An Elusive Compromise: Rhode Island Coastal Ponds and Their People

Virginia Lee

Coastal Resources Center
University of Rhode Island
Marine Technical Report 73

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ACKNOWLEDGEMENTS

Weaving together the threads of information that begin to give us an understanding of the coastal ponds has been a richly rewarding task. It would not have been possible without the aid of many people who value the ponds and who gave so generously of their time and thoughts. Too numerous to acknowledge by name here, most are mentioned as important sources in Appendix A of the report. I have benefited enormously from your contribution and thank each of you.

The research, the ideas, the interviews, the digging into dusty files in pursuit of the ponds that this report summarizes was done together with Scott Nixon. It was primarily his enthusiasm for the coastal ponds and his conviction that with knowledge and imagination they could be soundly managed that initiated this project. Through his efforts, the work has expanded into an exciting interdisciplinary URI research effort. Without his energy and insight much of this never would have occurred.

I am grateful to Stephen Olsen, Director of the Coastal Resources Center, for his support throughout and considerable efforts dedicated to editing this report. I wish to thank Debi Clarke also at the Center for her patience and skills that have helped produce the final document. Vicki Desjardins of the URI Publishing Office edited the final copy.

Many thanks are also due Henry Lisi who contributed the drawings that help illustrate an aspect of pond life that is not familiar to most of us, and to Micky Leonard and Steve Silvia who did the drawing and photographic work for the rest of the report.

DEDICATION

To C. Foster Browning

who shared his knowledge and experience of the ponds
and conveyed so much of the special spirit of the people and the place.

He'd do anything for you that you want and help you any time you want and you'd help him. Old Swamp Yankee, they call him. That's going to be gone pretty soon because there aren't many of us left.

(C.F.B. 1977 interview)

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I. INTRODUCTION

A string of shallow salt ponds stretches along the coast of southern Rhode Island from Watch Hill to Point Judith (Figure 1). These ponds are connected to the sea by narrow breachways that cut through the barrier spits which separate the ponds from the Sound. Although their relative isolation from major cities and their shallow depth have historically not made them attractive for intense development, pressure for residential housing and recreational facilities has been increasing rapidly during the past two decades. Their relatively small size and restricted exchange with offshore waters make the coastal ponds particularly susceptible to the stresses brought by man's activities. As transition zones between land and sea, they are affected both by development in the surrounding watershed as well as by changes in the larger marine environment, including some aspects of offshore fisheries management, oil spills, and beach dynamics.

Because there is so much potential for influencing their ecology, the ponds provide an excellent opportunity for developing and implementing integrated ecosystem-based management programs. Moreover, there is great public concern over the quality of the ponds and a growing appreciation of the need for sound management to deal with problems due to accelerated development, conflicting uses, pollution, overfishing, sedimentation, and the dilemmas posed by proposals to dredge breachways and channels. Recognizing these problems and opportunities, the Coastal Resources Management Council funded a one-year study to accomplish the following: 1) to summarize and synthesize available information on the ponds, 2) to describe changes that have taken place in the ecology of the ponds due to human activities, and 3) to formulate recommendations for what should be done to address these issues. Scott Nixon of the Graduate School of Oceanography and Virginia Lee of the Coastal Resources Center conducted the study in 1977. This report is a summary of that year's efforts.

Sources of Information

Information was gathered from published literature, reports of state agencies, thesis research, and special University class projects. A wealth of data on Charlestown-Green Hill Ponds has been collected at great expense and effort by the New England Power Company (NEPCO) in anticipation of constructing a nuclear power plant on the north shore of Charlestown Pond. Although it is no longer being considered for a power plant site the data are available to the public in the environmental impact statements for deposition of the former Charlestown Naval Air Station. To supplement and update the existing environmental information on the ponds we enlisted the help of 40 volunteer "pond watchers." These were people who lived on the ponds and had an active interest in them. They recorded weekly information on turbidity, fish kills, nuisance algal blooms, shellfishing, boating, and storm effects.

In addition to the literature survey and the data collecting by pond watchers, we tried to document the historical changes that have taken place in the ponds by interviewing "old-timers" who have lived on, used, and observed the ponds for many years. Since many have either made a living or supplemented the family income by harvesting a great variety of pond resources, several of these

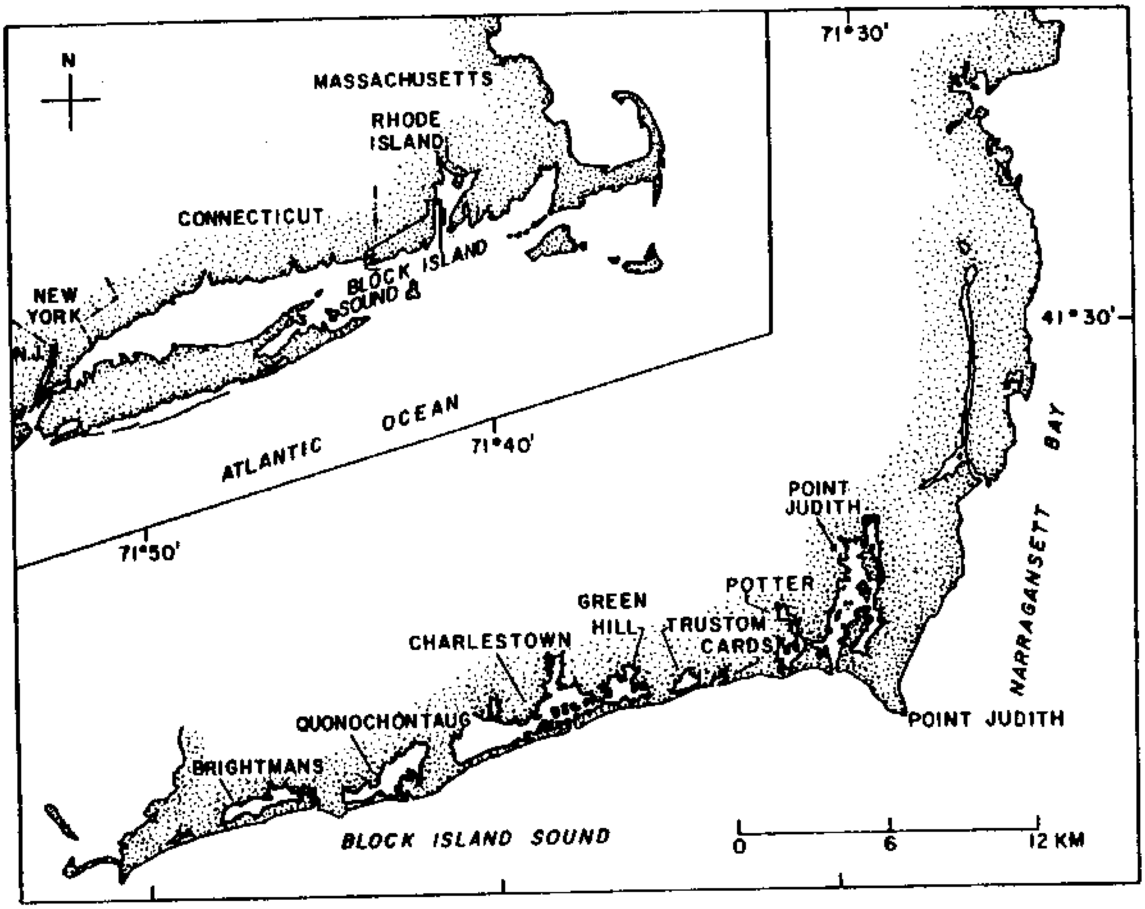


Figure 1. Rhode Island's South Shore salt ponds. The study area includes the ponds from Point Judith west to Charlestown Pond.

people took care to note changes as well as what might have caused the changes over time. Some of them made fishing logs, diaries, and photographs available to us. These personal histories of the "back side," as the south shore of Rhode Island was called, were supplemented by old newspaper articles, published histories, maps and records of town meetings kept in the local libraries and town halls. Aerial photographs of the south shore that have been taken for the federal government since the 1940s enabled us to document changes in land use and in the configuration of the ponds and barrier beaches since the hurricane of 1938. Appendix A includes a list of old-timers, pond watchers, government officials, and others who were interviewed. Appendix B lists sources of maps, charts, and photographs used to document activities in the ponds. Appendix C is a general bibliography for Rhode Island's coastal ponds.

Natural Characteristics of the Study Area

Rhode Island salt ponds are similar to other salt ponds or lagoons along the East Coast and elsewhere. They are all shallow estuarine embayments that lie parallel to the coast and are separated from the open ocean by barrier spits. Most of the south shore ponds are permanently connected to the sea through reinforced breachways and are flushed by the tides twice a day. Fresh water flows into the landward side of the ponds from streams and groundwater springs making the ponds less saline than Block Island Sound. They are inhabited by a great variety of organisms, ranging from brackish species such as oysters and blue crabs to salt water species such as scallops, blue fish, and flounder.

South Shore ponds rest for the most part on glacial outwash sediments of poorly sorted gravel which have been overlain along the landward side by fine, silty lagoonal sediments and on the seaward side by sand that has washed over the barrier beaches during storms or been transported into the pond through the breachways (Dillon, 1970). As sea level rises, storms wash sand from the ocean side over the top of the barrier beach and into the pond. As this process is repreated year after year, the barrier beach role back on itself and moves landward. The sands transported by overwash and breachways form extensive flats, bars, and shoals in the ponds.

Because they are shallow unturbid systems, sunlight penetrates through the water to the bottom, supporting dense beds of eelgrass and algae. The energy fixed by these benthic (bottom dwelling) plant communities together with that fixed by phytoplankton in the water column make the ponds very productive systems. Moreover, the shallowness of the ponds contributes further to their production by allowing nutrients and organic matter to be rapidly exchanged between the bottom and the water column. Carbon, nitrogen and phosphorus regenerated on the bottom from decaying plant and animal matter are readily mixed into the over-lying water where they are available both to fertilize the abundant plant growth and as a food source for a variety of fish and shellfish.

Although all the South Shore ponds share the same basic barrier spit-lagoonal characteristics, there are specific ways in which they differ from one another. They range from highly altered ponds like Point Judith, which has a permanent breachway and has been routinely dredged since the turn of the century, to large, moderately developed ponds like Quonochontaug and Charlestown, to small undeveloped ponds like Trustom and Cards, which are set in rural surroundings. Trustom and Cards are unlike the larger ponds in that they do not have permanent breachways. Because they are breached only occasionally, the salinity of these ponds is very low. Since we did not have the resources to study all the South Shore ponds, we decided to select ponds that covered a range of characteristics: Point Judith and Potter, Trustom and Cards, and Charlestown and Green Hill. A summary of their physical characteristics is given in Table 1.

Table 1. Characteristics of Rhode Island South Shore Ponds

Salt Ponds	Area[1] (acres)	Perimeter (m)	Length (m)	Width (m)	Av. Salinity ($^o/oo$)	Av. Depth (m)
Point Judith	1,530	33,200	5,500	2,000	30	1.8
Potter	329	15,600	1,100	1,200	28	0.6
Cards	43	3,970	1,100	900	10	0.4
Trustom	160	7,000	1,200	800	4	0.4
Green Hill	431	13,300	1,900	1,800	24	0.8
Charlestown	1,711	35,100	5,800	2,300	28	1.2
Quonochontaug	732	21,100	3,700	1,200	31	1.8
Winnapaug	446	15,600	3,400	3,500	30	1.5

[1]Stolgitis et al., 1976.

Historical Patterns Common to All the Ponds

After reviewing the literature, historical maps, and our conversations with old-timers, pond watchers, and government authorities, a general picture of how the ponds have changed as a result of human activities emerges. For at least 300 years, from 1600 to 1900, the ponds were estuaries abounding with fish and shellfish, set in a pastoral landscape. In colonial times, the level outwash plain that backs the ponds below the moraine was predominantly open pasture and tilled fields interspersed with wooded peninsulas stretching down between the ponds and pastures. The ponds were important sources of food and income throughout this period. There were large populations of smelt, white perch, alewife, and oyster in the ponds, and in the 1800s some local farmers made more money fishing the ponds than they did farming. Every fall and spring men would dig open the breachways to ensure the passage of migrating fish and to maintain the brackish water conditions necessary for oysters, smelt, perch, blue crabs, eels, and alewives. Trapping of muskrat, mink, otter, and fox occupied ten to twenty men as recently as the 1930s. Pelts brought a bounty in the early days and a handsome fee in New York markets in later years. During spring and fall abundant numbers of migrating waterfowl populated the ponds, and fed on the dense beds of widgeon grass that grew on the bottom. Widgeon grass and eelgrass were collected and banked against farmhouse foundations as insulation for the winter. Marsh grass was used as bedding and fodder for farm animals and to top the haystacks that dotted the fields in the years before hay was baled and stored under cover. Thus, the ponds were an integral part of local life. The great abundance and variety of pond resources were of central importance to the livelihood of families of farmers and fishermen.

Gradually, the ponds came to be esteemed for their recreational value. In the early 1800s summer visitors from inland cities and towns began to visit. Later, vacationers came from all over the country to stay in boardinghouses, farmhouses, and hotels grand and small. By the late 1800s Narragansett Pier developed into a popular resort. In 1876, the Narragansett Pier railroad was built, which linked the pier to the main Stonington and New York line. Thousands of passengers arrived at the pier by railroad in the summer. Day trips were arranged to Point Judith for clambakes, walks to the lighthouse, and sailing regattas. In the early 1900s summer-cottage communities grew up along the barrier beaches. While they were still fished by local farmers, the ponds were increasingly enjoyed by boaters, picnickers, painters, and bathers.

World War II marked a turning point. After the war there was a dramatic increase in the numbers of houses built around the ponds. New highways and increased standards of living made the ponds accessible and feasible as commuter communities. Prime agricultural land was lost to intensive residential developments. The numbers of people living around and using the ponds grew exponentially. The value of the ponds as sources of food and income was usurped by recreational benefits. To accommodate the needs of the burgeoning residential population, the ponds were altered dramatically. In the 1900s, stabilized breachways were constructed and the ponds were dredged to accommodate pleasure boaters. This radically changed the pond environment, for it affected tidal flushing, salinity, sedimentation, fisheries, and plant communities. The trend of rapid suburbanization continues today and brings a host of management problems. These problems and their historical development are discussed in the chapters that follow.

II. BREACHWAYS

Some of the major impacts of man's activities on the ponds are due to the construction of the permanent breachways. With the exception of Point Judith Pond, which was breached permanently in 1910, stabilized breachways were constructed between 1950 and 1960 in all the major South Shore salt ponds. In the case of Green Hill and Potter Ponds, instead of a direct connection to the Sound, stabilized breachways connect to adjacent ponds and thence to the sea.

Prior to the stabilized breachways, all the ponds were connected with the offshore waters of Block Island Sound by narrow, winding channels that were often blocked by beach sand transported by waves along the shore. This intermittent connection with the sea produced coastal ponds which were much less saline than they are now. At irregular intervals breachways were formed by natural events. During severe storms, ocean waves would wash over the barrier and cut channels through to the pond. In the spring and fall, enough freshwater from springs and streams would accumulate in the ponds to overflow the barrier beach and cut a breachway. These breachways would last from a week to a month, before they would fill in with sand shifted by the sea. Some years, these connections to the sea would be open more of the time than in others. When breachways had been closed for long periods, it was customary for local farmers and fishermen to dig a breachway with shovels or oxen and scoops in order to drain water from fields bordering the ponds and to open a passage for fish such as white perch, smelt, and alewives. Breachways would also be opened in ponds that harbored extensive oyster set in order to raise the salinity and enhance the growth and taste of the mature oysters. Before the stabilized breachways, all the ponds abounded with plentiful stocks of alewives or "buckeyes," smelt, perch, eels, and oysters and supported substantial fisheries for these brackish water species.

By assembling historical information on the shifts in the breachways and the motivations for such man-made alterations, we can study the consequences of these alterations on the ecology of the ponds and gain insight from the way management issues had been addressed in the past. This should yield some perspective by which to judge potential effects of future management decisions.

The Point Judith and Potter Pond Breachways

The best historical documentation exists for Point Judith Pond. Changes in the Point Judith breachway are mapped in Figure 2. In the 1600s and 1700s the pond was connected to the sea by a wide, deep natural breach considerably east of the present breachway. Although we have not been able to locate good-quality maps of the period, it appears from written accounts that the breach cut across a cobble beach at what is now Sand Hill Cove (Cole, 1889; D.W. Lockwood, 1897). In Colonial times, Point Judith Pond was a harbor for small coastal traders. According to an article in the Providence Sunday Journal (1889), which reviewed the history of the breach, this breach was from 30 to 50 feet wide and at least 10 to 15 feet deep. Vessels of 10 to 70 tons with a draft of 8 to 10 feet would regularly sail into the pond to load up with cheese and produce from local farms. This produce was taken to Providence, Newport, New York, and in some cases, the West Indies. During the Revolutionary War and the War of 1812, British sympathizers took produce and livestock out through the Point Judith breachway to supply British warships waiting near shore.

The Great September Gale of 1815 hit the coast with such force that it washed 30-foot-high sand dunes off the beach and into the pond, forming what are now salt marshes and clam flats, and filled in the breachway. According to Jonathan Clark, who was 15 at the time, "The great wind shoved the land flat before it and closed the wide breach in a jiffy" (Providence Sunday Journal, 1889). The gale winds piled water back up into the pond ten feet or more above normal (Cole, 1889). As the storm passed, the water swept back out to sea, cutting a new breachway a mile or so to the west (see Figure 2). The location of the breach created by the Gale of 1815 is marked today by the town line that cuts through Succatash Marsh just west of Jerusalem. When Narragansett was separated from South Kingstown in 1888, the boundary dividing the two towns was drawn through the breachway.

Just after the Gale of 1815, the breach was deep and wide enough to accommodate fairly large vessels. A local farmer, J.W. Knowles, kept a journal of observations on the pond in which he noted the following vessels going through the breach: a 40-ton vessel, the George Washington, in 1815; an 80-ton sloop in 1816; a 180-ton brig in 1819; and a 109-ton schooner in 1820. Vessels with an 8 to 10 foot draft could pass through the breach and sail on up the pond toward Wakefield (Providence Sunday Journal, 1889). The new breach, however, was in a less stable sandy section of beach than the pre-1815 breach, and it consequently shifted and shoaled. By the mid-1800s the breach became so shallow that only shallow-draft boats could pass through. According to George Tourgee, "Captain Elias Saunders built the first center board boat in Narrow River about the year 1850. It was a tarnation funny looking thing, but it could go in and out of the breach slick" (Providence Sunday Journal, 1889). There were at least two other centerboard boats, of 15 and 20 tons, that went in and out of the pond loaded with barley, cheese, and produce. In 1854, a 40-foot vessel with two centerboards was built in the pond to freight seaweed. She was decked over and could carry about 20 tons. For six years she carried seaweed collected from beaches at Sand Hill Cove and Matunuck through the breach and up to Wakefield, where it was sold to local farmers who used it to fertilize their fields. The depth and width of the breach changed year by year, from a narrow channel of 10 to 15 feet deep to a wide, shallow outlet only a few inches deep. With every big storm, the breach changed. "It was shut up by the play of the ocean and opened again by back pressure from the pond," according to the Providence Sunday Journal in 1889. Gradually, the breach became too shallow to permit even shallow-draft boats to pass regularly. In an 1873 survey of the U.S. Army Corps of Engineers, the breach was a narrow, crooked inlet only 1½ feet deep. The pond was quite brackish, since there was essentially no tidal exchange with the Sound. By 1888, another Army Corps survey reported a much deeper breach of 3 to 8 feet at low water. A stronger tidal current entered the pond at that time, creating a tidal range of 6 to 9 inches. In 1897, an Army Corps survey described the breach as "limited to a narrow channel of less than two-feet depth, with probably 6 inches of water rippling over a width of from 100 to 150 feet . . . easily fordable by ox teams at all times" (Lockwood, 1897). During the decade prior to 1900, the breach at the town line had closed each winter, in the spring fishermen dug the breach out by hand to let the buckeyes, perch, and bass into the pond. In an account by George S. Phillips, who helped dig the last of these breachways in 1900, it took four fishermen ten days to dig through the barrier. Once a trench was dug, the rush of water from the pond deepened and widened the channel.

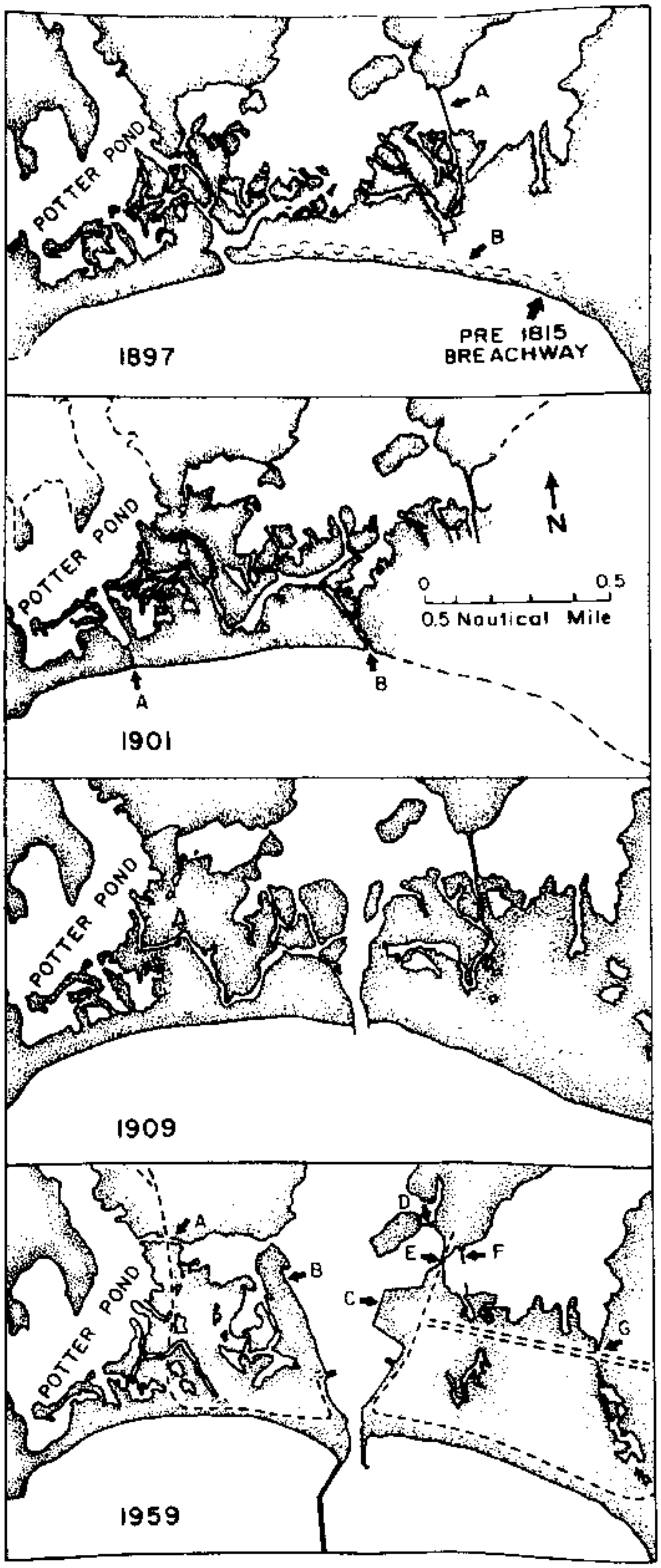
Figure 2. Maps of Southern Point Judith and Potter Ponds Showing Changes in the Location of the Breachways Over Time.

1897. The Great September Gale of 1815 closed the long-existing natural breach at Sand Hill Cove and opened a new breachway to the west, through what is now Succatash Marsh. The town boundary was established through this breachway when Narragansett was separated from South Kingstown in 1888. (A) indicates a stone causeway that led to Great Island, which was cultivated at the time. (B) indicates 10 to 25 foot-high sand dunes that lined the back of the beach. To the east of the causeway, a remnant flood tide delta is evident, denoting the location of a previous breachway.

