EXECUTIVE SUMMARY

A study of coastal resources management for Squibnocket Pond was conducted from May to December, 1989, based on limited fieldwork and a review of existing information. Squibnocket Pond is a brackish (10 o/oo) coastal pond connected to Menemsha Pond and the sea through a restricted, artificial channel ("Herring Creek"). Flow in the Creek changes direction with tidal periodicity, but exchange is insufficient to cause tidal displacements of surface elevation in the Pond. Variation in surface elevation instead is associated with rain events and, possibly, long period tidal oscillations. Current and salinity measurements in the Creek indicate an average seawater influx of 11,600 m^3/day, an average ebb flux of 26,600 m^3/day and a freshwater input to the Pond of 13,900 m^3/day.

The Pond is well mixed horizontally and vertically, with no evidence of stratification of salinity, nutrients or oxygen. Shellfish (clams, mussels, and oysters) are present but near their lower tolerance limit for salinity. Several indicators suggest the Pond is naturally eutrophic (highly productive): high chlorophyll **a**; high turbidity in the water column; high daytime dissolved oxygen levels; and abundant submerged aquatic vegetation (consisting predominantly of freshwater varieties). The tidal exchange and its pattern suggests materials entering the Pond are trapped inside for a long period of time.

Historical maps indicate the Pond was formerly connected to the sea through a natural inlet; other small, man-made connections have been created at two sites in the past. An artificial inlet through the barrier beach would probably be unstable, like all other inlets on the south shore of Martha's Vineyard, owing to active sand transport. Salinity in the Pond could probably be raised sufficiently for growing shellfish by improving exchange through the existing connection at Herring Creek, although this would not greatly increase flushing of the Pond. The direct salinity and biological response resulting from modest increases in exchange at Herring Creek would probably be in a state of flux for several years, and the biological response cannot be accurately predicted. However, the change would probably be reversible if, in the end, it were considered undesirable. Fecal coliform bacteria measurements suggest parts of the Pond are potentially subject to seasonal closures for shellfishing. This results from ambiguities in existing State regulations that do not distinguish between human and wildlife sources of this indicator. The implication is that management of Squibnocket Pond for shellfishing could be confounded by harvesting closure on the basis of these water quality standards.

Salinity modification to improve shellfishing may be deleterious to the alewife fishery. The alewife run at Squibnocket Pond presently has minor direct economic benefits, but is of significant cultural and historical value. The larger ecological role of alewives needs further evaluation; it is

believed the value of alewives is multiplied through their role as forage for sport fish in the area. Modest and inexpensive management steps are recommended, such as assuring passage of adults by enforcement of harvesting laws, identification and enhancement of spawning areas, and improved record keeping. Assessment of the future potential of this fishery is recommended.

Nitrogen-containing nutrients appear to limit plant growth during some periods of time. Present nitrogen loading to the Pond appears to be mainly conveyed by groundwater. For management purposes, the watershed is divided into three sectors: Nashaquitsa, Squibnocket Ridge, and Black Brook. Nashaquitsa, the most densely developed sector, presently is responsible for greatest nitrogen loading to the Pond (60%); but because of its large area, the Black Brook sector holds greatest loading potential if densely developed. If future land-use in the Squibnocket Ridge and Black Brook sectors increased groundwater nitrogen to the current level of Nashaquitsa, nitrogen loading to Squibnocket Pond would rise by a factor of three. Management of nutrient loading associated with human activities is promising for Squibnocket because of: its limited watershed and abundant wetlands; existing laws and self-imposed restrictions surrounding development; and an uncommon sensitivity and commitment of private landowners here to environmental protection.

The Gay Head Town landfill appears to be located within the Squibnocket watershed. No measurable impact was detected on nutrient concentrations in water samples from along Black Brook, which transects this portion of the watershed. A separate, commercial monitoring study of groundwater at the landfill concludes no significant increase of metals and other substances monitored was detectable. Some of the streams entering Squibnocket Pond, such as Black Brook, contain elevated levels of organic matter (62 ppm carbon) that colors the water dark brown. This is believed to be natural organic material, perhaps released by wetland vegetation and sediments.

