine Encephalitis among birds, which are the normal enzootic host, is uncommon on Cape Cod, where little of its breeding habitat (red maple and white cedar swamps) occurs. Although *C. melanura* does not bite humans, where it is common (e.g., southeastern Massachusetts, where large freshwater wetlands occur) it increases the frequency of the virus in the local bird population, thus increasing the potential for transmission from birds to humans by mammal biters like *O. cantator* or *O. sollicitans*.

3.10.2 SHELLFISHING

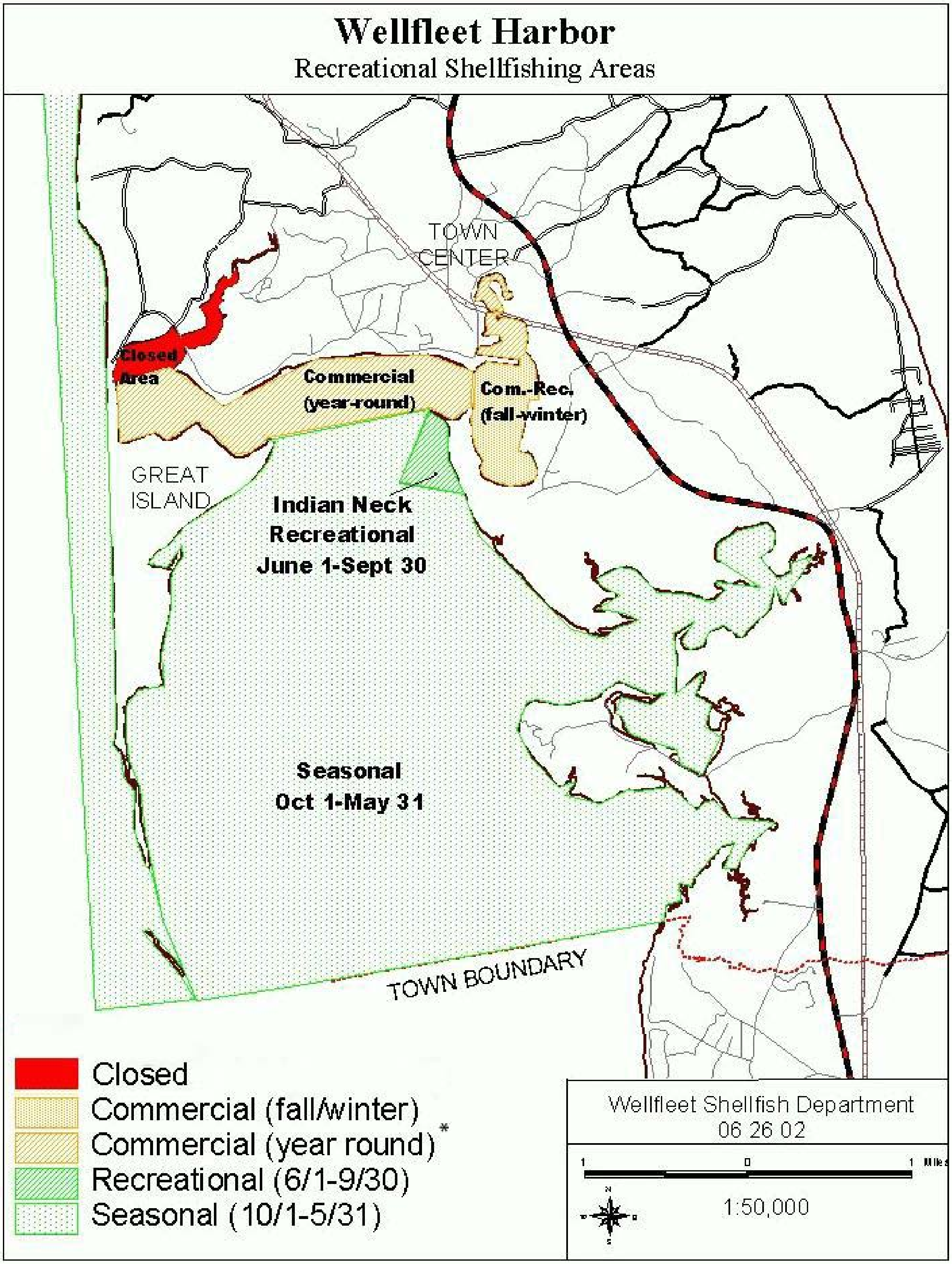
Tourism has surpassed commercial fishing as the main driver of the modern Wellfleet economy (Cataldo 2007). However, shellfishing remains a vitally important industry to Wellfleet's community identity and contributes considerable jobs and income to the local economy. Modern shellfishing also connects residents and visitors to an important aspect of Wellfleet's history, and confers status and name recognition to the community as the source for highly regarded Wellfleet oysters.

Historically, shellfishing harvests have fluctuated in Wellfleet. Shellfish in Wellfleet Harbor were consumed by Native Americans prior to the Pilgrims' arrival in the area in the 1600s (Cataldo 2007). Upon arriving to the area, the Pilgrims began harvesting shellfish in Wellfleet Harbor. The first major recorded decline of shellfish harvests in Wellfleet Harbor occurred during the 1770s (Cataldo 2007). However, the shellfish population rebounded, but declined again in the 1870s (Cataldo 2007). The first available record of the number of shellfish harvested amounts was in 1907 with approximately 145 shellfishermen harvesting 30,000 bushels of quahogs (Cataldo 2007). From 1915 to the mid-1920s, the number of commercial permits ranged from 10 to 60 permits per year. This number gradually increased over time and rose to 250 permits in the 1970s. Since the late 1990s, the number of permits has remained around 300 (Cataldo 2007).

Four commercially important species are harvested in Wellfleet: the hard clam, also known as the northern quahog (*Mercenaria mercenaria*); the eastern oyster (*Crassostrea virginica*); the bay scallop (*Argopecten irradians*); and the softshell clam or steamer (*Mya arenaria*). Although four shellfish species are harvested in Wellfleet Harbor, the town is best known for its eastern oysters and quahogs (Cataldo 2007). The quality of the shellfish products from Wellfleet is attributed to the high tide range and cold, nutrient rich waters of Wellfleet Harbor. Wellfleet oysters in particular are highly regarded by seafood enthusiasts and each October the town hosts the Wellfleet OysterFest to celebrate the oysters and the town's historical association with shellfishing (Wellfleet OysterFest 2011). The successful, long-standing shellfishery therefore has a more prominent local role than harvest values and job numbers alone would indicate. The connection with shellfishing distinguishes Wellfleet from other Cape Cod communities and contributes to a community identity that has both social and economic value.