1901. By 1901, the breachway at the town line had closed and a small breach was opening and closing near the site of the present permanent breachway (B). Local fishermen continued to hand dig breachways (A) to maintain the migration passage for white perch, smelt, and alewives. On March 22, 1901, the R.I. General Assembly passed legislation enabling the town to build the permanent breachway and appropriated $25,000 to supplement the town's appropriation of $13,000.

1909. The Town of South Kingstown and the State of Rhode Island dredged a seven-foot-deep channel through the beach and constructed short stone jetties to reinforce it. The tidal range in the pond became about 2.8 feet and salinity increased.

1959. By 1959, the shoreline and breachways had changed to a configuration that characterizes them today. By 1910, a 4-foot-deep by 20-foot-wide channel was dredged between Potter and Point Judith Ponds (A) which greatly increased the tidal flushing and salinity of Potter Pond. Dredge spoils from dredging the breachways and channels were used as fill on both sides of the Point Judith breachway. In 1939, Succatash Road was extended to Jerusalem, which changed from a jumble of fishermen's shanties to a small settlement. In 1934 and 1935, the State of Rhode Island dredged the Galilee turning basin to 12 feet and dredged an 8-foot-deep channel to Potter Pond entrance, and a 6-foot-deep channel up to Ram Point, at the head of the pond. The dredge spoil was used to build piers on both sides of the harbor, a causeway to Great Island (E) and to Little Comfort Island (D), and as fill on Succatash Marsh, connecting Gooseberry Island (B) to Jerusalem. In the 1950s, the dredge spoil was used to lay the foundation to the escape road (G) and new state piers (C). Remnants of the old stone causeway to Great Island (F) can still be seen today.


POTTER POND
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0.5 Nautical Mile
A
B
1901
POTTER POND
1909
POTTER POND
A
B
C
D
E
F
G
1959

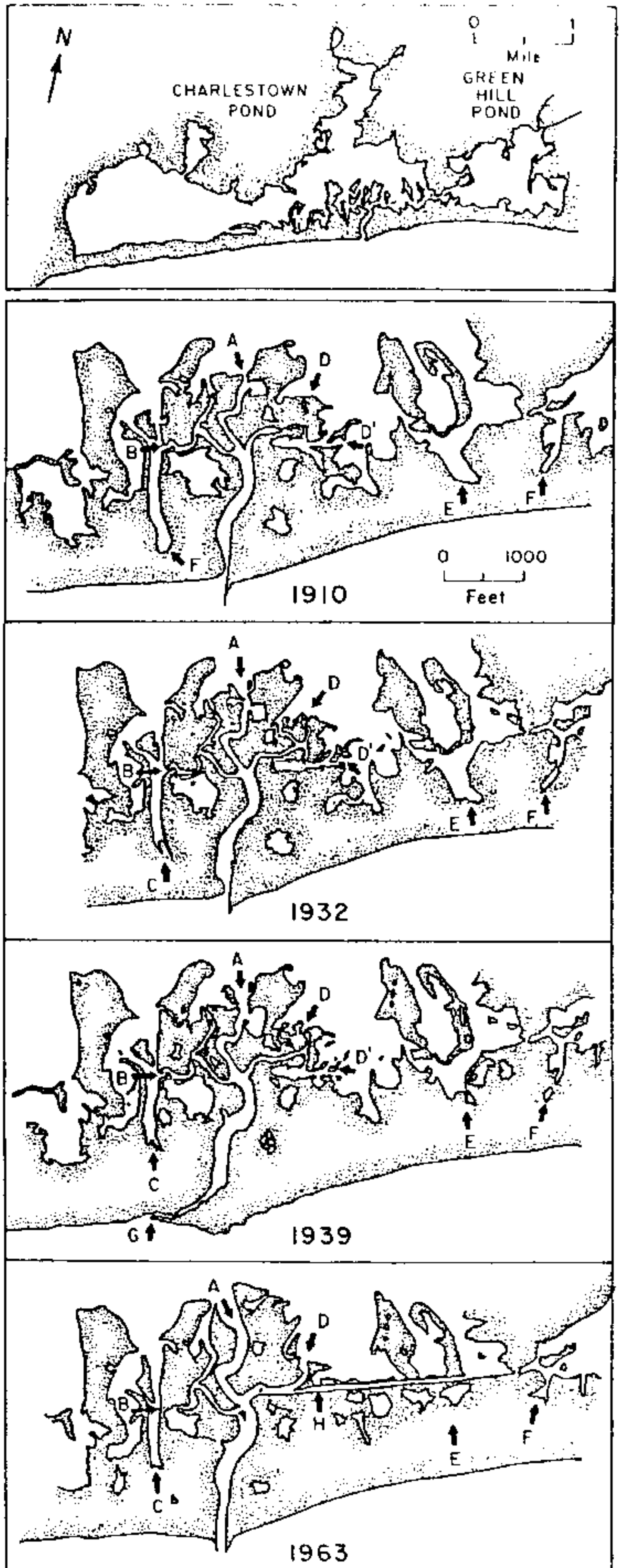
Figure 3. Maps of Charlestown and Green Hill Ponds Showing Changes in the Breachways Over Time.

1910. Several attempts had already been made to maintain a permanent breachway. In 1881, a riprap wall was constructed on the east side of the breach at the direction of the State of Rhode Island. This soon filled with shifting sands. In 1904 the breach was reinforced with a 200-foot fieldstone jetty and the channel was dredged in 1906. The wall caved in and the breach closed off in a storm in 1912. (A) marks the location of the main tidal channel that has persisted over time. (B) marks an ancillary channel that has closed off with increased sedimentation, and (D) marks a secondary channel that opened up and has become more prominent since 1910. (C), (E), and (F) mark inlets or temporary breaches that have been filled by storm surge overwash.

1932. The beach and breachway prior to the hurricane of 1938.

1939. The beach and breachway after the 1938 hurricane showing the changes due to the hurricane. The breachway itself was filled and altered (G) and much of the pond shore was filled (C), (E), (F).

1963. A channel excavated through the marshes and flats connecting Green Hill Pond directly to the breachway (H). Historically, Green Hill Pond has always been connected to the sea through Charlestown Pond. There has been a bridge across the connection at least since 1910. The channel was dredged by the State of Rhode Island in 1962 to give recreational boaters in Green Hill Pond easier access to the ocean. Later an earthen dam was placed at the breachway end of the channel. It was opened to boat traffic in the summer and filled in during the winter in order to lower salinity in Green Hill Pond to enhance oyster growth.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1939
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Table 2. Breachway History

Date	Point Judith-Potter Ponds	Charlestown-Green Hill Ponds
1700s	A 30- to 50-foot wide, 10- to 15-foot-deep breachway existed at Sand Hill Cove. Vessels of 10 to 70 tons passed through the breach to take on produce, cheese, and livestock.	Breach was probably close to its present location. Coastal trading ships came through the breach and docked at Cross Mills and Fort Ninigret. By 1752, the breach had become too shallow to allow boat passage.
1815	Great September Gale closed the breach at Sand Hill Cove and opened a new one to the west where the town line passes across the barrier beach. The storm surge swept 30-foot sand dunes back into the pond.	The Great Gale of 1815 created a storm surge 10 feet above high water, rolled over the beaches, and swept cattle from the pond islands and haystacks from the shore meadows. All the forests along the coast were prostrated.
1847	Saugatucket River dammed for water-driven mills in Wakefield.	
1873	The breach was a shallow outlet 200 feet wide and about 1½ feet deep. The pond level was 4½ feet above mean sea level. There was essentially no tide in the pond and passage of fish was much reduced. Mill wastes conspicuous in pond.	
1881		Riprap wall was built by the State of Rhode Island on the east side of breachway to reinforce a permanent connection to the sea. It proved to be a failure, since shifting sands often closed it off.
1888	The breachway was a winding, narrow channel 3 to 8 feet deep at MLW. Pond level was 2½ feet above mean sea level, and there was a tidal range in the pond of 6 to 9 inches. Narragansett separated from South Kingstown using the breach as a boundary.	

Table 2 (cont.)

Date	Point Judith-Potter Ponds	Charlestown-Green Hill Ponds
1897	Breach was a shallow, winding channel 150 feet wide and less than 2 feet deep. The pond level was about 2½ feet above mean sea level, with a tidal range of about an inch.	
1904-1910	The State of Rhode Island and the Town of South Kingstown dredged a 7-foot-deep breachway through the beach at the site of the present breach and constructed short stone jetties. The tidal range in the pond increased to 2.8 feet and the salinity increased. The Army Corps completed construction of the offshore breakwaters and anchored the western jetty firmly to the beach. A 4-foot-deep, 20-foot-wide channel was dredged from Point Judith through to Potter Pond.	The 50-foot-wide breachway was dredged and reinforced with a 200-foot fielstone jetty to prevent shoaling and closing of the breach. A 1912 storm damaged the wall and closed the breach, which thereafter opened and closed periodically.
1938	The Great Atlantic hurricane swept over the beach at Sand Hill Cove and over the beach at Matunuck into Potter Pond, washing sand dunes into the ponds and forming sand flats visible as shoals north of the barrier today.	The hurricane swept over the barrier, cutting 7 surge channels through East Beach, washing dunes into the pond and washing at least 90 beach houses back across the pond almost to Route 1.
1954	Hurricane Carol did $2.5 million worth of damage to the pond area. It washed huge volumes of sediment from the foundation of the escape road into East Pond. The water level rose 11.9 feet above mean sea level at Matunuck.	Hurricane Carol washed houses, barns, boats, and sand into the pond. Increased transport of sediment in through the breach and shoaling of the pond was first noted as a problem by URI researchers.
1962		Channel to Green Hill Pond dredged to connect it directly to Charlestown breach. Salinity increased in Green Hill.

In the late 1800s, Wakefield and Narragansett Pier were prospering towns, due to the woolen mills in Peacedale and the superb summer resort facilities at Narragansett Pier. For years, the town merchants tried to convince the state and federal governments that it was worth the expense to build a stabilized breachway in the pond, dredge a channel to its head, and create a protected small harbor for coastal trade and transportation. The towns would then save the considerable costs of rail freighting coal and commercial goods. It cost one dollar more per ton to bring coal to Wakefield by train than it would by boat. "Farmers were paying $2.50 a ton more for chemical fertilizer than they would have to pay if it were shipped by water" (Providence Sunday Journal, 1913).

Each of the three surveys conducted by the U.S. Army Corps of Engineers in 1873, 1888, and 1897, assessed the project as impractical. The potential benefit to the region in marine trade did not merit the enormous expenditures required to build a stabilized breachway. The cost of dredging just a one-mile channel through the breach to 8 feet deep was about $400,000 in 1888 (Lockwood, 1897). Building reinforcing breakwaters or dredging a channel the length of the pond was even more expensive. Finally, a Harbor of Refuge was planned outside the pond. The Corps had been contemplating such a project since 1873 because a safe harbor was badly needed for the busy coastal traffic, which in 1889 was estimated at 50,000 ships a year. Point Judith was a notorious hazard, the cause of many wrecks for ships rounding the Point en route between Newport and Providence and New York. From 1905 to 1914, the Army Corps worked on building a series of large stone breakwaters offshore of Point Judith which form the Harbor of Refuge that exists today.

Planning the Harbor of Refuge buttressed the town's argument for a stabilized breachway. Commercial interests in Wakefield wanted to boost development in South County by making a port that would accelerate shipments of coal and produce and tie coastal traders to the rail lines between Boston and New York. Moreover, during the late 1800s wastes from the mills along the Saugatucket River were becoming increasingly conspicuous in the pond, and more flushing with ocean water was needed to dissipate this pollution. The shoaling breach also restricted fish migration. Consequently, bass and perch fisheries were declining. Local residents and fishermen joined the merchants in pressing for a stabilized breachway because they wished to enhance declining fisheries and rejuvenate the oyster population. In 1889, it was reported that oysters which spawned in the pond died off because the water was so stagnant. In 1900, the South Kingstown town council appropriated money "for connecting said salt pond with the ocean providing thereby a circulation of water for the propogation of fish and oysters" (South Kingstown Town Council Minutes, 1900). Although Narragansett could not be persuaded to contribute money, it deeded the land along the breachway to South Kingstown so that the project could proceed. In 1901, the State of Rhode Island appropriated $25,000 to supplement the town's efforts. Thus, between 1902 and 1910, a 7-foot-deep channel was dredged where the breachway is today, and the sides were reinforced with two stone jetties. In 1909, the state also contracted to have a permanent breachway to Potter Pond dredged to a width of 20 feet and a depth of 4 feet at mean low water (Rhode Island Public Works Department, 1911).

The task of building the breachway was enormous and the execution ingenious. According to H. Browning (1978 interview), rocks for the original western leg of the Harbor of Refuge were taken from Blackberry Hill, Matunuck, a few miles to the west. Five-tone fieldstones were hauled to the beach on a two-oxen cart fitted with a hand-crank winch. Then rails were laid on crossties along the beach, and flatcars, each holding a rock, were hauled by horses along the rails to the breachway. Later, quarried stone was hauled over land from Westerly.

The Charlestown and Green Hill Pond Breachways

Fifty years after construction of the breachway at Point Judith, the breachways of the other major salt ponds were also stabilized. The small ponds, Trustom and Cards Ponds, are exceptions and have natural breachways to this day. In the early days, the Charlestown breachway opened and closed naturally several times a year. In the 1600s and 1700s if the breach closed in the spring, farmers/fishermen would dig a breach by hand, using horse-drawn scoops and shovels, to make a passage for anadromous fish. Farmers would also dig a breach to drain pond water from bordering fields and from pond side springs that were important freshwater supplies. The natural breach at Charlestown Pond in the 1700s was large enough to allow European coastal trading ships to pass through it, some of which stopped to trade with the Narragansett Indians at Fort Ninigret (Conover, 1961). But it gradually shoaled in and by 1752 had to be opened by hand each spring and fall. In the late 1800s, when the oyster business was booming in Narragansett Bay, the state looked to the salt ponds for a source of seed to be transplanted to the beds in the Bay for later harvest (Goode, 1884). It was thought that when the breachways closed, conditions in the pond became too fresh for the oysters to grow even though they spawned prodigiously. In an effort to enhance the pond oyster stock as a potential seed source for the bay oyster fishery, the state contracted in 1881 for the Charlestown breach to be reinforced by a rock wall on the west side, but it soon shoaled in. In 1904, the state paid for the dredging of a 50-foot-wide breach and reinforced both sides with stone jetties (Whaley, 1969). By 1906, this too had shoaled so badly that the town had it dredged again. After World War II, housing development increased around the pond and residents pressured for another reinforced breachway in order to flush the pond free of pollution. In response, the state in 1952 paid $64,790 to have the breach dredged to a depth of 3 feet and a width of 120 feet and to build stone jetties that extended into the Sound from the breach (Figure 3). Similar stabilized breachways were also constructed in Brightman's and Quonochontaug Ponds in the 1950s.

The reasons for constructing these breachways were similar to those used to justify the Point Judith breachway 50 years earlier. Residents and officials were convinced that the oyster fishery would be vastly improved by higher salinities and greater flushing. A breachway was also seen as a way to relieve stagnation and pollution. In Point Judith Pond, the pollution load was caused primarily by sewage and mill discharges from the town of Wakefield, while in Charlestown Pond pollution was caused by sewage from houses bordering the pond. In both cases, the stabilized breachway was to provide boat access to the ocean. For Point Judith Pond, residents and merchants wanted to improve access for commercial ships, and for Charlestown Pond residents were eager for a passage for recreational boats.

Effects on Pond Ecology

The stabilized breachways are examples of management efforts that have had far-reaching and unexpected results. Constructing permanent connections to the sea changed the basic character of the ponds. Construction of permanently open breachways made what was once a seasonally brackish water estuary into a high salinity tidally flushed system. Such basic changes in salinity and flushing altered the pond habitat and the kinds of organisms dwelling there.

Loss of Brackish Water Fisheries. Although the history of pond fisheries will be discussed more thoroughly in the following chapter, it should be noted that the overall effect of the breachway on fisheries was the demise of the very fisheries they were meant to enhance. The abundant brackish water fisheries that yielded thousands of pounds of alewives, perch, and oysters annually were ultimately lost. In many cases, they were replaced by less abundant populations of species such as quahogs, bay scallops, and winter flounder.

One of the major arguments proposed for constructing the permanent breachways was the improvement of the anadromous fisheries and the oyster stock, since it was seen that the shoaling breachways were restricting the passage of migrating fish and the flow of seawater necessary to feed and fatten seed oysters. In the days before permanent breachways, the ponds supported extensive oyster beds, and thousands of oysters were harvested each year. According to Goode (1884), the State of Rhode Island considered using the ponds as a source of oyster seed for the large and lucrative Narragansett Bay fishery. By the late 1800s, the breachways in Point Judith and Charlestown had shoaled so much that they were closed most of the year and the ponds were so brackish that the oyster spawn was prolific but the set died as it matured. The state contracted to dredge and stabilize the breachways in the hope that increased flushing of the ponds would enhance the oyster fishery by bringing in more phytoplankton food and carrying out toxic wastes. Accordingly, when the state directed a riprap wall to be built in the Charlestown breach (1879), it leased out sections of the pond for oyster culture. Similarly, the year the state appropriated money to build the Point Judith breachway (1901), it gave the town authority to lease oyster lots in the pond to Rhode Island residents who wished to fish them.

Indeed, in the year immediately after the opening of the Point Judith breachway, the oysters did well. In the early days, oysters grew on any hard bottom. They grew so thick off Great Island that walking there cut up a pair of boots (Bob Smith, 1978 interview). The Dykstra family shipped thousands of bushels of oysters by rail directly to big hotels in Newport, Narragansett, Hartford, and New York in the 1920s and 1930s. They would fish the beds in fall and winter. In the winter they cut large holes in the ice and could harvest six bushels with tongs from a single hole.

But the opening of the permanent breach was the beginning of the extinction of the oysters because spawning gradually declined when the ponds became more saline. The pattern of the loss of the oyster fishery was described by Jake Dykstra, whose family dominated the Point Judith oyster fishery after 1914. At first, the natural population grew and was fished. However, the oysters did not spawn in the higher salinities and were consumed by salt water predators such as the oyster drill and starfish. Soon there were no longer natural sets on the beds, spat had to be gathered elsewhere and put on the beds. In the 1930s, rowboats were filled with young oysters from the shores and brackish coves of the pond and shoveled off onto beds that were 6 to 8 feet below the surface. The oysters spawned only along the edges of the pond, where rain and runoff made the water less saline. Later, in the 1940s and 1950s, spat had to be brought in from Jamestown or other ponds that were still brackish. At first, spawning stopped, then the oysters disappeared from most of the pond retreating back to fresher water.

A similar pattern occurred in Charlestown Pond. One argument in support of the 50-foot-wide reinforced breachway dug in 1904 was enhancement of the oyster fishery. But the salinity so increased that spawning was inhibited and the oyster crop suffered heavy damage. As the breach shoaled and the west wall eventually caved in, the pond became more brackish and the oyster fishery recovered. Oysters were again plentiful in deep water or shoal. In the 1930s and 1940s, local residents fished Charlestown and Green Hill (although Green Hill oysters were smaller and less in demand), easily getting the six-bushel limit every day. They were sold to local restaurants or kept in the basement all winter to feed the family. Oysters layered between wet burlap would keep for months. During the Depression some local children peddled oysters door to door before school.

Disregarding the early lessons how how stabilized breachways can effect oyster fisheries, the permanent breachway in Charlestown Pond was constructed in 1952 and the channel dredged to Green Hill Pond in 1962. A major argument in each case was the enhancement of the fishery. Shortly after the construction of the breachway, oysters could be found only in a few of the back coves where freshwater spring or streams feed into the pond. An earthen dam had to be built across Green Hill channel in order to block tidal flushing in Green Hill Pond and lower the salinity sufficiently to regain oyster spawning conditions.

Increased Sedimentation. Preliminary estimates from comparisons of aerial photographs over time suggest that the construction of the permanent breachways approximately doubled the rate of sedimentation in the ponds along the south shore (Simpson, 1977). Thus, the ponds may be shoaling twice as fast with the breachways as they did without them. As in the case of the fisheries, the use of the breachways as a management tool had results that were counter to the intent. A major justification for the construction of these breachways was to provide access to the ocean to residents and merchants. Ironically, the increase in sedimentation that has resulted from their construction has created a nuisance for boating activity.

The increased sedimentation makes routine dredging in Point Judith Pond necessary, and the public is now pressuring for dredging in the other ponds as well. The effects of dredging and problems of spoil disposal, of course, bring a host of other management concerns.

The geology and sedimentation of the ponds is discussed in detail in Chapter IV.

Alteration of Other Resources

When the ponds became high salinity tidally flushed lagoons, other changes in the ecosystem occurred that are perhaps less dramatic than the loss of the brackish fisheries and the increase in sedimentation. For instance, the dominant pond vegetation changed from widgeon grass, Ruppia to eelgrass, Zostera (see Figure 4). It is difficult to know if the productivity of the ponds has altered, because there were no quantitative data on production gathered before the building of permanent breachways. Surveys of duck food and dominant vegetation were made by researchers at URI (Wright et al., 1949; Wood and Palmatier, 1954), but they only provide lists of species and not quantitative studies. According to the old-timers, dense beds of widgeon grass grew like thick meadows over the pond bottom. The grass was so thick in Potter Pond that muskrats had difficulty diving through it and could therefore be easily shot (C.F. Browning, 1978 interview). The grass was so thick during Prohibition that it was difficult to row a skiff through it--a major annoyance, since the coves and inlets along the Rhode Island shore provided a haven for the rum-runners. After the breachways, less dense beds of eelgrass replaced the widgeon grass.

The decline of the widgeon grass may have had effects on the waterfowl populations in the ponds. As a food source, widgeon grass is generally preferred over eelgrass by waterfowl. Again, there is no quantitative information to indicate what the numbers of waterfowl were before and after the breachways. The Rhode Island Audubon Society and the Rhode Island Department of Environmental Management make annual counts of the ponds, but only once during the year. Since waterfowl concentrations respond quickly to local wind and weather conditions, once-a-year counts are not good indicators for comparing year-to-year changes in the population. However, it is the general concensus from people who have lived on the ponds that the waterfowl population has declined. There are stories that the ponds were covered with great rafts of ducks before the breachways went in, especially during spring and fall migration. There used to be numerous coot, bluebills, whistlers, black ducks, redheads, canvasbacks and mergansers. As an example of the abundance of waterfowl, C.F. Browning recounted but there were so many ducks in the ponds that at the turn of the century two boys shot a barrel ful of coot in a weekend on Potter Pond and shipped them off to New York to market. These birds are no longer present in large numbers on any of the ponds with stabilized breachways.

