Designing a Protocol for Monitoring

The Great Salt Pond and its Watershed,

Block Island, Rhode Island

by

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PART 1. INTRODUCTION

1.1 Purpose of My Study

Ten miles off the coast of Rhode Island lies New Shoreham, also known as Block Island [**Figure 1.1**]. At the center of Block Island is a 1000-acre saltwater pond called the Great Salt Pond. Surrounded by rolling hills, sandy shores and wood farmhouses, the Great Salt Pond has a quiet, rustic character that attracts boaters from up and down the East Coast of the United States. But Block Island tourism has been on the rise since 1960, bringing changes—crowds, cars, expensive house rentals, jet skis and bumper boats.

Many islanders are concerned: Can the Great Salt Pond continue to be healthy if building and tourism continue? When, in 1986, high bacteria concentrations from boater sewage discharge closed the pond to shellfishing,[1] and a large ferry terminal was proposed, a citizen group formed—the Committee for the Great Salt Pond (CGSP).[2] To date, however, no study has examined the Great Salt Pond and its watershed as a whole system to identify and rank threats to it. Noting the lack of cohesion in environmental data collecting on the island, the Block Island Steering Committee on Natural Resources reported this:

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[1] The pond was declared a Federal No Discharge Area (for marine sewage) in May 1993. This was the first such designation in Rhode Island. In 1996, shellfish beds in the north of the pond were reopened for a limited season.

[2] The mission of the CGSP is: To help protect and enhance the environmental quality of the Great Salt Pond, including its shorelines and wetlands, and to promote appropriate and productive uses of the Pond's resources by residents, visitors, and local businesses.

> "The concerned public agencies and private groups [on Block Island] should agree on an adequate program of inventories and monitoring, establish protocols and assign responsibilities to get data…"[3]

This thesis lays the foundation for a comprehensive data-gathering program—a monitoring protocol—that will help to inform management decisions about the Great Salt Pond. The purpose of the data-gathering program will be to 1) locate pollution sources that cannot be identified by single indicators; 2) identify significant trends that are not apparent in short-term studies; 3) collect information before it is needed, so that it is available in case of a crisis.

Monitoring schemes are often designed to "indicate overall long-term health or lack of health" of a management area.[4] However, assessing the health of the Great Salt Pond is not straightforward: humans have influenced nearly every aspect of the present pond—its chemistry, biology, and physical shape. Many species living in and around the Great Salt Pond today were not present historically. Rather than attempting to maintain particular health standards in the pond, then, managers need to assess what goals for management are appropriate, and then tie monitoring to those goals. The Town Charter, Harbor Management Plan, and New Shoreham Comprehensive Plans together articulate three broad goals for island governmental protection: protecting public health, protecting human quality of life, and protecting natural resources.[5] While these goals may not

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[3] Kingsbury, Read et al. *An Activist Environmental Agenda: Report of the Natural Resources Steering Committee to the New Shoreham Town Council*. New Shoreham, RI, 1996.

[4] Haddon, Patricia. *Citizen Volunteer Water Quality Monitoring Program: Church Creek Monitoring Data Analysis*. Annapolis, MD, 1990.

[5] Town Charter: "We, the people of the Town of New Shoreham, commonly known as Block Island…" have created a charter "in order to secure the peace, safety, welfare and best interests of the Town." The

always conflict, they may, at times, require sacrificing one for the good of another. For this reason, a consensus should be reached about priorities for pond management before a monitoring program is undertaken.

Next, to create a program for monitoring the Great Salt Pond, these basic questions should be answered:

1) How does the natural system of the Great Salt Pond function? How is this system changing over time?
2) How do humans influence the Great Salt Pond system? Which human influences are most threatening? [6]
3) What indicators effectively track these threats to the Great Salt Pond?

Once these questions have been answered, the next step in creating a monitoring protocol is to decide on an appropriate monitoring strategy, which will depend on budget constraints and human resource availability. Finally, responsibility for monitoring can be delegated, and specific monitoring procedures can be defined.

1.2 Present Monitoring

The monitoring presently done in the Great Salt Pond watershed is patchy: 1) The New Shoreham Harbors Department, in conjunction with the Rhode Island Department of

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Harbor Management Plan calls for "the improvement and protection of the water quality, natural resources, and aesthetic values of the Great Salt Pond." The New Shoreham Comprehensive Plan states a need for "protecting the island's extraordinary heritage for those who follow, seeking to reconcile opportunity for current benefit with considerations of the generations to follow."

[6] The definition of a "threat" will also depend on goals for pond management.

Environmental Management (RIDEM), monitors bacteria concentrations; 2) The Rhode Island Department of Environmental Management (RIDEM) does triennial shoreline surveys of point source pollution,[7] and periodic shellfish surveys; 3) The Nature Conservancy monitors bird populations on an annual basis; 4) The Committee for the Great Salt Pond (CGSP) makes periodic measurements of water clarity,[8] pH, and salinity of pond waters.[9]

Since 1991, the Harbors Department has measured fecal coliform bacteria[10] concentrations in the pond. They sample fourteen sites twice a month in the summer (mid-May though mid-September), and once a month through the rest of the year. This data is the most complete data set existing on water quality in the Great Salt Pond.

Six sites of the 14 sampled regularly result in fecal coliform levels that are significantly higher than the others.[11] [See **Appendix A** for a map of sample site locations.] These areas have mean summer concentrations which are consistently higher than shellfishing

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[7] These surveys attempt to locate "actual and potential" sources of bacteriological contamination by looking for pipes, culverts, and drains with nearby algal growth. These surveys have not revealed any significant inputs to the pond since 1994. RIDEM. *Block Island and Great Salt Pond shoreline survey*. Providence, RI, 1999.

[8] CGSP's measurements of water clarity indicate that pond water clarity varies from twelve to twenty-one feet.

[9] CGSP's salinity measurements indicate that salinity varies between 29 and 34 parts per thousand. (Ocean water is typically 35 parts per thousand.)

[10] Fecal coliform levels in the Great Salt Pond have many sources: septic systems, marine overboard discharge of sewage, birds, seals, dogs, cows, horses and deer. While measuring fecal coliform will help to ensure that the public is not exposed to high levels of bacteria without knowing it, this method does little to help to identify sources of the bacteria.

[11] These sites are Sites #1 (Harbor Pond), #2 (Hog Pen), #3 (Payne's), #4 (Champlain's), #5 (South harbor), and #14 (Trim's Pond).

standards, and in some cases are too high for swimming.[12] However, even among these "bad sites," there is tremendous variation in fecal coliform concentrations in the summer months, both within and among sites on different sampling dates **[Figure 1.2].** This complicates analysis, but does suggest that fecal coliform bacteria is not equally distributed across the pond. The remainder of the testing sites (#6-#13) have a mean summer fecal coliform concentration that is lower than the federal standard set for shellfishing. All sites have negligible fecal coliform concentrations in the winter. There appears to be a decline in average summer fecal coliform concentrations in the Great Salt Pond since 1993, but the trend is short (only over the past four years), and averages may be skewed by a few extremely high sample concentrations **[Figure 1.3].** [13]

[12] In Rhode Island salt waters, RIDEM requires that mean fecal coliform concs. may not exceed 14/100 ml, and >10% of samples may not exceed 49 for shellfishing. Swimming waters should not average more than 70/100 ml.

[13] Data collected before data testing was moved to the State-approved lab in 1992 appears to be uniformly low. It is likely that these low measurements are not indicative of true fecal coliform levels in the Great Salt Pond, but instead represent error in sample analysis.

Figure 1.2. Average fecal coliform concentrations of "bad sites" in summer months (Sites #1-5 and #14 in June-September). Bars represent standard error.

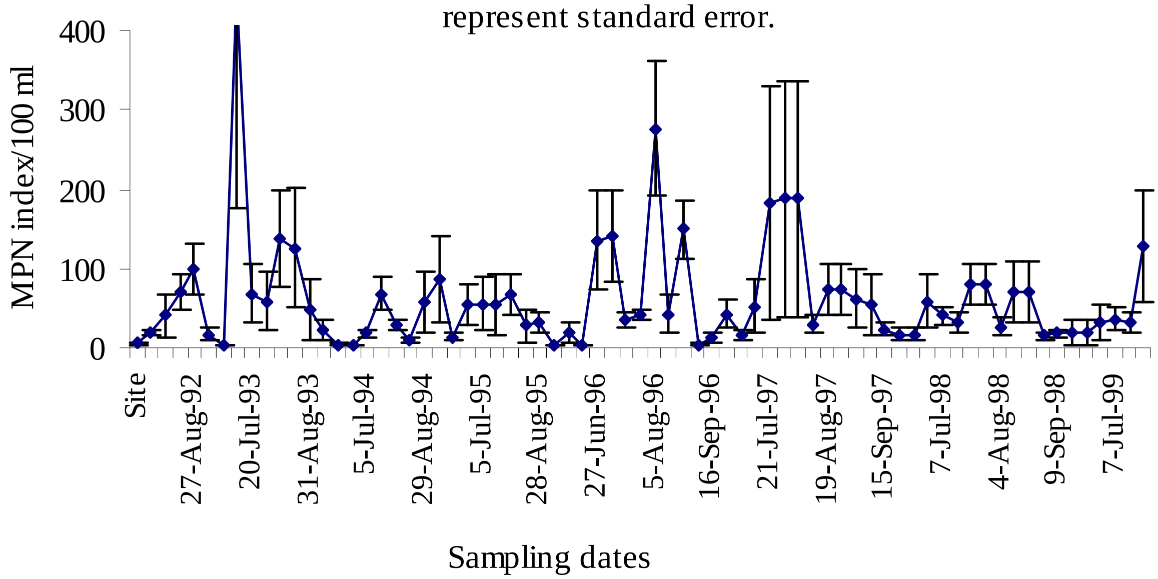
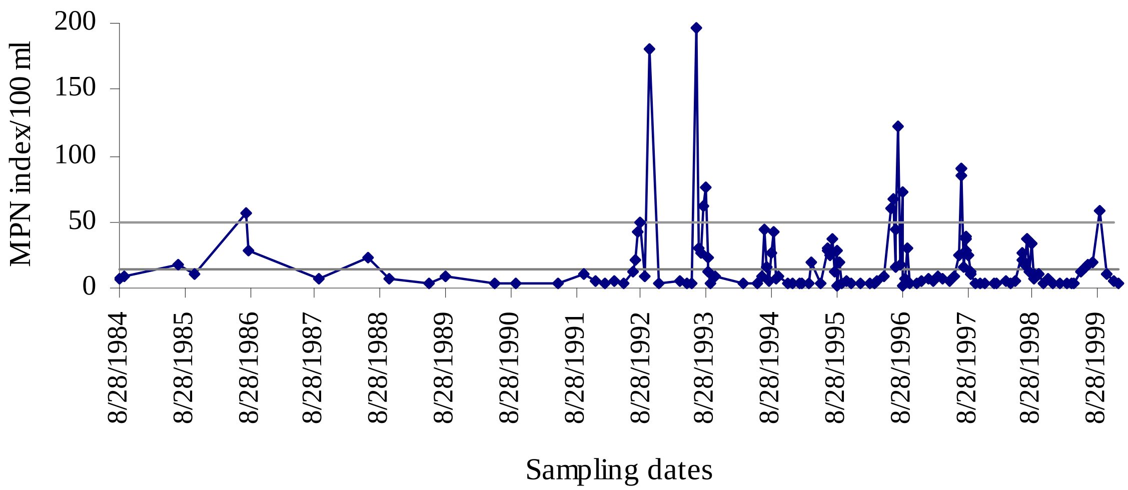


Figure 1.3. Average fecal coliform concentrations across 14 sites in the Great Salt Pond (Jan-Dec). A downward trend is indicated post-1993. Sources: RIDEM Water Resources, New Shoreham Harbors Dept. (Minimum swimming and shellfishing requirements shown)



PART 2. WATERSHED ASSESSMENT: THE "NATURAL" SYSTEM

Block Island is small enough that none of it is free from human influence. The Great Salt Pond is especially affected by humans—without human alterations, the pond would be brackish, and closed to the ocean. Aquatic life in the pond would bear little resemblance to what presently lives there. The shape of the shoreline would be different. So, when speaking of "preserving" the "natural" resources of the Great Salt Pond, we must realize that the Great Salt Pond is actually not, even now, in a "natural" state, i.e. unchanged by humans.[14] When we decide to manage these resources then, we should realize that we do not have the choice of returning the Great Salt Pond to its "natural" state. In deciding what indicators to monitor in the Great Salt Pond ecosystem, we must begin by making decisions about what about the present environment we wish to preserve for the future.

2.1 Natural History of the Great Salt Pond

The Great Salt Pond was formed 3000 years ago, when coastal erosion and sedimentation closed in a basin in the center of Block Island.[15] Today, the surface area of the pond is just over 800 acres at mean low tide.[16] The Great Salt Pond watershed drains about 1700 acres, or 27 percent of Block Island.[17] [18] **[Figure 2.1].** About 1800 years ago, Native

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[14] The Nature Conservancy document, "A Plan for Long Term Ecosystem Conservation on Block Island" (1991) considers Block Island to be "an anthropogenic landscape."

[15] Sirkin, Les. *Block Island Geology*. Watch Hill, RI: Book & Tackle Shop, 1996.

[16] This study includes the tributary ponds, Harbor Pond and Trims Pond as part of the Great Salt Pond.

[17] The most convenient way to define the watershed is to use surface topography, and assume that drainage patterns of surface and groundwater follow the same flow patterns. In reality, groundwater gradients may differ somewhat from surface topography.

[18] RIGIS. Database on-line, 2000.