The shellfishing industry does not create a large number of jobs in a regional context, but employment in this industry represents a higher percentage of total employment in Wellfleet than it does in Cape Cod as a whole. In 2005, an estimated 200 people worked on aquaculture sites in Wellfleet Harbor (Cataldo 2007), while average annual employment in Wellfleet was 1,557 (BLS 2011a). A 1994 survey found that 14 percent of Wellfleet residents had worked in shellfishing or fishing in the past or were currently employed in the industry (Cataldo 2007). By comparison, less than 1 percent of total employment in Barnstable County in 2008 was in the commercial fishing and aquaculture industries (BEA 2011c).

The Town of Wellfleet has designated areas in Wellfleet Harbor for commercial harvesting of wild shellfish, aquaculture leasing operations, and recreational harvest of shellfish (figure 3-21). There are approximately 2,500 acres open for wild commercial and recreational shellfishing and approximately 262 acres leased for aquaculture in Wellfleet Harbor (Cataldo 2007; Moles, pers. comm. 2011a). Currently, shellfishing is prohibited in a 90-acre area immediately downstream of the Chequessett Neck Road Dike and within the Herring River due to poor water quality caused by fecal coliform bacteria (Cook, pers. comm. 2011). Additionally, an area of the Herring River downstream of the dike that is between Wellfleet Harbor and the closed shellfishing zone is now open only seasonally (from September through March) due to high levels of fecal coliform (Town of Wellfleet 2007). Shellfishing is not allowed in any part of Wellfleet Harbor when temperatures are at or below 28°F, which typically occurs in December, January and February.



Source: Town of Wellfleet 2011. Edited by The Louis Berger Group in 2012.

* Not all of this area is open year round. Portions of the area of the Herring River downstream of the dike between Wellfleet Harbor and the closed shellfishing zone are open only seasonally, from September through March annually (Town of Wellfleet 2007).

FIGURE 3-21: REGULATED SHELLFISHING AREAS OF WELLFLEET HARBOR

Historically, commercial wild shellfish harvests in Wellfleet have fluctuated with no clear trends, whereas aquaculture harvests have increased since 1989. Although the Town of Wellfleet has supported aquaculture since the 1850s, harvest data has only been available since 1989 (Town of Wellfleet 2006). The largest reported harvest of wild shellfish, which includes quahogs, oysters, and clams combined, between 1955 and 2007 was approximately 91,000 bushels, which occurred in 1971. However, in most years, the total harvested amount of wild shellfish has been less than 20,000 bushels. Between 1989 and 2000, aquaculture harvests have remained relatively constant between 5,000 and 10,000 bushels harvested per year. Between 2000 and 2010, aquaculture harvests have increased and fluctuated between 17,000 and 40,000 bushels annually (Moles, pers. comm. 2011c; Churchill, pers. comm. 2011).

Tables 3-17 and 3-18 present wild and aquaculture shellfish harvest and value data. On average between 2006 and 2010, the wild shellfish catch (excluding lobster and crabs) in Wellfleet Harbor represented approximately 30 percent of the total harvest of all shellfish. In 2010, the wild shellfish harvest represented approximately 37 percent of the total volume and value of all shellfish harvested (McAfee, pers. comm. 2011). On average, between 2007 and 2010 approximately 2 percent of all wild shellfish commercially harvested in Wellfleet Harbor came from an area of the Herring River downstream of the Chequessett Neck Road Dike. The area of the Herring River immediately downstream of the dike is permanently closed to shellfishing. However, a seasonally open shellfishing area is located just southeast of this area, between the permanently closed area and greater Wellfleet Harbor area, which starts at the northeasternmost point of the Great Island (Town of Wellfleet 2007). In 2009, shellfish harvested from the seasonally open area downstream of the dike represented 4 percent of the total wild shellfish harvest (McAfee, pers. comm. 2011).

TABLE 3-17: VALUE AND LANDED LIVE WEIGHT OF WILD-HARVESTED SHELLFISH (2006–2010)

Year	Wellfleet Harbor		Seasonally Open Area of the Herring River Downstream of the Dike	
	Live lbs.	Value	Live lbs.	Value
2006	929,370	$1,168,648	*	*
2007	718,011	$891,857	2,105	$5,058
2008	577,791	$793,308	7,612	$16,497
2009	716,961	$944,806	25,602	$36,493
2010	973,572	$1,550,012	12,729	$34,145

Source: McAfee, pers. comm. 2011.

* Herring River values and land live weight data are included in Wellfleet Harbor data. Data for the Herring River for 2006 are confidential; therefore data is not displayed. Values are the value paid by the primary buyer of shellfish at the initial point of sale after the fish are harvested. Values may therefore be considered wholesale values.

TABLE 3-18: VALUE AND VOLUME OF AQUACULTURE HARVEST (2007–2009)

Year	Species	Bushel Amounts	Bushel Value ($)	2009 Value ($)
2007	Quahogs, Little Necks	22,869	68.00	1,555,092
	Quahogs, Cherrystones	81	32.50	2,632
	Quahogs, Chowder	86	22.50	1,935
	Eastern Oyster	4,629	100.00	462,900
	Soft-Shelled Clam	1	80.00	80
	TOTALS	**27,666**		**2,022,639**
2008	Quahogs, Little Necks	22,915	60.00	1,374,900
	Quahogs, Cherrystones	81	28.00	2,268
	Quahogs, Chowder	86	15.00	1,290
	Eastern Oyster	4,723	110.00	519,530
	Soft-Shelled Clam	1.0	75.00	75
	TOTALS	**27,806**		**1,898,063**
2009	Quahogs, Little Necks	12,710	60.00	762,630
	Quahogs, Cherrystones	20	28.00	560
	Quahogs, Chowder	8	15.00	120
	Eastern Oyster	4,770	110.00	524,700
	Soft-Shelled Clam	4	75.00	300
	TOTALS	**17,512**		**1,288,310**

Source: Moles, pers. comm. 2011b.