It is difficult to know if the loss of a preferred food source in the ponds may have reduced the waterfowl population, because they are subject to so many outside factors. The ponds are stopping places for migrating geese and ducks that use the Atlantic flyway. The birds are vulnerable to changes in habitat, weather, and hunting pressure along the entire length of the flyway as well as to adverse conditions in breeding areas during the summer. At best, a tenuous link can be made between declining populations that visit the ponds and changes to the salt pond environment. Furthermore, changes in land use and loss of natural areas around the ponds also affect the kinds and numbers of birds using the area. Swans have come into the ponds since the 1950s. Although coincidental with the stabilized breachways, their appearance was due to their rapidly expanding range and population. The same is true of the Canada geese,

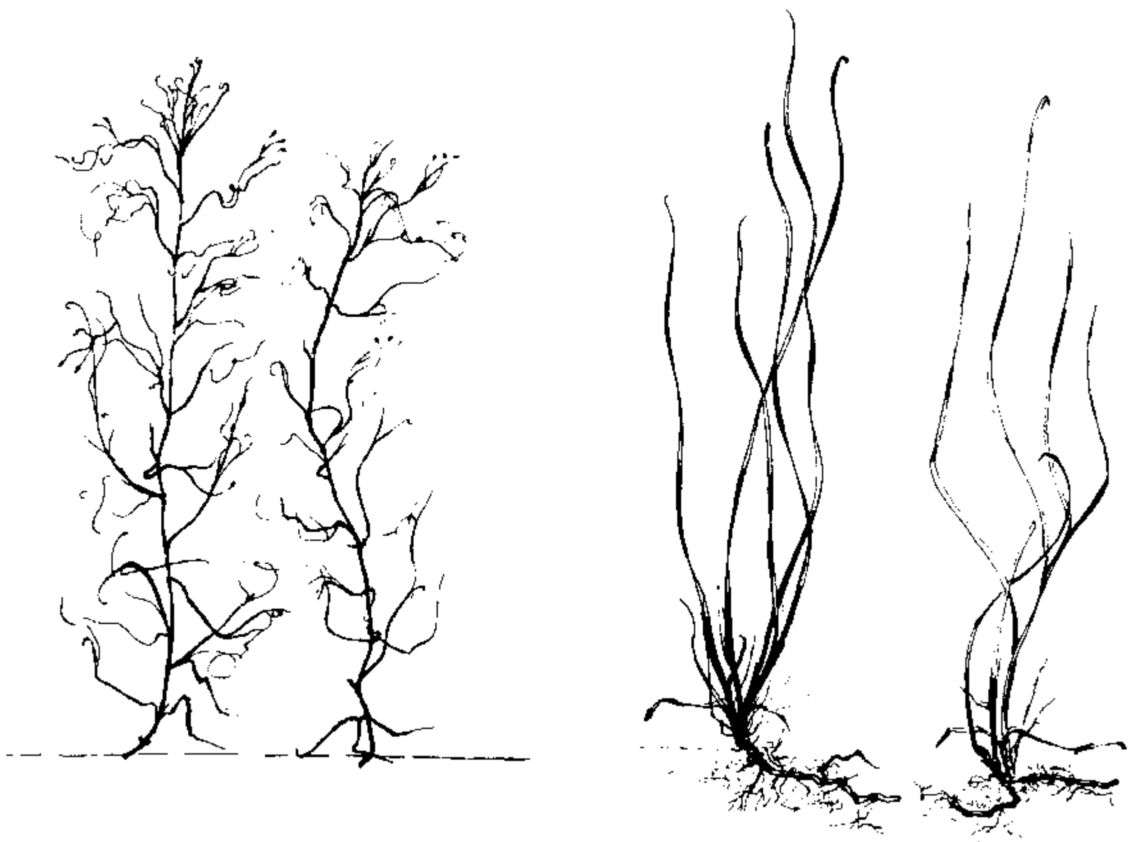


Figure 4. The two dominant sea grasses that grow in the ponds. Widgeon grass (Ruppia maritima), depicted on the left, is a preferred waterfowl food. After the breachways were stabilized, it was replaced by eelgrass (Zostera marina), depicted on the right.

which were a rare sight before the breachways but in recent years have become abundant. It is believed that changes in farming practices, primarily the planting of nearby fields with rye, have been a major factor in enticing geese to the ponds.

Another resource that was lost because of the breachways was the muskrat. Trapping of all sorts of animals used to be an important source of income to a surprising number of local residents. From 1925 to 1960, Charlestown, Green Hill, Quonochontaug, and Brightman's Ponds were trapped for muskrats by at least ten people (J. Serra, 1978 interview). Trapping normally occurred from November through December, and each man took about 50 muskrats per pond. An annual total of about 50 were taken from Trustom and 50 from Cards. At $4 and $5 per pelt, this provided some $1,000 extra income per person for two months' effort. With ten people trapping, the muskrat population of the ponds provided the area with at least $10,000 extra income. Trapping was especially heavy during the Depression and the world wars. There was virtually no muskrat population after the stabilized breachways were constructed. Since muskrats rely on cattail marshes, a brackish water habitat, and on constant water level, they could not survive the low tide exposure and the change to more saline marsh vegetation. Overhunting and loss of habitat to residential development probably also contributed to their demise.

These secondary effects of the stabilized breachways on the numbers of birds and mammals inhabiting the ponds are examples of the far-reaching and subtle results of management strategies. Even the direct effects of the breachways on fisheries and boating were unexpected, and in some ways contrary to the expressed goals. The breachways had multiple costs in terms of losing the brackish water fisheries, increasing sedimentation, and altering vegetation and waterfowl populations. Many of these could have been anticipated with careful study and some of the effects ameliorated. The breachways did achieve greater flushing of the ponds, which alleviated some symptoms of stagnation and eutrophication.

References

Browning, C.F. 1978 interview.

Browning, H. 1978 interview.

Cole, J.R. 1889. History of Washington and Kent Counties. W.W. Preston, New York. 1344 pp.

Conover, R.J. 1961. A study of Charlestown and Green Hill Ponds, Rhode Island. Ecology. 42: 119-140.

Dykstra, J. 1978 interview.

Goode, G.B. 1884. The Fisheries of Rhode Island. Part IV. The Fisheries Industries of the United States, Vol. 2. U.S. Commission of Fish and Fisheries. pp. 283-310.

Livermore, W.R. 1889. Preliminary examination of entrance to Point Judith Pond. Annual report of the Chief of Engineers, U.S. Army. pp. 642-643.

Lockwood, D.L. 1897. Survey of the inner harbor at Point Judith Pond, R.I. House Committee on Rivers and Harbors. 55th Congress. House document #132. pp. 1-5 (with maps).

Providence Sunday Journal. 1889. Wakefield's Hope; a breakwater and permanent breach at Point Judith. p. 1.

Rhode Island Public Works Department. 1911. Report to Committee on Potter Pond Breachway. May 15, 1911.

Serra, J. 1978 interview.

Simpson, E. 1977. A photogrammetric survey of back barrier accretion on the Rhode Island beaches. Masters Thesis, Univ. of R.I.

Smith, R. 1978 interview.

South Kingstown Town Council Minutes. 1900. No. 11.

Warren, G.K. 1874. Survey of Point Judith Lake (Pond), R.I. Annual report of the Chief of Engineers, U.S. Army. Appendix 10. pp. 117-120.

Whaley, C.T. 1968. Intrusions on Natural Domain Must be Understood. Providence Evening Bulletin. February 22, 1968. Letter to the editor.

Wood, R.D. and E.A. Palmatier. 1954. Macroscopic Algae of the Coastal Ponds of Rhode Island. Am. J. Botany, 41: 135-142.

Wright, T.J., V.I. Cheadle, and E.A. Palmatier. 1949. A survey of Rhode Island's salt and brackish water ponds and marshes. R.I. Dept. Agr. and Conserv. Div. Fish and Game. Pittman Robertson Pamphlet No. 2.

III. FISHERIES

History of Pond Fisheries

The ponds were important sources of fish and shellfish long before recorded histories of the area. Archeological excavations of summer encampments of Narragansett Indians atCharlestown and Potter Ponds provide evidence of the bounty of the ponds in Colonial times. There are large waste heaps at both sites dating from the 1600s with oyster, quahog, and soft-shell clam shells scattered through them. Typically, the Narragansetts arrived at their shore fishing camps in early spring, after a winter spent inland in forest hunting camps. They planted crops on the coastal fields and harvested shellfish, much of which they dried for the winter. Fort Ninigret on Fort Neck Cove in Charlestown Pond was one such summer fishing camp. Large waste heaps of good-sized oyster shells are evidence of the prodigious oyster crop the ponds yielded in the 1600s. A midden at Fort Ninigret consists of about 65% oyster shells, 25% softshell clam shells and the rest miscellaneous (Salwen and Meyer, 1977). The Fort was also an important wampum manufacturing site, where valuable purple wampum was roughly cut from quahog shells to be finely worked later at winter camps. The chips of purple shell indicate that quahogs must also have been abundant in the pond.

Later, as the coast was settled by farmers, the ponds continued to be valuable and bountiful sources of fish and shellfish. Since the pond's breachways were open only intermittently, the ponds were much more brackish than they are today and supported large populations of brackish species among which alewives, perch, and oysters were particularly abundant. Figures 5 and 6 are drawings of the major fish and shellfish in the ponds. For years through the 1860s and 1870s, over 6,000 barrels of alewives and 1,000 barrels of perch, eels, smelt, flatfish, clams and oysters were taken out of Point Judith Pond (Providence Sunday Journal, 1889).

Buckeyes. The ponds abounded with buckeyes (alewives), anadromous herring-like fish that each spring migrate along the coast and into freshwater to spawn. In the 1700s, large numbers of buckeyes were caught commercially in the coastal ponds. According to C.F. Browning (1973), they were salted, packed, and shipped by the barrelful to the West Indies and South America, where they were traded for "logwood," a natural dye used used for cloth. From 1600 to 1900, salt was crucially important for preserving fish. About one bushel of salt (70 lbs.) was used to preserve a barrel of fish (200-250 lbs.) (Gersuny and Poggie, 1973). During the Revolutionary War, trade stopped when the British swept the sea clear of American ships. After the war, trade resumed. About 1,000 barrels of pond buckeyes were annually shipped from Narragansett and South Kingstown in the 1800s (Narragansett Times, 1887; C.F. Browning, 1973). At an average of 400 fish per barrel worth 1¢ each, this amounted to $400,000 worth of buckeyes per year, a tidy sum in the 1800s. By the 1920s, the buckeye trade ended because the Germans had invented synthetic dyes to replace the natural ones. After 1920, buckeyes seined in coastal ponds were used for lobster bait, or smoked and sold for local consumption. In the 1920s and 1930s, Green Hill Pond and Foster's Cove in Charlestown Pond yielded 130 barrels of buckeyes each spring to a local fisherman, at the time worth $4.30 per barrel, half of which was profit (C.F. Browning, 1977 interview). During the 1920s through the 1940s, 12,000 to 18,000 fish were sold annually by C.F. Browning to local stores. A fisherman could make $100 in 6 weeks, a good income when wages were commonly $20 per month. In those years there were 12 to 15 smokehouses of

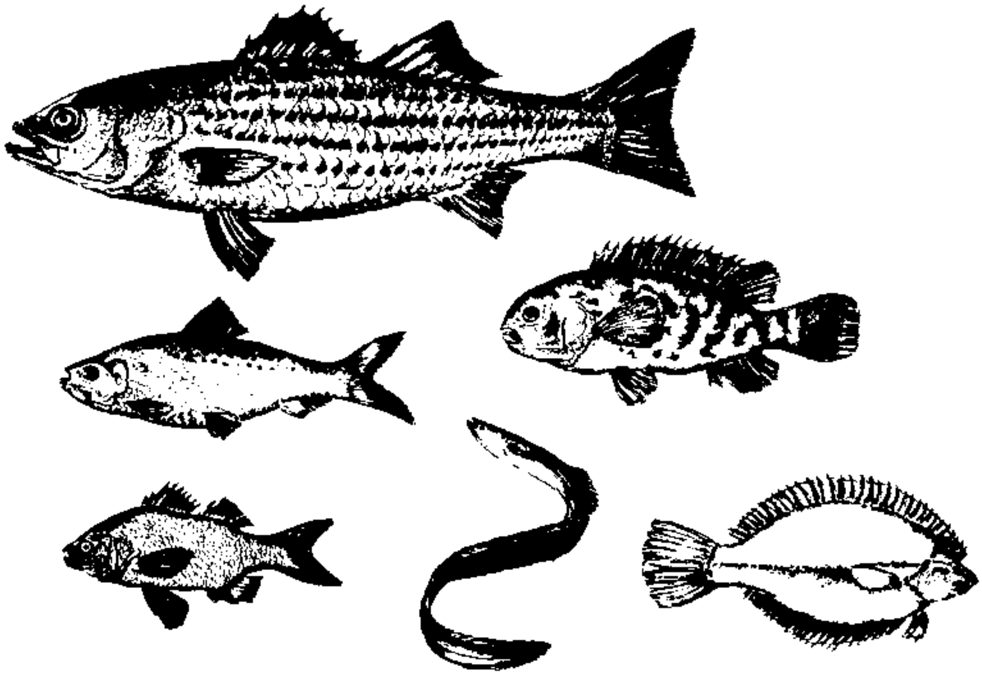


Figure 5. Major finfish in the coastal ponds. Top: striped bass. Middle: alewife of buckeye (left), blackfish or tautog (right). Bottom: white perch (left), eel, winter flounder (right).

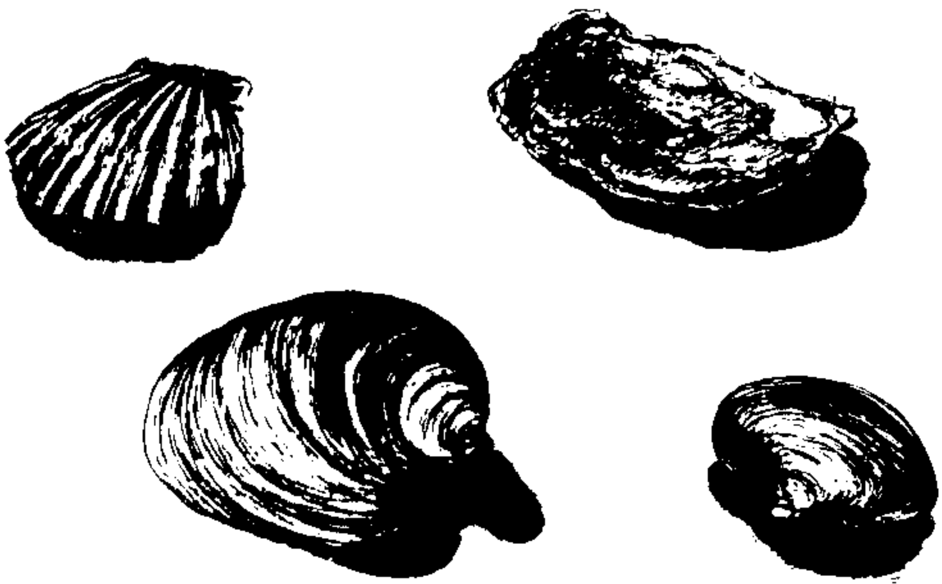


Figure 6. Major shellfish in the coastal ponds. Top left: bay scallop. Top right: American oyster. Bottom left: hard clam or quahog. Bottom right: soft-shelled clam or steamer.

of different size along the south shore, all smoking buckeyes caught in the ponds. An average house held 2,000 fish on smoking racks. The local buckeye fishery in Charlestown and Green Hill Ponds was lost when the breachway was permanently opened in the 1950s, as it had already been in Point Judith and Potter Ponds in the early 1900s. Apparently, the salinity in the ponds increased to a level that was no longer conducive to spawning for the large numbers of buckeyes that supported a fishery. A few still inhabit the back coves and provide a small harvest.

White Perch. White perch provided another lucrative seasonal fishery. Typically, they were fished from October to May, caught in 600-foot seines that were about 12 feet deep. The nets were sewed by local women with hemp twine made in the local water driven twine walk at Green Hill or shipped in to Narragansett Pier from Boston (Browning, 1973; Narragansett Times, 1939). A fishing gang of two to six men would haul seine regularly during the season. They stored their gear in shacks along the edge of the ponds. Other men went into business carting salt and barrels to the shacks, and barrels of salted fish back to town to be shipped by rail or by boat to New York's Fulton Fish Market.

Widgeon grass grew so thick in the ponds before the permanent breachways that special "grass seines" had to be used. These were weighted with about 125 pounds of lead to hold the bottom down as the net was pulled through the grass. Wooden hoops were sewn to the bottom of the net to keep it from winding up in the grass. The extra weight made the nets so heavy that they were hauled in with the aid of a wooden capstain anchored on shore. The seine would be let out from a square-ended 18-foot skiff that was rowed in an arc from the shore. Once set, the seine would be hauled in by two to four men, depending on the size of the gang. Usually four men could haul a seine four times a day and two men two times a day. Buckeyes, perch, and bass were all seined in this manner. An artist's rendition of hauling seine is depicted in Figure 7 and a detail of the net is shown in Figure 8.

Perch were also fished under the ice in winter through openings maintained by the fishermen. The net would be carried out onto the pond and let down through a large hole in the ice. Once the seine was under the ice, it would be moved toward shore with long poles worked through a row of holes in the ice. The men would clamp wooden grips (known as "grampus") to their boots for traction (H. Browning, 1978 interview). The perch were sold fresh to local markets or salted and shipped to New York.

The fishermen made "pots," or holding pens, by closing off coves in the ponds with stone walls and wood fences. Fish would be dumped in the pots after each haul until there were enough to send to market. The fish in the pots would be fresh and accessible for months, a valuable quality in the days before refrigeration. Furthermore, they could be kept until the market offered the most advantageous price (Matzinger, 1977). Figures 9 and 10 are maps of Point Judith and Potter Ponds showing the locations of the old hauls and fish pots.

At least as early as the 1700s, Potter Pond was known as Fish Pond because of the excellent fishing there, and Perch Cove was labeled as such on the early maps. Potter Pond yielded over 300 barrels (60,000 lbs.) and Point

Figure 7. Seining in the ponds before the stabilized breachways. The net was laid into the water from the stern of the scow, as it was rowed in an arc from shore. Then it was hauled in with the aid of capstains. The fish were barreled and carted to shacks to be preserved in salt and packed for market.

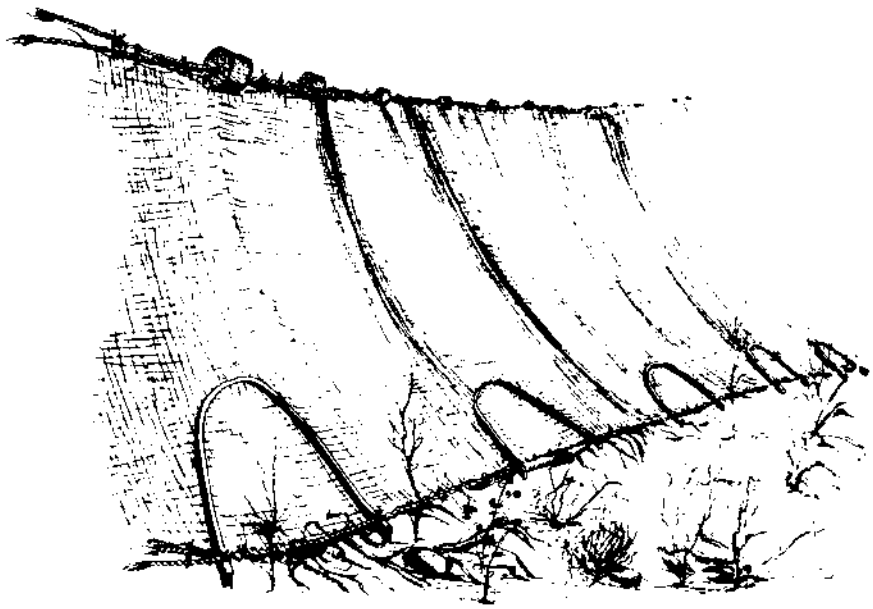


Figure 8. The grass seine. The bottom has extra weights to hold it down in the dense widgeon grass. The wooden hoops allow the net to slide over the bottom without getting entangled in the grass.

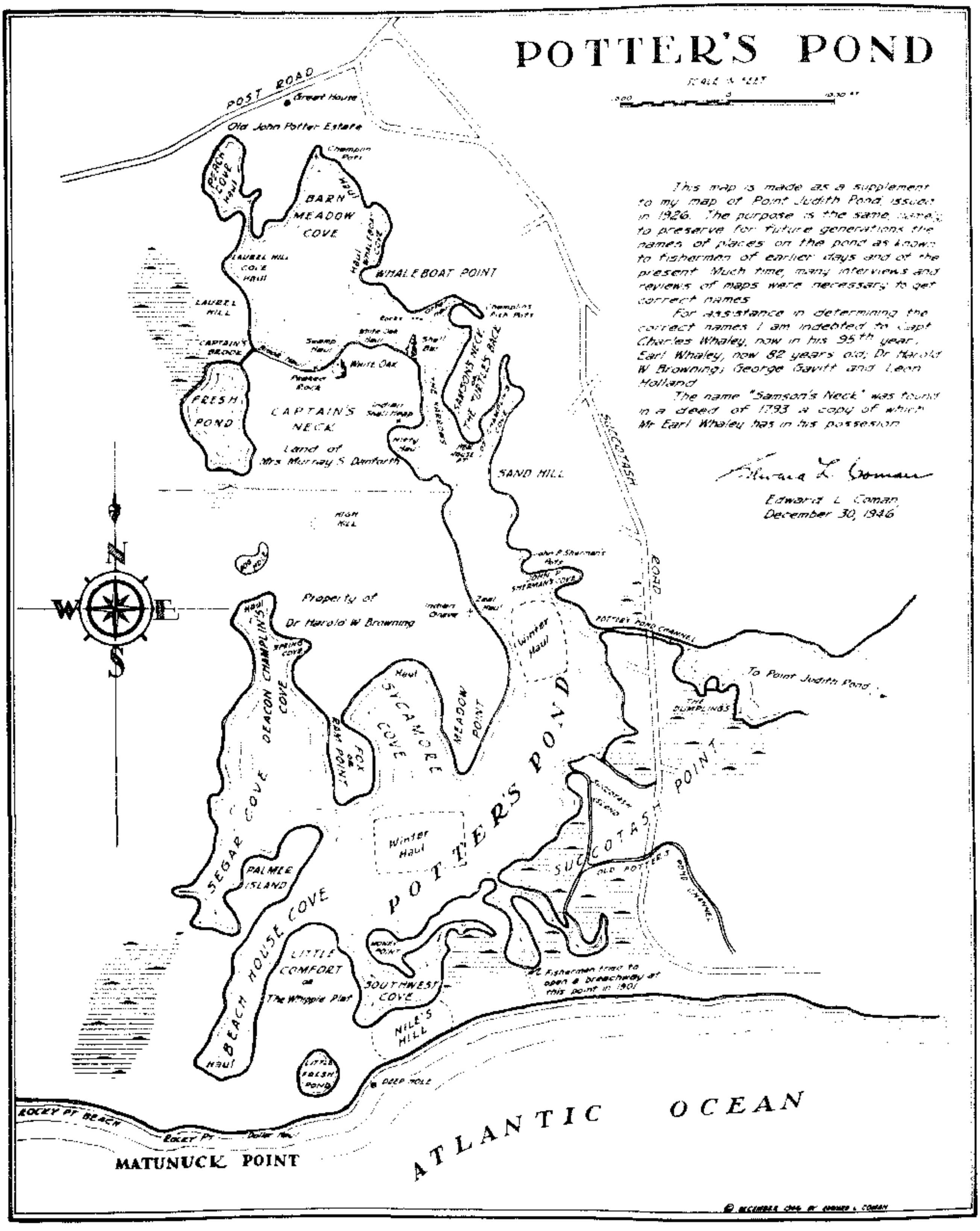


Figure 9. Map of Potter Pond showing locations of the "fishing hauls" or seining sites, and the "fish pots" where the catches were held until being shipped to market.