Americans began living around the shores of the Great Salt Pond.[19] Piles of discarded shells and bones reveal the ancient presence of many shellfish in the pond, including oysters (*Crassotrea virginiana*) and soft-shelled clams (*Mya arenaria*), as well as fish such as Atlantic sturgeon (*Acipenser sturio*) and striped bass (*Roccus lineatus*).[20] This evidence, combined with written accounts,[21] suggest that the pond was brackish until it was permanently breached to the ocean. Pond aquatic communities today are typical of northeastern seashores.[22]

Block Island was discovered by Europeans in 1524 and settled in 1661.[23] In 1665, the first islander petitioned the Rhode Island Assembly to breach the pond and create a harbor for the island.[24] After many temporary, minor breach attempts and over 250 years, the "Great Pond" (as it was formerly called) was finally breached to the ocean in

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[19] Bellantoni, Nicholas F. "Faunal Resource Availability and Prehistoric Cultural Selection on Block Island, Rhode Island." Ph.D. diss., University of Connecticut, 1987.

[20] McBride, Kevin. Nomination for the Great Salt Pond Archaeological District, National Register of Historic Places Inventory, U.S. Department of the Interior, National Park Service,1985.

[21] From Livermore, 1877: "The Great Pond, therefore, is a body of fresh water, artificially, or incidentally salted enough to make it brackish most of the time." "There is one point…of vital importance…[the pond] freezes completely in winter."

[22] Common shellfish species include quahogs, surf clams, blue mussels, and slipper shells, with occasional scallops. Today, American oysters are rare in the pond. The most common small finfish are Atlantic silversides (*Menidia menidia*), American sand lance (*Ammodytes americanus*), mummichog (*Fundulus heteroclitus*), striped killifish (Fundulus majalis). Frequently caught in the Pond are striped bass, winter flounder, bluefish, squid, and summer flounder. Algae species include the introduced *Codium fragile*, *Fucus*, *Ulva lactuca*, *Ascophyllum nodosum*, and *Enteromorpha* species.

[23] Downie, Robert M. *Block Island: The Land*. Block Island, RI: Book Nook Press, 1999.

[24] Since "discovery," Europeans complained that Block Island had no harbor. A 1670 plea argued that breaching the pond would "make a convenient harbor there, to the encouradging [sic] fishing designs." In 1773, the need for the harbor was given as "the necessity of swimming their horses, cattle and sheep to the vessels and hoisting them aboard…the value of a harbor to fisheries; the convenience of the Great Pond for a harbor, and its fish; advantages to the colony…" (Livermore, 1877).

1895.[25] Since then, the pond has had to be dredged eight times to remove sediment that built up in the channel.[26] [27] At the same time that settlers attempted to make a harbor in the Great Salt Pond, they also cleared the surrounding land for farming.[28] In the past 250 years, then, and especially the past 100 years, the pond and its watershed have changed dramatically. In addition, to build roads and increase farmland, islanders filled in several marshy areas around the pond.[29] Given these changes, seems likely that the Great Salt Pond and its watershed are in neither in a static nor an equilibrium state, but instead are actively responding to human influence **[See Figure 2.2].**

The breachway has broad-reaching effects on the pond. The size of the channel affects the salinity of the pond, which in turn affects the suitability of the pond for habitat for fish, shellfish spawning and survival.[30] Olsen and Lee (1984) cite several examples of breachways leading to decline of fisheries in Rhode Island salt ponds.[31]

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[25] A breach 300 feet wide and 18-25 feet deep was made in the northwest corner of the pond in 1895 (O'Donnell, 2000; Livermore addendum, 1961). Before this final success, settlers attempted to breach the pond in 1686, 1699, 1707, 1882, 1887, and probably many other times not recorded (Livermore, 1877; Ritchie, 1957). In 1902, Trim's and Harbor Pond were dredged to become permanently connected to the Great Salt Pond.

[26] O'Donnell, Edward, U.S. Army Corps of Engineers. Emailed information on dredging history of Great Salt Pond,2000.

[27] On the ocean side of the island, longshore currents carry sediment northward from the west side around the north side of the Great Salt Pond. The large jetty is not totally successful at protecting the inlet from sedimentation. (Sirkin, 1996)

[28] The island was cleared of trees by the mid-1700's, and remained so until the 1940's. Rozenzweig, Laura T., and Dennis B. Wolkoff. *A Plan for Long Term Ecosystem Conservation on Block Island*. Providence, RI: The Nature Conservancy, 1991.

[29] Examples: Trim's Pond was filled east of Fort Island to make Ocean Avenue. The south of Harbor Pond was filled to make East Side Drive.

[30] In other Rhode Island salt ponds, low salinities following spring thaws "would kill off such predators as oyster drills and starfish" (Olsen and Lee, 1982). Low salinities may also be optimal for some shellfish species.

The flushing rate of the pond will determine how quickly pollutants are removed from the pond. The Pond should flush all of its water in 4.6 tidal cycles (2 1/4 days), if water mixing is perfect.[32] However, a five-day hydrographic study concluded that the flushing rate in the GSP was slower than predicted.[33],[34] The study also concluded that the water in the pond circulates counterclockwise, and that water from the center of the pond migrates into the southernmost parts of the pond. Since both Trims and Harbor Ponds are shallow, far from the channel, and connected to the rest of the GSP by narrow mini-channels, flushing from those Ponds is likely to be very slow.

Not really a pond. The Great Salt Pond evades traditional definitions of aquatic environments, but can probably best be defined as a permanently breached coastal lagoon. Lagoons are "areas of relatively shallow water that have been partly or wholly sealed off from the sea by the formation of depositional barriers, usually of sand or shingle, built up above high tide level by wave action."[35] Due to variations among

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[31] Breachways "reduced the range of habitat types in the ponds, changing the abundance and type of food organisms, reducing the ability of areas near the breachway to conserve eggs and larvae, and permitting important shellfish predators to become residents in the pond" (Olsen and Lee, 1984).

[32] The volume of the Great Salt Pond is approximately 430,000,000 ft^3 (57 Mgals) at low tide, and 550,000,000 ft^3 (73 Mgals) at high tide. Department of Health and Human Services, Northeast Technical Services Unit. *Hydrographic Study of Great Salt Pond, Block Island, RI: October 2-6, 1986*. Providence, RI, 1986.

[33] Flushing rate is influenced by tidal range (which will vary throughout the lunar cycle), volume of salt water input (which changes with the amount of sedimentation in channel), amount of fresh water input (which changes with rainfall over course of year), and wind patterns.

[34] Department of Health and Human Services, Northeast Technical Services Unit. *Hydrographic Study of Great Salt Pond, Block Island, RI: October 2-6, 1986*. Providence, RI, 1986.

[35] Bird, Eric C.F. "Physical setting and geomorphology of coastal lagoons." In *Coastal Lagoon Processes*, ed. Bjorn Kjerfve. New York: Elsevier, 1994.

lagoons in climate, geomorphology, sediment supply and tidal range, lagoons vary considerably in their biology.[36] In fact, "there may be as many lagoonal environments as there are lagoons!"[37] Even within the Great Salt Pond watershed, there are many different habitats: tidal wetlands, beach/dune environments, and scrub/shrub fields. The pond too, contains diverse environments: sand flats, intertidal areas, seagrass beds, deep waters.

2.2 Key Management Issues

From a human perspective, threats to the natural system of the Great Salt Pond are processes which change the present state of the resource. I evaluate these over the long term, and rank them according to toxicity of impacts, scale, trend and persistence in the watershed. [**See Table 2.1]** Details are below.

Land habitat loss. When humans clear land for pastureland, animals living there are displaced. When humans abandon pastureland, species that prefer open habitats are displaced. So, in these cases, habitat is lost from a species perspective but not necessarily overall. In some cases, such as land development for residential homes, land is taken out of use permanently. This kind of land use fragments habitats for all land species, and can

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[36] Nixon, S.W. "Nutrient dynamics, primary production and fisheries yields of lagoons." In *Oceanol. Acta: Proceedings from the International Symposium on Coastal Lagoons*, 357-371, 1982.

[37] Barnes, R.S.K. *Coastal lagoons: The natural history of a neglected habitat*. Cambridge, England: Cambridge University Press, 1980.

negatively affect the survival of many populations, especially those with small numbers of individuals.[38]

Status. When French navigator, Verrazzano, described Block Island in 1524, he said that "It was full of hills, covered with trees…"[39] This is not true today, nor has it been true since the settlers cleared the land for farming 250 years ago. But with the decline of farming in the early part of the twentieth century, island land has begun to recover. Shrubs[40] grow well in the windy, salty Block Island environment, and today cover 160 acres in the Great Salt Pond watershed. Forest now covers 330 acres of the watershed.[41] **[Figure 2.3].** Together, these covered 30 percent of the watershed in 1995. Land used for agriculture has declined since 1939 **[Figure 2.4]**. In 1995, cropland and pasture together made up 10 percent of watershed land. **[Table 2.2]**

As a consequence of forest succession, several endangered species are losing their habitats. The American burying beetle (*Nicrophorus americanus*), Northern blazing star (*Liatris scariosa*), and Bushy Rockrose (*Helianthemum dumosum*),[42] for example, prefer

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[38] Fragmentation of land leads to an increased susceptibility of populations to extinction due to large catastrophic events (e.g. hurricanes or disease), environmental variability (e.g. drought), and loss of viable genetic material. Wilcox, B and D. Murphy. "Conservation strategy: the effects of fragmentation on extinction." *American Naturalist* 125 (1985): 879-887.

[39] Livermore, S.T. *History of Block Island*. Forge Village, MA: Murray Printing Co., 1877.

[40] Common species of scrub/shrub habitat include shadbush, bayberry, arrowwood, black cherry, and rose. Rozenzweig, Laura T., and Dennis B. Wolkoff. *A Plan for Long Term Ecosystem Conservation on Block Island*. Providence, RI: The Nature Conservancy, 1991.

[41] Wetlands and forested wetlands are counted together in 1995 land use coverages. Wetlands cover an additional 190 acres of the watershed.

[42] *N. Americanus* is a Federally Endangered Species. *L. scariosa* is a species of federal concern, *H. dumosum* is endemic to southern New England, and is declining throughout its range.

habitats that have been recently disturbed.[43] These species benefited from past human land clearing activities, and now require habitat mowing or burning to maintain them.

Table 2.2. 1995 Land Cover in the Great Salt Pond Watershed.
Calculated from land use/land cover images in the RIGIS database.

Land Cover Type	Acres	Percent cover
Residential	494	29%
Scrub	198	12%
Wetlands	330	19%
Cropland	7	0.4%
Forest	330	19%
Pastureland	172	10%
Total	**1700**	

Residential= Any type--low, medium or, high density
Scrub= Shrub and brush areas undergoing reforestation
Wetlands= Forested and non-forested wetlands
Cropland= Cropland, intense farming, and tillable land
Forest= Deciduous, mixed or evergreen forest with >50 coverage
Pastureland = Pasture, hay fields, land not suitable for tillage

The island's position at the south tip of New England makes it a crucial stopover for migrating birds. The USFWS states that Block Island is "one of the most important migratory bird habitats on the East Coast."[44] The West Beach area, which includes land at the north end of the Great Salt Pond is home to one of the largest Herring and Great Black-backed gull colonies in New England. Birds such as the Northern Harrier (*Circus cyaneus*), which is now only found on offshore islands in Rhode Island and

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[43] Raithel, Christopher. *American Burying Beetle, Recovery Plan*. West Kingston, Rhode Island: New England Field Office, U.S. Fish and Wildlife Service, 1991.

[44] USFWS. *Northeast Coastal Areas Study: Significant Coastal Habitats, Site 28 (Rhode Island).*, 1991.

Massachusetts, require large expanses of open land for nesting and feeding.[45] The gradual succession of agricultural land to forest will benefit species such as the Northern Harrier.

Permanent development of land may negatively affect survival of many species. American oystercatchers (*Haematopus palliatus*), for example, nest on Beane Point, an area currently protected by the U.S. Fish and Wildlife Service. The birds cannot expand their nesting area, because in other areas, their nests would be trampled and their eggs eaten by cats and dogs.[46] In 1995, 300 acres had been set aside as open space in the watershed. Even so, several rare species have disappeared from Block Island during the 1980's and 1990's.[47]

Pond habitat loss. Pond habitats can be changed by development, such as dredging or dock construction, which can increase total dissolved solids and sediments, as well as increase bacteria and nutrient concentrations in pond waters. Changes in habitat conditions can create conditions that are unsuitable to some species. While development may not necessarily decrease overall biodiversity in the pond, it may result in a shift in community species that may or may not be desirable to humans.

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[45] Rozenzweig, Laura T., and Dennis B. Wolkoff. *A Plan for Long Term Ecosystem Conservation on Block Island*. Providence, RI: The Nature Conservancy, 1991.

[46] Use of overland vehicles on beaches, feral cats and dogs threaten this community even now, despite protection.

[47] At least three threatened or endangered species have stopped appearing on Block Island in recent years: Piping Plover (*Charadrius malodus*) (fed. end.), Northeastern Beach Tiger Beetle (*Cicindela dorsalis dorsalis*) (fed.thret.), Regal Frittilary Butterfly (*Speyeria idalia*) (State end.) (USFWS. *Northeast Coastal Areas Study: Significant Coastal Habitats, Site 28 (Rhode Island)*., 1991.

Status. The shallows of the entire Great Salt Pond have been designated as Type 1 waters (conservation areas), and construction there requires special permits from the state Coastal Resources Management Council.[48] Nonetheless, an application for a 200-foot dock from a private home in the mid-1990's was initially approved for construction.[49] In early 2000, a marina submitted an application for a 225 square foot expansion of its facilities into the pond.[50]

The inner ponds (Trims and Harbor Ponds) are thought to be a productive nursery for juvenile finfish.[51] This is a function of the inner ponds' low flushing rates, shallow depth, high summer temperatures, and nutrient richness **[see Figure 2.5]**. [52] In addition, the presence of eelgrass, *Zostera marina*, in Trim's Pond may affect productivity. A number of studies have shown that eelgrass beds support more juvenile fish and decapods than

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[48] Olsen, Stephen and George Seavey. *The State of Rhode Island: Coastal resources management program, as amended*. Providence, RI: University of Rhode Island and CRMC, 1990.