Note: Little Necks range in size from 25.4 to 36.4 mm. Cherrystones range in size from 36.5 to 41.3 mm. Any Quahog larger than 41.3 mm is considered a Chowder (Cataldo 2007). Figures reported for 2008 and 2009 might include wild shellfish production.

Since 1989, aquaculture harvests of quahogs and oysters have fluctuated but have generally increased over time (Moles, pers. comm. 2011c). In 2009, the eastern oyster represented approximately 40 percent of the total aquaculture harvest value and quahogs represented nearly 60 percent of the total aquaculture harvest value (Moles, pers. comm. 2011b). In 2009, quantities of harvested quahogs were almost half those of the harvested quantities that occurred in 2007 and 2008.

Various methods are used to increase wild shellfish stock and harvests. For instance, cultch (old clam and oyster shell) is currently spread in various portions of Wellfleet Harbor, including the area of the Herring River downstream of the dike (see figure 3-22), to provide suitable substrate to which spat can bond. Spat is a larval oyster that is beginning to develop a shell. The spreading of cultch benefits wild oyster harvesting operations by providing more substrate habitat than what would be available naturally. Cultch, like naturally occurring oyster beds, is susceptible to being covered by sediment (Koch, pers. comm. 2011c).

Shellfish aquaculturists also use various methods to protect and increase the productivity and growth of shellfish stock. In designated areas of Wellfleet Harbor (see figure 3-22), shellfish aquaculturists raise oysters in cages that are elevated above the harbor bottom to protect the oysters from being covered by sediment. Aquacultural operations also use 'Chinese hats' to grow and mature spat. These Chinese hats allow aquaculturists to collect and nurture their own seed, rather than having to buy seed from a commercial hatchery. Chinese hats are shallow plastic cones that can be stacked upon one another, bonded by a cement mixture, resulting in 3 to 4 feet tall stacks that are set into the water before the reproductive season. When spat are of appropriate age, they are removed from the Chinese hats and planted in the raised aquaculture oyster beds for later harvesting (Koch, pers. comm. 2011c). Generally, Chinese hats are tall and sit above the sediment on the bottom of the harbor.

In the designated aquaculture areas, aquaculturists also use nets to protect quahogs from predators while they mature. These nets are kept over the quahogs year round and are only removed while the clams are being harvested or to remove sediment from portions of the nets (Koch, pers. comm. 2011c).

According to the Cape Cod 1998 General Management Plan, the NPS is an upland owner of the shellfish beds residing within Cape Cod National Seashore; however, the Commonwealth of Massachusetts has preeminence in the area of shellfishing, and state statute devolves responsibility for managing shellfishing and aquaculture to local communities. The General Management Plan states that, therefore, the NPS will cooperate with state agencies and local towns on shellfish aquaculture activities within seashore boundaries as long as customary low technology and a dispersed character of small shellfishing grants for individuals and families are maintained and if cultural patterns of use and enjoyment are sustained, as long as marine biodiversity is safeguarded. Furthermore, when national seashore managers are approached to evaluate aquaculture activities, they consider the aquaculture species proposed, the potential impacts of increased aquaculture development on marine systems and other environmental, recreational, and aesthetic impacts, and the density of aquaculture use in balance with other values of the tidal flats and coastal area (NPS 1998).

3.10.3 FINFISHING

Finfishing, like shellfishing, is an important industry and recreational activity in Wellfleet and connects residents and visitors to an important aspect of Wellfleet's history. Bluefish, striped bass, and winter flounder are predominant salt water sport fish within Wellfleet Harbor.

Bluefish (*Pomatomus saltatrix*) and striped bass (*Morone saxatilis*) are the two predominantly fished species today in Wellfleet Harbor and the greater Cape Cod waters and are dependent on an estuarine environment at some point in their lifecycle. Striped bass represent an important commercial commodity throughout both Massachusetts and Cape Cod. The value of the striped bass fishing industry in Massachusetts in 2010 was approximately $3.6 million (NOAA 2012), with Cape Cod accounting for one-half to two-thirds of this amount (Town of Wellfleet 2006). The commercial finfishing industry has declined in Wellfleet in recent years; as a result, the industry has shifted toward recreational finfishing (Town of Wellfleet 2006). Recreational finfishing is addressed further in "Section 3.10.7: Recreational Experience and Public Access."