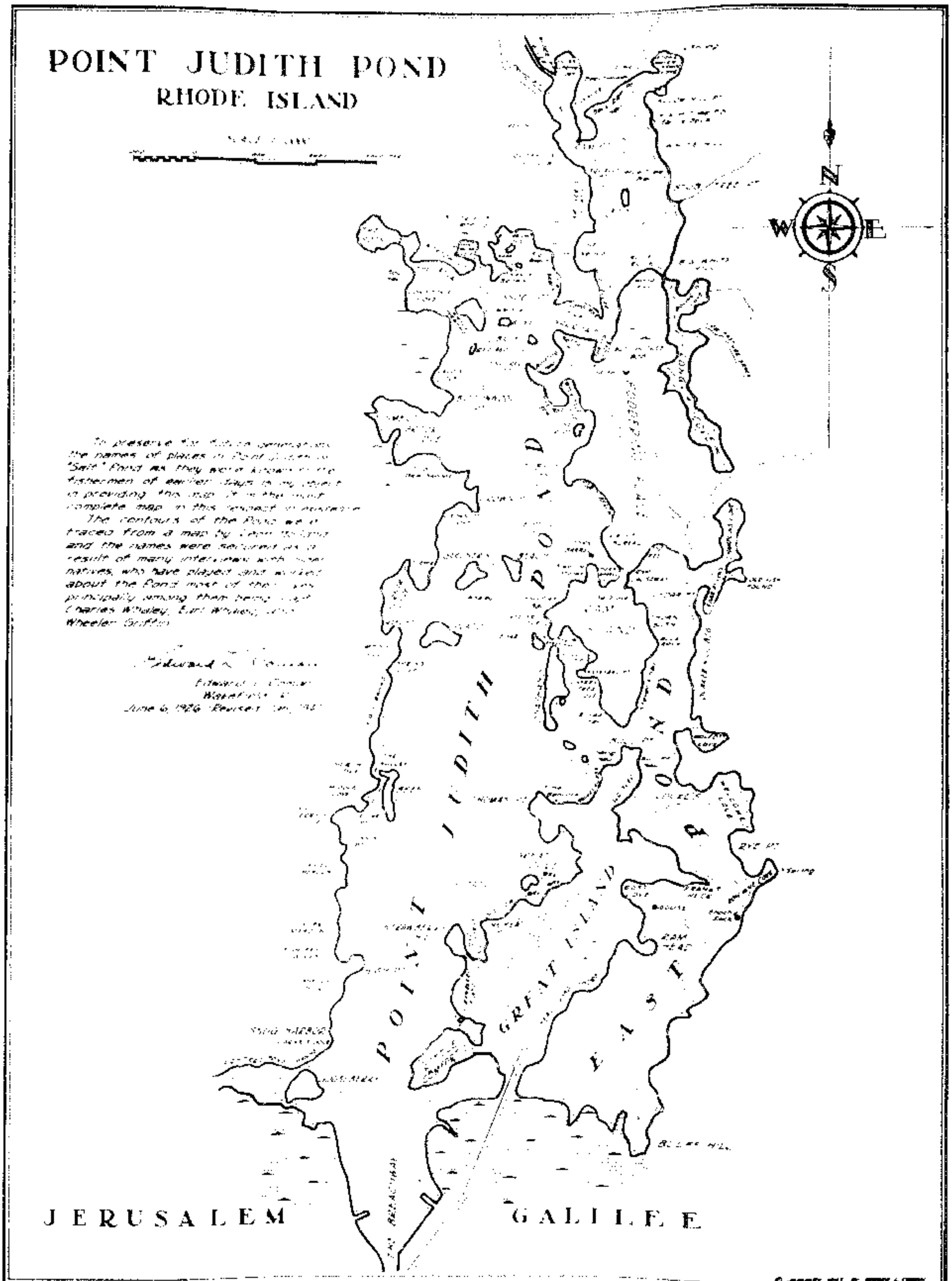


Figure 10. Map of Point Judith Pond indicating the old place names and locations of some of the fish hauls and pots.

Judith well over 1,000 barrels each spring in the 1800s (about 200,000 lbs.). Some of the best areas were the "spring holes" in Potter Pond, which attracted both the fish and the gangs of fishermen. The amount of fish caught in one haul in these areas would vary from year to year: 3 barrels in 1883, 30 barrels in 1888, 30 barrels in 1898 (Narragansett Times, 1939). But 30 barrels in one haul at about 200 pounds per barrel was a good-sized catch. The last big haul in Point Judith Pond occurred in 1894, when the Griffin gang got 40 barrels through the ice. In 1880, there were 21 seines hauling in Point Judith Pond. In 1902, when the new breach opened, there were nine spring seines and four winter gangs working the pond. After 1902, there were no regular gangs seining Point Judith Pond (Narragansett Times, 1939). The opening of the breachway in the early 1900s meant the demise of the perch fishery as well as for the buckeye fishery. White perch swim into brackish coves and inlets in the spring to spawn. When the salinity in the ponds increased with the construction of permanent breachways, the abundance of these fish dropped. Now local fishermen get only 800 to 1,000 pounds of perch each year from Potter Pond.

Charlestown, Green Hill, and Trustom Ponds were also seined for perch, but there is very little data available on the amounts taken. Prior to World War II, there were approximately four seining gangs that worked the Narrow River, four in Point Judith and Potter and six in Trustom, Cards, Green Hill, and Charlestown. In the 1930s, Foster Browning hauled 12 barrels of perch out of Trustom Pond. That one haul brought $700. More typically, he would get 5 or 6 barrels out of Trustom. In the 1950s, Thaddeus Holburton would get 1,000 pounds of perch a year from Trustom. But, as he explains it, one haul would "clean it out." Trustom became more and more fresh as the breachway was opened less frequently, and in the last haul taken, the fish were too stunted to send to market. Today, the perch fishery has disappeared from Trustom and Cards Ponds, as it has from the others, but it was because the water became too fresh rather than too salty for the perch to spawn.

In the 1920s, one gang caught 400 barrels at 400 perch per barrel from Fosters Cove in Charlestown Pond. Just after World War II, Thaddeus Holburton took 3,500 perch in one haul in Green Hill Pond. That year, from December to April, he got 50,000 pounds of perch from Green Hill, Trustom Pond and Fosters Cove in Charlestown. This good catch was apparently the result of little fishing during the war. Fosters Cove would regularly yield 1,000 pounds of perch per haul before the breachway was built in the 1950s. One year after the permanent breachway was constructed, there were not enough perch to make seining worthwhile in Charlestown Pond although they are seasonally a small portion of the commercial catch. There are still some fished in Green Hill, however, especially near the springs and freshwater stream outlet.

Striped Bass. At first, bass were caught by hook and line, later by seines. The first seine used in the ponds was made about 1840, and the first haul caught 40,000 striped bass in Point Judith Pond in 1845 (Whaley, 1939; Providence Sunday Journal, 1889). Fishing gangs would camp in fish shacks on the ponds and beaches during the spring while they fished both in the ponds and along the ocean. The fish would be barreled and salted and then carted to the railroad or pier to be shipped to market. One man carted 600 barrels of bass for three gangs around 1850, according to Whaley (1939). In 1867, Griffins gang took 198 barrels, about 37,600 pounds of striped bass, through the ice one day in Point Judith. This brought them $6,802. In December of the same year, the Whaley gang caught 30 barrels at Toby's Point. As much as 90 barrels of bass were caught in exceptionally good hauls. At 190 pounds of bass per barrel and a market price of 20¢/pound, a good haul meant a substantial income. Records and newspaper reports on Point Judith Pond indicate that there were about 21 seines with about four men per seine hauling in the pond in 1880. As a consequence of the large amount of fish in the ponds, many of the local farmers supplemented their incomes by fishing; nine out of every ten men within two miles of the ponds went fishing (Whaley, 1939). They could get a haul of fish in the morning, then farm the rest of the day, or, if members of a fishing gang, then could fish for weeks in the winter and spring (after the fields were sown) and then return to farming in early summer.

Bass were abundant up through the 1800s and then declined. By the 1800s, the breachway was so shoal that the migrating fish couldn't get into the pond. After a permanent breachway was dredged, the pond was so saline that fish no longer entered to spawn and bass fishing was poor from 1900 until 1910 (C.F. Browning, 1977 interview). Bass do not spawn in the ponds but migrate along our coast and apparently pursue bait fish into the ponds. When the salinity of the ponds increased after the breachways, large numbers of perch and alewives no longer came into the ponds to spawn and the bass stopped coming in to feed. This simple causal connection is complicated by the fact that the entire coastal bass fishery is subject to complex patterns of fishing pressure and spawning success. The population follows an erratic pattern of good and bad years regardless of changes in the coastal ponds.

Oysters. A history of the oyster fishery has been presented in the breachway chapter. As already noted, native oysters were abundant in all the ponds prior to the permanent breachways. Point Judith, however, has the most interesting history. In the 1800s there were abundant oyster beds in the pond. Farmers could rake as much as 20 bushels in a morning, fill a wagon and cart them home or to market. For a few years after the breachway was built, in 1906, natural oyster set burgeoned all over the pond. The town leased out portions of the pond bottom to citizens interested in maintaining ground for an oyster fishery. Huge quantities of oysters were commercially grown in the pond, originally from natural set and eventually from set brought in from Jamestown and other South Shore ponds. Point Judith Pond was one of the most important managed oyster grounds in the state prior to World War I.

In the 1920s and 1930s, thousands of bushels of oyster seed were obtained from Trustom and Charlestown Ponds and put out on the leased beds in Point Judith Pond. Although beds were leased from 1908 to the last lease, which was issued in 1968, the commercial fishery had started to decline by the 1930s. After the breachway was opened, the productive beds gradually retreated up the pond to fresher waters. Prior to the 1930s, oysters were still good-sized above the Narrows and in Long Cove in Point Judith Pond. The Dykstras had commercial beds in the narrows from 1914 until the 1930s, when the state closed them because of sewage pollution in the upper pond. Apparently the hurricane of 1938 and 1954 smothered the beds on the southern ends of all the south shore ponds. Oysters were plentiful in East Pond before the old causeway was removed and the bridge to Great Island was put in, about 1954. Increased tidal exchange, high salinity and additional predators such as drills and starfish caused the decline of the indigenous oysters.

Oyster fisheries flourished in the other ponds too, although they were not as extensive as in Point Judith Pond. There were good natural oyster sets in Segar and Seaweed Coves in Potter Pond until the pond was permanently breached in 1910 (T. Wright, 1977 interview). There were also extensive oyster beds in Charlestown and Green Hill Ponds before the breachways. It is evident from the large numbers of large-sized oyster shells found in Indian shell middens in Fosters Cove and Fort Neck Cove in Charlestown Pond and f. .u an excavated Indian encampment on Potter Pond that oysters were abundant in the ponds at least since 1000 A.D. (Salwen and Meyer, 1978). Oysters grew in dense beds along the back of the barrier beaches and in bars that are still present as heaps of dead shells that form shoals today. In the late 1800s, the state commissioned the Charlestown breachway to be dredged and reinforced to enhance the oyster stocks in Charlestown Pond as a source of set for the lucrative Narragansett Bay oyster fishery. In the 1930s and 1940s, commercial oystermen used to get 20 bushels of seed oysters a day from Green Hill Pond to seed their beds in the Bay. From Trustom Pond too, over 1,000 bushels of oysters were taken per year as seed for the commercial fishery (C.F. Browning, 1977 interview). Around 1930, truckloads were taken from Trustom to seed the Dykstras' beds in Point Judith Pond. However, most of the oysters harvested prior to the 1930s were consumed by local families. A few days after the Trustom breach was opened, and the oysters were tastier because of the salt water, local people from farms as far away as Kenyon and Shannock would come for the oyster harvest. They would get 8 to 10 bushels per family and store them in barrels in back of the house all winter, thawing and eating a portion whenever they wanted.

In a pattern similar to that in Point Judith, the oysters grew and were plentiful for a few years after the breachway opened in Charlestown and Green Hill Ponds. Then an absence of new set was noticed. The natural oyster population declined, receding to back coves where freshwater springs and streams maintained more brackish conditions conducive to spawning and inhospitable to predators.

Bay Scallops. With the building of the stabilized breachways, the abundant brackish water fisheries faded, and the smelt, buckeyes, perch, and oysters gave way to more salt-tolerant species such as flounders, quahogs, and bay scallops. Bay scalloping replaced oystering as the next major fishery in Point Judith Pond and increased during the 1930s as the oyster fishery declined. Either because seed scallops were brought from the Kickamuit and Warren Rivers and planted in lower Point Judith Pond in 1929 or because the breach caused increased exchange of pond and offshore waters, bay scallop population and the fishery in Point Judith flourished through the 1930s, 1940s, and 1950s. Scallops were first seen at the southern end of the pond, and they moved north year by year. An average of 300 loads of scallops a day (17 bushels were taken from the pond during the first 30 days of the season in the 1940s (Whaley, 1978 interview). According to Thomas Wright, past director of Fish and Game of the Rhode Island Department of Natural Resources, during the first

60 days of the excellent 1940 season, it was estimated, 250,000 bushels of bay scallops were taken by licensed boats in Point Judith Pond. At that time, there were about 600 licensed boats dredging for scallops from October to December. The boats would drag four to six scallop dredges behind them and bring the scallops into dock by the end of the morning when the boat was full. Family and friends would shuck the catch in the afternoon (Babcock, 1978 interview). A scallop dredge is depicted in Figure 11. Most of the scallops were sold through local fish markets and restaurants. The rims or scrap meat (called gurry) shucked from the eye muscle was used to bait eel pots.

Bay scallops also came into Charlestown Pond after the permanent breachway was built in 1952. In 1952, seed was taken from Point Judith to seed the other ponds. However, the fishery has never been as extensive in other ponds as it was in Point Judith Pond. Apparently, Potter and Green Hill Ponds are too brackish to support an abundant scallop population. Scalloping does not occur in Trustom or Cards Ponds because neither has sufficient exchange with the sea.

Present Fisheries

At present, the major fisheries in the ponds are blackback flounder, eels, quahogs, and scallops. There is some effort at culturing oysters. A small number of fishermen support themselves by commercially fishing the ponds and a few supplement other incomes by fishing after work and during vacations. Some rough estimates have been made of the commercial catches. There is also a sizable recreational fishery effort in the ponds, but it is very difficult to estimate the numbers of participants and their total catch. Consequently, it is difficult to compare commercial and recreational catches.

In order for a fisherman to support himself, he must be able to switch from one fishery to another as the seasons progress, a common pattern in near-shore fisheries. In midwinter, quahogs and oysters are fished in Charlestown and Green Hill Ponds and quahogs in Point Judith. Flounder are commercially fished in the fall and spring. Later in the spring, perch and striped bass dominate the fishery, followed by eels in the summer and bay scallops in the fall. Although perch and flounder are present in the summer, they are considered to be too sparce to warrant commercial efforts. Most of the recreational fishing occurs in the summer and it is for quahogs, flatfish, tautog, bass, and other finfish. All summer long, especially on weekends, there are great numbers of people fishing from breachways, docks, bridges, and skiffs while clammers work all accessible flats.

Winter Flounder. Winter flounder support the major finfishery in the ponds today. The adult flounder come into the ponds to spawn from December through April. Although some are washed out with the tides, most of the larvae that develop from the spawn stay in the pond over the summer. The following spring, many move offshore as juvenile fish. It has been shown that the ponds are very important spawning grounds and nursery areas for the flounder that stock the offshore fishery. Saul Saila in 1961 estimated that Charlestown and Green Hill Ponds are the source of 25 percent of the Block Island Sound fishery.

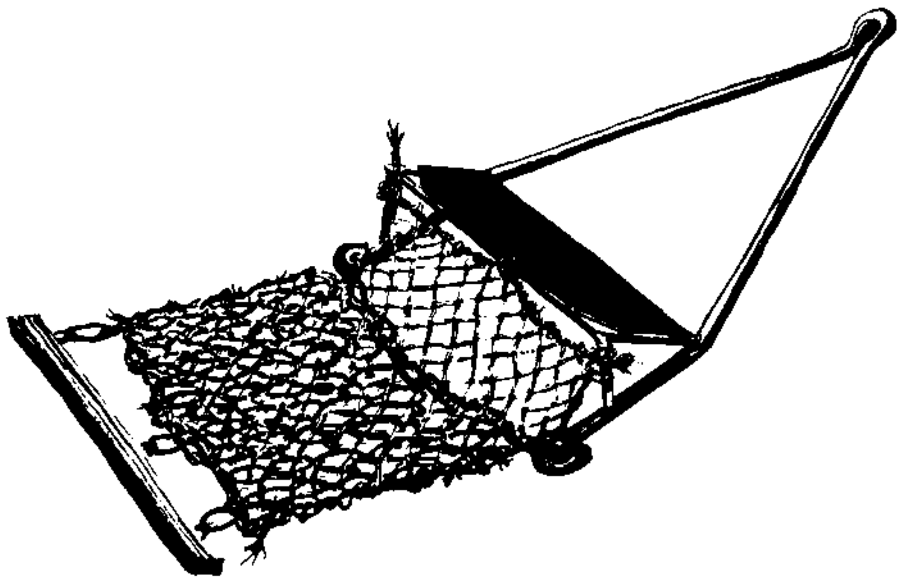


Figure 11. A drawing of a scallop dredge which is towed behind a boat. It consists of a vane that holds the dredge down, a metal frame and a ring mesh bag that will withstand the abrasion of being dragged over the bottom. The wooden bar assists in dumping the contents on deck.

Prior to World War II, flounder were considered trash fish and catches were not compiled for this species. Consequently, there is no way to compare the present flounder catches quantitatively with those of the past. It is known that they did inhabit the ponds before the breachways were stabilized. Apparently, before the permanent breachway, the flounder used to enter the ponds more readily than did the perch or buckeyes. Men would go down and spear them as they swam in and out of the shallow, twisting natural breachways. They were also caught in seines and fyke nets in most of the ponds, although there is no record of numbers caught by these methods.

At present, there are two commercial fishermen who trawl for flounder in Charlestown Pond and there are two or three who set fyke nets for flounder in Potter and Green Hill Ponds. A fyke net is a tube-shaped net that is staked to the bottom (see Figure 12). It is often not visible at the surface. Those used in the ponds have leaders of 50 to 100 feet and an opening of 6 to 7 feet. Inside the net and holding it open are hoops and funnels of netting. They are flattened so they will not roll along the bottom. A fisherman typically sets about six of these nets in a pond and hauls them every two to three days. Fyke nets are particularly effective in catching flounder, and they are usually used from March through May and from September until late November, or until the ice sets in.

Between the part-time and full-time commercial fishermen, an average year presently yields about 20,000 pounds of flounder from Charlestown Pond; an additional 12,000 pounds are split fairly evenly between Green Hill and Potter Ponds. There are not enough flounder in Quonochontaug to make it worth fishing, according to the local fishermen. Point Judith Pond is too populated with boat traffic and there are too many people tampering with nets and buoys. In addition, it has stronger tidal currents than the other ponds. Even though there are more flounder in Point Judith than in the other ponds, it is not fished commercially. Commercial flounder fishing, therefore, occurs primarily in Charlestown, Potter and Green Hill Ponds. The fish are sold to local markets and to the Fishermen's Co-op in Point Judith, which ships them out of state.

Recreational fishing, from the shore and from boats, is a popular pastime in all the ponds. Of the variety of fish caught by hook and line, winter flounder dominate (other species include scup, striped bass, mackerel, tautog, summer flounder, sea robins, and conners). According to a survey by T.P. Smith and K.E. McConnell of URI in 1979, an estimated 7,000 recreational finfishing trips were made to Charlestown and Green Hill Ponds and 10,000 trips to Point Judith and Potter Ponds in the spring and summer (April-July). It is estimated that the catch was bout 6,000 winter flounder from Charlestown and Green Hill and about 47,000 flounder from Point Judith and Potter. Apparently, most of the flounder taken in Charlestown and Green Hill Ponds are taken from small boats, while in Point Judith and Potter most successful fishing is done from the shore, particularly along the breachway jetties. An additional difference between the fishermen in the two ponds is that two-thirds of the sport fishermen at Point Judith and Potter Ponds are Rhode Islanders, while more than half those fishing Charlestown and Green Hill Ponds are from out of state, primarily from Connecticut. Assuming that the estimates from the recrea-

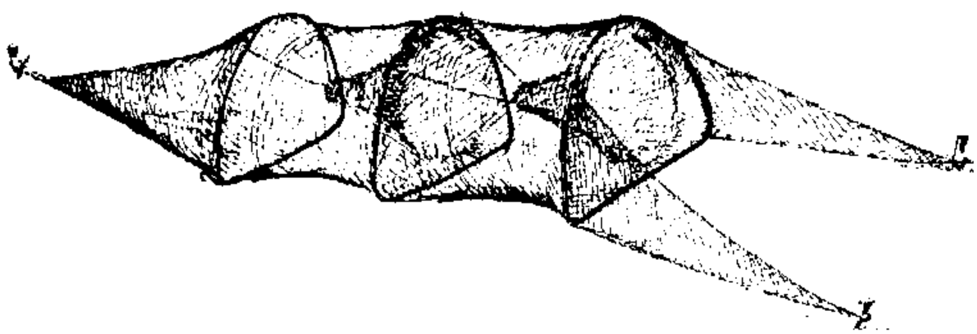


Figure 12. A fyke net is used to catch winter flounder commercially. The net is staked to the bottom of the pond and the fish enter the broad end of the funnel and then are trapped inside. A leader or line of net (not depicted here) comes off the front end that leads the fish into the trap.

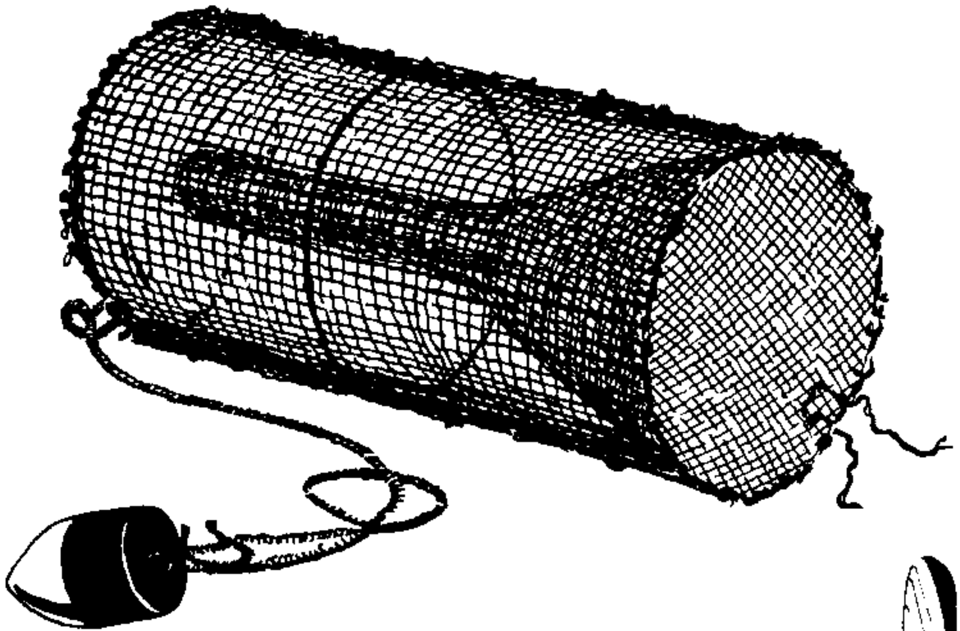
tional fishing survey do give an accurate approximation, and assuming the average flounder caught in the ponds weighs a little less than half a pound, then the recreational fishery is about the same size as the commercial flounder fishery. However, the sport fishery occupies many more people and may be a much larger source of revenue to the local economy in terms of money spent in local trade for food, gas, and gear.

Eels. Eeling is presently a major commercial fishery in the ponds. From May through November eels are captured in pots or traps baited with mussels, squid, horseshoe crabs, or scallop rims during scallop season. Pots came into use about 1900. Prior to that, eels were caught with spears or even with seines. They are still speared through the ice in wintertime. With a 16-foot-long pole, a competent fisherman can spear about five eels out of a one-foot hole in the ice. As many as 33 eels can be caught per hole in the ice if the fishermen are lucky enough to find a pocket of muddy bottom in which the eels are concentrated. Figure 13 is an artist's rendition of an eel pot and the barbed eel spear.

Whereas eels used to be eaten locally or shipped by the barrel (200 pounds of eels per barrel), to New York City markets, they are now bought by a few specialized buyers who export them to burgeoning European markets. In Europe and Japan, eels are considered a great delicacy, and an increasingly rare one since local stocks have been overfished. In 1972, the annual export of eels from the U.S. was estimated to be 24,000 tons to Europe and 25,000 tons to Japan (Jurgensen and Crow, 1977) and this has since increased. Every week a tank truck comes down from an export firm in Massachusetts to collect live eels from salt pond fishermen. The eels must weight over 100 grams and be alive and in good condition. They are bought for about 50¢/lb. In 1977, about 50,000 pounds of eels were taken from the ponds (Feiner and Steiger, 1977). The fishery is becoming more and more popular. Eel pots are simple to maintain, and can be set and hauled easily before or after a regular job. There are probably some 20 people fishing eels in the ponds from May to November.