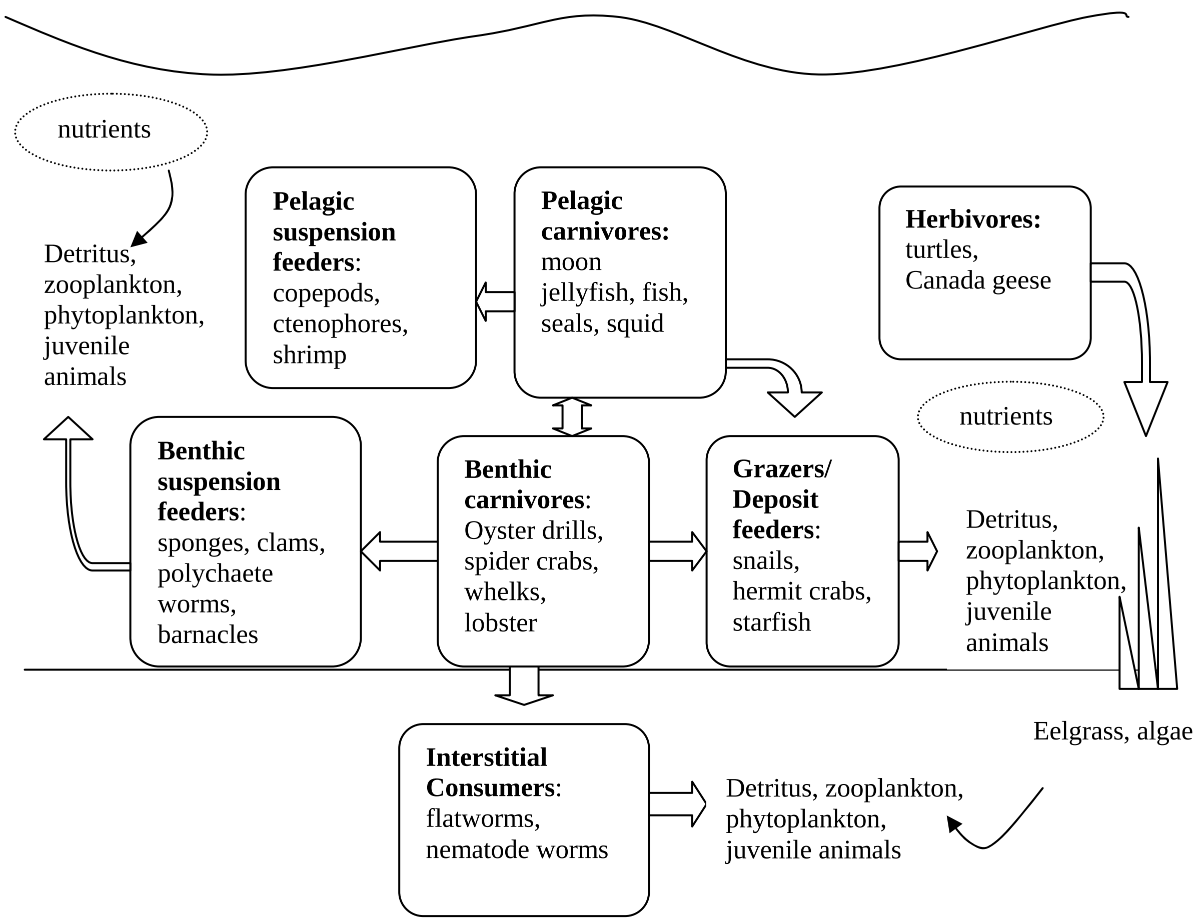
[49] After several public hearings, this Coastal Resources Management Council decision was reversed.

[50] Olsen, Stephen and George Seavey. *The State of Rhode Island: Coastal resources management program, as amended*. Providence, RI: University of Rhode Island and CRMC, 1990.

[51] Neuman, Melissa. "Distribution, Abundance, and Diversity of Shoreline Fishes in the Great Salt Pond, Block Island, Rhode Island." M.S. thesis, University of Rhode Island, 1993.

[52] Nutrients nourish phytoplankton, which in turn feed bacteria and zooplankton. It is these small animals which feed juvenile finfish, shellfish and squid. However, if nutrient concentrations nourish too much phytoplankton, oxygen levels can become depleted in the water column. If anoxic conditions are created, juvenile fish and others cannot survive.

Figure 2.5. A simplified view of trophic interactions in the Great Salt Pond.[53]
Animals listed are examples.



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[53] Barnes, R.S.K. *Coastal lagoons: The natural history of a neglected habitat*. Cambridge, England: Cambridge University Press, 1980.

areas without eelgrass.[54] So, a decline in eelgrass could spell reduced productivity of finfish in the Pond. While anecdotal evidence exist of past eelgrass (Z*ostera marina)* in the pond, eelgrass presently is only found in Trim's Pond, west of the Ocean Avenue Bridge.[55] Today, very little grows on the bottom of inner Harbor Pond, although anecdotal evidence suggests that there may have been eelgrass there as recently as 1997.

Introduction of nonnative species. The introduction of nonnative land and marine species can alter community species composition, as well as affect nutrient cycling and ecosystem energy flow among trophic levels.[56]

Block Island is a biodiversity hotspot,[57] hosting a number of rare species that have been extirpated from the mainland. Because the island lacks land mammals such as raccoons, squirrels and fox, ground-nesting birds can raise young unhindered by predators. The American Burying Beetle, a federally endangered species, is thought to have survived well on Block Island because it did not have to compete with land mammals for prey.[58] Introduction of land mammals today threatens these rare populations.

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[54] Dawes, Clinton J. *Marine Botany*. New York: John Wiley and Sons, 1981.

[55] (Personal observations, Summer 1999). Islanders have noted past presence of eelgrass beds by the Coast Guard Station, in Harbor Pond, as well as near Mosquito Beach.

[56] MacIsaac, Hugh J. "Potential abiotic and biotic impacts of zebra mussels on the inland waters of North America." *American Zoology* 36 (1996): 287-299.

[57] Biodiversity hotspots can be defined as geographic areas that are rich in species, have high levels of endemic species, have many rare or threatened species, or whose habitats are under threat Reid. "Biodiversity Hotspots." *Tree* 13, no. 7 (1998): 275-279..

[58] There was also an abundance of ring-necked pheasant carcasses, their preferred food. Raithel, Christopher. *American Burying Beetle, Recovery Plan*. West Kingston, Rhode Island: New England Field Office, U.S. Fish and Wildlife Service, 1991.

Marine invasions tend to arrive from other continents, brought over on boat bottoms, as ship ballast or through commercial fish trading.[59] Although Block Island does not participate in international trade, recreational vessels commonly visit from the Caribbean and Europe. The most likely source of local invasions are likely to be from vessels in New England waters that bring creatures that have invaded there first.

The exotic algal species, *Codium fragile,* or Dead Man's Fingers, exists in large beds in many areas of the Great Salt Pond.[60] This species was only introduced to the United States in the 1950's,[61] so it has been in the pond less than 50 years.

As more land is developed, more boats visit, and more people travel to and from the island, species introductions are likely to increase both in the pond and on land. Across New England, marine bioinvasions tripled in the 1990's from 1980's invasions. Present assessments conservatively estimate that New England is experiencing approximately one new marine invasion every 20 months.[62]

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[59] Carleton, J.T. "A steady stream of invading marine organisms creates ecological roulette in New England waters." *Estuarine Research Federation Newsletter* 19, no. 4 (1993): 11.

[60] Unlike eelgrass, which is a favorite home of bay scallops (*Argopecten irradians*), *Codium* attaches itself to scallops, preventing them from swimming away from predators, their best defense.

[61] Massie, Frederick D., ed. *The Uncommon guide to common life of Narragansett Bay*: Save the Bay, 1998.

[62] Carleton, J.T. "Marine Bioinvasions of the Northwest Atlantic Ocean: Bay of Fundy to Long Island Sound." *Monograph in preparation* (2000).

Overfishing. Overfishing in the Great Salt Pond could lead to a replacement of desirable species by other, less appealing ones. In addition, overfishing will affect recruitment of young fish, and may influence predator-prey relationships in the pond. Intense fishing of American oysters (*Crassotrea virginica*) early in the twentieth century may be one of the reasons for their relative absence today.[63] Clams were in such abundance in 1896 that a map was drawn up to divide the shallows into acre-size plots for harvesting.[64] [65]

Surveys of quahogs (*Mercenaria mercenaria*) have been periodically performed in deeper parts of the pond.[66] The most recent survey, in 1992, shows a decrease in the overall shellfish density from the 1978 and 1983 surveys.[67] In addition, the 1992 survey found more smaller quahogs (littlenecks) and fewer large quahogs (chowders) than the previous surveys **[See Figure 2.6]**. This relative increase in small quahogs coupled with an overall decrease in shellfish abundance could be the result of overfishing, but may also be the result of several shellfish relocation efforts undertaken by the town.[68]

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[63] Breaching the Pond is also likely to have played a part. In other Rhode Island salt ponds, breachways have lead to "the demise of the oysters and other formerly abundant species such as white perch and alewives" (Olsen and Lee, 1982).

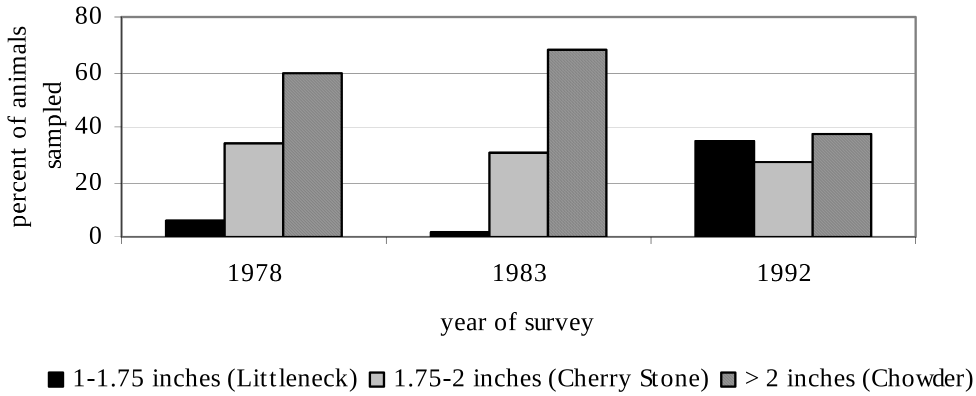
[64] Also, a commercial shellfishing plant, the American Oyster Company, made profitable business in the Great Salt Pond until the 1930's, often catching 500 bushels/acre. Rozenzweig, Laura T., and Dennis B. Wolkoff. *A Plan for Long Term Ecosystem Conservation on Block Island*. Providence, RI: The Nature Conservancy, 1991.

[65] Chase, Chas F. "Map of Great Pond Harbor, Block Island, RI showing Shell Fish Flats",1896.

[66] I have records of surveys in 1961, 1973, 1978, 1983 and 1992.

[67] The 1992 survey had a significantly lower catch per dredge tow (.67 bushels per tow) than earlier studies in 1978 (2.5 bushels per tow) and 1983 (2.2 bushels per tow). Ganz, Arthur R. *A shellfish dredge survey of the Great Salt Pond, Block Island, RI*. Wakefield, RI: Rhode Island Division of Fish and Wildlife, Coastal Fisheries Laboratory, 1978, 1983, 1992.

Figure 2.6. Size-frequency of quahogs (Mercenaria mercenaria) dredged in the Great Salt Pond. Surveys were performed in 1978, 1983, and 1992. Sources: (Ganz, 1978;1983;1992)



Fishing in the pond is not closely monitored. Logbooks kept by two fish and tackle shops record exceptional catches of fish **[Table 2.2].** These data are inconclusive, as they show little pattern in fish catch or fish size over time (fish size not shown due to variability in fisherman's estimates). Anecdotal evidence points to a decline in the winter flounder fishery in recent years.

Table 2.3 Records of fish catch at local fish and tackle shops
Sources: "Go Fish" logbooks at Twin Maples and Oceans and Ponds, Block Island.

Year	Records	Number of fish caught	Average fish catch
1993	16	19	1.2
1996	21	64	3.0
1997	11	35	3.2
1998	13	24	1.8
1999	6	14	2.3

[68] Also note that during this period, summer shellfishing was prohibited.

Since 1996, shellfish license sales have hovered close to 1000 per year, although yearly totals do not appear to be calculated.[69] The Shellfish Warden, however, reports that the number of recreational shellfishermen seems to have been increasing steadily since 1996.[70] Present effort is concentrated in a few shallow sand flats, and has potential for "fishing out" these areas. Commercial shellfishing effort has declined to negligible amounts in recent years. A handful of commercial lobstermen are still active on Block Island, and a few set traps in the Great Salt Pond. However, in recent years, lobstermen seem to catch more spider crabs (*Libinia sp.*) than lobster. While spider crabs can have natural, locally-occurring booms in population, such a boom in the Great Salt Pond is troubling, and may warrant further study.