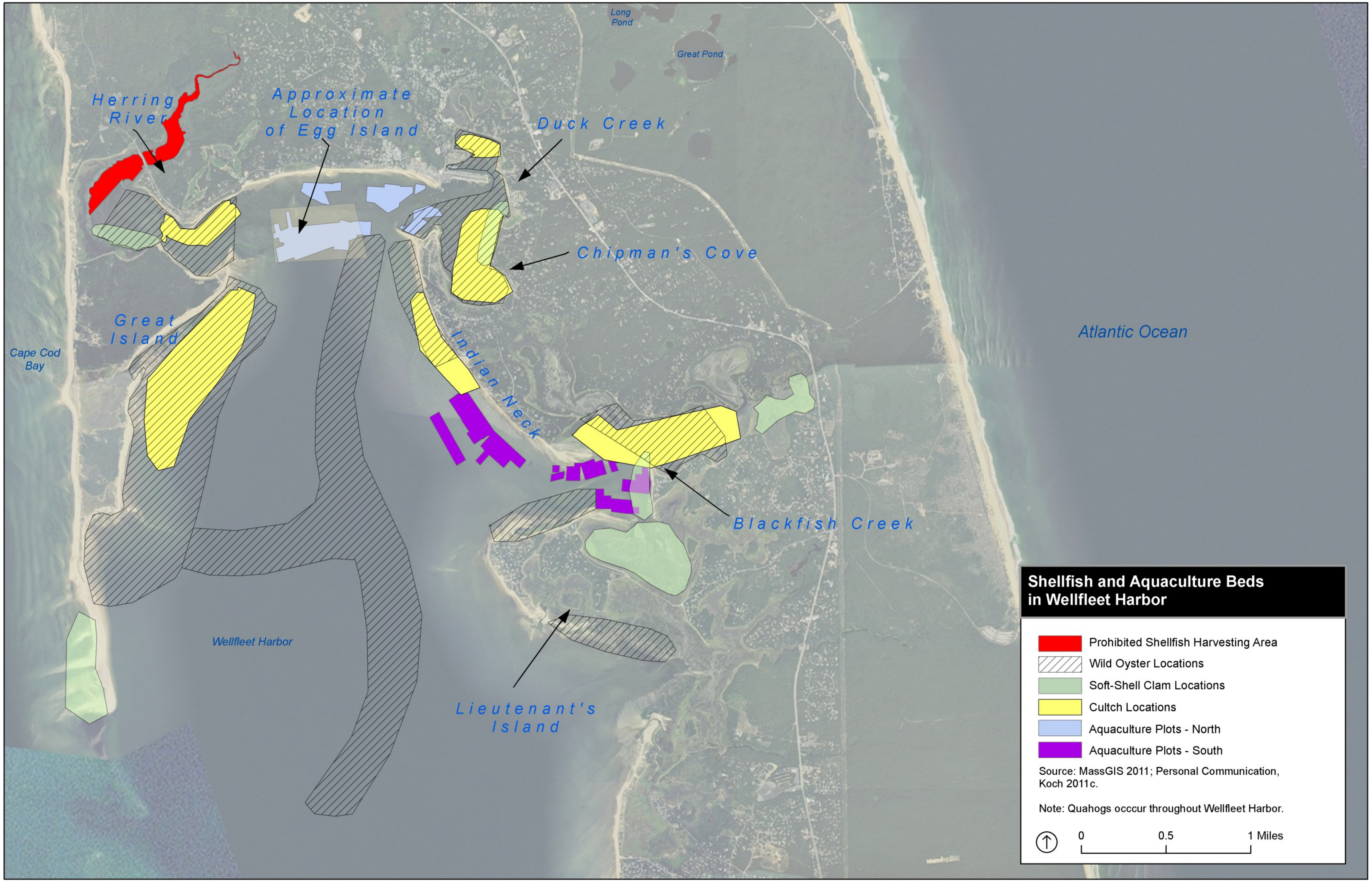


FIGURE 3-22: SHELLFISH AND AQUACULTURE BEDS IN WELLFLEET HARBOR (LOCATIONS APPROXIMATE)

Estuaries provide habitats for finfish, such as the winter flounder (*Pseudopleuronectus americanus*), to spawn and grow; typically, salt marshes are important spawning habitats, provide protection from predators, and offer food for both juvenile and adult finfish (NPS 2011e). Throughout the nation, estuaries play a crucial role in supporting the fishing industry. Approximately 75 percent of the 10 billion pounds of the total United States. commercial fish landings annually, worth over $3.8 billion, are species that are dependent on estuarine conditions for at least some stage of their lifecycle (Pendleton 2008). Additionally, increased tidal exchange and salinity in an estuary can lead to greater species diversity and finfish abundance (Portnoy et. al. 2005).

Table 3-19 summarizes the total commercial finfish harvests (i.e., catch) and values for Wellfleet between 2006 and 2010. The amount of landed commercial finfish has fluctuated over the period from 2006 through 2010. These values are relatively small compared to the shellfish harvest values. In 2009, the value of landed commercial finfish in Wellfleet Harbor represented less than 1 percent of the aquaculture and wild commercial shellfish harvest values. In 2009, the amount of commercial finfish landed in Wellfleet, at 9,606 pounds, made up a small portion of the total amount of commercial finfish landed in the state of Massachusetts, which had a total landed weight of approximately 356,000,000 pounds (McAfee, pers. comm. 2011; NPS, pers. comm. 2011c).

TABLE 3-19: TOTAL COMMERCIAL FINFISH HARVEST IN WELLFLEET, MA (2006–2010)

Year	Finfish [a,b]	
	Live lbs.	Value
2006	7,390	$8,085
2007	9,130	$13,148
2008	7,684	$9,806
2009	9,606	$16,439
2010	3,009	$5,174

Source: McAfee, pers. comm. 2011.

a Finfish include species such as bluefish, cod, winter flounder, and striped bass. Shellfish include species such as the northern quahog, blue mussel, eastern oyster, crabs, and lobster.

b The finfish identified were landed in Wellfleet and were not explicitly caught in Wellfleet Harbor. These finfish could have come from anywhere, including Cape Cod Bay, and were landed in Wellfleet.

According to the Cape Cod 1998 General Management Plan, a consistent policy toward stocking programs for fishing would be developed in cooperation with the Massachusetts Division of Fish and Wildlife and the use of native species will be encouraged in such programs. Additionally, this General Management Plan stated that fishing within the national seashore (focusing on native species) is allowed at levels compatible with the purposes of the seashore and with sustainable populations and ecosystems. Efforts are made to minimize conflicts with other visitor uses and private property. Finally, finfish aquaculture is permitted within the seashore, subject to several conditions outlined in the General Management Plan, and Finfish habitat cannot be altered merely to support game animals (CACO NPS 1998).

3.10.4 LOW-LYING PROPERTIES

Approximately 390 non-federally owned properties lie partially or fully within the Herring River flood plain that occurred prior to construction of the Chequessett Neck Road Dike. These properties include residential land, parcels owned by non-profit organizations, non-federal conservation land, commercial parcels, municipal lands, and undeveloped land (Town of Wellfleet

2011). In total, these parcels cover approximately 354 acres of land within the Herring River flood plain[3]. Table 3-20 summarizes the types of properties. Figure 3-23 identifies all privately owned land within the flood plain.

TABLE 3-20: LOW-LYING PROPERTIES IN THE HISTORIC FLOOD PLAIN

Property Type	Percentage of Properties
Residential	82%
Commercial	3%
Undeveloped	7%
Municipality	5%
Conservation, Non-Profit	3%

Residential Property

Residential land comprises approximately 17 percent of the total land within the historic flood plain. Approximately 82 percent of non-federal lands are private residential properties having a portion of their land within the pre-dike flood plain. These properties are primarily in the Upper Pole Dike Creek, Mill Creek, and Bound Brook sub-basins.