Quahogs. Quahogs, or hard-shelled clams, have been an important shellfishery ever since the permanent breachways increased the salinity of the ponds. There is some commercial quahoging in all the ponds, and the catch varies from 200 pounds to over 4,000 pounds per fisherman per year. In the early 1950s, there were about 10 commercial diggers on Charlestown Pond and about 20 on Point Judith. Now there are approximately half that many. Most of the fishing effort is recreational. Especially during the summer, hundreds of recreational quahoggers frequent the shallow flats that lie behind the barrier beaches in all the ponds. The intertidal flat north of Galilee escape road in the East Pond of Point Judith is a particularly popular spot.

Bay Scallops. The bay scallop fishery has also been a very important commercial and recreational shellfishery in the ponds ever since the opening of the breachways. However, the bay scallop has mysteriously come and gone, while the quahogs have steadily supported a fishery. From 1960 to 1977, there were not enough scallops in the ponds to support a fishery. In 1969 Rhode Island's



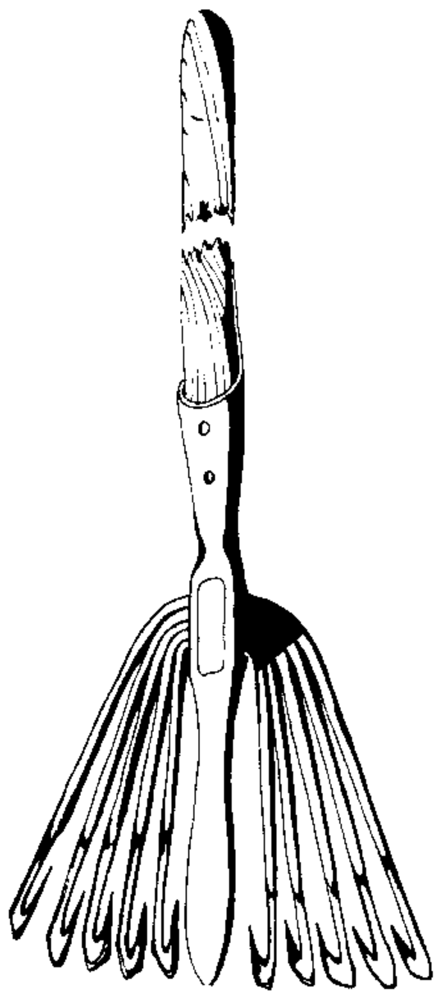


Figure 13. Eel pots are baited and set on the bottom to trap eels. The barbed eel spear attached to a long handle is worked from the surface. It is jabbed into the mud and eels are caught on the barbs as it is brought upwards to the surface.

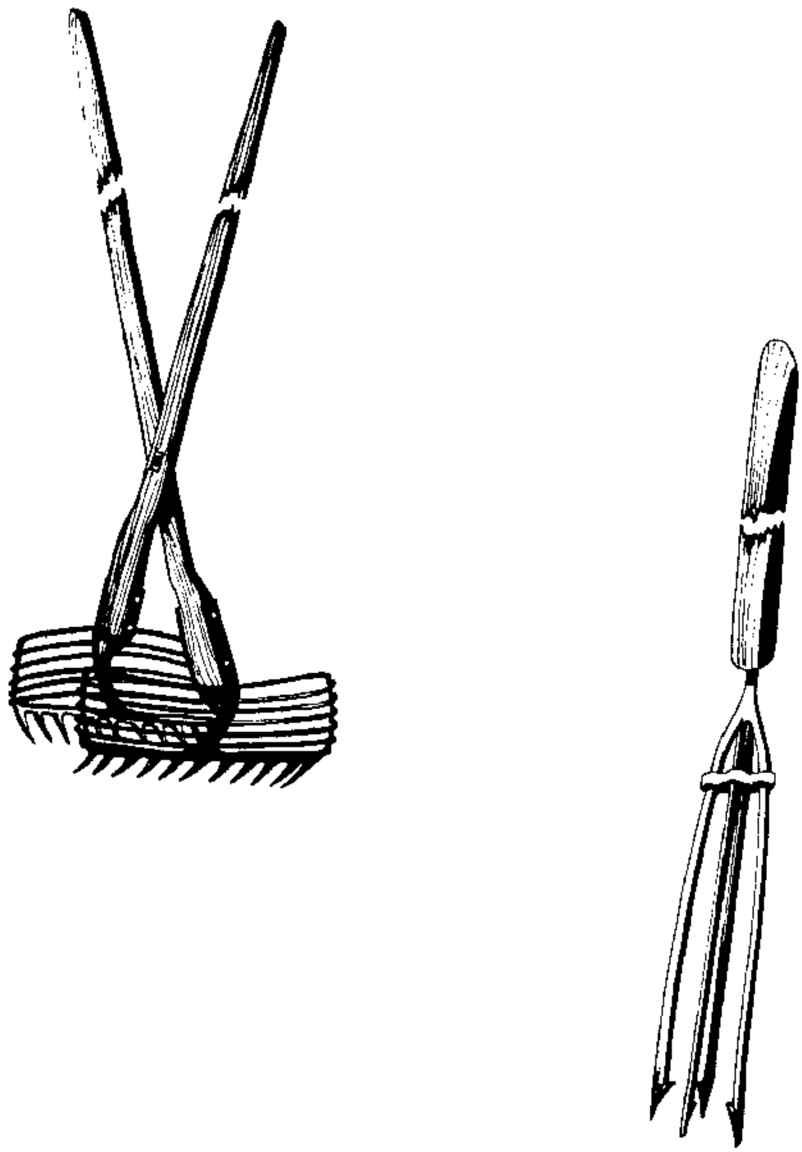


Figure 14. Quahog fishing implements. The tongs are worked in a scissor-like motion by a man in a boat. As they are scraped from the bottom, quahogs are held in the baskets and then lifted up into the boat. The four-pronged devise is attached to a long pole and also worked from above. The prongs are sprung so that when they are forced down over a clam, they grasp it and it can be pulled up out of the bottom.

Department of Environmental Management (DEM) seeded Point Judith Pond with seed from Long Island. 1970 was a good scallop year. Each year from 1976 through 1979 DEM seeded Charlestown Pond but not Point Judith. There were good scalloping years in both ponds from 1977 through 1979. It appears that virtually no seed has survived to support a fishery in 1980. Scallops, unlike quahogs, steamers, or mussels, generally live only one to two years. Since they mature and spawn in their first year, the adult population can be fished intensively, since few will survive to the second year anyway. However, there is no resident spawning stock to keep the population going if the young of the year are damaged by environmental changes or fishing activity. The fishery effort for scallops is very intense and short-lived, with the season limited to the fall months, from September to December.

Oysters. At present, there are small oyster populations in the brackish back coves, where fresh water from springs and streams lower the salinity of the water. Potter and Point Judith Ponds still harbor a few oysters in the upper reaches, and Green Hill Pond has quite an abundant population but the oysters seem stunted and have thin, soft shells riddled with holes from parasites or predators. In Charlestown Pond, a natural set still occurs in Fosters Cove, Fort Neck Cove and along stretches of gravelly shoreline. The populations are small and are closely cropped by the local residents.

In recent years, there has been renewed interest in the potential of oyster culture. Several fishermen have rafts for collecting spat in Charlestown, Green Hill, and Potter Ponds. They plan to either grow out the oysters in hanging culture or set them out on leased portions of the pond bottom to mature. These are pilot projects and as yet there is no indication of their commercial viability.

Major Problems Facing the Pond Fisheries

Overfishing. A general concern among residents around the ponds is that too many people are fishing a limited resource and therefore the stocks of finfish and shellfish are being depleted. Local residents note the herds of people on the intertidal flats, in boats, on bridges and breakwaters, and are indignant and alarmed. Commercial fishermen are certain that sport fishermen are irresponsibily depleting the resource. The sports fishermen are equally convinced that the commercial interests are doing the same. However, there is virtually no quantitative information on the size of the various stocks, on the amount of effort, or on the effect of fishing on the various populations. A research project at URI is underway that is designed to acquire this information.

Are the flounder being overfished? Although it is difficult to tell quantitatively, the commercial fishermen's assessment is that the stocks have not decreased significantly over the last decade. There are two commercial fishermen in Charlestown Pond. It is in essence a fishery closed to and cared for by them. They have fished the pond for years; they know the patterns of the fishery and are careful to husband the resource so that it lasts. As of yet, the fishery appears not to have been overexploited. However, there is growing concern on the part of these men that too many part-time fishermen are hurting the fishery. The sportsmen, on the other hand, are convinced that commercial fishing is depleting the stock. Data is presently being gathered by the URI research team to assess how many people fish the ponds and how the fishing effort varies over time in order to determine whether or not the flounder are being drastically depleted.

Since the numbers of people commercially fishing for eels, as well as the number of pots per person, is steadily increasing, there is concern that the eel fishery will be overexploited. It is an easy fishery to enter; requiring little capital investment, time, or skill, and as such can readily bring too much fishing pressure on a limited resource. Furthermore, there are indications that other eel populations along the Northeast coast are being overfished. For instance, the mouth of the Merrimack River in Massachusetts used to yield 100,000 pounds of good-sized eels a year; it now yields 80,000 pounds a year, but they are all under 100 grams and therefore too small for export. A population dominated by small eels is indicative of overfishing. In contrast, the Rhode Island pond eel fishery yields consistently good-sized eels, according to the buyer. The undersized eels are sold locally as bait. The total commercial catch has been about 50,000 pounds for 1977, 1978, and 1979. However, very little is known about the population dynamics and potential sustainable yield of pond eel populations. There has been some research (Bieder, 1971) on the population in Point Judith Pond, which indicates that eels stay in Point Judith Pond until they are eight or nine years old and then migrate to sea to spawn. Aside from this research and the catch records of buyers, there are few data available. Studies should be undertaken and management policies considered in case fishing effort does become too great.

There is great concern on the part of local residents as well as people who commercially and recreationally shellfish in the ponds that the quahogs are being drastically overfished. The evidence, however, is only anecdotal. Typical comments are: "In the 1950s, one could fill a bucket with quahogs in one hour; now it takes two or three hours to get half a bucket. You're often lucky to get anything. What clams are to be found are only the size of a 50-cent piece or smaller, a sure sign that the large ones are being overfished. The flats where the recreational people usually fish are all overfished, people take many undersized clams. The warden does not enforce size limits." There is also considerable concern that much of the recreational quahogging is done by people from Connecticut who are viewed as irresponsibly ravaging a Rhode Island resource. The general concensus is that because of overfishing, access to the resource should be limited; there should be more comprehensive management policies and the rules that exist should be enforced.

Pollution. There is widespread feeling that gas and oil pollution from outboard motors has had a dramatic effect on the larvae of all the major fish and shellfish in the ponds. Again, there are not data to substantiate this view, but it is a concern that is frequently voiced. The problem if it is real will increase as greater use is made of the ponds for marinas, waterways to the ocean, waterskiing, and motorboating.

Some lifelong observers maintain that oil pollution caused the demise of the scallop fishery. In the 1960s there were large oil slocks over sections of the pond surface from the crankcase and carburetor drippings of outboard motors. Oil slicks were a common occurrence from old outboard motors that burned a higher ratio of oil to gas than do more modern designs. By 1972, motors were built that recycled the excess gas and operated on leaner oil mixtures (Chmura and Ross, 1978). Conditions have improved since then. Now there are occasional slicks from creosoted pilings used for private and public docks and marinas. Creosote is a preservative derived from petroleum, and petroleum hudrocarbons are known to be toxic to the larvae of marine organisms.

The loss of the scallop fishery may have also been due to overfishing or to other environmental factors or both. There is some indication, at least in Point Judith Pond, that the scallop set was initially concentrated toward the southern end of the pond. The concentration of scallops slowly moved up the pond year by year, perhaps because planktonic larvae were swept up the pond along the bottom. Since salinity decreases away from the breachway, the scallops may have moved up the pond to a point where salinity was too low for them to spawn. Thus, the fishery dies out. Basically, however, little is known about the dramatic changes in bay scallop populations in all southern New England waters as well as in the ponds. No one really knows what triggers the population to take hold or die off. Recently the State of Rhode Island has been transplanting scallop seed to the pond in an attempt to revitalize the fishery. There is, however, no correlation between these activities and abundant scallop years.

Eutrophication. Pollution from excessive fertilization is also considered to be a major problem in the ponds, particularly in coves where circulation is sluggish. It is thought that nuisance algae are increasing because of increased nutrients coming into the ponds from surrounding residential developments. Flounder fishermen report that algae are becoming more and more dense on the pond bottom and fouling their nets. Trawls come up with about 12 bushels of algae with each bushel of flounder even though most of the algae passes through the 4½-inch mesh in the net. The abundance of algae is not only an impediment to fishing. When the temperatures rise in late summer, oxygen is used up by decomposing algae, making it scarce for bottom-dwelling organisms. When oxygen levels are very low, young flounder either leave the pond or die of suffocation. After oxygen levels are depleted, toxic hydrogen sulfide is often produced, causing the rotten egg smell that lurks over mud flats and back coves. The increased algal growth may be making the pond environment less hospitable as a nursery and spawning area for a variety of fish and shellfish. For instance, in the summer of 1978, Fosters Cove in Charlestown Pond went anoxic for so long that the oyster spat growing on the aquaculture rafts died.

Since there has been no monitoring of basic parameters such as nutrient and oxygen concentrations or primary production, it is difficult to know whether or not eutrophication is an increasing threat to pond life. Even though development is increasing around the ponds, which adds nutrients from septic leakage, road runoff, and lawn fertilizer, there may have been low-level inputs of fertilizer from cultivated fields that surrounded the ponds in the 1940s and 1950s. Surveys of the general ecology of Charlestown and Green Hill Ponds were conducted by URI investigators in the late 1950s (Conover, 1961; Saila, 1961, 1966; Smayda, 1962; Fish, 1964). Comparison of these data with surveys done for NEPCO in the 1970s (Marine Research) and the URI pond research being conducted now may help answer the question at least for these two ponds. Present research will measure nutrient inputs from runoff, septic seepage, groundwater, tidal flushing, and benthic regeneration, as well as production of algae, eelgrass, and shellfish. These data will be used to assess whether or not eutrophication is increasing to the detriment of the pond fisheries.

Aquaculture. There is enormous resistance to aquaculture, or managed fisheries, on the part of the traditional fishermen throughout the state, reminiscent of the old Western range wars between the farmers and the cattlemen. The fishermen are afraid the aquaculturists will tie up sections of the ponds for their exclusive use and a fisherman must be able to move freely to pursue the resource. Consequently, there is a fierce opposition to aquaculture in the ponds.

A managed pond oyster fishery, however, was extremely productive in the past. If pollution and eutrophication are degrading the pond environment, then efforts to provide new substrates for larvae to set, to be able to move shellfish to growth-conducive areas of the ponds, and other such intense fishery management techniques may be effective ways to optimize the fishery. Limited aquaculture is probably a compatible and wise use of the ponds. The ponds are relatively small, closed systems, more easily managed for fisheries enhancement than are open coastal waters. Conflicts of use between fishermen, recreational boaters, and aquaculture projects must be worked out. Poaching also presents a problem. In order for a fisherman to lease ground and put a major investment of effort and equipment into it, he must be able to protect it. Armed guards cruising at night and the shotgun wars of the historical Bay fishery are not an appropriate answer. Legal rights and responsibilities must be defined and enforced.

Vandalism. Intensive development of the ponds and growing numbers of vacationers make vandalism an increasing problem for the fishermen. Every year more gear, boats, motors, and buoys are stolen. The summer tourists that ski and boat on the ponds have little understanding or respect for the fishermen's way of life. Often what is not stolen is cut or broken or moved, creating a burdensome expense for the fishermen. As a consequence, they are constrained to setting their nets or pots after dark and retrieving them before first light in order to avoid vandalism. Speed boaters run a foul of lines and gear and create high wakes that are a nuisance, even a hazard, to recreational fishermen anchored in canoes or small boats. Future management policy might consider limiting speeds or the engine size permitted on the ponds. Considering that oil from outboards is a toxic pollutant, perhaps motor boat use should be totally prohibited in some areas of the ponds, as it is in some freshwater ponds in the state.

References

Babcock, Elmer (Mrs.) 1978 interview.

Bieder, 1971. Age and growth of the americal eel Anguilla rostrata (Lesueur) in R.I. M.S. Thesis, Univ. of R.I.

Browning, C.F. 1973. Commercial buckeye fishing in South Kingstown in: Pettaquamscutt Perspectives: an oral history. B. McIlvaine and N. Willis (eds.) Kingston, Rhode Island Branch of American Association of University Women.

Browning, C.F. 1978 interview.

Browning, H. 1978 interview.

Chmura, G.L. and N.W. Ross. 1978. The Environmental Impacts of Marinas and Their Boats. A literature review with management considerations. URI Marine Memorandum 45.

Dykstra, J. 1978 interview.

Feiner and Steiger, Inc. 1977. Eels bought from Rhode Island South Shore Ponds. Newburyport, Mass. Annual records.

Holburton, Thaddeus. 1978 interview.

Jurgensen, K.M. and G. Crow. 1977. The $6-million eel, or from bait to delicacy in four years. 42nd North American Wildlife Conference. Wildlife Management Institute. pp. 329-335.

Matzinger, M. 1977. Some tall and short fish stories of old South County. Maritimes. 21: 5-8.

Narragansett Times, September 9, 1887.

Narragansett Times. 1939.

Providence Sunday Journal. December 1, 1889. Wakefield's Hope; a breakwater and permanent breach at Point Judith. p. 1

Salwen, B. and S. Meyer. 1978. Indian archeology in Rhode Island. Archeology Nov.-Dec. pp. 57-58.

Smith, R. 1978 interview.

Smith, R.P. and K.E. McConnell. 1979. Marine Recreational Finfishing in Charlestown-Green Hill and Point Judith-Potter Ponds. Feb.-July 1978. Xeroxed report. Dept. of Resource Economics, URI.

Whaley, C. 1939. Fishing in Potters Pond. Narragansett Times. January 2, 1939.

Whaley, C. 1978 interview. Letter from his father C.T. Whaley to Prov. Evening Bulletin.

Wright, Thomas. 1978 interview.

IV. SEDIMENTATION

Sedimentation and shoaling in the ponds is a growing problem. As more people live around the ponds and want to use them for boating and fishing, the shifting sands and shoaling channels cause increasing concern.

Geologically, it is in the nature of the salt ponds to undergo a process of gradual filling. Over thousands of years, storms and ocean waves wash beach sand over the barriers and into the ponds. In this way, the barrier continually moves slowly landward, maintaining itself in pace with gradually rising sea level (Regan, 1979). Chunks of peat that once formed marshes inside the pond are occasionally exposed on the seaward side of the barriers (Dillon, 1970). It is evident that the ponds are shoaling. However, the rates at which they are shoaling and the relative importance of various sources of sediment are not well known.

Major Processes of Sedimentation in the Ponds

Transport from Storm Washover. The continued shoaling of the ponds as a result of storms washing sand over the barriers and into the ponds may be traced in historical records. The buffeting of coastal Rhode Island by numerous winter storms, gales, and hurricanes is a fact of nature. Though severe storms do not occur in a regular pattern, they certainly occur frequently, as can be seen in Table 3. The Great September Gale of 1815 was one of the most severe hurricanes to have its dramatic effects on the salt ponds recorded. The ocean storm waves washed over the beach, leveling 30-foot-high sand dunes and pushing the sand back into the ponds. Again, dunes were leveled and extensive washover occurred in the hurricane of 1938. As can be seen in aerial photographs taken just after the storm, the beaches were cut by several storm surge channels through which sand was washed into the ponds. These sand flats formed the quahog beds that are fished today. The hurricane of 1954, though less severe than the storms of 1815 or 1938, also caused extensive washover and deposition of sand on flats inside the ponds. In an unfortunate coincidence, the fill for the Galilee escape road had just been put in place when the hurricane of 1954 washed it into Point Judith Pond, adding extra sediment to the southern part of East Pond. More fill was brought in to rebuild the road.

Storms continue to be a major force for transporting sand. Although there have not been severe hurricanes in recent years, winter storms have washed sand over the beaches on frequent occasions. One of the most notable was the blizzard of 1978, which caused severe erosion on Charlestown beach and washed sand over the barrier and into the pond in several areas. Although not as spectacular as a major hurricane, the winter and fall storms that are common along the coast cause continual small inputs of sediment to the ponds.

Transport Through the Breachways. The breachways, since they are an opening to the sea, have always been another means of sediment transport into the ponds. In the early days of the natural breachways, shifting sands would create shoals, and eventually seal off the breach. There are extensive flood tide deltas deposited in the ponds at the mouth of the breachways. Surf and ocean waves have enough turbulent energy to suspend sand grains, which are

Table 3. Hurricanes That Have Struck The South Shore of Rhode Island

DATE	REMARKS
1635, August 15	Tide at Narragansett 14 ft. higher than ordinary; 8 Indians drowned. Hit at high tide.
1638, August 3	Tide flowed twice in 6 hours about Narragansett and rose 14 or 15 feet above ordinary spring tide. Probably highest tide ever experienced.
1641, November 12	A great tide along the coast of Mass. Records do not indicate effect on R.I. coast.
1723, October 20	Tide one foot higher than ever known before. (Providence)
1761, October 24	Highest tide into the harbor of Providence that hath been known in the memory of man.
1770, October 19	Immense loss of life and property along the coast.
1815, September 23	Tide rose 11.8 feet above mean high tide in Providence.
1821, September 3	Considerable damage was done to trees, etc. (Providence). Greatest intensity felt at New York where tide rose 13 feet in one hour.
1841, October 3	Some damage was done to the shipping and many chimneys were blown down. (Providence).
1866, October 30	The tide was forced by the wind to an unprecedented height--doing much damage. The water also overflowed the wharves on the east side. (Providence)
1869, September 8	...the wave which rolled in there (Narragansett Pier) was the heaviest ever known.
1877, October 4-5	Severe storm of wind and rain... (Newport, R.I.)
1878, October 23	Severe storm--rain falling in torrents. Some of the wharves were flooded. (Providence)

DATE	REMARKS
1896, September 9-10	At Block Island the storm was considered the severest on record at this season of the year.
1904, September 15	One of the most memorable storms--, and for intensity it has seldom been equalled. Telephone lines were blown down, trees uprooted, streets gutted, cellars flooded. (Providence)
1924, August 26	Boats were broken up on rocks and sunk and cottages and stores along the shore at Narragansett Pier were flooded during the storm, which was accompanied by the worst surf experienced in years.
1933, September 16-17	Rhode Island took the shock of a raging storm as it passed by out at sea. Streets were flooded, trees stripped, boats beached, docks weakened, telephone service disrupted and transportation facilities crippled. (Providence)
1934, September 9	Damage in Providence was extensive, trees uprooted, electric poles levelled and shipping in Narragansett Bay paralyzed.
1936, September 19	Worst coastal storm in years swept Rhode Island shores; torrential rainfall and gale winds.
1938, September 21	A hurricane and tidal wave swept over the state, taking a death toll of 262 persons, causing damage estimated at $100,000,000 and completely prostrating the commonwealth in the worst disaster in its history. Winds above 95 mph and tidal waters rose 13.21 feet above mean high water in Providence.
1944, September 14	At Narragansett Pier the tide rose to 9.0 feet above mean sea level. Storm came at ebb tide. Trees were uprooted, telephone and electric lines were blown down, pavements ripped up and buildings flooded. Many homes along the South County shore were blown from their foundations. Winds were 82 mph with gusts up to 100 mph.
1950, September 11	Tide rose to 4.1 feet above mean sea level at Newport and estimated at 6.4 feet above mean sea level at Providence. Tides along Rhode Island shore were held back by prevailing offshore wind. Hurricane passed at sea.