Erosion/Sedimentation

Erosion and sedimentation are geologic processes that constantly change the shape of the Great Salt Pond. Humans influence the rates of these processes by land use practices. A basic rule of thumb for erosion is "the more intensive the [land] use, the greater the erosion."[71] In the Great Salt Pond, eroded material will run off in surface waters to increase the turbidity of pond water and decrease the clarity. Many organisms are sensitive to the amount of sediment in the water column, particularly benthic plants, such as eelgrass, which require light and cannot move to adjust their position. Areas under

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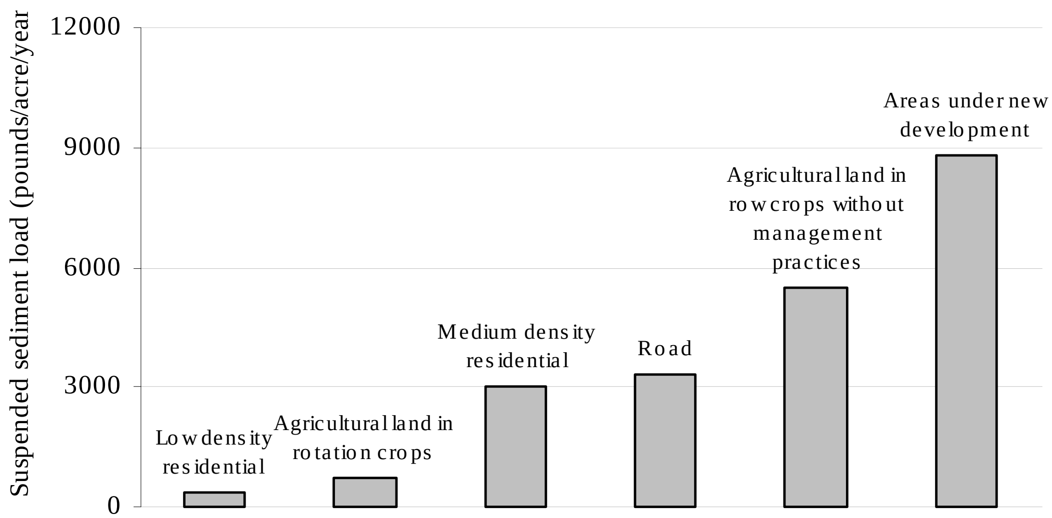
[69] Baker, Joan, New Shoreham Harbors Department. Correspondence with Block Island shellfish Commission on Shellfish licenses, 1996-1999.

[70] Hopf, John, Block Island Shellfish Warden. Correspondence between Shellfish Warden and Harbormaster, 1996-1999.

[71] Terrell, Charles R. and Patricia Perfetti. *Water quality indicators guide: Surface Waters*. Washington, DC: USDA, Soil Conservation Service, 1989.

new development are very prone to sediment loss, as are dirt roads **[Figure 2.7].**[72] Most human-induced erosion in the Great Salt Pond seems to come from dirt roads, but also includes new development.

Figure 2.7. Sediment loss as it relates to land use practice. Source: Terrell, 1989



[72] Island soils are derived from glacial morainal till. High permeability associated with these soils accounts for the lack of surface streams on the island, and may result in less erosion in other areas.

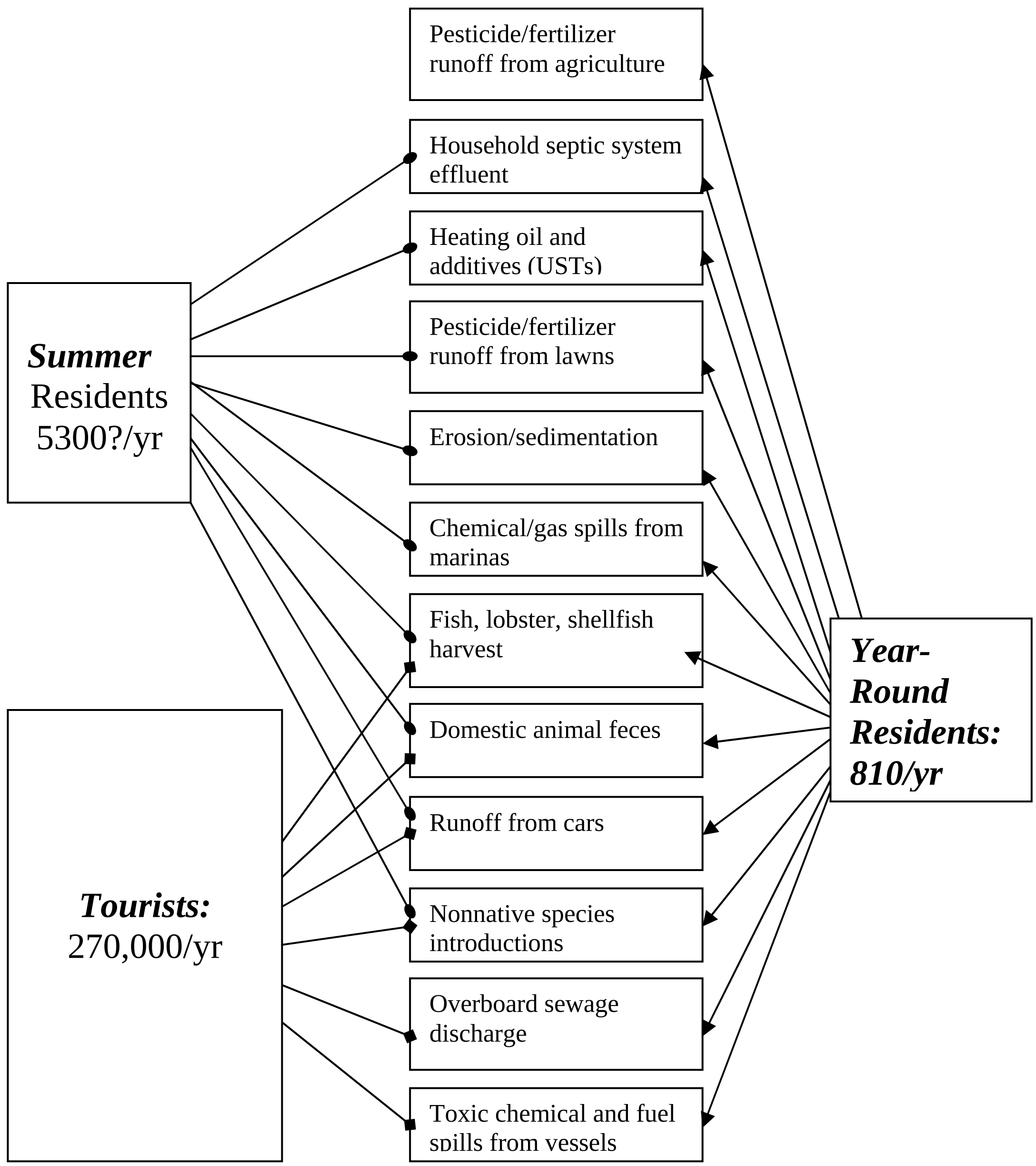
PART 3. WATERSHED ASSESSMENT: HUMAN INFLUENCE

3.1 Block Island populations

Today, the Great Salt Pond is a harbor and a fishery, as well as a place to swim, kayak, windsurf and play. The watershed encompasses two gas stations, several restaurants and hotels, a cemetery, pastureland, and more than 300 private homes. Many human activities and land uses can produce significant changes in the pond and its watershed, both to the natural system and to factors that affect human health and welfare. Because Block Island attracts a large summer population, human impacts surge in summer months. In addition, different populations—year-round residents, summer residents, and tourists[73] —make different demands on the Great Salt Pond **[Figure 3.1]**. The overall intensity of human impact varies with the size of these populations.

Winter populations on Block Island are simple--the only people on the island are residents. However, summer populations are much more complicated—they consist of year-round residents, summer residents that own property, renters, daytrippers, hotel occupants, and boaters. To calculate the typical island summer population, I adjusted peak visitation estimates from the New Shoreham Comprehensive Plan based on calculations I made of average stay on the island, occupancy rates, and total summer visitation [**Figure 3.2, Appendix B for calculations**]. I calculate there are typically between 7,000 to 11,000 people on Block Island in the summer season. Of these, one half are summer or year-round residents, and one half are tourists.

Figure 3.1. Sources of human impacts on the Great Salt Pond and its watershed. If the "Tourists" box were to scale, it would be 50 times larger than the "Summer Residents" box, and 300 times larger than the "Year-Round Residents" box.



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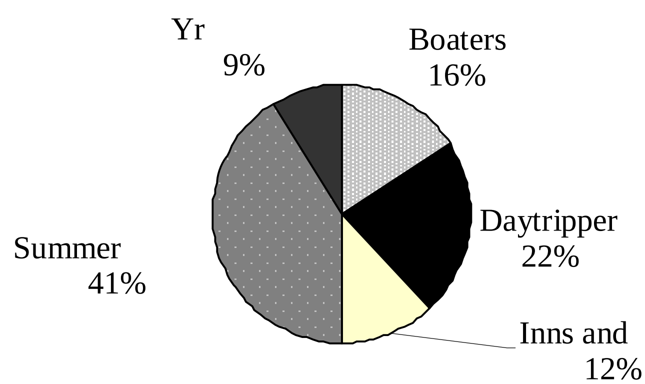
[73] I define "summer residents" as landowners that only occupy their property in the summer. I define "tourists" as non-landowners, i.e. renters, boaters, daytrippers, and hotel occupants.

Figure 3.2 Typical Block Island population on a summer day.



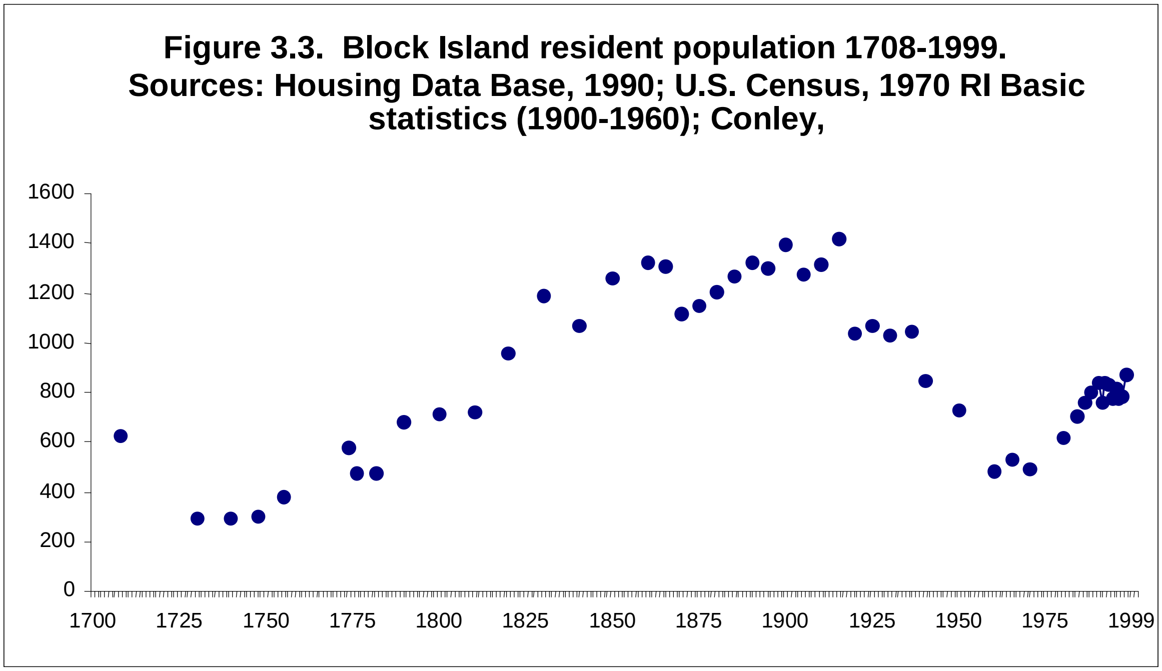
Trends in Year-round Resident population. To assess island resident population change over time, I rely mainly on state and federal census data **[see Figure 3.3]** [74] The pattern appears cyclical: after peaking at 1,414 in 1915, island population dwindled to 486 by 1960. A tourism study in 1964 notes the "surprising" amount of available land on the island, and laments that "many of the permanent residents are retired…" [75] During the

1970s and 1980's, however, winter population doubled. In the 1990's, population has remained relatively stable at about 800, still much lower than the 1915 peak. Year-round resident populations have relatively large effects on watershed resources due to their constant presence there. If resident populations remain stable, resident population

[74] Resident population on the island has been recorded in U.S. Census data once every decade since 1790. Rhode Island state census data have also been collected by decade, offset by five years from the U.S. Census data, since 1865. In addition, for the past few decades, a yearly on-island head count has been conducted on Groundhog Day. These data give a good sense for winter occupancy of houses on Block Island, as well as for the pattern of year-round resident growth over time.

[75] U.S. Department of Commerce, Technical Assistance Project. *Survey of tourism in the State of Rhode Island, including a special report on Block Island*. New York, NY, 1965.

resource impacts are likely to remain stable as well. Future increases in winter populations would intensify pollutant loadings associated with development, particularly household septic system effluent.

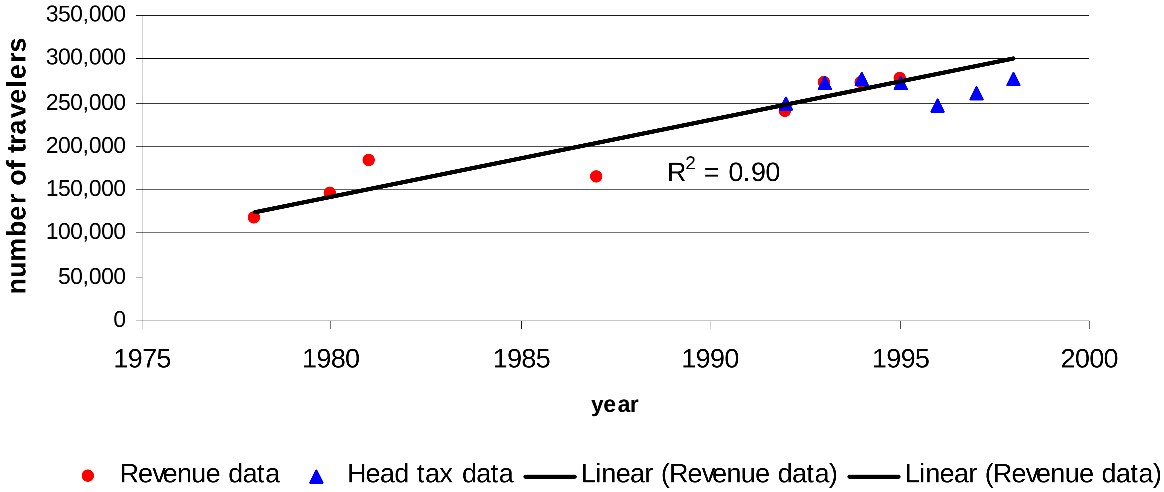


Trends in Tourist populations. Tourists make up about 60% of island population on a typical summer day, but are absent from October to May. This flux of people, and therefore resource use, has different effects on the Great Salt Pond than the winter population. The biggest risk to the watershed from increased tourism is likely to be the potential for overboard sewage discharge from vessels in the Great Salt Pond,[76] but also includes increased runoff from cars and bacterial runoff from domestic animals.