Commercial Properties

In addition to the golf course, there are 10 other commercial properties in the pre-dike flood plain. Three are in Upper Pole Dike Creek along Route 6 in Wellfleet. Eight other commercial properties are on the south end of Upper Pole Dike Creek. Commercial properties are used for restaurants and small business offices.

Undeveloped, Municipal, and Non-Profit Properties

Three other classifications of properties exist in the pre-dike Herring River flood plain. These properties include undeveloped land, municipal lands owned by the Towns of Wellfleet or Truro, and non-profit lands. Most of the properties classified as non-profit are owned by the Wellfleet Conservation Trust. Other properties are owned by religious organizations.

Chequessett Yacht and Country Club

The CYCC, established in 1929, is a semi-private country club southeast of the Chequessett Neck Road Dike in the Mill Creek sub-basin. The CYCC nine-hole golf course covers approximately 106 acres, with approximately 37 acres of this land located within the Mill Creek sub-basin in the historic flood plain (HRTC 2007). Portions of the golf course were built on former salt marsh. The low elevation, subsidence caused by diking and tidal restriction, and poorly drained soils have created present day flooding problems on the golf course. Property elevations on the CYCC property range from below Wellfleet Harbor mean sea level to about 60 feet above mean sea level (NPS pers. comm. 2011a; USGS 2008; MassGIS 2011).

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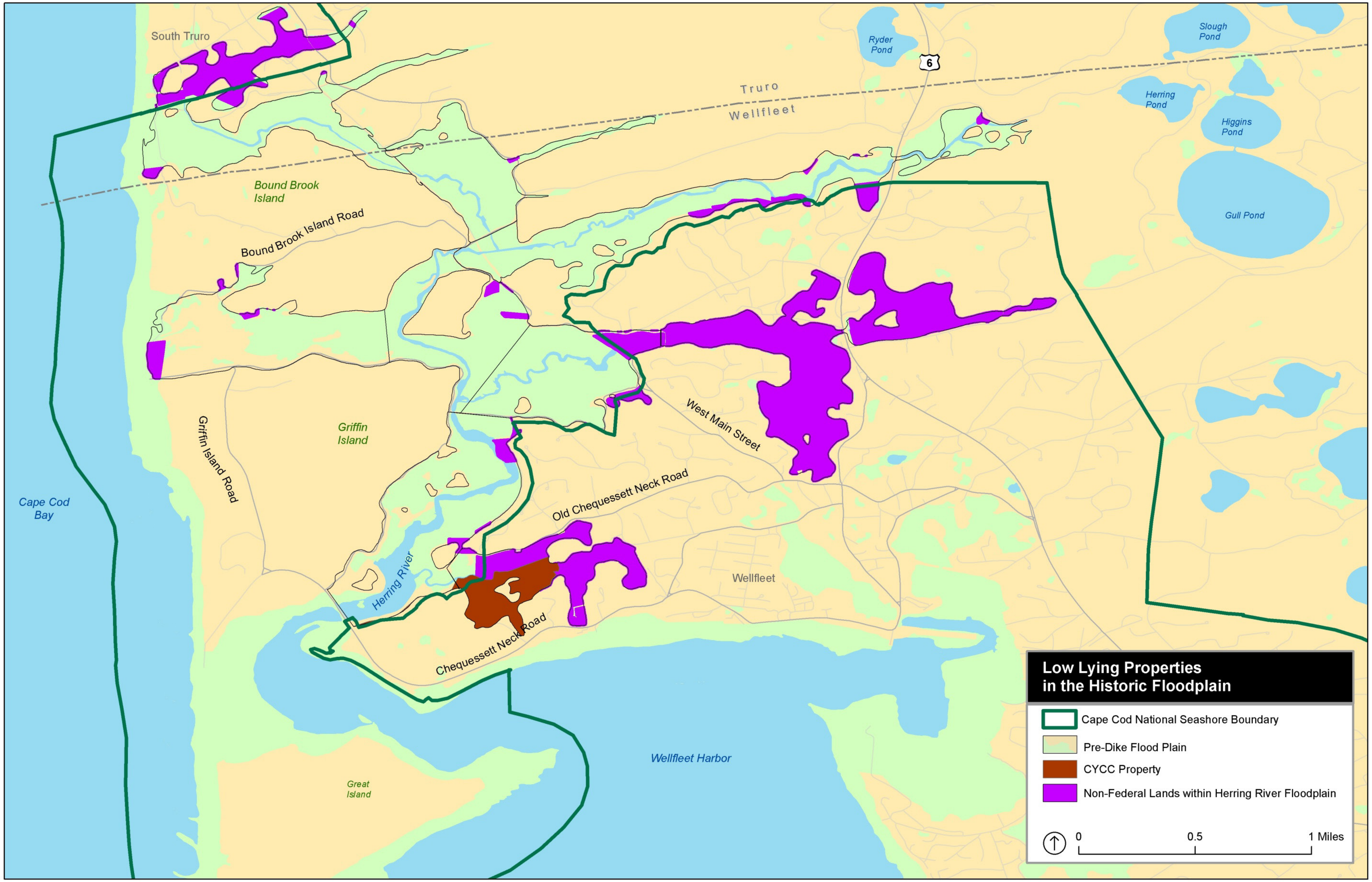
[3] The CYCC is excluded from this analysis and is analyzed separately, below.



Source: Town of Wellfleet 2011.

FIGURE 3-23: CURRENT NON-FEDERAL LAND OWNERSHIP IN THE HISTORIC (PRE-DIKED) HERRING RIVER FLOOD PLAIN

3.10.5 LOW-LYING ROADS

Several segments of low-lying roads occur within the historic Herring River flood plain and may be susceptible to flooding after tidal exchange is restored. These are public roads that cross the river and various tributary streams and link upland areas that surround the estuary. They range from infrequently traveled fire roads to moderately busy paved roads. The major low-lying roads identified as potentially affected by the project are portions of High Toss Road, Old County Road, Pole Dike Road, Snake Creek Lane, Old Chequessett Neck Road, Duck Harbor Road, Ryder Beach Road, and Bound Brook Island Road. These roads are summarized in table 3-21 (ENSR 2007b) and depicted in figure 3-24. Several other short road segments and minor roads are also included in the table and figure.