DATE	REMARKS
1954, August 31 (Carol)	One of the greatest hurricanes in recent years. Exceeded only by September 1938 hurricane. At Narragansett Pier the tide rose to 12.8 feet above mean sea level. Preceded by only a few minutes warning, Hurricane Carol swept across the state leaving 19 dead and scores injured. Property damage was estimated at $90,000,000. Many summer colonies like those at Misquamicut were almost completely obliterated. Throughout the state almost 3,800 homes were destroyed. Sustained winds were 90 mph, with gusts of 110-115 mph.
1954, September 11 (Edna)	At Providence the tide rose to 5.5 feet above mean sea level. Hurricane eye split prior to reaching Rhode Island coast. Hurricane Edna hits the state with torrential rains and winds from 40-50 mph.
1954, October 15	Brought torrential rainfall and river flooding to interior of Rhode Island; negligible tidal flooding in southern New England.
1955, August 19 (Diane)	Hurricane Diane, her winds abated by an inland trip, brought 6.13 inches of rain to Rhode Island, causing the worst flood in the state's history. Most serious damage was in the Blackstone Valley.
1960, September 12 (Donna)	Hurricane Donna, with sustained winds of up to 58 mph and gusts up to 81 mph, swept across Rhode Island. No deaths were recorded and there was no tidal wave.
1961, September	Sand erosion--greatest damage at Misquamicut and Sakonnet Point--Apple and corn crops suffered.
1972, September (tropical storm, Carrie)	High winds and rough seas; damage greatest around lower Narragansett Bay--many boats driven ashore at numerous marinas.

Hurricane Survey Interim Report, Narragansett Pier, Rhode Island, U.S. Army Corps of Engineers, New England Division, Waltham, MA, April 1960.

U.S. Dept. of Commerce, NOAA Environmental Service Data, National Climatic Center, Federal Building, Ashville, S.C. 28801.

1979 Journal-Bulletin Rhode Island Almanac.

Figure 15. Photograph of the sediment washed over the barrier and into Quonochontaug Pond by the hurricane of 1938. This overwash process occurs with severe storms in all the ponds.

carried into the ponds on flood tide. The sand is deposited in the calmer water inside the pond. Relatively small waves and slower currents inside the ponds cannot resuspend the sediment and carry it back out to sea. As a result, sand builds up year after year on the shoals and sandbars of these deltas.

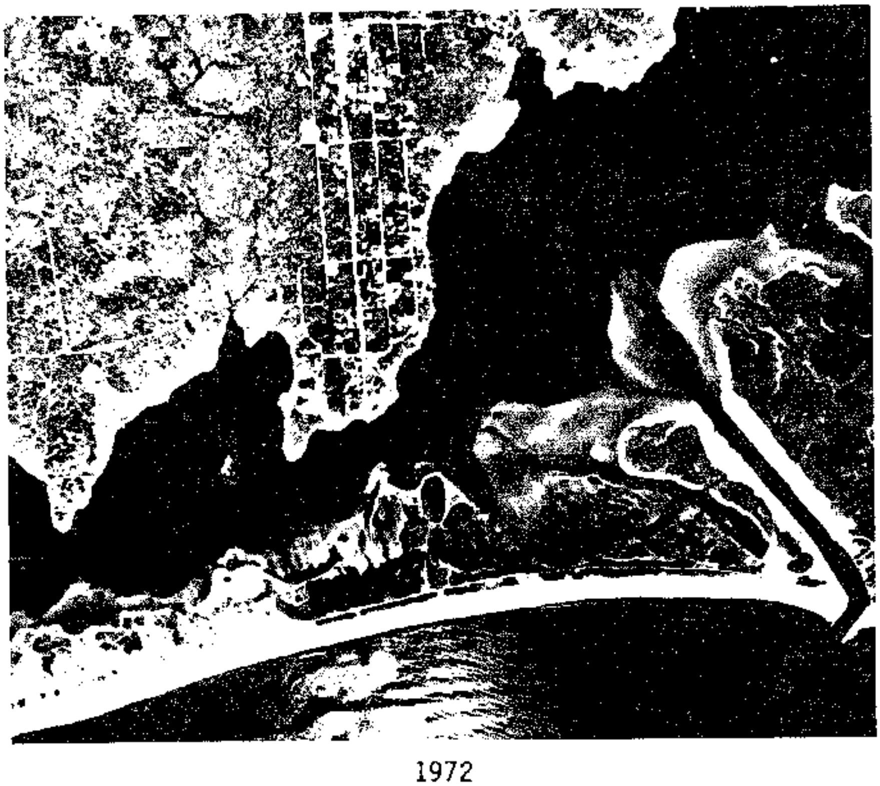
When man built the stabilized breachways, he exacerbated the problem. Since the reinforced breachways stay open to the sea continually, the transport of sediment into the pond occurs at an accelerated rate. Graphic evidence of the effect of the stabilized breachways in increasing deposition of sediments in the ponds can be seen in photographs of Quonochontaug Pond, taken before and after the stabilized breachway was constructed (Figure 16). It is estimated that building the stabilized breachways has doubled the overall rate of sedimentation in the ponds (Simpson, 1977). Shoaling of the channels and passages in the area of the flood tide delta is particularly acute.

Some excellent bathymetry work was carried out by the Army Corps of Engineers in 1910 in preparation for a proposed intercoastal waterway project. Comparison of the depths recorded on these maps to present depths should give a good indication of areas and rates of extensive shoaling. However, in 1910 most of the ponds had not been permanently breached. The continual seepage of freshwater into the ponds from springs and streams filled the ponds several feet above mean sea level. When the breachways permanently connected the ponds to the ocean, the water level in the ponds dropped two to three feet, depending on the pond. Since the accumulation of sediment has for the most part been much less than this, a comparison of bathymetry will not yield a sedimentation rate.

Inputs from the Land. The landward edge of the pond is a relatively insignificant source of sediment, according to research by Dillon (1970) and Conover (1961). The moraine, the line of low hills that lies to the north of the ponds, blocks runoff and stream flow into the ponds. Furthermore, the outwash soil is very permeable and absorbs rainfall rather than shedding it as sheet flow or runoff. Most of the fine sediment in the pond is probably the result of the winnowing of glacial till and outwash. Fine-grained sediments are deposited in the back coves, where tidal and wind-driven currents are weak. These sediments are enriched with fine organic particles and fecal pellets from pond organisms (Dillon, 1970).

There is anecdotal information that suggests that there are additional sources of sediment derived from the land. In the early 1900s, the land around the ponds was predominately used for agriculture, and winter northeasterlies apparently blew fine soil off the fields into the ponds. Most of the potato fields had been sold for residential housing by the 1960s. However, winter winds still blow fine topsoil off the remaining fields and into the ponds. House and road construction in addition to bulkheading and filling adds sediment to the back edges of the ponds. There is a large mud flat in Perch Cove in northern Potter Pond that is formed from sediment carried off Route 1 through a storm drain that shunts road runoff into the cove. There is also some concern that eutrophication is increasing the deposition of organic particles in the back coves.

1941



1972

Figure 16. Aerial photograph of Quonochontaug Pond showing the large amount of sand transported into the ponds after the permanent breachway was opened.

The rates and quantities of sedimentation from these landward sources are not known. In most areas of the ponds (except the tidal deltas), the sedimentation rate is probably on the order of tenths of inches, 1,000 times less than the water level drop that occurred when the stabilized breachways went in and less than the smallest unit measured by the Corps (.1 feet). Furthermore, many small-scale dredging projects have taken place since then. Hence, a sedimentation rate for the ponds is difficult to obtain. Geologists at URI are presently conducting research to address this question and quantify amounts and rates of sedimentation and erosion in the ponds.

Problems Created By Sedimentation

Sandy, shallow flats are accumulating in the ponds and impede motor boating and sailing as well as curtail boat access to the ocean. Moreover, the accumulation of sediment restricts tidal flow and flushing of the ponds. As a result, most of the ponds are thought to be increasingly stagnant, according to local residents. They are pressing the state to remedy the shoaling problem by dredging the ponds.

Dredging. The state is reluctant to respond to the call for dredging for several reasons. First, the financial cost to dredge areas as large as a pond is enormous. Even in federal projects such as the Army Corps plan to dredge Brightman's Pond and stabilize Misquamicut Beach, the state must pay a portion of the cost, an estimated \$3 million in a \$12 million project (Army Corps, 1977). Also, the environmental consequences of altering water movement and flushing characteristics are very difficult to predict. Furthermore, there are substantial problems associated with the disposal of dredge spoils.

Point Judith is the one pond that has been dredged routinely. Table 4 is a summary of the amount of documented dredge spoil removed from the pond since 1900. There have been additional undocumented private efforts at various docks and marinas. It is evident that once dredging is initiated as a policy for a pond, uses and expectations develop that rely on dredged channels. The sedimentation rate is high enough that dredging must continue as a long-term enterprise, possibly with increasing frequency. At least in Point Judith, one project of dredging the tidal flats at the mouth of the breachway and a channel up the pond was not enough. Pressure for continual maintenance dredging must be realistically considered before projects in the other ponds are initiated.

Even though Point Judith Pond sediment is clean, it is becoming increasingly difficult to dispose of the spoils. The most recent dredge spoils were deposited on parking lots adjacent to the pond until they could be trucked away to various on-land sites. One sound suggestion for disposal of pond sediment is to place it on the front of selected barrier beaches. This would not only be a reasonable answer to the disposal problem but would alleviate the severe erosion that is occurring along the ocean side of some South Shore beaches. Spoils would have to be deposited on the beach in the right areas to restore the most geologically stable shape and slope of the beach front and not just dumped haphazardly.

Table 4. Summary of Dredging Activity in Point Judith Pond[1]

Date	Agency	Thousands of Cubic Yards	Comments
1901	South Kingstown and State of Rhode Island	135	Breachway Construction
1909	South Kingstown	17	Potter Pond Channel
1934-35	State of Rhode Island[2]	2720	35-acre harbor to 12 feet., 8-foot channel and 6-foot channel to Wakefield
1951	Army Corps	194	Improvement of 15-foot and 6-foot channels and 10-foot anchorage
1953	State of Rhode Island	300	"Borrow" for escape road foundation and fill, dredging for access to piers
1956	Army Corps	62	Maintenance of 15-foot and 6-foot channels
1959	Army Corps	63	Maintenance of three 15-foot channels and the 6-foot channel
1963	Army Corps	47	Maintenance of the 15-foot channels
1963-68	Private	42	Ram Point Marina, upper pond
1971	Army Corps	20	Maintenance of 15-foot entrance channel
1977	Army Corps	72	Extension of 15-foot channel
1977	State of Rhode Island	20	Access to piers

[1]Does not include dredging carried out entirely in the Harbor of Refuge of small-scale privately financed dredging (if any) in the ponds.

[2]Volume of spoil estimated from project specifications and pond bathymetry in Army Corps surveys of 1909 and 1935.

Erosion. The other side of the deposition problem is erosion. The ocean side of the barrier beaches are eroding, some more dramatically than others. In some cases, houses that have been built on the beaches have been undermined and have collapsed into the sea; in other cases, the property is being eaten away. Some of the sand that is lost from the beach ends up inside the pond. Once in the pond, it is no longer available to keep the beach renewed. Since there is little other source of sand offshore, the beaches are eroding shoreward at the rather high rate of 0.7 feet per year (Regan, 1979). There is great public pressure on the part of beach property owners to build on the beach. Then they demand that something be done to save their property when the beach erodes. Since it is the essence of the beach to be continually shifting, it is not a good foundation for development.

Erosion is a problem inside some of the ponds as well. In many instances, the landward shores of the ponds are composed of soft glacial till. These sand and gravel banks erode with the forces of wind and rain. Boat wakes create waves that are as high as any set up by major storm winds, and they erode the banks. Consequently, more and more of the shoreline has been bulkheaded or riprapped, but at considerable expense to private landowners. Frequently, the structures are more substantial and expensive than they need to be to protect the shore from everyday erosion but not sufficient to protect against major storm damage. Much of the bulkheading is an unnecessary expense and the same erosion protection could be achieved more cheaply with judicious plantings and stormwater diversion. In addition, grassy shallows that may be important spawning habitat have been replaced by bulkheads. The aesthetic appeal of a natural shoreline is being sacrificed for engineered structures.

References

Conover, R.J. 1961. A study of Charlestown and Green Hill Ponds, Rhode Island. Ecology. 42: 119-140.

Dillon, W.P. 1970. Submergence effects on a Rhode Island barrier and lagoon and interferences on migration of barriers. Journal of Geology. 78: 94-106.

Regan, D.R. 1976. An aerial photogrammetric survey of long-term shoreline changes, southern Rhode Island coast. Unpub. M.S. Thesis, Univ. of R.I., Kingston.

Simpson, E. 1977. A photogrammetric survey of back barrier accretion on the Rhode Island beaches. Masters Thesis, Univ. of R.I.

USACE. 1960. Bathymetry maps prepared for the intercoastal waterway project.

USACE. 1977. Rhode Island Coastal Area. Water Resources Development. pp. 53-61.

V. LAND USE

Changing Patterns of Human Interaction with the Ponds

Indians. The Indians were the first to make use of the ponds and the land around them. There are several encampments that have been archeologically excavated in Charlestown and Potter Ponds that provide a glimpse of what the ponds offered them.

There is evidence that archaic Indians inhabited a fishing camp by a sheltered cove on the west side of Potter Pond from 1000 to 500 B.C. Since sea level was about 10 feet lower at that time than it is today, the camp was probably on a freshwater stream that flowed out of Kettlehole Pond, that is now the upper basin of Potter Pond. There is evidence of freshwater fish but no salt water fish or shellfish in this early site. Later it was a summer camp site for woodland Indians, and probably continuously inhabited from 1000 A.D. to the 1600s (Salwen, 1965). The refuse heaps from this later site are comprised primarily of oysters with some quahogs, soft shells, mussels, scallops, and surf clams. According to historical records of early settlers, the Niantic Indians would move out of their winter camps in the wooded interior to the coast in early spring. Crops would be planted in the grasslands along the coast and summer camps would be set up to catch, dry, and store fish and shellfish for the winter.

Fort Ninigret on Fort Neck Cove in Charlestown Pond is another example of a summer Indian camp, but a larger, more important one, which was fortified as trade with the Europeans developed. It is one of the few coastal Indian fortifications in southern New England that remains from the 1600s. Archeological excavations conducted by researchers at New York University indicate that the site had been occupied at least twice, once between 700 and 1300 A.D. and again in the 1600s (Salwen and Meyer, 1978). In the 1600s, it was apparently an important trading post, and the Dutch came here in search of furs. Dutch artifacts such as clay pipe fragments, Dutch china plate fragments, metal implements including hatchet heads and a jew's-harp have been found. The manufacture of wampum was apparently an important activity at the fort, since beads, drills, and polishing stones were found among the shells. After contact with the Europeans, wampum became a source of wealth and power as a currency of exchange with traders and with other Indian tribes. It was used as legal tender by the Puritan settlements from 1630 to 1670 (Salwen and Meyer, 1978).

Early Farmers. When the colonists settled Rhode Island, they took over most of the Indian land and their ways of using it (with the important addition of individual ownership). The early farmers planted corn and vegetable crops, hunted for game, and fished the ponds. The land that extends south of the moraine down to the sea is some of the best agricultural land in the state. It is flat, glacial outwash, relatively rock-free, and is primarily composed of rich Bridgehampton silt-loam soil. The early South County farm consisted of about 200 acres of cropland and pasture on the glacial outwash plain, 10 to 100 acres of woodlot up on the rocky moraine, 100 to 200 feet of beach from which seaweed was collected to fertilize the fields, and 12 acres of salt marsh grass which was used to top the haystacks and for animal fodder and bedding (H. Browning, 1978 interview).

In the 1700s, the land around Point Judith Pond was divided into large farm tracts known as the Narragansett Plantations. In many ways, they resembled Southern plantations, including a reliance on extensive slave labor. In contrast to Southern plantations, where cotton was raised as a cash crop, South County plantations raised livestock and horses. The famous Narragansett pacer was raised here, an exceptionally smooth gaited horse which was a valuable attribute in days when traveling meant long hours on horseback over rough trails. Cattle were raised to make cheese, which was a major commodity of trade. Hogsheads of cheese made in South County were shipped via Newport and New York, to the rest of the colonies, England, and the West Indies.

Seaweed was an important resource in the 1800s. An important source of fertilizer, it was spread in large quantities on crop fields. In 1893, seaweed comprised about one-fourth of all the fertilizer used on Rhode Island farms (Parker, 1976). In the 1800s, sailboats were built to carry seaweed from the beaches up Point Judith Pond to Wakefield (Providence Sunday Journal, 1889). Farmers came to buy it, or traded one cord of wood for one cord of weed. In the early 1900s, the "smart set" in town used it as lawn fertilizer.

Along the ocean side of the barrier, certain sections of beach were known as "seaweed beaches" because the weed would accumulate in thick windrows after storms. They were usually the rockier stretches. There was one at Sand Hill Cove off the "common lot," where any farmer could have access to it, three off Matunuck, and more down by Quonochontaug and Weekapaug (H. Browning, 1980 interview). Seaweed rights to a stretch of beach were deeded to local farmers, who in turn sold privileges to anyone who wanted to harvest it. Farmers from as far away as Shannock would come down to the beach after a storm with ox carts, which they would park over the section of beach to be harvested. Competition was keen. According to one old-timer, there was no such thing as a friend on the seaweed beach. Once the weed was banked above the tide line, its ownership was established and it could be carted away at the farmer's convenience. Later it would be mixed with manure or spread directly over the fields about six to ten inches deep (C.F. Browning, 1978 interview).

Use of seaweed as fertilizer declined during the 1900s, partly due to mechanization--tractors and trucks replaced animal power on the farms and they bogged down on the sandy seaweed beaches. Also, in the 1930s the federal government launched vigorous sales campaigns to convince farmers to convert to using chemical fertilizers.

Mills. With the farms came another important use of the land, the water-powered mills. Streams were dammed, low places flooded for mill ponds, and mills built to grind locally grown corn and to weave woolen fabric from wool from local sheep. In the early 1800s, there were at least ten mills that had dammed streams that flowed into the ponds to take advantage of the water power. There was a mill at Cross Mills in Charlestown, a woolen mill and a twine walk for making seine twine on the brook that flows into Green Hill Pond, a grist mill, a saw mill, and a woolen factory on Perryville Brook that flows into Cards Pond. There were mills on Smelt Brook, which flows into Point Judith Pond, and of course, the large Peacedale mills on Saugatucket River.

There were also at least two cider mills, but they were not water-driven. One at Perryville was turned by two men and one at Matucuck by a pair of oxen. Each produced about 200 gallons of cider from each pressing (Browning, 1969).

Since at least 1790, the Saugatucket was dammed for one small woolen mill, a saw mill, and a grist mill that ground oil from flax seed. In 1823, Peacedale was a tiny village of five houses, one woolen mill, one grist mill, and about 30 people. In 1828, the Peacedale mill, which had been operated by four generations of Hazards, was the second largest of the 20 woolen mills in Rhode Island (Stewart, 1962). It was the first mill possibly in the United States to use a variety of machinery in a single building for carding, spinning, and weaving. Because of the influence and prosperity of the mill, the town of Peacedale grew from 30 people in 1823 to 1,500 people by 1900, 40 percent of whom worked in the mill. A post-war business boom lasted from 1865 to 1906, when labor strikes disrupted business, and the mills were sold in 1918 (Steward, 1962).

Early Recreation. The cool sea breezes, long stretches of beach, and entrancing landscape around the ponds have enticed vacationers for years. From the late 1800s until World War I, the "backside" was a favorite summering area for people from Providence and neighboring states. With the blooming of the resort communities at Watch Hill and Narragansett Pier in the 1890s, recreational uses of the ponds prospered. People came from Philadelphia, New York, and the Midwest to enjoy their summers. Initially, people came by train to Westerly or Kingston, stayed at hotels in town, and were transported in farm carts to the ponds or the beach for the day. Eventually, farmers took on boarders, often 10 to 20 in a farmhouse for the season. Then small hotels or boardinghouses began to dot the landscape near the ponds. There were five such hotels between Green Hill and Matunuck (C.F. Browning, 1977 interview), one of which is presently Theatre-by-the-Sea. Each had 50 to 60 boarders on weekends, and employed about ten people as staff. Wives and children would stay for a month or so and be joined by husbands on the weekends. The hotels would transport them to the beaches or picnic spots by ox carts or horse-drawn wagon. Clambakes were a favorite revelry all along the shore. Various associations and civic groups from all over southern New England would visit for a day of games, boating, and feasting on shellfish gathered from the ponds.

By the late 1800s, wealthy people began to build summer houses in the areas. The first summer houses were built on the barrier beach at Charlestown Pond; they were destroyed in a storm in 1912. Later, more were built along the barrier beaches from Point Judith west to Napatree Point off Watch Hill. Most of these houses were destroyed in the hurricane of 1938. Recreation in the off-season was an attraction as well. In the late 1800s, people would come from as far as New York to hunt quail, pheasants, and fox in the fields around Point Judith Pond.

Post-War Boom

World War II marked a major turning point in land use around the ponds. All sorts of major changes occurred. The late 1930s saw the decline of the dairy farms and a shift to potato farming. After the war, farming became mechanized. Horse-drawn carts and plows were replaced by tractors, trucks, and milking machines. Roads were greatly improved. Route 1 was a major route between Boston and New York since Colonial times, when it was known as Queen Anne's Highway or the Old Post Road. It was, however, a dirt track until 1910. Travelers had to stop for cattle and to open and close gates all along Route 1, from Charlestown to Wakefield. In the 1940s, it was upgraded to a macadam two-lane highway, which made the land around the ponds easily accessible to commuters and tourists for residential development (Figure 17). With the improved road network, land transportation became more efficient and dependable, causing a decline in sea transportation. Coal barges and trading schooners that had brought fuel and goods to the residents of the backside had been replaced first by the railroad and then by the highways. After the Stonington Railroad was built between Boston and New York in 1837, it carried most of the textiles, produce and people in and out of South County. Then after World War II the highways became the main routes of transportation.

The most dramatic change in land use was the loss of farmland and open space. Farmland had begun to be sold off and developed as small residential parcels before World War II in areas like Great Island in Point Judith and Fort Neck Cove in Charlestown. In 1942, the Navy took 588 acres of prime farmland on the north shore of Charlestown Pond to build an airbase for training night fliers for World War II. But the real burgeoning of development started in the 1950s and continued to increase through the present. This shift in land use is graphed in Figure 18. It is particularly evident in the transfer of farmland to urban-residential land around Charlestown and Green Hill and Point Judith and Potter Ponds. The pattern is not so prominent around Trustom and Cards Ponds because much of that area is still in large holdings.

The 1954 hurricane occurred at a time when increasing numbers of houses were being built along the shore. The enormous destruction of property caused by the hurricane persuaded the towns along the South Shore to adopt floodplain zoning and the federal flood insurance program. The National Flood Insurance Program has had the unexpected effect of accelerating development in flood-prone areas in coastal lowlands and barrier beaches by subsidizing development in these hazardous areas.

Increased residential development around the ponds, first as seasonal vacation houses and now as more and more year-round housing, brought a new emphasis on recreational use of the ponds. In the late 1950s and early 1960s there was a burst of marina development to accommodate the burgeoning recreational boating, especially in Point Judith Pond. By 1978, there were 903 slips available at 15 salt pond marinas.