[76] Another effect of vessels is the introduction of toxic chemicals via bilge pumping, graywater release, and runoff from decks and engines. Vessels may also be responsible for the introduction of nonnative species to the pond.

To quantify change in Block Island tourism over time, I looked at ferry ticket sales, because ferries are the primary mode of transport to the island.[77] My figures show that ferry ridership has increased by 138 percent since 1978, and has been increasing by close to 9000 people per year over that period **[Figure 3.4, Appendix C for calculations]**.[78]

Figure 3.4. Total number of people travelling by ferry to Block Island per year.



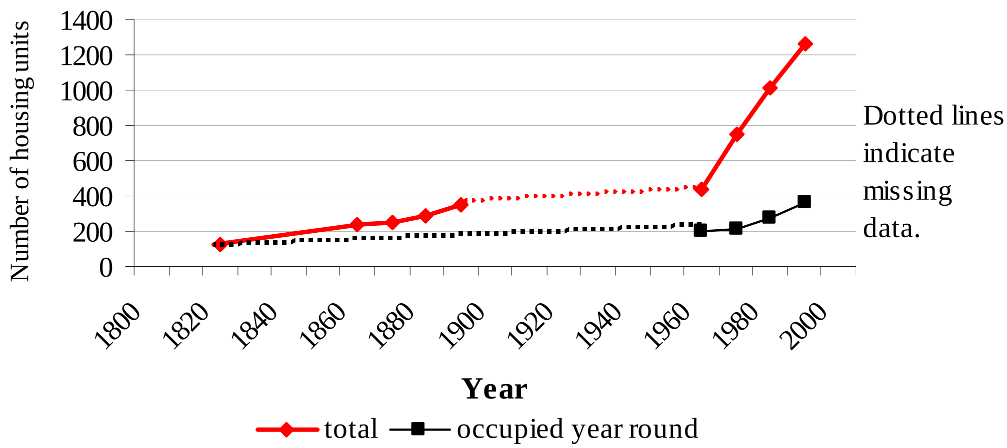
Trends in Summer Resident population. According to the Special Area Management Plan for Rhode Island salt ponds, "the major water pollution problems in the [Rhode Island salt pond] region are directly related to the density and distribution of development

[77] Interstate Navigation, the company that presently carries 90 percent of ferry travelers to the island, does not release sales information. I was able to calculate ridership by two methods: 1) Periodic reports by Interstate Navigation to the Rhode Island Public Utilities Commission expose their raw income from ticket sales; 2) The Town of New Shoreham has collected a $.50 tax/head on arriving ferry travelers since 1992.

[78] A useful tool for calculating resource impacts would be to know the total number of rooms in the watershed, as well as the percent these rooms that fill to capacity in the summer season (occupancy rate). I could not locate these figures. To estimate the occupancy rate of hotels for the 1999 peak season (June, July, August), I interviewed managers at 4 hotels (responsible for 8 of island's listed 30 hotels). These hotels had an 86 % occupancy rate for the 1999 season

within the watersheds of the salt ponds." [79] When I compare the total number of housing units on Block Island with the number of units occupied year round[80] **[Figure 3.5],** I see that : 1) There has been a 300 percent increase in the overall number of housing units on Block Island since 1960; 2) 80 percent of units built since 1960 are not occupied year-round, i.e. they are for seasonal use. This building boom in vacation homes indicates a significant increase in the number of summer-only residents on Block Island. Annual building permit approvals[81] are not steadily increasing **[Figure 3.6].** From 1965-1998, building permit approvals averaged 24 per year. During the 1990's (1990-1998), building permits averaged 21 per year. This decrease may be the result of increased island building regulations.

Figure 3.5. Number of housing units on Block Island. Compares total number of units to units occupied year-round. Sources: 1990 Census data, 1970, 1987, 79-80 Rhode Island Basic Economic Statistics.



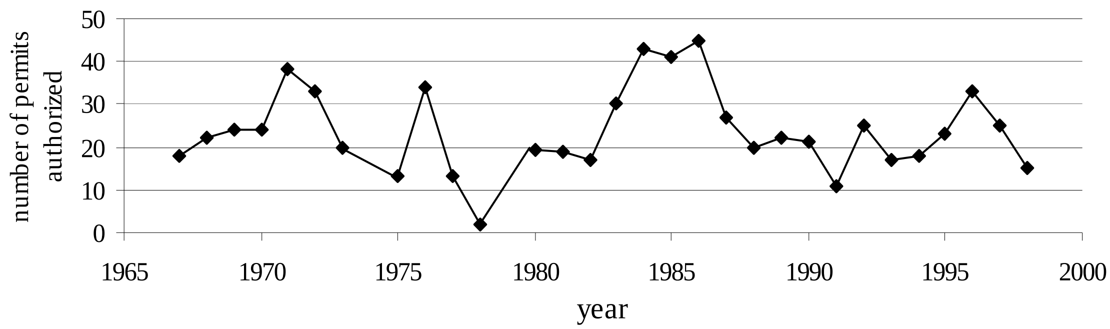
[79] Olsen, Stephen and Virginia Lee. *Rhode Island's Salt Pond Region: A Special Area Management Plan*. Kingston, RI: University of Rhode Island, 1984.

[80] The number of housing units on the island have been recorded by U.S. Census data since 1790, but are generally reported at the county level and so are not useful for collecting town data. The 1990 Census is a notable exception. The State of Rhode Island also periodically publishes a report on housing statistics, and these sometimes provide town housing statistics data. I found that older data were easier to access at the State level.

[81] Construction must begin within six months of permit approval (Marc Tillson, 2000).

To look at building patterns within the Great Salt Pond watershed, I looked at aerial photography from 1939 and 1995, and digitized it using GIS software (ArcView/Info). These images show that the number of buildings in the watershed increased by 62% from 229 in 1939 to 371 in 1995 **[Figure 3.7].** The distribution of the buildings is also very different. While buildings were concentrated in the south watershed in 1939, the buildings are spread widely throughout the watershed in 1995.[82]

Figure 3.6. Number of building permits authorized by New Shoreham Building Inspector (1965-1998).



Sources: RI Basic Economics Statistics, NS building Dept, Housing Data Base

Today, 87% of the watershed is zoned for residential use, and 8 % for commercial **[Figure 3.8]**.[83]

Increasing summer residency in the watershed will result in intensified use of septic and sewer systems, lawn fertilizers and pesticides, as well as increased use of electricity and fresh water.

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[82] This pattern is not surprising, as most new buildings are summer homes that can be accessed by car.

[83] A buildout analysis that does not take into account limits to development from wetlands or coastal regulations would be useful.

3.2 Key Management Issues

I ranked the issues by toxicity of impacts, scale, trend, and persistence in the watershed. **[Table 3.1]** Details are below.

Household septic effluent. About 90 percent of houses in the watershed use individual sewage disposal systems (ISDS) for sewage disposal.[84] These ISDS's leach most of the fluid that passes through them into the surrounding soil. If the soil is reasonably permeable, most effluent will eventually return to groundwater. But whether a septic system functions correctly will be determined by 1) surrounding soil type;[85] 2) distance to surface water; 3) the age and type of system, and 4) its maintenance schedule. Effluent released from a traditional septic system[86] will contain high levels of bacteria, nutrients, and often contains toxic materials, including zinc, copper, nickel, lead, cadmium, and arsenic.

Septic effluent nutrients (mainly nitrogen and phosphorus) have been shown to persist in septic effluent despite physical filtering, which, under ideal conditions, usually removes

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[84] Joubert, Lorraine. *Water Quality Impact of Changing Land Use on Block Island, Rhode Island: Summary of MANAGE model input values and assumptions*. Kingston, RI: University of Rhode Island, 1996.

[85] Especially the depth of the seasonal high water table (SHWT) and the permeability of the soil.

[86] A traditional septic system consists of "a buried tank where waterborne wastes are collected, and scum, grease and settleable solids are removed from the liquid by gravity separation; and a subsurface drain system where clarified effluent percolates into the soil" (Canter, 1986). In a traditional septic system, septic effluent is only treated by anaerobic decomposition that occurs in the tank before seepage, and by gravitational settling of solids or evaporation (Canter, 11986; Loomis, 1994). Although bacteria may be removed as the effluent passes through soil outside the tank, the amount removed will depend on the distance traveled between the tank and either groundwater or the Great Salt Pond itself.

only 10-20 percent of nitrogen loaded.[87] Nutrients filter slowly through soils, and remain in the system long after release. Bacteria from septic effluent will pose the greatest threat to the Great Salt Pond when a tank overflows and raw effluent runs off to surface water. Septic effluent can also carry toxic pollutants that are added to the septic system from sinks or toilets. Chemicals such as bleach can not only kill the anaerobic bacteria that break down solids in the septic tank, but can also persist in groundwater.

Status. Three hundred of the nine hundred individual sewage disposal system's on Block Island fall in the Great Salt Pond watershed **[Figure 3.9]** [88]--one septic system per 5.6 acres. By assuming a constant usage of 50 gallons/person/day[89] and an occupancy of 2.4/household,[90] I calculate that the approximate loading of septic effluent to the Great Salt Pond watershed is 6.7– 8.8 Mgals (millions of gallons) per year **[see Appendix D for assumptions and calculations].** This represents approximately 15% of annual water use on Block Island, and corresponds to figures calculated by Veeger et al (1996).[91]

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[87] Shoreham, Town of New. *Amendments to the Zoning Ordinance of the Town of New Shoreham: Article 5, Section 506 et al.* New Shoreham, RI, 1998.

[88] Baker, Carol and others. Block Island GIS. Database, 2000.

[89] U.S. Environmental Protection Agency, Office of Water Program Operations. *Design Manual: Onsite wastewater treatment and disposal systems*. Washington, DC, 1980.

[90] This is the average occupancy on Block Island reported in the 1990 U.S. Census.

[91] Veeger et al. state that 37-38 Mgals per year are returned to groundwater through septic system leaching across the whole island. This would mean 10.6 Mgals from the GSP watershed (28 percent of land). Note: presently 60 percent of fresh water used on Block Island is treated by the Block Island Wastewater Treatment Facility and released to the ocean. The addition of more sewer lines in the Great Salt Pond watershed could result in a significant loss of groundwater recharge to the aquifer.

Of this 6.7-8.8 Mgals of septic effluent, most of it will return to groundwater, and some of this ground water will find its way to the Great Salt Pond. If the septic system[92] is sited within 150 feet of the Great Salt Pond, effluent has close to 100 percent chance of reaching the pond by leaching through the soil.[93]

Even if a septic system is greater than 150 feet away, it may still pollute the pond via surface flow if it is surrounded by poor soils. Thirty-two percent of Great Salt Pond watershed soils have seasonal high water tables (SHWT) less than 3.5 feet, the minimum depth considered to be adequate for effluent absorption by soils **[See Figure 3.10].** [94] MANAGE software (Method for Assessment, Nitrogen loading and Geographic Evaluation of watersheds) developed by URI, assumes that septic systems located on such poor soils will have a failure rate of 70 percent. MANAGE also assumes that when such systems fall in areas of high intensity land use, their risk of failure is 100 percent. [95] In my assessment, 415 acres (218 parcels) in the Great Salt Pond watershed have a high potential for septic system failure due to poor soils combined with high intensity land use. **[Appendix E** a lists these parcels and MANAGE assumptions**].**

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[92] I assume all septic systems are traditional septic systems. Innovative and alternative systems (A&I) have much lower pollution ratings, but few are installed in Rhode Island.

[93] The Rhode Island Department of Environmental Management requires 150 foot minimum distance between a septic system and a shoreline feature in South Shore Critical Resource Areas. Analysis of septic system failure at the University of Rhode Island agree that systems closer than 150 feet of surface water are likely to fail (MANAGE, 2000).

[94] MANAGE analysis (see below) assumes that soils with SHWTs less than 3.5 feet are unlikely to adequately absorb septic effluent, which will likely run off as surface water. Method for Assessment, Nitrogen loading and Geographic Evaluation of watersheds (MANAGE) model, URI Cooperative Extension. 2000.

[95] Joubert, Lorraine. *Water Quality Impact of Changing Land Use on Block Island, Rhode Island: Summary of MANAGE model input values and assumptions*. Kingston, RI: University of Rhode Island, 1996.

Septic systems may also fail if they are not pumped regularly (about every 3 years[96]). In addition, older septic systems may fail—for example, steel tanks tend to erode. Overall, septic effluent loading to the pond watershed is likely to be increasing over time, as more houses are built, and more septic systems are installed.[97] Present monitoring of bacteria and nutrients levels in the pond does not enable tracking of septic system contributions. My analysis tells us that, even under present land use, there is a likelihood of septic system failure in the Great Salt Pond watershed. As buildout continues, we can expect the problem to intensify.

Marine overboard sewage discharge. The Great Salt Pond is one of the busiest summer recreational harbors in the northeast. In the summers of the 1990s, the pond averaged 580 liveaboard boats/day, with peak July's averaging as high as 955 (1993) [Figure 3.11].[98] In 1999, weekend boat counts averaged 65 percent higher than mid-week counts,[99] which is typical. Boaters living on their boats produce sewage waste, which historically has been dumped into the Great Salt Pond.

But since 1993, the Great Salt Pond has been designated as a No Discharge Area (NDA), which means that the discharge of treated and untreated boat sewage is prohibited.

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[96] Loomis, George. *Guide to On-Site Sewage Disposal Systems Design: Site Suitability and Permit Review*. Kingston, RI: URI, 1994.