TABLE 3-21: SUMMARY OF LOW-LYING ROADWAYS IN THE HERRING RIVER FLOOD PLAIN

Road Name	Approximate Lowest Elevation (ft. NAVD88)	Approximate Length (ft.) in Flood Plain (below 6 ft. NAVD88)
Paved Roads		
Bound Brook Island Road/Old County Road	2.3	3700
Pole Dike Creek Road	2.7	3105 (two segments)
Duck Harbor Road/Griffin Island Road	5.5	1284 (two segments)
Old Chequessett Neck Road (Snake Creek Rd)	5.4	703
Old County Road (Paradise Hollow), Wellfleet	3.2	289
Old County Road (Lombard Hollow), Truro	3.5	197
Old County Road (Prince Valley), Truro	4.0	119
Approximate Length of Low Paved Roads		*9397*
Sand and Fire Roads		
Duck Harbor Road, Fire Road West of Herring River	4.0	4574
High Toss Road, From Pole Dike Rd to Rainbow Lane	4.0	3299
High Toss Road, Causeway Across Flood Plain	3.1	1017
Rainbow Lane (Snake Creek Road)	4.0	992
Mill Creek Lane	5.5	395
Ryder Beach Road, Truro	4.0	349 (three segments)
DPW Yard Driveway	5.0	101
Approximate Length of Low Sand and Fire Roads		*10,727*
Approximate Length of All Low Roads		**20,124**

High Toss Road—High Toss Road begins at an intersection with Pole Dike Road and extends to a dead end on Griffin Island. It crosses the Herring River approximately one mile upstream of the Chequessett Neck Road Dike. The road is unpaved and provides access to several residential areas and to Rainbow Lane. From Rainbow Lane to its end, High Toss Road is a causeway, crossing the Herring River flood plain and is only slightly higher than adjacent wetlands. At the western end of the road, a tidally restrictive, 60-inch-diameter, 24-foot-long concrete culvert conveys the Herring River beneath the road. Portions of this road, including the entirety of the causeway crossing the flood plain, are between 3 and 5 feet in elevation (ENSR 2007b).

Pole Dike, Bound Brook Island, and Old County Roads—Despite the separate names, these three road segments form a single, continuous route traversing the eastern edge of the Herring River and Bound Brook flood plains. From High Toss Road, Pole Dike Road extends north, crosses Pole Dike Creek, and turns into Bound Brook Island Road. Bound Brook Island Road crosses both the Herring River and Bound Brook, and turns into Old County Road in Truro, which extends to Ryder Beach Road and beyond. The route is heavily traveled, particularly for access to the Wellfleet transfer station. It also provides a key alternate to Route 6, linking the centers of Wellfleet and Truro. Together these roads comprise about 2 miles, with more than 7,000 feet occurring at elevations below the historic flood plain. Several sections, mostly near stream crossings, are below 3 feet and just slightly higher than adjacent wetlands.

Rainbow Lane—Rainbow Lane runs north/south along the eastern part of the Lower Herring River flood plain and provides access from High Toss Road to several residential properties. Rainbow Lane, as it extends to Old Chequessett Road, is overgrown and impassable to vehicles beyond the developed properties and used mostly by walkers. Rainbow Lane is also known locally as Snake Creek Road.

Old Chequessett Neck Road—Old Chequessett Neck Road is a paved public road extending from West Main Street in Wellfleet to its end at Chequessett Knolls Road. This road runs along the eastern edge of the Lower Herring River sub-basin and the northern edge of the Mill Creek Sub-basin. It is also known locally as Snake Creek Road.

Duck Harbor Road—Most of Duck Harbor Road is an unimproved, dirt road that runs north to south from Chequessett Neck Road to north of High Toss Road and along the northern edge of Griffin Island. Several sections are overgrown and vehicles are rare. The road is used primarily for walking. There is also a busier paved section of Duck Harbor Road at the northwest edge of Griffin Island connecting Griffin Island Road to a public landing at Duck Harbor.

Ryder Beach Road—Ryder Beach Road is a paved and unpaved public road in Truro that runs west from Old County Road to Ryder Beach for approximately 0.6 mile and beyond to several residential properties.

FIGURE 3-24: LOW-LYING ROAD SEGMENTS IN THE HERRING RIVER HISTORIC FLOOD PLAIN

3.10.6 VIEWSCAPES

Currently, there are approximately 700 acres of woodlands and shrublands in the flood plain, while open water and salt and brackish marsh account for 88 acres primarily located in the Lower Herring River sub-basin. Freshwater marsh and meadows account for approximately 222 acres within the flood plain.

The existing landscape character differs markedly between the upper and lower portions of the historic flood plain, with vegetation changing dramatically from north to south. This change is primarily a function of the existence of ponded freshwater and drained salt marshes in the upper flood plain, whereas brackish conditions exist toward the more open waters near the mouth of the river at the Chequessett Neck Road Dike. The upper Herring River flood plain is a wet forest environment characterized by abundant dense vegetation. Examples of these viewscapes are portrayed in figures 3-25 and 3-26.

Compared to the woodland in the northern portions of the historic flood plain, the landscape of the lower Herring River is more open, with expansive views in many directions. Grasses and other low-growing vegetation dominate in this area, with some trees present at the periphery (figure 3-27). Larger structures including the dike and several houses are also apparent at the mouth of the flood plain. In Mill Creek, the CYCC golf course is the prominent visual component. Access roads, ranging from narrow dirt roads to two-lane paved roads, weave through portions of the flood plain, offering glimpses of the estuary. Broader views are generally obscured by trees and dense shrub thickets.