Pollution, a Result of Activities on the Land

Land derived sources of pollution to the ponds have been noted for some time. In the late 1800s pollution from the Peacedale mills and from town waste became increasingly evident in Point Judith Pond. The need for flushing of mill waste from the pond was emphasized by local citizens in their argument to construct a stabilized breachway. Later, when the oyster industry was thriving, the upper pond would become red one day and green the next, depending

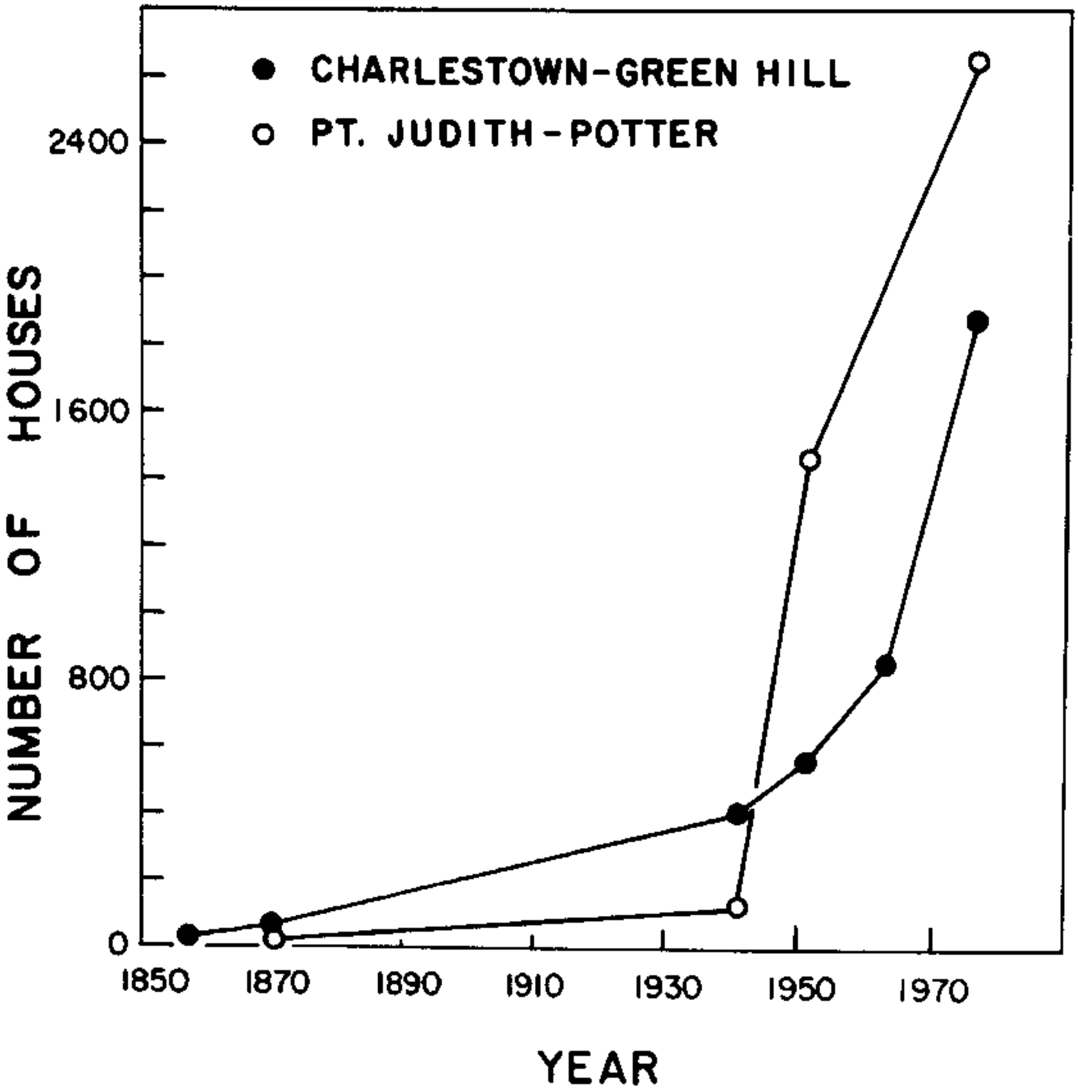


Figure 17. A graph of the dramatic increase in housing development in the area around the ponds south of Route 1. Note the particularly rapid growth rate since the 1950s.

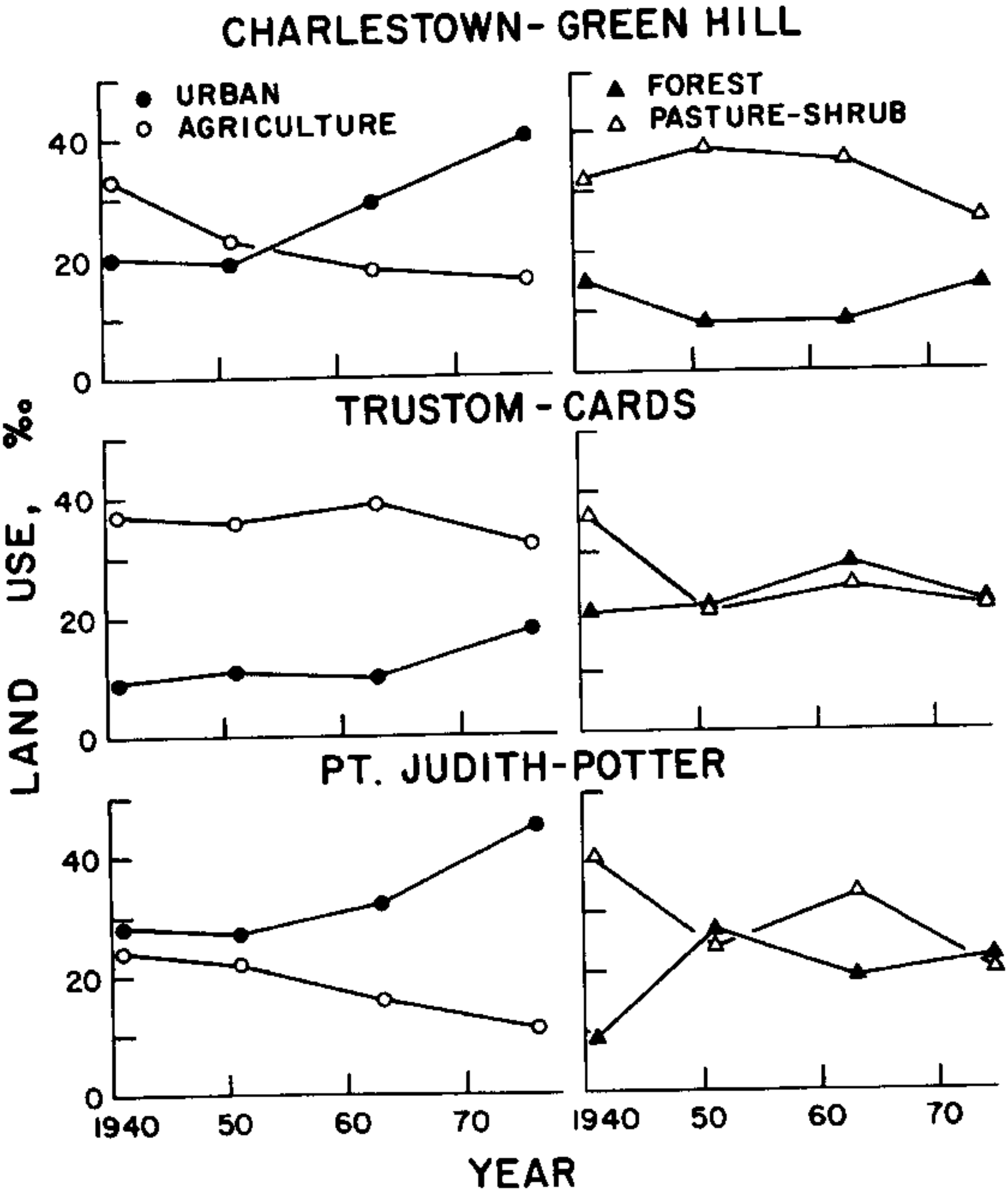


Figure 18. A graph of changes in land use over time around each of the ponds. Note that urban or residential development has occurred on the prime agricultural lands with the exception of Trustom and Cards.

on the dye used in the mills that day. On days when the cloth was washed, the upper pond would be full of soap suds. It was usually too opaque to see to the bottom, but good-sized, healthy-looking oysters could be pulled up at any time. In the 1940s, Peacedale mills reached a peak in operations and were discharging 2 to 3 million gallons of wastewater a day into the Saugatucket River. In 1946, upper Point Judith Pond was closed to shellfishing because of high coliform levels presumably due to sewage discharges from Wakefield. Conditions worsened as development intensified, and by 1969 the pollution line in Point Judith Pond was extended down to Crown Point. A primary treatment system was installed in the Peacedale mills to reduce BOD loads and collect sludge. Flushing the ponds to relieve stagnation and pollution was also a major argument for establishing the breachways to other ponds in the 1950s.

In 1969, certified septic systems became required in new houses. Previously, all sorts of sewage disposal systems had been used, ranging from pipes that discharged directly to the ponds to old 50-gallon drums buried as holding tanks. These systems and the recycling capacity of the ponds worked as long as there were only a few people who stayed for the season or for weekends. The ponds had the rest of the year to process the nutrient loading. But as development intensified and large numbers of people began to live around the ponds year round, conditions degraded. In 1973, the pollution area closed to shellfishing in Point Judith Pond was extended to cover more than half the pond (below Plato Island). In 1973, the town of South Kingstown responded to the problem by installing a sewer system that will treat much of the effluent that enters the Saugatucket River and Point Judith Pond.

Since most of the soil around the ponds is glacial outwash of coarse gravel, the percolation rate is very high. Water can readily move down through the soil to the water table. Since much of the drinking water is supplied by private wells, sewage began to contaminate drinking water as well as the ponds. Town water was piped into Great Island, the developments on the southwest end of Potter Pond, and some areas of Green Hill. Development continues and septic systems are used in lots very close to the pond edge, since most of the area was zoned in the 1950s and 1960s for small summer cottages. Septic seepage is probably increasing the nutrient loadings. The extent of the problem is being investigated by the pond research effort at URI.

References

Browning, C.F. 1977 interview.

Browning, C.F. 1969. Early industry on the backside. Pettaquamscutt Reporter. 6: 2-4.

Browning, H. 1978 and 1980 interviews.

Parker, H. 1976. Charlestown and the ocean. In: Reflections of Charlestown, Rhode Island. 1876-1976. Utter Company, Westerly, R.I. pp. 18-28.

Providence Sunday Journal. 1889. Wakefield's Hope; a breakwater and permanent breach at Point Judith. December 1, 1889. p. 1.

Salwen, B. 1965. Sea levels and the archaic archeology of the New England coast. Ph.D. Thesis. Columbia Univ. 257 pp.

Salwen, B. and S. Meyer. 1978. Indian archeology in Rhode Island. Archeology. Nov.-Dec. pp. 57-58.

Stewart, P.C. 1962. A history of the Peacedale Manufacturing Company. M.S. Thesis, Univ. of R.I. 146 pp.

VI. SUMMARY

It is evident that the ponds have been altered in many ways throughout their history. Some of the alterations were done with forethought and some were not. Some attempts to manage the ponds for a specific goal have resulted in unexpected, even contrary consequences. The stabilization of the breachways is a prime example. It was a major management strategy which was intended to enhance the oysters fishery and accomodate the needs of boaters for open access to the sea. However, breachway stabilization projects caused the eventual decline of the brackish water fisheries and increased shoaling in the ponds which impedes the boaters.

Besides the alterations to the ponds that have been the result of direct management efforts, another more subtle but potentially damaging change has occurrd - a shift in the relationship of the people to their ponds. Whereas the ponds used to be an integral part of life, a vital source of food, income and recreation, to most of the families who lived around them, they have gradually become separated, and somehow diminished for us. Increasingly they are viewed merely as a means to an end; as highways to the sea, as speed boat playgrounds as a full larder for a weekend's fishing, as something to get past on the way to the ocean beaches. As the uses become more fragmented and fewer people take responsibility for the welfare of the pond systems, we lose much of what is special about them, and we lose options for maintaining the natural heritage they offer us. We need to combime the efforts of government officials, local residents, tourists and researchers to thoughtfully assess the best ways to manage these unique resources. We need to work toward providing the right mix of man and nature in the south shore ponds.

Our Next Step: The URI Pond Research Project

As a result of this effort to pull together information on the coastal ponds, and in an effort to gether data pertinent to the major management problems now plaguing them, an interdisciplinary research effort by investigators at URI has been initiated. It is a three-year multifaceted research project funded by Sea Grant, the Office of Coastal Zone Management, the State of Rhode Island and the towns of Narragansett and South Kingstown. The research is tailored to find answers to the specific management problems described in this report. Dr. Jon Boothroyd is conducting experiments to quantitatively describe the sources, sinks and rate of sedimentation in the ponds, as well as to assess the impact of the breachways in increasing sedimentation. Dr. Marilyn Harlin and Boyce Miller are researching the role of aquatic plants in the pond system. They are addressing such questions as the conditions under which the plants respond to nutrient enrichment and create a nuisance to boating and home owners around the ponds, whether the beds of eelgrass slow water movement, and if the plants accelerate sedimentation in the ponds. They are also working in conjunction with Dr. Stan Cobb on the effects of swan feeding on bottom vegetation. Dr. Cobb is conducting a survey of the waterfowl and swan populations on the ponds and looking into the interaction of swans and ducks and geese in order to give information to the state and federal authorities who are responsible for managing Trustom Pond Santuary and coastal waterfowl habitat in the rest of the State. Dr. Malcolm Spaulding is developing a mathematical model of the hydrodynamis of the ponds that will help in predicting effects of various management options on the ponds. With the aid of the model he will be able to address such issues as the effect of channel dredging or culverting on currents and tides and on the dispersion of sediment during a dredging operation. Dr. Scott Nixon is conducting experiments to assess the amounts of nutrients that are coming into the ponds from various sources. He is assessing the relative importance of inputs from the sea, compared to inputs from land via runoff or septic seepage or ground water inflow. This work is designed to yield information that will aid in establishing set back requirements and policies to alleviate runoff from various forms of land use so that the ponds do not get overloaded with nutrients that trigger nuisance algae blooms or cause oxygen depletion that would harm the fisheries. Dr. Richard Crawford is conducting a study of the pond's fisheries. His work is addressing the question of whether or not fish and shellfish are being overfished and what the relative commercial and recreational catches are. He is also investigating the role of the ponds as a nursery for flounder that are important in the Block Island Sound fishery. Fishery information is being supplied to the Department of Environmental Management to use in developing fisheries management strategies for the ponds. Stephen Olsen at the Coastal Resources Center at URI is heading up the work that will formulate sound management policies which incorporate the information gathered by the research team. He is working to coordinate the research efforts with the needs of state, town and local authorities who are responsible for managing the ponds.

In the process of working on this project, a vast amount of information was assembled including reports, old maps, anecdotes, histories, diaries, and old photographs that give a compelling sense of what life was like on the "backside" and what changes have brought us to the present. This report does not do justice to it all, but only gives a glimpse of some of the stronger themes. A book that will try to convey the unique qualities and special history of the place is planned for the near future. Scott Nixon intends to write an ecological history of the interactions of man and nature in the ponds that will explore in detail the many topics that were only briefly mentioned or omitted in this report.

APPENDIX A. PEOPLE INTERVIEWED

Pond Watchers

Frank W. Arnold, Charlestown Pond
Peter W. Arnold, Charlestown Pond
Peter H. Arnold, Charlestown Pond
Thomas L. Arnold, Charlestown Pond
William F. Arnold, Charlestown Pond
John Baer, Green Hill Pond
David Bannerman, Charlestown Pond
Herbert Bell, Trustom Pond
Joan Brown, Charlestown
Mark Bontecov, Card Pond
George Boutilier, Point Judith Pond
Bruce Buck, Point Judith Pond
Raymond Carr, Point Judith Pond
Anne Carr, Point Judith Pond
Clarkson Collins, Potter Pond
John C. Dawson, Green Hill Pond
E.R. Delugio, Potter Pond
Mrs. C. DeW Gibson, Potter Pond
Mrs. Edwin Drew, Green Hill Pond
William Durfee, Charlestown Pond
Alfred E. Farrant, Green Hill Pond
Bruce Fellman, Trustom Pond
Roger Freeman, Potter Pond
Arthur Ganz, Charlestown Pond
John Goggin, Charlestown Pond
Lisa Gordon, Trustom Pond
Glayton Goss, Charlestown Pond
Rudolph F. Greiser, Point Judith Pond
James Griffin, Charlestown Pond
Jennifer Griffin, Charlestown Pond
Alfred Hale, Green Hill Pond
Bill Harris, Card Pond
Douglas Jackson, Green Hill Pond
Gaytha Langlois, Green Hill Pond
Carl Lindgren, Charlestown Pond
David Lord, Point Judith Pond
Dr. Frank Louzon, Point Judith Pond
Henry Lisi, Card Pond
Joan Lisi, Card Pond
John MacPhee, Point Judith Pond
Grace MacPhee, Point Judith Pond
Mrs. Charles Marshall, Potter Pond
Henry Meyer, III, Card Pond
Mrs. Barbara Migel, Charlestown Pond
Hank Parker, Charlestown Pond
Jack H. Papazian, Green Hill Pond
Mrs. Elizabeth Perkins, Potter Pond
Mrs. Bruce Randall, Charlestown Pond

APPENDIX A (cont.)

Pond Watchers (cont.)

Gary Rayner, Charlestown Pond
Stuart Rayner, Charlestown Pond
Mac Richardson, Trustom & Green Hill Ponds
Henry C. Safford, Charlestown Pond
J.T. Saunders, Charlestown Pond
William D. Sieczkiewicz, Charlestown Pond
Francis Smith, Charlestown Pond
Douglas S. Spencer, Charlestown, Green Hill and Card Ponds
Lewis Stelljes, Point Judith Pond
Gus Steneck, Charlestown Pond
Lousie Steneck, Charlestown Pond

Historical Perspective

Frank Arnold, Charlestown Pond
Tom Arnold, Charlestown Pond
William Arnold, Charlestown Pond
Mrs. Elmer Babcock, Point Judith and Potter Ponds
David Bannerman, Charlestown Pond
Karl Benitz, Green Hill Pond
George Boutilier, Point Judith
C. Foster Browning, Green Hill, Trustom, Cards, and Potter Ponds
Harold Browning, Potter Pond
Clarkson Collins, Potter Pond
Lodowick U. Collins, Potter Pond
William Durfee, Charlestown and Green Hill Ponds
Jake Dykstra, Point Judith and Potter Ponds
Joseph Eddy, Point Judith, Charlestown and Potter Ponds
Mrs. Richard Feeley, Potter Pond
Leon Grinnell, Charlestown and Green Hill Ponds
Alfred Hale, Green Hill Pond
Thaddeus Holburton, Narrow River, Potter and Green Hill Ponds
Mark Hutchins, Green Hill, Potter Point Judith and Narrow River
Douglas Jackson, Green Hill
Dick Johnstone, Charlestown Pond
Mrs. Charles Marshall, Potter Pond
Sandy Meyer, Charlestown Pond
Lynwood Rathbone, Charlestown Pond
Harvey Safford, Charlestown Pond
Bert Salwen, Charlestown Pond
Bob Smith, Point Judith and Potter Ponds
Clifford Tucker, Point Judith Pond
Chet Whaley, Charlestown and Point Judith Ponds
Lloyd Whitford, Trustom and Card Ponds

APPENDIX A (cont.)

Officials

Kenneth R. Duhamel, Charlestown Planning Board
Patricia A. Morgan, President, Charlestown Town Council

Donald L. Goodrich, Chairman, Narragansett Planning Board
Michael Lapisky, Narragansett Conservation Commission
Maurice Loontjens, Jr., President, Narragansett Town Council
Donald J. Martin, Narragansett Town Manager
Frank Robinson, Civil Defense Warden, Narragansett

Stephen Alfred, South Kingstown Town Manager
Alfred J. Coffin, President, South Kingstown Town Council
Philip J. Donahue, South Kingstown Conservation Commission
Anna Praeger, South Kingstown Town Planner
Foster Sheldon, South Kingstown Town Clerk
Robert S. Stewart, Jr., Chairman, South Kingstown Planning Board

Mr. Santo L. Algiere, Chairman, Westerly Planning Board
Richard D. Comolli, President, Westerly Town Council
Salvatore J. Frebisacci, Chairman, Westerly Planning Board
Glen J. Miller, Westerly Town Manager

Alfred Hawkes, R.I. Audubon Society, Trustom Pond Sanctuary

Don Tiller, U.S. Fish and Wildlife Refuge, Trustom Pond

Ted Diluglio, R.I. Department of Environmental Management
Art Ganz, R.I. Department of Environmental Management
Bill Lapin, R.I. Department of Environmental Management
Mac Richardson, R.I. YCC Summer Program, Trustom Pond
Dick Sisson, R.I. Department of Environmental Management
Ed Wood, R.I. Department of Environmental Management

Jack Lyons, Chairman, Coastal Resources Management Council
Joe Turco, Coastal Resources Management Council
Chet Whaley, Coastal Resources Management Council

APPENDIX B. SOURCES OF POND MAPS, CHARTS, PHOTOGRAPHS

Maps and Charts

National Archives, Washington, D.C.
U.S. Army Corps of Engineers, New England Division, Waltham, Mass.
R.I. Department of Environmental Management, archives
R.I. Historical Society, Providence, R.I.
Providence Public Library, Providence, R.I.
URI Library, Rhode Island Collection, Kingston, R.I.
Towns of Narragansett, South Kingstown, Charlestown. Map archives

Photographs

URI Geology Department, aerial photograph collection
New England Power Company, Westborough, Mass. Thermal I.R. aerial photographs
Rhode Island Historical Society, photographic collection
Roger Williams Museum, glass plate negative collection
Westerly Historical Society, Westerly Library. Photographic collection
Mrs. Mini Mitchell
C. Foster Browning
Narragansett Times
Mrs. Elmer Babcock
Clarkson A. Collins, Jr.
George Utter, Westerly Sun, historical photograph collection
Pettaquamscutt Historical Society
Miss Louise Hoxie
Willis Clark

APPENDIX C. RHODE ISLAND COASTAL POND BIBLIOGRAPHY

Dredging

Chief of Engineers U.S. Army. 1945-1970. Harbor of Refuge and Point Judith Pond, Point Judith, R.I. Annual report.

Examiner of Rivers and Harbors. 1950. House Committee on Public Works. 81st Congress, 2nd Session. pp. 435-530.

Russell, H., J. Myers, J. Karlsson. 1972. A statement of the environmental impact of a proposed dredging and filling operation on Winnapaug Pond and its adjoining salt marsh. Rhode Island Dept. Nat. Res. Div. Fish Wild. Leaflet No. 36.

U.S. Army Corps of Engineers. 1961. Intracoastal Waterway Atlantic Section. U.S. Gov. Printing Office, Washington, D.C.

USACE. 1976. Final Environmental Impact Statement: proposed improvement dredging of Point Judith Harbor and Pond, Galilee, Rhode Island. New England Division Report. Waltham, Mass. 35 pp.

USACE. 1976. Small navigation project Point Judith Harbor and Pond, Rhode Island. New England Division. Waltham, Mass. Detailed project report. 27 pp.

USACE. 1977. Rhode Island Coastal Area. Water Resources Development. pp. 53-61.

Ecology

Algmin, J. and others. 1973. Green Hill: Development and a Barrier Beach. Community Planning Report, URI. 46 pp.

Audubon Society of Rhode Island. 1974. A summary of 1974 Interpretive Activities and Recommendations for Educational Development on Land Owned by U.S. Fish and Wildlife Service and Audubon Society of Rhode Island. Adjacent to Trustom Pond, South Kingstown, R.I.

Bannerman, D.B. 1976. Ninigret Pond and its breachway. Mimeo report. 7 pp.

Coastal and Offshore Environmental Inventory - Cape Hatteras to Nantucket Shoals. URI Mar. Pub. Series No. 2. GSO occasional Pub. No. 5, 1973.

Coastal Resources Center. 1974. An Environmental Study of a Nuclear Power Plant at Charlestown, R.I. URI Marine Tech. Report No. 33.

Collins, C. 1976. Potter Pond, a high salinity tidal lagoon in Southern Rhode Island. Term Paper for Ocg. 401, Univ. of R.I.

Conover, R.J. 1961. A study of Charlestown and Green Hill Ponds, Rhode Island. Ecology. 42: 119-140.

Conover, R.J. 1958. Physical, chemical and biological observation on Charlestown and Green Hill Ponds, Rhode Island, with recommendations for their future management. URI/GSO.

Environmental Analysts, Inc. 1974. Terrestrial Ecology Survey, Charlestown, Rhode Island, site semi-annual report, April 1 - September 30, 1974.

Fish, C.J. and H.P. Jeffries (P.I.s). 1961. Environmental relationships of benthos in salt ponds. Progress report January 1, 1960 - December 30, 1960. URI/GSO Tech. Report No. 61-2.