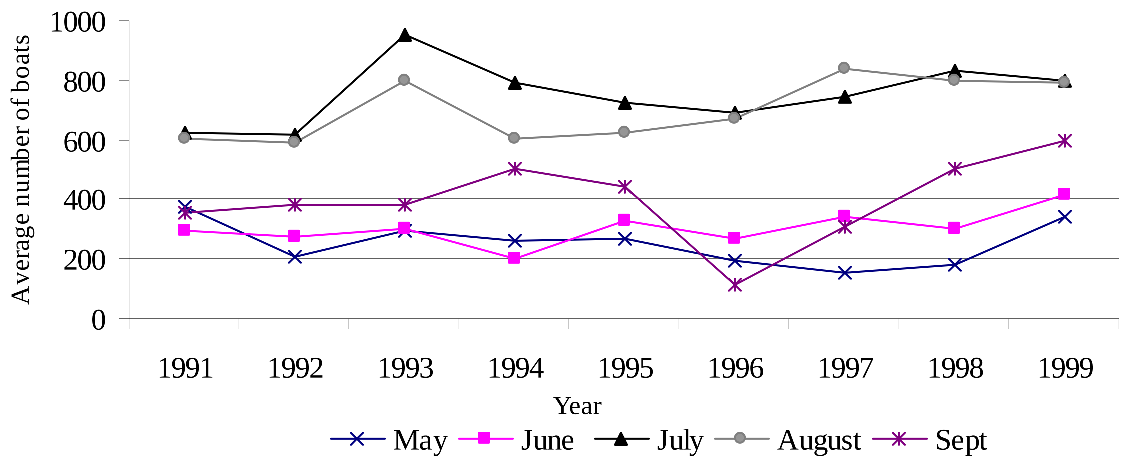
[97] This increase could be mitigated by the installation of "innovative and alternative" septic systems, as recommended by the Amendments to the Zoning Ordinance of the Town of New Shoreham: Article 5, Section 506 et al., 1998.

[98] The number of boats visiting the great Salt Pond has been counted two times/week by the Harbors department since 1992.

[99] In 1999, weekend the weekend average was 862 boats, midweek averaged 522 boats.

While the NDA rules are straightforward, questions remain about the compliance rate of the boater population to these rules. Sewage that is illegally dumped into the pond is known as marine overboard discharge.

Figure 3.11 Average number of boats in the Great Salt Pond.
Calculated from Harbors Dept bi-weekly boat counts.



Although recreational boats are not required to have a Marine Sanitation Device (MSD), all boaters that use their toilets must have a holding tank, or a "porta-potty" in a NDA**.**

Unlike sewage in a septic tank, overboard sewage discharge does not have solids removed by gravity and anaerobic decomposition before release. Raw sewage contributes all of its bacteria, pathogens and nutrients directly into the pond. However, vessel overboard discharges are likely to be flushed from the pond within a relatively short time—complete flushing of the pond has been found to take more than four days,[100] but may take as much as two weeks.

[100] Department of Health and Human Services, Northeast Technical Services Unit. *Hydrographic Study of Great Salt Pond, Block Island, RI: October 2-6, 1986*. Providence, RI, 1986.

Status. Anecdotal evidence tells us that in the 1980s, people found sludge washed up on the shores of the pond, as well as toilet paper and the like. These days, no such sludge patterns are evident. The trend in summer boat visitation is not clear from ten years of boat counts, but is revealed anecdotally. Certainly, the amount of sewage pumped each season by Harbors department workers is steadily increasing, although the overall number of boats pumped is still small compared with the overall number of boats visiting. **[see Figure 3.12]**

Eight percent of boats registered for moorings in the Great Salt Pond in 1999 had neither a holding tank nor a porta-potty.[101] If this is typical of boats that visit the harbor, then 40-50 boats/day on average in the summer do not have appropriate gear for living in a No Discharge Area. In addition to boats without appropriate MSDs, a number of vessels do not correctly use their Y-valves.[102] The Harbors department estimate that there are a large numbers of non-compliant Y-valve users--as many as 25% of liveaboards in the Pond at any given time.[103] With these estimates,[104] 180 to 200 boats/day may be discharging overboard sewage into the pond, despite the NDA

[101] Of the 290 boats registered for moorings to the Town of New Shoreham in 1999, 132 were larger than 25.*'* Of these 132 "liveaboards," 115 had either a Type III MSD or a porta-pottie. This leaves 17 boats (8%) which are of liveaboard size but which do not have legal right to be lived on in the Great Salt Pond.

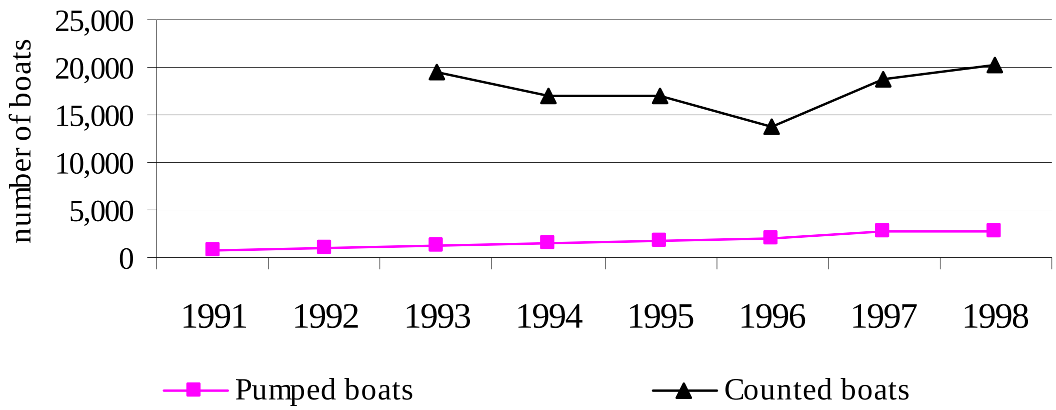
[102] In holding tank systems, a "Y-valve" controls the discharge of waste into the holding tank, which should be secured and closed in a NDA.

[103] (Harbors Department, personal communication).

[104] Assumes average of 570 boats at 25% non-compliance due to y-valves, 8% due to no MSD.

designation. This could result in 10,000 to 17,000 pounds per season being released into the pond.[105]

Figure 3.12. Total annual number of boats pumped compared with the total number of boats visiting. (The boat count total is likely to be low, as is it a raw total of boats counted by Harbors Department each year.)



Underground storage tanks. In 1990, there were 194 underground storage tanks (USTs) reported in the Town of New Shoreham.[106] Veeger et al. note that “leakage from such storage tanks can cause serious and widespread contamination” [1996]. Nationwide, frequency of UST leakage is estimated at 6 to 25 percent.[107] That would mean that Block Island could have 12 to 50 leaking tanks—or more. These tanks are expensive to clean up, and release heavy oil residue, which can remain in the soil for years. The Block Island Power Company, whose facilities are close to Harbor Pond, have

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[105] Calculation: (180-200 boats)(2-3 people/boat)(.31 lbs/p/day)(92 days) = 10,267 to 17,112 lbs/summer.

[106] Veeger, Anne I. et al. *Hydrogeology and Water Resources of Block Island, Rhode Island*. Providence, RI: U.S. Geological Survey, 1996, Report 94-4096.

[107] Sementelli, Arthur and Robert Simons. "Regulation of Leaking Underground Storage Tanks: Policy enforcement and policy alternatives." *Economic Development Quarterly* 11, no. 3 (1997): 236-251.

already been forced to remediate leaked diesel fuel from a leaky underground storage tank.

Animals: Dogs, horses, cows, birds, seals, deer. ***Pet dogs, horses and cows as well as wild birds, seals and deer that live in the Great Salt Pond watershed all contribute some amount of bacteria and nutrients via fecal matter either directly or via runoff to the pond. Recent studies have shown that contributions to fecal coliform concentrations from nonhuman warm-blooded animals is often underestimated. However, fecal coliform from animals usually contains many fewer pathogens that threaten human health than human waste. Animals do contribute to fecal coliform concentrations in the pond.***

Dogs. No one knows how many dogs summer on Block Island, as most will not be registered there, and many come and go on boats. The Harbors Department estimates that 25% of incoming liveaboard carry dogs.[108] By assuming that 10-25% of boats and 10% of houses in the watershed have dogs,[109] I calculate that dogs produce 7-15,000 pounds in the watershed per year. Because dogs are often walked around the perimeter of the pond, their fecal matter is likely to contribute directly to the pond's bacteria and nutrient concentrations. **[Figure 3.13; Appendix E for calculations]**

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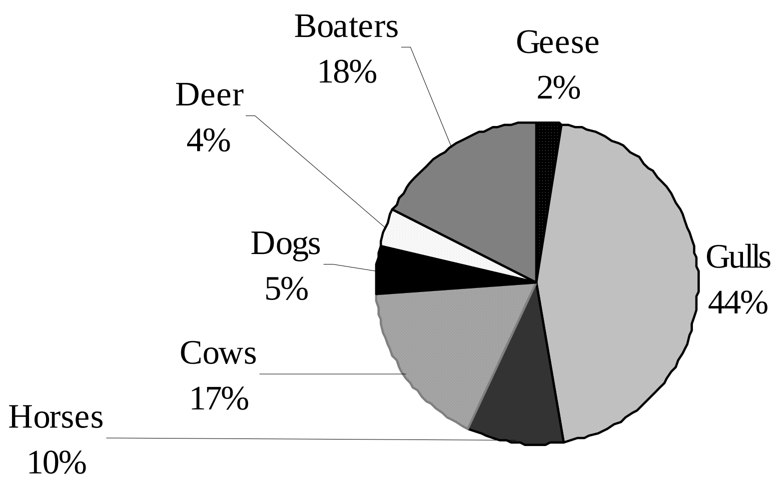
[108] Constantine, Larry, Town of New Shoreham Harbormaster. Personal communication, 2000.

[109] This results in 98-195 dogs visiting per summer. An average dog produces 413 g (.8 lbs) of solid waste/day (Calci, 1998). I assume dogs are present only in the summer season.

Figure 3.13. Summer raw fecal matter inputs to the Great Salt Pond and its watershed by various actors.



Cows and horses. These animals are sparse on the island and in the watershed (approximately 100 individuals on island, approximately 6-12 in the watershed). Nonetheless, each animal produces more than 100 times the amount of fecal matter produced by a single person in one day.[110] I calculate that cows contribute 103,000 to 206,000 lbs of fecal matter annually to the watershed.

Birds. Large Herring and Black-Backed gull colonies are centered in the Great Salt Pond watershed, and so nutrient and fecal coliform contributions by these animals may be significant. From the Nature Conservancy count of 670 gull nests in 1999, I calculate that fecal matter contributed annually by gulls is 136,000 to 273,000 lbs/year.[111] Because the gulls live in the north part of the pond, however, their fecal matter may be deposited

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[110] Calci, Kevin R. et al. "Occurrence of male-specific bacteriophage in feral and domestic animal wastes, human feces, and human-associated wastewaters." *Applied and Environmental Microbiology* 64, no. 12 (1998): 5027-5029.

closer to the breachway, and hence be flushed from the pond rather quickly. Small colonies of Double-crested Cormorants also flock in the north end of the Great Salt Pond. Their contribution to fecal coliform concentrations is likely to be smaller than that of gulls, but population size is unknown.

Canada geese spend some time in the Great Salt Pond, usually near the eelgrass bed in Trim's Pond, a food source. These birds are not counted annually, but numbers are estimated to be less than one hundred. Assuming these birds stay for six months on Block Island, they would contribute 4-18,000 lbs fecal matter/year to the watershed. Because these birds spend their time in the extreme south end of the pond, in an area that is not well-flushed, their fecal matter may well contribute to the high fecal coliform concentrations in that area.

Deer. The Rhode Island Department of Environmental Management (RIDEM) estimated that there were 250 deer on Block Island at the beginning of the 1998-1999 hunting season.[112] If there are between 90-250 deer on the island,[113] then deer contribute roughly 18-51,000 lbs of fecal matter to the watershed per year. Some of this fecal matter is likely to be deposited near the pond, and would contribute directly to the bacteria levels in the pond.

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[111] This figure assumes that all 668 pairs of gulls counted in 1999 contribute 75% of their fecal matter to the Great Salt Pond watershed, each nest has 1.5-2 birds, each bird contributes 500 g/day, and birds remain in the watershed for 6 months.

[112] Woronoff, Kristen. "Deer Population Healthy, herd size questionable." *Block Island Beacon*, March 23, 2000. A recent estimate by George Mellor states that the deer population may be as high a 600.

Although cows and horses are large contributors to fecal matter production, their already low and declining numbers and distance from shore and surface water deem them to be unlikely worry sources in the future. Birds definitely have potential for affecting pond fecal coliform concentrations. The number of dogs walked in the watershed is unknown, but all anecdotal evidence points to a sharp increase in dog numbers on the island.

Runoff from agriculture and lawns. Lawn fertilization can contribute significantly to ground and surface water nitrogen levels. [114] A URI study showed that heavily fertilized lawn turf can release as much as twelve times more nitrogen to groundwater than a less intensively fertilized area.[115]

Although lawn acreage is increasing on Block Island with increased development of residential land, lawn runoff may not be as much of a problem there as on the mainland. Islanders do not apply fertilizers in the same quantities as on the mainland, according to locals. Nonetheless, lawn runoff of nitrogen may be significant. Using assumptions of the MANAGE model,[116] I calculate that lawn fertilization could contribute as much as 63

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[113] During the 1999 season, 163 deer were shot. Figure assumes that all deer spend 28 percent of their time in the watershed (they spend as much time in the watershed as anywhere else).

[114] Heckman, Joseph R. et al. *How to protect water quality and have a beautiful lawn*. Newark, NJ: Rutgers University, 1999.