FIGURE 3-25: AERIAL VIEW OF WOODED WETLANDS AROUND MERRICK ISLAND IN THE HERRING RIVER FLOOD PLAIN

FIGURE 3-26: CURRENT CONDITIONS IN UPPER HERRING RIVER SUB-BASIN FRESH WATER MARSH AND WOODED WETLAND

FIGURE 3-27: CURRENT CONDITIONS IN LOWER HERRING RIVER FROM CHEQUESSETT NECK ROAD DIKE

The presence of coastal wetlands and water features can affect the value of lands and properties. Bodies of water have historically been population magnets and property values along the coasts are indicative of this value. Environmental psychologists have explained this appeal to water as the desire to return to the natural state of existence (Pitt 1989). Others have suggested that water and water views hold attention and interest more effectively than urban scenes (Ulrich 1981). The added value of waterfront properties has implications for homeowners' wealth, but can also benefit local governments by generating higher property taxes.

Provencher, Sarakinos, and Meyer (2006), in their study of property valuations following the removal of control structures under river restoration efforts, suggest that residential property values near a free-flowing stream are higher than identical properties in the vicinity of a small impoundment. Johnston et al. (2002) examined the value of salt marshes to residents of Rhode Island. Although the authors did not directly analyze property values, they found that residents placed greatest value on mosquito control and protection of shellfish habitat, followed by protection of fish and bird habitat.

The Wellfleet Assessor's Office identifies properties in three neighborhood types based on their proximity to the Seashore or a body of water; (1) woodlot[4], (2) water-influenced, and (3) National Seashore (Vail, pers. comm. 2011). The Wellfleet Assessor's Office values properties that are located in the Seashore neighborhood (inholdings located within the Seashore boundary), in general three times higher than comparable woodlot neighborhood properties. Properties that are located in the water-influenced neighborhood, (lots that are located next to a body of water such as the ocean or harbor), are on average valued 2.2 times higher than comparable woodlot neighborhood properties (Vail, pers. comm. 2011). There a number of water-influenced properties in the Mill Creek sub-basin, as well as Seashore inholdings across the Herring River sub-basins; however, the majority of properties in the Herring River flood plain are identified as non-water-influenced or woodlot properties.[5]

3.10.7 Recreational Experience and Public Access

The Herring River flood plain provides numerous recreational opportunities to local residents and visitors. The restoration project may have impacts on some of these activities. Under the General Management Plan for Cape Cod National Seashore, the Herring River is zoned as a natural area where development is limited and recreational activities are to remain passive and unobtrusive. A brief description is provided of the primary recreational opportunities that are available in the Herring River area.

Recreational Finfishing—Historically, the Herring River has been heavily used by local residents and visitors for recreational fishing. Today, the area still provides limited recreational fishing opportunities. Although several freshwater fish species inhabit the Herring River (these species are identified in section 3.6) and access points to the river occur in several locations, fishing upstream of the Chequessett Neck Road Dike is rare because of poor habitat and the generally depauperate condition of the freshwater fishery. In contrast, fishing off of the downstream side of the dike is extremely popular, especially during striped bass and bluefish seasons when the dike is almost

[4] Woodlot neighborhood properties are properties that are not located within the boundaries of the Seashore or are not located within close proximity to, or have their property values influenced by, a body of water.

[5] There are properties within the Town of Truro boundaries that have not been assessed.

constantly occupied by fishermen. In addition to striped bass and bluefish, winter flounder are an important recreational finfish species in the Wellfleet Harbor area.

In addition to recreational fishing along the Herring River, a large trip boat for recreational fishing operates out of the Town of Wellfleet's marina, as do many smaller charters. Six sport fishing charter companies were listed on the Wellfleet Chamber of Commerce's website in November 2011. These Charter boats take paying customers out into Cape Cod Bay to fish (Wellfleet Chamber of Commerce 2011). Recreational fishermen also use private boats, which can be launched from multiple spots around Wellfleet including the town's marina (Town of Wellfleet 2006). Currently, 57 Bait and Tackle Shops are in business on Cape Cod and provide fishing equipment and bait to recreational fishermen (NPS, pers. comm. 2011c). The closest bait and tackle shop to Wellfleet is located in Eastham, approximately 8 miles south from the Wellfleet Town Pier.

Recreational Shellfishing—Wellfleet Harbor is a popular location for shellfishing. Shellfishing areas are regulated and include specific regions for aquaculture and recreational shellfishing. Recreational shellfishing is currently limited to two areas in Wellfleet Harbor, Indian Neck and an area open seasonally on the east side of Wellfleet Harbor (see figure 3-22). Although the portion of the Herring River just downstream of the Chequessett Neck Road Dike is designated as a shellfish harvest area, it is permanently closed because of fecal coliform pollution originating from the river (see sections 3.6 and 3.10.2).

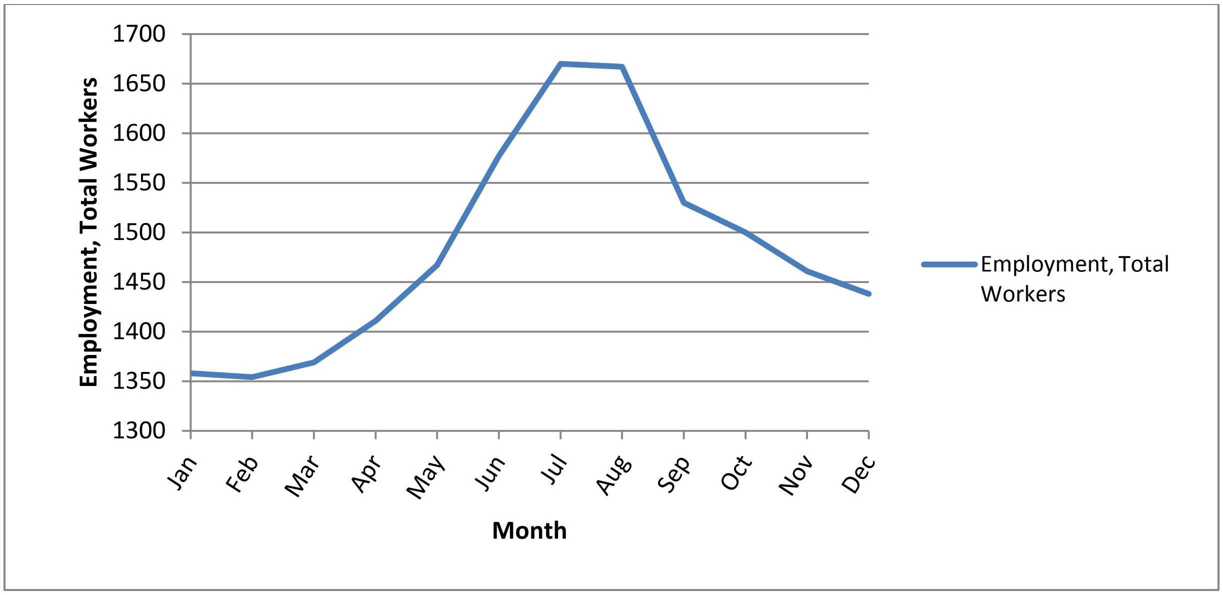
Boating—There are no official canoe/kayak launches on the Herring River. However, the river can be accessed at several locations and canoes and kayaks are seen occasionally.