Fish, C.J. (P.I.) and others. 1964. Environmental relationships of benthos in salt ponds. Grad. School of Oceanog., URI Tech. Report No. 3., Vol. 1 & 2.

Gray, G.W., J. Myer, H. Russell, R. Sisson, J. Stolgitis. 1971. Probable effects of a proposed breachway on the ecology of Green Hill Pond. Leaflet No. 33.

Hahm, W. 1970. Green Hill. Unpublished term report in Planning. Yale Univ. 18 pp.

Hicks. S.D. 1970. Changes in sea level on Rhode Island's coast. Maritimes 16 (4).

Marine Research, Inc. 1974. Charlestown Site Study Progress Report, April - September, 1974. 126 pp. Falmouth, Mass.

Marine Research, Inc. 1975. Charlestown Study, Appendices 1-8, Mimeo Report. Falmouth, Mass.

Marine Research, Inc. 1976. Charlestown Site Study Annual Report, April 1975 - March 1976.

Marshall, N. and S.B. Chenoweth. 1960. The Point Judith Pond Survey, summer 1960. URI/GSO.

Myers, A.C. 1973. Sediment reworking, tube building, and burrowing in a shallow subtidal marine bottom community: rates and effects. Ph.D. Thesis, Univ. of R.I.

NEPCO, 1978. Final Environmental Report - Charlestown Nuclear Power Station. New England Power Company, Waltham, Mass.

Nixon, S.N. and V. Lee. 1980. The Flux of Carbon, Nitrogen and Phosphorus between Coastal Lagoons and Offshore Waters. In: Coastal Lagoons: Present and Future Research, Part II - Proceedings. UnESCO (in press).

Olsen, S.B. and M.J. Grant. Rhode Island's Barrier Beaches: Volume I and II. URI Mar. Tech. Report No. 4.

Phelps, D.K. 1964. Functional relationships of benthos in a coastal lagoon. Ph.D. Thesis, Univ. of R.I.

Preble, D.E. 1974. Potter Pond: a barrier salt pond problem evaluated. R.I. Div. of Fish Wild., Dept. Nat. Res. Leaflet No. 41.

Seavey, G.L. 1975. Rhode Island's Coastal Natural Areas: Priorities for Protection and Management. Coastal Resources Center, URI Marine Tech. Report No. 43.

Short, F.T., S.N. Nixon, and C.A. Oviatt. 1974. Field studies and simulations with a fine grid hydrodynamic model. An environmental study of a nuclear power plant at Charlestown, R.I. Univ. of R.I. Marine Tech. Report No. 33. VIB 1-27.

Westerly Sun Index. Westerly Public Library, Westerly, R.I.

Wood, R.D. 1968. Preliminary Tidal Differences for Point Judith Pond, R.I. Mimeo report of Aquatic Plant Ecology Class, Univ. of R.I.

Youth Conservation Corps. 1976. Trustom Pond: Bounty to Bleakness. Preliminary report on Trustom Pond, 1976 summer survey. Xeroxed report.

Finfish

Arnold, E.L. 1941. Validity of scale analysis as a means of age determination of the winter flounder (Point Judith Pond). M.S. Thesis, Univ. of R.I.

Bieder, R.C. 1971. Age and growth in the American eel, Anguilla rostrata in Rhode Island. M.S. Thesis, Univ. of R.I.

Berry, R.J., S.B. Saila, and D.B. Horton. 1965. Growth Studies of Winter Flounder, Pseudopleuronectes americanus (Walbaum), in Rhode Island. Trans. Am. Fish. Soc., 94 (3): 259-264.

Bond, G.W. 1968. Breeding cycle and maturation of the sticklebacks, Alpedes quadrecus (Mitchell), Casterosteus aculeatus (Linnaeus) and Purgituis purgituis (Linnaeus) in two Rhode Island estuaries. M.S. Thesis, Univ. of R.I.

Feiner and Steiger, Inc. 1977. Eels bought from Rhode Island South Shore Ponds. Newburyport, Mass. Annual records.

Georgeoff, R.M., Jr. and M.T. Haskins. 1976. Population density and diversity in small fish at Potter's Pond. 1976 N.S.F. Summer High School Institute Student Research Report. GSO, Univ. of R.I.

Gersuny, C. and J.J. Poggie. 1974. Fishermen of Galilee. URI Marine Bulletin Series No. 17. 116 pp.

Jurgensen, K.M. and Crow, G. 1977. The $6-million eel, or from bait to delicacy in four years. 42nd North American Wildlife Conference. Wildlife Management Institute. pp. 329-335.

Keiffer E. 1970. A lifetime study of the marine science. Interview with Chester Whaley. Maritimes. 14: 1-2.

Lowe, T.P. 1975. Reproductive ecology of oyster toad fish (Opsanus tau) in Charlestown Pond, R.I. Ph.D. Thesis, Univ. of R.I.

Mulkana, M.S. 1966. The growth and feeding habits of juvenile fishes in two R.I. estuaries. Gulf Research Reports. 2: 97-168. Also a M.S. Thesis, Univ. of R.I.

Saila, S.B. 1961. A study of winter flounder movements. Limnol. Oceanog., 6: 292-298.

Saila, S.B. 1961. The contribution of estuaries to the offshore winter flounder fishery in Rhode Island. Proc. Gulf and Caribbean Fish Inst. 14th Session, pp. 95-109.

Saila, S.B., D.B. Horton, R.J. Berry. 1965. Estimates of the theoretical biomass of juvenile winter flounder, Pseudopleuronectes americanus (Walbaum) required for a fishery in Rhode Island. Fish. Res. Bd. Canada. 22: 945-953.

Smith, T.P. and K.E. McConnell. 1979. Marine Recreational Finfishing in Charlestown-Green Hill and Point Judith-Potter Ponds. Feb.-July 1978. Xeroxed report. Dept. of Resource Economics, URI.

Stolgitis, J.A., J.F. O'Brien and M.J. Fogarty. 1976. Rhode Island salt ponds fisheries inventory. Rhode Island Division of Fish and Wildlife fisheries Report No. 2.

Whaley, C.T. 1969. Intrusions on natural domain must be understood. Narragansett Times. February 22, 1969.

Winn, H.E., W.A. Richkus, and L.K. Winn. 1975. Sexual dimorphism and natural movements of the American eel (Anguilla rostrata) in Rhode Island streams and estuaries. Helg. Wiss. Meers. 27: 156-166.

Geology

Beale, R.A. 1975. Beach-nearshore sediment dispersal, Matunuck Point, Rhode Island. Unpub. M.S. Thesis, University of Rhode Island, Kingston.

Brown, C.W. 1938. Hurricane and shoreline changes in Rhode Island. Geographic Review. 29: 0416-1430.

Coddington, W. 1976. Relationships between dynamic nearshore processes and beach changes at Napatree Beach, Rhode Island. Unpub. M.S. Thesis, University of Rhode Island, Kingston.

Collins, B.P. 1974. Suspended material transport in lower Narragansett Bay and Western Rhode Island Sound. M.S. Thesis, University of Rhode Island, Kingston.

Corps of Engineers. 1950. South shore, State of Rhode Island, beach erosion control study: Letter from the Secretary of the Army. House Document No. 49, 81st Congress, 2nd Session, 52 pp.

Corps of Engineers. 1957. Beach erosion control report on cooperative study, South Kingstown and Westerly, Rhode Island: U.S. Army Engineer Division, Boston, Mass. 40 pp.

Corps of Engineers, 1961. Shore protection planning and design. Technical Report No. 4, Beach Erosion Board, Office of the Chief of Engineers, Washington, DC. 241 pp.

Corps of Engineers. 1962. Point Judith, Rhode Island: report on an interim hurricane survey: House Document No. 521, 87th Congress, 2nd Session.

Dillon, W.P. 1970. Submergence effects on a Rhode Island barrier and lagoon and inferences on migration of barriers. Journal of Geology. 78: 94-106.

Donovan, N. 1977. Wave energy and beach response on three southern Rhode Island beaches. M.S. Thesis.

Fisher, J.J. (In press). Jetties and shoreline changes in Rhode Island. Geoscience and Man. Louisiana State University.

McMaster, R.L. 1960. Mineralogy as an indicator of beach sand movement along the Rhode Island shore. Jour. Sed. Petrol. 30: 404-413.

McMaster, R.L. 1961. (Comp.) Transit surveying of selected Block Island Sound beaches in Washington County, Rhode Island, 1961-1975. Unpub. report, Coastal Resources Center, University of Rhode Island, Kingston.

McMaster, R.L. and L.E. Dekay. 1979. Status of beach immediately East of Charlestown Breachway: January 1977-December 1978. Interim Report, Coastal Resources Center, University of Rhode Island. 7 pp.

Morang, A. 1979. Documentation and preliminary evaluation of causes of severe erosion east of the Charlestown breachway, Rhode Island, during the winter of 1976-1977. Data report to Coastal Resources Center, University of R.I. 50 pp.

Nichols, R.L. and A.F. Marston. 1939. Shoreline changes in Rhode Island produced by the hurricane of September 21, 1938. Geol. Soc. Amer. Bull. 50: p. 1357.

Olsen, S.B. and M.J. Grant. Rhode Island's Barrier Beaches: Volume II. URI Marine Tech. Report No. 4.

Regan, D.R. 1976. An aerial photogrammetric survey of long-term shoreline changes, southern Rhode Island coast. Unpub. M.S. Thesis, University of Rhode Island, Kingston.

Simpson, E. 1977. A photogrammetric survey of back barrier accretion on the Rhode Island beaches. Masters Thesis, Univ. of R.I.

History

Browning, C.F. 1969. Early industry on the "backside." Pettaquamscutt Reporter. Vol. 6: 2-4.

Browning, C.F. 1973. Commercial buckeye fishing in South Kingstown in: Pettaquamscutt Perspectives: an oral history. B. McIlvaine and N. Willis (eds.) Kingston, Rhode Island Branch of American Association of University Women. pp. 12-27.

Bradner, L. 1921. Ninigret's Fort. Rhode Island Historical Society Collections. 14: 2-5.

Campbell, W. 1973. The Peace Dale Manufacturing Company. In: Pettaquamscutt Perspectives. B. McIlvaine and N. Willis (eds.) Kingston, Rhode Island Branch of American Association of University Women. pp. 28-38.

Carroll, C. 1879. Narragansett Pier. Harpers Magazine. 59: 161-177.

Denison, F. 1878. Westerly and its witnesses. J.A.R.A. Reid, Providence.

Fowler, W.S. and H.A. Luther. 1950. Cultural Sequence at the Potter Pond Site. Mass. Archeological Society Bull. pp. 91-102.

Gersuny, C. and J.J. Poggie, Jr. 1973. Harbor Improvements and Fishing at Point Judith. Rhode Island History. 32: 22-32.

Goode, G.B. 1884. The Fisheries of Rhode Island. Part IV. The Fisheries Industries of the United States, Vol. 2. U.S. Commission of Fish and Fisheries. pp. 283-310.

Goodwin, W.B. 1932. Notes regarding the origin of Fort Ninigret in the Narragansett County at Charlestown. Rhode Island Historical Society Collections. 25: 1-16.

Hazard, T.B. 1930. Nailer Tom's Diary 1778-1840. Merrymount Press, Boston, Mass. 808 pp.

Henwood, J.N.J. 1969. A short haul to the Bay; a history of the Narragansett Pier Railroad. Stephen Greene Press, Brattleboro, Vermont. 48 pp.

Lockwood, D.W. 1897. Survey of inner harbor at Point Judith Pond Rhode Island. Office of the Chief of Engineers, U.S. Army. Report to the Committee on Rivers and Harbors, U.S. House of Representatives. 50th Congress, 2nd Session. Document No. 132. 5 pp. plus map.

Matzinger, M. 1977. Some tall and short fish stories of old South County. Maritimes. 21: 5-8.

Meyer, S. 1977. Summary of the archeological testing conducted at Fort Ninigret, Charlestown Rhode Island in 1976. Mimeo Report. 26 pp.

Mochetti, L.J. 1979. Life's Little Pleasures. The photographs of J. Henry Burke 1900-1919. Friends of the Westerly Public Library. Westerly, Rhode Island. 76 pp.

Narragansett Times, September 9, 1887.

Parker, H. 1976. Charlestown and the Ocean. In: Reflections of Charlestown, Rhode Island 1876-1976. Utter Co. Westerly, R.I. pp. 18-28.

Pettaquamscutt Historical Society. 1963. Ships, Sailors, and Seaports. Kingston, Rhode Island. 51 pp.

Phillips, G.M. 1973. The story of the digging of the breachway. As told by G.S. Philips.

Providence Sunday Journal. December 1, 1889. Wakefield's Hope; a breakwater and permanent breach at Point Judith. p. 1.

Providence Sunday Journal. 1913. Wakefield's Seaport Dream Goes. December 14, 1913. p. 8.

Rhode Island Department of Public Works. Annual reports. Rhode Island State Library, State House.

Rhode Island Public Works Department. 1911. Report to Committee on Potter Pond Breachway. May 15, 1911.

Salwen, B. 1965. Sea Levels and the Archaic archeology of the New England coast. Ph.D. Thesis, Columbia University. 257 pp.

Salwen, B. and S. Meyer. 1978. Indian archeology in Rhode Island. Archeology Nov.-Dec. pp. 57-58.

South Kingstown Town Council Minutes. No. 11. 1900-1907.

Stedman, O.H. 1973. Narragansett Pier Railroad. In: Pettaquamscutt Perspectives. B. McIlvaine and N. Willis (eds.) Kingston, R.I. Branch American Association of University Women. pp. 28-39.

Stewart, P.C. 1962. A History of the Peace Dale Manufacturing Company. M.S. Thesis, Univ. of Rhode Island. 146 pp.

Westerly Sun. 1950. No. 5 of Westerlies Vanishing Scenes--The old shore dinner house on Brightman's Pond. January 30, 1950.

Whaley, Earl C. 1939. Fishing in Potters Pond. Narragansett Times. January 2, 1939.

Whaley, Earl C. 1939. History of Fishing on Point Judith Pond. Narragansett Times. January 12, 1939.

Whaley, C.T. 1968. Intrusions on Natural Domain Must be Understood. Providence Evening Bulletin. February 22, 1968. Letter to the editor.

Cole, J.R. 1889. History of Washington and Kent Counties. W.W. Preston. New York. 1344 pp.

Macrophytes

Conover, J.T. 1968. The importance of natural diffusion gradients and transport of substances related to benthic marine plant metabolism. Botanica Marina. 11: 1-9.

Dawson, C.G. 1977. Some aspects of the antecology of Ascophyllum nodosum (L.) of Point Judith Pond. M.S. Thesis, Univ. of R.I.

Halvorsen, W.L. and W.E. Gardiner. 1976. Atlas of Rhode Island Salt Marshes. CRC/URI Marine Memorandum No. 44.

Hargraves, P.F. 1965. On the seasonal changes in plant periphyton in a salinity gradient. M.S. Thesis, Univ. of R.I.

Hill, D.E., and A.E. Shearin. 1970. Tidal Marshes of Connecticut and Rhode Island. Conn. Agricultural Exp. Station. Bull. No. 709.

Marshall, N. and K. Lukas. 1970. Preliminary observations on the properties of bottom sediments with and without eelgrass, Zostera marina, cover. Proc. Nat. Shellfisheries Assoc., 60: 107-111.

Nixon, S.W. and C.A. Oviatt. 1972. Preliminary measurements of midsummer metabolism in beds of eelgrass, Zostera marina. Ecology, 53: 150-153.

Nixon, S.W. and C.A. Oviatt. 1973. Analysis of local variations in the standing crop of Spartina alterniflora. Botanica marina, 16: 103-109.

Oviatt, C.A., S.N. Nixon, and J. Garber. 1977. Variation and Evaluation of Coastal Salt Marshes. Environmental Management. 1: 201-211.

Short, F.T. 1975. Eelgrass production in Charlestown Pond: an ecological analysis and numerical simulation model. M.S. Thesis, Univ. of R.I.

Short, F.T., S.W. Nixon, and C.A..Oviatt. 1974. Field studies and simulations with a fine grid hydrodynamic model. An environmental study of a nuclear power plant at Charlestown, R.I. Univ. of R.I. Marine Tech. Report No. 33 VIB 1-27.

Smith, E.M. and R.D. Wood. 1973. The salinity gradient and vegetation in the Saugatucket River Estuary. URI Marine Tech. Report No. 6. 5 pp.

Vaughn, C.F. 1971. An ecological survey of the macroscopic algae of Point Judith Pond, R.I. M.S. Thesis, Univ. of R.I.

Wood, R.D., P.E. Hargraves. 1969. Comparative Benthic Plant Ecology by SCUBA-Monitored Quadrats. Hydrobiologia, 33: 561-586.

Wood, R.D. and E.A. Palmatier. 1954. Macroscopic Algae of the Coastal Ponds of Rhode Island. Am. J. Botany, 41: 135-142.

Wright, T.J., V.I. Cheadle, and E.A. Palmatier. 1949. A survey of Rhode Island's salt and brackish water ponds and marshes. R.I. Dept. Agr. and Conserv. Div. Fish and Game. Pittman Robertson Pamphlet No. 2.

Plankton

Jeffries, H.P. 1955. A comparative study of zooplankton production in Rhode Island Salt Ponds. Masters Thesis, Univ. of R.I.

Jeffries, H.P. 1962. Salinity-space distribution o f the estuarine copepod genus Eurytemora. Int. Revue ges. Hydrobiol. 47: 291-300.

Jeffries, H.P. 1962. Succession of two Acartia species in estuaries. Limnol. Oceanog. 7(3): 354-364.

Marshall, N. 1970. Food transfer through the lower trophic levels of the benthic environment. Marine Food Chains. Iliver Boyd Edinburgh. pp. 52-66.

Marshall, N., C.A. Oviatt, and D.M. Skauen. 1971. Productivity of the benthic microflora of shoal estuarine environments in Southern New England. Int. Revue ges. Hydrobiol., 56: 947-956.

Marshall, N., Skauen, D.M., and C.A. Oviatt. 1970. Sensitivity of benthic microflora to pollution gradients. Final project report, FWQA Project 18050 DXY-6/70.

Schenck, H. Jr. 1970. Turbidity profiles of Point Judith Pond and West Passage, Narragansett Bay. URI Dept. of Ocean Engineering. Sea Grant Publications. Memorandum No. 1M. 13 pp.

Smayda, T.J. 1962. Some quantitative aspects of primary production in a Rhode Island Coastal Salt Pond. pp. 123-125. Proceedings of the first National Coastal and shallow water research conference. NSF & ONR.

Tomas, C.R. 1971. An ecological survey of the plankton of Point Judith Pond. Masters Thesis, Univ. of R.I.

White, H. 1975. The phytoplankton and zooplankton of the Charlestown Pond and the Point Judith Pond systems. Unpublished report. Coastal Resources Center. 16 pp.

Williams, L.W. 1906. Notes on Marine Copepods of Rhode Island. Am. Nat., 40: 639-660.

Shellfish

Bennett, J.R. 1971. A study of the recreational shellfishery of Point Judith and Potter Ponds, South Kingstown and Narragansett, R.I. M.S. Thesis, Univ. of R.I.

Canario, M., K. Kovach, and R. Green. 1965. Shellfish survey of Bluff Hill Cove Narragansett, R.I. R.I. Div. Conservation, Dept. Nat. Res. Leaflet No. 18.

Cooper, R.A., S.B. Chenoweth, and N. Marshall. 1964. Condition of the quahog, Mercenaria mercenaria from polluted and unpolluted waters. Chesapeake Science, 4(4): 155-160.

Davis, R.L. and N. Marshall. 1963. The feeding of the bay scallop Aequipecten irradians. Proc. Nat. Shell. Assoc., 52: 25-29.

Ganz, A.R. 1973. Ecological studies of transplanted oysters Cassostrea virginia (Gmelin) M.S. Thesis, Univ. of R.I.

Ganz, A.R., 1975. A shellfish survey of Brightman's (Winnapaug) Pond, Westerly, Rhode Island. R.I. Dept. Nat. Res. Div. Fish Wild. Leaflet No. 42.

Ganz, A.R. and YCC. 1975. A shellfish survey of Quonochontaug Pond, Charlestown and Westerly, R.I. R.I. Dept. Nat. Res. Div. Fish Wild. Leaflet No. 46.

Gaucher, T.A. 1965. Dispersion in a subtidal Mya arenaria (Linnaeus) population. Ph.D. Thesis, Univ. of R.I.

Nayak, R.K. 1964. Some Aspects of the environmental biology of Mya arenaria (Linnaeus), in Green Hill Pond, R.I. M.S. Thesis, Univ. of R.I.

Saila, S.B. and T.A. Gaucher. 1966. Estimation of sampling distribution and numerical abundance of some mollusks in a R.I. salt pond. Proc. Nat. Shellfish Assoc. 56: 73-80.

Sisson, R.T. 1970. Occurrence of Bay Scallop Seed in Rhode Island. Project 3-113-R. R.I. Div. Cons., Dept. Nat. Res. Leaflet No. 32.

Wood, R.S. and YCC. 1976. A shellfish survey of Green Hill Pond, South Kingstown, Rhode Island. R.I. Dept. Nat. Res. Div. Fish Wild. Leaflet No. 47.

Woodruff, S. 1961. Report on observations of oysters in Charlestown Pond and Green Hill Pond over the summer of 1960. URI/GSO special report.

Zuraw, E.A., D.E. Leone, and W.J. Summers. 1969. Ecology of bivalve molluscs and the culture of Mya arenaria. General Dynamics #U-413-69-089, NTIS: AD696 132. 98 pp.

Jeffries, H.P. 1966. Internal condition of a diminishing blue crab population (Callinectes sapidus) Cheasapeake Science 7: 164-170.

Storms

Brown, C.W. 1938. Hurricane and shoreline changes in Rhode Island. Geographic Review. 29: 0416-1430.

Cry, G.W. 1964. Tropical cyclones of the North Atlantic Ocean, tracks and frequencies of hurricanes, and tropical storms. 1871-1963. U.S. Dept. of Commerce, Weather Bureau Tech. paper No. 55.

Devens, R.M. 1885. Our First Century. C.A. Nichols and Company. Springfield, Mass. Hugh Heron, Chicago, Il.

Environmental Science Data, National Climatic Center, Federal Building, Asheville, SC.

Gordon, B.L. 1976. Hurricanes in Southern New England. The Book and Tackle Shop. Watch Hill, R.I.

Greene, L.R. 1938. The hurricane, September 21, 1938. Westerly, Rhode Island and vicinity. Utter Co., Westerly, R.I.

Hammond, C.F. 1968. Watch Hill in the hurricane of September 21, 1938. Sea Side Topics. Vol. 35. Utter Co., Westerly, R.I.

Hurricane Carol Lashes Rhode Island. 1954. Providence Journal Company. 80 pp.

Hurricane Survey Interim Report. 1960. Narragansett Pier, Rhode Island. Army Corps of Engineers. New England Division. Waltham, Mass.

Miller, H.C. 1975. Coastal flood plain management and the national flood insurance program. A case study of three Rhode Island communities. Environmental Comment. pp. 2-15.

Providence Journal. 1954. Hurricane leaves 16 dead, scores hurt, $100,000,000 damage along R.I. Coast. September 1, 1954. Providence, R.I.

Rhode Islander. 1978. Hurricane '38. The Providence Sunday Journal Magazine. September 17, 1978.

Rhode Island Severe Storm Data. U.S. Dept. of Commerce, NOAA.

Roberts, C.G. and P.T. Browning. 1968. The hurricane and tidal wave of September 21, 1938.

Sundial. 1978. 1938 Hurricane. September 18, 1978, Westerly, R.I.

Wood, L. and J. Preble. 1977. In the Wake of '38. Oral history interviews with Rhode Island survivors and witnesses of the devestating hurricane of September 21, 1938. South Kingstown High School and Rhode Island Committee for the Humanities. 254 pp.

Wyman, D. 1954. Salt water injury of woody plants resulting from the hurricane of September 21, 1938. The Arnold Arboretum Garden Book. Van Nost Rand Company, New York. pp 327-333.