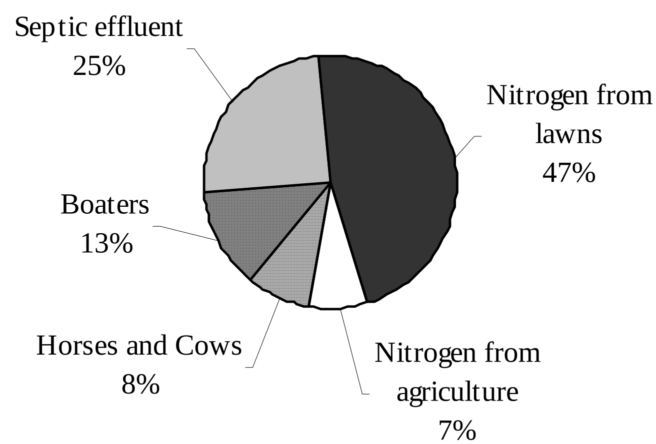
[115] Wright, William R. and Aram Calhoun. *Homeowner's guide to managing your lawn to protect water quality*. Kingston, RI: University of Rhode Island, 1988.

[116] MANAGE assumes that 25 percent of residents fertilize their homes, that (on average) 45 percent of residential land is used as lawn, and that nitrogen application is 4 lbs/1000 square feet/year.

percent of the nitrogen loading to the pond [117] [**Figure 3.15; Appendix H for calculations**].

Only one, six-acre parcel used for cropland falls within the Great Salt Pond watershed. It is unlikely, then, that agriculture presents a large risk to water quality of the Great Salt Pond. However, fertilizer use on lawns and for agriculture is growing 5-8 percent every year nationally.

Figure 3.14. Estimated annual nitrogen loading contributions to the Great Salt Pond Watershed.

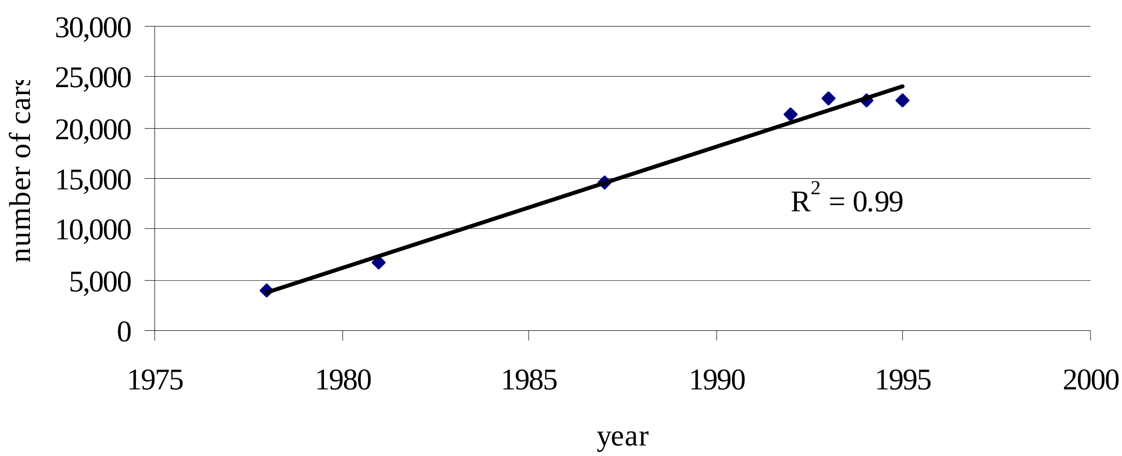


Runoff from cars. Cars are best known as air polluters. But cars also leak and burn a host of pollutants that can runoff to surface waters. This runoff comes from road-surface degradation, vehicle exhaust emissions, tire degradation, de-icing compounds as well as

[117] This is an overestimation, because I have not found figures for nitrogen loads from birds, dogs and deer.

atmospheric deposition/precipitation.[118] Road runoff from highways has been found to contain high levels of particulates, oil/hydrocarbons, PCBs (polychlorinated biphenols), as well as bromide and chloride. Moderate concentrations of nitrogen, phosphorus, iron, lead, mercury, nickel and zinc are also found.[119] Recently, more and more dirt roads have been paved on Block Island. This practice will decrease sediment loading from these areas considerably. In addition to causing headaches for drivers who get caught in traffic on their way to the post office, this situation is becoming increasingly hazardous as cars, mopeds, bicycles, pedestrians and dogs share the same few roads.

Figure 3.15. Number of cars visiting Block Island annually. Calculated from car ticket sales on ferries. Assumes every car makes a round trip. Source: Public Utilities Commission.



Status. Interstate Navigation is the only regular carrier of motor vehicles to Block Island. Although the company will not release figures for the number of cars it carries, I

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[118] Perry, R., A.E. McIntyre. "Impact of motorway runoff upon surface water quality." In *Effects of land Use of Fresh Waters: Agriculture, Forestry, Mineral Exploitation, Urbanisation,* ed. J.F. Solbe. Chichester: Ellis Horwood Limited, 1986.

[119] [ibid]

calculated this figure using Interstate's revenues from motor vehicle traffic as reported to the Public Utilities Commission **[see Appendix C for calculations]**. My figures show that car visits to the island have increased by 575 percent since 1978, and are increasing by an average of 1200 per year **[Figure 3.15]**.

Landfill effluent. Landfill effluent may carry such toxics as cadmium, lead, mercury, nickel, copper, zinc, and asbestos.[120] These elements become more soluble and mobile in the anaerobic conditions of being buried. Veeger at al, found that a well (NHW 264) south of the Block Island landfill (toward the Great Salt Pond) was not contaminated by landfill effluent, and that landfill effluent will flow west to the ocean from the landfill site. If this is true, then the Great Salt Pond should not be affected directly by effluent in the future.[121]

Power plant residue. Two small ponds next to Harbor Pond were used for cooling by the Block Island Power Company for several decades. The Block Island Power Company uses diesel engines to generate electricity, and used to pump pond water to cool them. Today, they use a closed-circuit cooling system utilizing radiator-type heat exchangers to discharge heat.[122] A side-effect of the old, open-circuit system was occasional leakage of

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[120] Bullock, Peter and Peter Gregory. *Soils in the Urban Environment*. Boston: Blackwell Scientific Publications, 1991.

[121] Toxic flows north of the pond into the gull colony breeding area could, of course, affect watershed communities.

[122] du Pont, Henry, former employee of Block Island Power Company. Personal communication, 2000.

hydrocarbons into the cooling ponds. Whether the Power Plant leaks affect Harbor Pond is not known.[123]

Chemical and gas spills from marinas; Boat fuel spills. Besides the potential for releasing overboard sewage, boats release chemicals into the pond every day. Vessels release bilge water and graywater[124] which can contain various toxic chemicals in the form of household cleaners, drain cleaners, teak finish, boat cleaning products, and motor oil. Anti-fouling bottom paints create slow leaching of chemicals into the water column as well. The amount of toxic spillage is not known. When boats "gas up" in the Great Salt Pond, a certain amount of fuel spillage inevitably occurs. This fuel may drop directly into the pond, run off from ship decks, or leak from outboard motors. No measurements have been made of gasoline spills in the Great Salt Pond. If every boat drips .1 gallons of gasoline of oil/day, that would add up to 57 gallons/day, or 5200 gallons per summer. The impacts of these releases are likely to depend on the location of the release—whether it is close to shore or near the breachway, etc.[125]

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[123] The power company also polluted groundwater under the plant via a leaky underground storage tank, which has since been remediated.

[124] Graywater is water from showers and sinks. This water is not regulated, and is generally released directly from vessels into surrounding waters.

[125] These affects are not negligible. In March 2000, a Common Murre was found covered in oil in the north part of the Great Salt Pond (Comings, 2000).

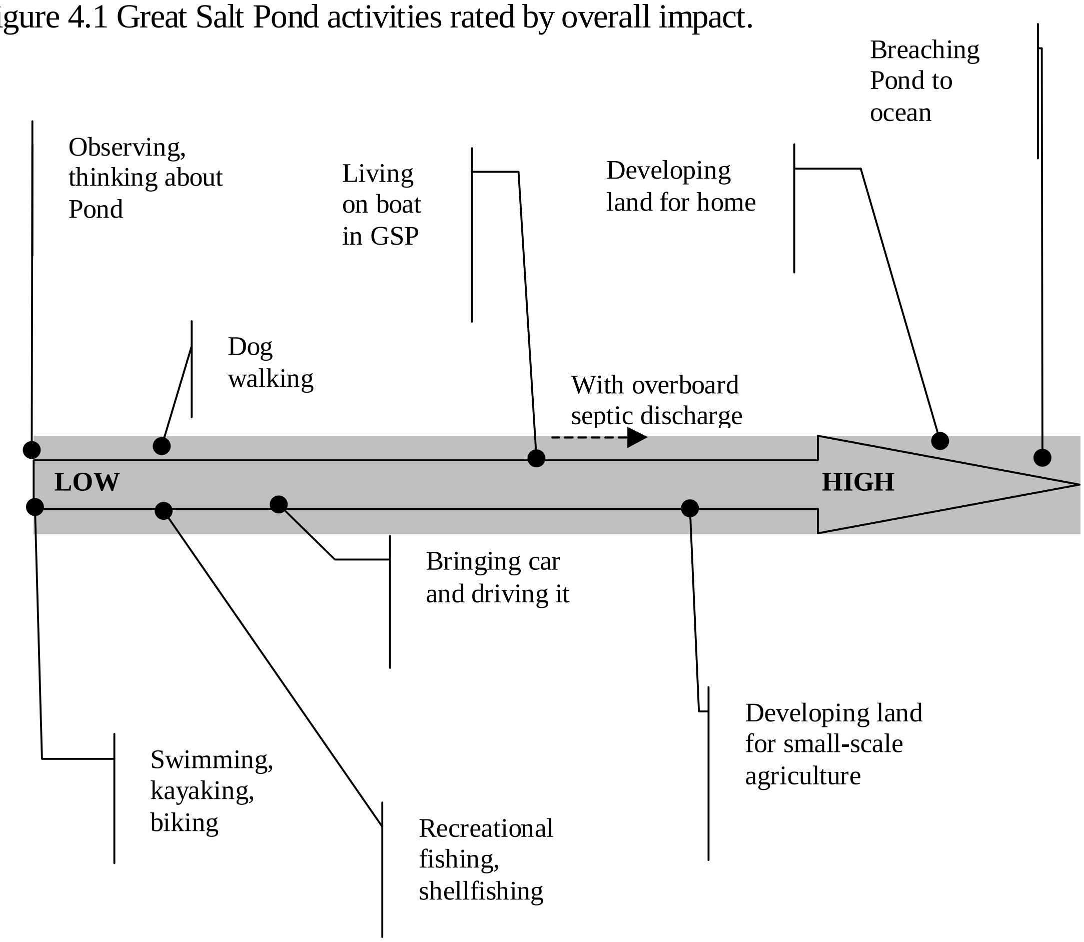
PART 4. SELECTING EFFECTIVE INDICATORS AND ASSIGNING MONITORING TASKS

4.1 Review of Findings

The biological system of the pond and watershed is in flux, as is revealed by succession of old fields to forests, changes in fish and shellfish catch, and increases in some invasive species in the watershed. Many observed changes in the biota, such as increases in predators such as spider crabs, appear to reflect long-term human influences more than short term. Maintaining the breachway has the most broad-reaching effects on the biology of the pond itself. **[Summary Table 4.1]**

Since the 1960's, there have dramatic increases in summer tourist visitation, car visitation, year-round resident population, and the number of housing units on Block Island, especially seasonal units. I have identified fourteen primary impacts that present human activities have on the Great Salt Pond Watershed. Of these, land development affects seven, using land for agriculture affects five, maintaining a harbor affects four to five, driving a car affects two, fishing and dogwalking affect one each, swimming, kayaking and observing the Great Salt Pond have no obvious primary effects on the pond and its watershed [**See Figure 4.1**]. Highest risk threats to the pond and watershed are septic system effluent, marine overboard discharge, and underground storage tanks, due to their relative toxicity, large scale, and persistence in the watershed over time.

Figure 4.1 Great Salt Pond activities rated by overall impact.



4.2 What indicators are effective and appropriate?

An ideal pollution indicator increases linearly with pollution. Unfortunately, few indicators have a direct cause-and-effect relationship to the underlying pollution source. Some indicators are general, giving an overall sense of changes in the resource, but often give only vague hints as to the source of such changes [e.g. bacteria concentrations in the Great Salt Pond]. In contrast, site-specific indicators identify point sources of pollution, but usually cannot provide information about system-wide effects [e.g. monitoring individual septic systems for leaks]. Due to time and/or budget constraints, there often must be tradeoffs between measuring simpler, general indicators and measuring site-specific indicators [Table 4.2]**. This is**

particularly true for water quality indicators, as water mixing tends to hide pollution sources. When creating a monitoring protocol, resource managers need to select a monitoring strategy that is feasible given budget and labor constraints. Table 4.3 **shows monitoring tasks associated with high, medium, and low risk threats to the Great Salt Pond.**

Table 4.2 Possible monitoring strategies for the Great Salt Pond and its watershed

ACTION	IMPLICATIONS
Monitor general indicators only	*Easiest to implement. If problems occur, targeting sources of problems can be difficult.*
Monitor general indicators, and, if trouble spots appear, begin monitoring at pollution sources	*Baseline data on sources may not exist when it is needed. Time lag before data is available may increase damages.*
Monitor pollution sources that present high risk threats in addition to general indicators.	*This combination approach allows for a baseline to be collected for high risk activities, to increase likelihood of detection before major damages occur, while keeping track of overall effects. Requires defining "high risk" activities.*
Monitor pollution sources only.	*Lacks information about the big picture. While changes in inputs may be observed, overall changes may go unnoticed.*
Monitor all general indicators and all pollution sources.	*Most complete approach. Likely to be very costly and labor-intensive. May result in more data being collected than can be effectively analyzed.*

igh Priorities for Monitoring

Using my matrix for risk assessment of threats to the Great Salt Pond, I have determined that the following should be high priorities for monitoring:

1) **Fecal coliform[126]/enterococcus bacteria concentration measuring:** Fecal coliform is presently monitored at fourteen sites, twice monthly in summer, once monthly in winter by the New Shoreham Harbors Department in conjunction with RIDEM.[127] This procedure should identify sites with high bacteria concentrations, which are feared for their association with water-borne pathogens--bacteria, viruses, protozoans, fungi, or parasites--that cause fever, diarrhea, gastroenteritis, hepatitis, dysentery and even cholera. [128] Sewage effluent in drinking water or shellfish can be a source of human illness through ingestion, inhalation, or body contact. Sources of fecal coliform in the Great Salt Pond include household septic system effluent, marine overboard discharge, and runoff from domestic and wild animals. Increased frequency (five times per month is used by the Department of Health in questionable areas) of fecal coliform testing in the south of the pond would help to clarify when

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[126] Fecal coliform, which is found in the guts of all warm-blooded animals, was chosen as a proxy for marking the presence of human sewage effluent in water. Recent studies have shown, however, that fecal coliform concentrations are often controlled by the presence of animals other than humans, and that fecal coliform concentration is not always well correlated with human water-borne pathogens.