Trails and Camping—The 8-mile Great Island Trail is the only official hiking trail near the Herring River, but is across the harbor and not within the project area. Several fire roads, such as the remote portions of Duck Harbor and Bound Brook Island Roads on Griffin and Bound Brook Islands are popular for walking. There is no legal camping in the area around Herring River.

Wildlife Watching and Hunting—Hunting for upland game and migratory waterfowl is permitted at the Seashore. Specific game species include white-tailed deer (*Odocoileus virginianus*), eastern cottontail (*Sylvilagus floridanus*), wild turkey (*Meleagris gallopavo*), gray squirrel (*Sciurus carolinensis*), red fox (*Vulpes vulpes*), gray fox (*Urocyon cinereoargenteus*), raccoon (*Procyon lotor*), and opossum (*Didelphis spp.*). Hunting is currently permitted from approximately Jeremy Point on Great Island, north to the Bound Brook basin, and in the Upper Herring River sub-basin to the west. Birding and wildlife viewing is a popular activity in the Herring River vicinity.

3.10.8 Regional Employment Conditions

Tourism is the primary driver of the Cape Cod economy (Cataldo 2007), although other factors also influence the seasonal nature the region's economy. Following a pattern observed in all Cape Cod towns, economic activity and employment levels in Wellfleet rise in the spring, are at their peaks during the summer months, decline in the fall, and are lowest during winter months. Figure 3-28 depicts this pattern in a typical year (Bureau of Labor Statistics 2011c).



Source: Bureau of Labor Statistics 2011c.

FIGURE 3-28: EMPLOYMENT LEVELS IN WELLFLEET. JANUARY 2010 TO DECEMBER 2010

Since the fall of 2008 when the economic recession began, national and regional economies have been affected by losses in jobs and income. Unemployment rates have also risen since 2007, reflective of the current economic downturn. Employment by industry was analyzed in 2007 and 2010 to assess the available workforce to support the construction of the project.

In 2010, 24 percent of the employment in Cape Cod, (Barnstable County), was associated with retail sales, accommodations, and food and beverage establishments, reflecting the important tourism economy in Wellfleet and across the Cape. Other important sectors in Barnstable County include health care and social assistance (13 percent), government (11 percent), and construction (8 percent). From 2007 through 2010, Barnstable County lost over 5,000 jobs, a 4 percent decrease during this period. Overall, unemployment rates have also increased since 2007, rising approximately 4 percent in Wellfleet and Barnstable County between 2007 and 2010. Employment by industry in Barnstable County is summarized in table 3-22 for 2007 and 2010; additionally the number of jobs lost or gained is also summarized along with the percentage change in employment during this period.

Restoration of Herring River involves construction of one or more dikes, the elevation of several low-lying roads, the relocation or elevation of a portion of the golf course, and variety of potential actions as tide exchange is reintroduced, such as vegetation removal and dredging. All of these actions will support jobs that are expected to benefit the regional economy, primarily in the construction sectors. In 2010, the construction industries accounted for over 11,500 jobs in Barnstable County, while in the nearby Boston metropolitan area, the construction industry accounted for over 136,000 jobs. The construction industry has been especially affected by the economic downturn. Between 2007 and 2010, the construction industry in Barnstable County lost over 2,300 jobs. With workforce available in both Barnstable County and in the Boston metropolitan area, there should be sufficient supply of construction workers to support the restoration project.

TABLE 3-22: 2007 AND 2010 EMPLOYMENT BY INDUSTRY FOR BARNSTABLE COUNTY, MA

Industry	2007 Employment	2007 Percent of Total	2010 Employment	2010 Percent of Total	Loss or Gain of Jobs 2007-2010	Percent Change 2007-2010
Farm employment	459	0%	462	0%	3	1%
Forestry, fishing, and related activities	(D)	(D)	(D)	(D)	(D)	(D)
Mining	(D)	(D)	(D)	(D)	(D)	(D)
Utilities	412	0%	403	0%	-9	-2%
Construction	13,839	10%	11,448	8%	-2391	-17%
Manufacturing	2,214	2%	1,950	1%	-264	-12%
Wholesale trade	2,439	2%	2,271	2%	-168	-7%
Retail trade	20,735	15%	17,958	13%	-2777	-13%
Transportation and warehousing	2,572	2%	2,457	2%	-115	-4%
Information	2,202	2%	2,041	1%	-161	-7%
Finance and insurance	4,775	3%	5,923	4%	1148	24%
Real estate and rental and leasing	10,449	7%	9,641	7%	-808	-8%
Professional, scientific, and technical services	9,694	7%	9,575	7%	-119	-1%
Management of companies and enterprises	695	0%	513	0%	-182	-26%
Administrative and waste services	7,456	5%	7,407	5%	-49	-1%
Educational services	2,073	1%	2,299	2%	226	11%
Health care and social assistance	17,491	12%	18,187	13%	696	4%
Arts, entertainment, and recreation	5,235	4%	5,099	4%	-136	-3%
Accommodation and food services	15,161	11%	15467	11%	306	2%
Other services, except public administration	8,080	6%	7639	6%	-441	-5%
Government and government enterprises	15,597	11%	15696	11%	99	1%
Total employment	142,999	100%	137,809	100%	-5,142	-4%

Source: Bureau of Economic Analysis 2011c; The Louis Berger Group 2011.