[127] The Rhode Island Department of Health requires regular testing of drinking water and tests all state-operated waters on a regular schedule. The Great Salt Pond, however, is under jurisdiction of the Town of New Shoreham, and so is not monitored by the Rhode Island Department of Health. The U.S. Environmental Protection Agency (EPA) now recommends measuring *enterococcus* bacteria or *Escherichia coli*, which are considered to have a higher degree of association between concentration and disease outbreaks [EPA, 2000 #20] However, fecal coliform concentration is still the standard by which water quality is judged in many states, including Rhode Island, and is the indicator presently monitored in the Great Salt Pond

[128] RIDOH. Rhode Island Beaches webpage, www.health.state.ri.us/beaches/index.html,2000.

and where high concentrations occur, and help in decisions regarding the safety of swimming in these areas.

2) **Water clarity**.[129] This indicator monitors turbidity, including sediment load and phytoplankton density.[130] It is presently monitored sporadically by the Committee for the Great Salt Pond. A good program would monitor several sites in a regular way—two times per month in the summer may be sufficient. Such water clarity monitoring should reveal major changes nutrient dynamics in the pond.

3) **Septic system inspections.** An analysis of bacteria, nutrients and toxic inputs from septic systems should begin with a census of existing systems. [131] Next, regular septic system inspections should begin (recording tank locations, age, type, size and condition every 3-5 years), starting with those systems located on soils with shallow water tables and those located within 150 feet of the Great Salt Pond. [132] A record should be kept of septic system pumpouts to find out if systems are being pumped regularly.[133] A yearly report by the town Wastewater Manager of number of installations, overflows and septic system failures would make information accessible.

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[129] Water clarity is a measure of the distance one can see into the water from the surface. The standard measurement is to use a Secchi disk, a black and white disk that is lowered into the water until it can no longer be seen.

[130] As turbidity increases, water clarity is reduced.

[131] This process has been done in the Great Salt Pond watershed. See Figure 3.9. Applications for septic system installation and repair since 1992 are stored digitally at RIDEM.

[132] The New Shoreham Zoning Ordinance, Article 5, Section 506, requires regular ISDS inspections, and should ensure that appropriate systems are installed in the future that will not contaminate groundwater or the Great Salt Pond.

[133] This is a primary function of septic system inspections advocated by New Shoreham Zoning Ordinance, Article 5, Section 506.

4) **Boater survey of compliance with the No Discharge Area.** Knowing the amount of sewage discharged from boats into the Great Salt Pond is important, but difficult to monitor because discharge happens underwater, and is infrequent. Tactful boater surveys may be the best method of estimating boater compliance.

5) **Boat counts.** Presently, the New Shoreham Harbors Department counts all liveaboard vessels in the Pond twice a week from mid-May to September. The raw sum of boats counted in these surveys is often quoted as the number of boats that visited the harbor that year. However, this is likely to be a gross underestimation of the real total number of boats visiting. If this tally were compared to a tally of the number of vessels registered to marinas and town moorings per season, this would make a more accurate estimation of total boat visits per summer. The number of boats visiting the pond would establish the overboard discharge potential and provide a base number for calculating percent compliance.

6) **Underground Storage Tank Mapping.** A UST database should be generated that includes the age, locations, and condition of tanks. A map of tanks could be generated using GPS.[134] Periodic inspection of tanks, particularly old tanks (greater than 10 years?) would help to establish the real risk of contamination.

7) **Summer Occupancy Rate.** Establishing the number and type of summer visitors has several important uses—it would enable more accurate calculations of pollution loads, and would help planners to pinpoint strains on infrastructure. A summer head

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[134] A digital Global Positioning System

count such as the winter Groundhog Day Count[135] would help to give a realistic idea of summer occupancy patterns.

8) **Visitor and car tally**. Ferry ridership can be calculated from head tax information, but could be retrieved more directly from Interstate Navigation, if they can be persuaded to release this information. Perhaps the Rhode Island Public Utilities Commission could solicit the information from Interstate. Information on cars ticket sales should be readily available from Interstate as well, or it can be calculated from revenue reports to the PUC, but this method is indirect. A Visitor Tally including ferries, airlines, and boats would be useful in estimating human impacts.[136]

9) Land cover mapping Land use/land cover of the island (including forest/scrub cover) was mapped in 1960, 1970, 1988 and 1995. [137] The BIGIS database records designated open space , as well as undeveloped land parcels. The Nature Conservancy has created coverages of critical habitat for endangered species on the island. This information can be combined to track and quantify habitat loss/change over time.

10) Eelgrass (*Zostera marina*) bed health. Eelgrass is important as habitat for juvenile fish and shellfish, and it is a good proxy for changes in water conditions due to changes in sedimentation rate, nutrient levels, flushing rate, or other conditions.[138]

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[135] Every Groundhog Day, citizens gather at the Samuel Peckham, share knowledge, and send messengers to each house to count the number of occupants.

[136] The Block Island Town Clerk compiled similar figures from Head Tax information in 1994 and 1995.

[137] 1988 and 1995 land use/land cover is available digitally on GIS as part of the RIGIS database.

[138] Excess nutrient loading and reduced light availability negatively affect eelgrass survival (Short and Burdick, 1995; Burkholder et al., 1992). Because eelgrass is sensitive to these factors, it appears to be a good general indicator of water quality (Dennison et al, 1993).

Tracking eelgrass changes would involve monitoring the existing eelgrass bed once or twice yearly, identifying bed boundaries, sampling plants, and searching for any new beds.[139]

11) **Algae survey.[140]** Monitoring pond algae indirectly monitors nutrient inputs as contributed by septic effluent, marine overboard discharge, domestic and wild animal waste, as well as natural fluctuations in algal communities[141] Shoreline walks once or twice a season might serve to locate areas with increased algae populations. Shoreline surveys performed by DEM on a triennial basis would supplement this monitoring. Mapping beds of the algae *Codium fragile* (Dead Man's Fingers) in the pond might help to trace changes in its population over time.

Medium Priorities for Monitoring

12) Islander nitrogen use survey. **This is presently unknown, and a survey of nitrogen fertilizer sales on the island as well as a survey of islander fertilizer use would help to establish what the loading to the watershed is.**

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[139] Specific procedure described in the "Protocol Manual for Salt Pond Watchers" (1991).

[140] In Rhode Island salt ponds, increased available nutrient inputs appears to lead to increased macroalgae densities, and not to increased water column nutrient concentrations. It may be more useful , then, to monitor algae growth than water column nutrient concentrations. Lee, Virginia and Stephen Olsen. "Eutrophication and management initiatives for the control of nutrient inputs to Rhode Island coastal lagoons." *Estuaries* 8, no. 2B (1985): 191-202. Taylor, D., S. Nixon, S. Granger, B. Buckley. "Nutrient limitation and the eutrophication of coastal lagoons." *Marine Ecology Press Series* 127 (1995): 235-244.

[141] In Rhode Island Salt Ponds, nitrogen appears to be the limiting nutrient to algal growth Taylor, D., S. Nixon, S. Granger, B. Buckley. "Nutrient limitation and the eutrophication of coastal lagoons." *Marine Ecology Press Series* 127 (1995): 235-244.

13) Mapping of buffered areas. **By looking at aerial photos on GIS, buffered areas[142] could be identified, as well as poorly buffered areas. This would help more carefully determine runoff loading from cars, nitrogen, and erosion.**

14) Flushing rate study. **Because pond flushing is extremely important to removal rates of pollutants and to pond life, I recommend that a more complete flushing study be implemented. Such a study could assist in future estimations of nutrient and toxic chemical loading capacity of the pond.**

15) Building permit tally. **Tracking the number of approved building permits, and number of new construction sites would help assessments of development pressure on the watershed.**

16) Survey shellfish. **Annual shellfish surveys, especially in the shallow areas where a dredge cannot go, would help to determine whether present fishing effort is sustainable. Tallying yearly shellfish permits would indicate recreational fishing effort.**

17) Finfish surveys. **Finfish surveys could be conducted following the methodology used by Melissa Neuman.[143]**

18) Geese, cormorant and gull counts. Geese and cormorant censuses performed along with gull nest counts would help to establish fecal coliform inputs from these birds.

19) Survey of Pets. Survey boaters and residents about pet ownership—specifically dogs, cats, cows, geese and horses—would help to assess impacts of these animals on

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[142] A buffer is land that is not groomed that separates cultured land from the Great Salt Pond.

[143] DEM conducted a finfish study in 1999. Neuman, Melissa. "Distribution, Abundance, and Diversity of Shoreline Fishes in the Great Salt Pond, Block Island, Rhode Island." M.S. thesis, University of Rhode Island, 1993.

the watershed. A question about favorite dog-walking spots would highlight areas of impact.

20) **Monitoring nutrients in feeder streams.** Measure nutrient concentrations in ephemeral streams that feed the Great Salt Pond during spring thaws and summer storms[144] in an attempt to spot high levels of nutrients in these areas.

Low(er) monitoring priorities

21) **Spider crab study.** An investigation into the biology of the spider crab, *Labinia sp.*, may provide insight into the reason for its recent abundance in lobster traps. A study of its abundance in the pond over time would reveal changes in its population.

22) ***Community list of "Sacred Places."*** With more development comes an inevitable crowding of houses. This can result in the loss of special viewsheds, picnic areas, and the like. A survey/list of valued "Sacred Places" would enable planners to track these over time, and perhaps conserve them. Such a list was suggested in the New Shoreham Comprehensive Plan, and may have been completed. (?) A GIS coverage exists of town cultural resources.

23) ***Sediment testing*.** Chemical sampling of sediments near commercial areas of the pond might reveal the presence of toxins from marinas, the landfill, or from the Power Company.

24) ***Toxic chemical use survey.*** This survey would help to assess the loading of household chemicals, lawn care products, and boat chemicals to the Great Salt Pond.

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[144] During these times runoff from lawns, septic tanks, cars, erosion etc. will be most intense.

This could be part of the nitrogen use survey, but would include boaters as well as summer and year round residents.

25) The number of harbor tows/accidents. To begin to assess congestion problems on the island from boat traffic, the yearly tally made by the Harbormaster of the number of boat tows/accidents could be used. This tally should give some reflection of the crowding in the pond, because with more boats, less space exists between boats, and more potential exists for anchor tangling.[145]

4.3 Implementation

Issue: Organization. I recommend that Great Salt Pond stakeholders—landowners, conservation groups and town planners—discuss management goals, and to debate which, if any, should take priority over others **[Table 4.4].** Stakeholders would identify those who are interested in pursuing a monitoring protocol, and would enable the implementation process to begin. A Monitoring Group could then be formed, which will manage and exchange information from the monitoring program. Such groups as the Committee for the Great Salt Pond, New Shoreham Harbors Department, and the Nature Conservancy, who already do some island monitoring, may have the appropriate resources to undertake leadership roles in the monitoring program.

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[145] Although this figure will fluctuate according to weather patterns, there should be some correlation between closeness of moored and anchored boats and the number of times boats tangle in each other's anchors.

Table 4.4 Great Salt Pond Stakeholders

The Committee for the Great Salt Pond
New Shoreham Town Council
New Shoreham Harbors Department
New Shoreham Chamber of Commerce
Block Island Shellfish Commission
Block Island Conservation Commission
Block Island Land Trust
Block Island Conservancy
The Nature Conservancy
Block Island Historical Society
Block Island Economic Development Foundation
Block Island Resident's Association

Issue: Budget. A useful monitoring program will be long-term, easy to manage, cost-effective, and sensitive to small changes in resources. In 1999, Block Island was approved as one of three towns to receive part of a $4 million grant for the EPA National Decentralized Treatment Demonstration Project. One of the objectives of this project is "to design and implement a monitoring program to track water trends in surface water and groundwater…"[146] While the EPA national Wastewater Demonstration Project has set aside funds for monitoring, other funding options should be discussed by the Monitoring Group, such as outside fundraising.

Issue: Delegation of monitoring responsibility. Delegation responsibility for monitoring will be an important part of implementing the monitoring program. Suggestions for delegation of monitoring assignments are summarized in **Table 4.3**.

[146] Towns of New Shoreham, South Kingston, and Charlestown, RI. *Block Island and Green Hill Pond Watershed, Rhode Island: EPA National Decentralized Treatment Demonstration Project, Draft scoping outline*. : Submitted to EPA, State and Tribal Assistance Grants, 1999. Monitoring funds primarily target fresh waters, but may be available for Great Salt Pond monitoring as well.

Groups ranging from Block Island School to the Block Island Historical Society, to RIDEM may wish to participate in data gathering.

Issue: Data Management. While many different teams of people may gather data, it should end up in a centralized location, if possible. URI's Watershed Watch (the Salt Pond Watchers) program compiles a database on Rhode Island Salt Pond water clarity, chlorophyll-a, nutrients, and bacteria, and would be a ready recipient of such data from the Great Salt Pond.[147] Ideally, the Monitoring Group could hire a database manager, who could receive the diverse information from the data collectors, create a databases, and perform simple statistical analyses to look at trends over time. A yearly report of the Monitoring Group would circulate findings, and illuminate potential problem areas to a large audience.

In short, all of the pieces exist for the creation of a comprehensive monitoring program on Block Island—the next step is to do it.

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[147] In 1988-89, the Committee for the Great Salt Pond participated in this program.