Several challenging management concerns bear on the coastal resources of Squibnocket, such as: preservation of assets with largely subjective value (e.g., the coastal vista and wilderness ambience); the relationship and balance between private rights and governmental power in resource management; the use of ignorance of a sensitive resource as a means for protecting it (e.g., for archaeological sites and endangered species); and the balance and politics of shared government jurisdiction in the management and allocation of limited resources.

Our study illustrates the need for and value of a comprehensive and integrated approach in managing coastal resources at Squibnocket; we feel the study provides structure and substance to what is bound to be an ongoing process.

MANAGEMENT CONSIDERATIONS

Because of the complexity of natural systems, management decisions surrounding coastal resources generally need to be based upon incomplete information--hopefully the best information available. Since more than one political entity has jurisdiction over parts of Squibnocket Pond, unilateral management measures may be subject to challenge by other interested parties. As is normally the case in management of limited resources the questions of allocation and distribution of benefits need to be addressed.

Exchange with the Sea

For several years it has been proposed to construct an opening between Squibnocket Pond and the sea. Our review of historical information indicates that the Pond formerly had a natural breachway on the spit near Squibnocket Beach, and two small artificial connections to the sea of which one, Herring Creek, is still open. Because of the importance of salinity and flushing in terms of habitat, the extent of exchange with the sea is of primary importance to living coastal resources of the Pond and the larger sphere of biota and human activities that depend on them. As indicated earlier, the conspicuous marine invertebrates in the Pond are at or near their lower salinity tolerance limit; and the abundant submerged aquatic vegetation present is of a freshwater variety, presumably near its upper limit of salinity.

A question that must inevitably be addressed is what would be the biological response to increased exchange? This question is vastly more difficult to answer than may seem to be the case. One is inclined to assume organisms favoring higher salinities would be enhanced or introduced, while those favoring lower salinities or fresh water would decline. This is an oversimplification, however, because, for example, the introduction of predators, competitors, nuisance species or diseases can have an over riding affect. In the case of Squibnocket Pond, management options regarding exchange with the sea would probably be reversible and any one would not preclude future adoption of alternatives.

Decreased exchange with the sea

As one management option the present connection to the sea could be modified to prevent the incursion of seawater, so that over a few years Squibnocket Pond would become a fresh pond. It would become the largest freshwater pond on Martha's Vineyard and could provide the Island with increased habitat diversity for wildlife, as well as recreational and artisanal commercial potential. The Pond in this condition may be a better alewife spawning area than at present, if one or more fish ladders were provided to insure access by the adults.

As a fresh pond, Squibnocket Pond may have high dissolved organic carbon content, given that its principal streams drain wetlands and are stained brown with "tannins". The Pond may also be subject to catastrophic inundation by the sea during storms, with habitat instability associated with abrupt changes in salinity. If the Pond level were allowed to rise significantly, it could increase the potential for natural breaching of the barrier. An estimated 3 to 6 years would be required to flush out existing seawater and several additional years for expression of the direct biological response to the change.

Free Exchange with the sea

An unstructured natural inlet to the sea, occurring naturally or induced through human activities, would cause a major alteration in the salinity and flushing of Squibnocket Pond. The resulting pond may well resemble Menemsha Pond in terms of living coastal resources and habitat. Data of Walsh et al. (1979) indicate the salinity of Menemsha Pond departs very little from Vineyard Sound (see Table 6), despite known sources of fresh water entering the Pond.

From the general relationship between the volume of tidal exchange and the cross sectional area of natural inlets, it is possible to estimate the size of an unstructured inlet for Squibnocket Pond for different tidal range scenarios (Table 11). For perspective, the present inlet to Menemsha Pond has a cross sectional area of about 38 m^2 (410 ft^2) according to Moody (1988). This is about 30% of the predicted equilibrium cross sectional area for an unstructured inlet at Menemsha Pond. The very long inlet channel at Menemsha would have the effect of reducing the natural cross sectional area.

An inlet that resulted in tidal fluctuations matching scenario C (Table 11) would result in a major increase of flushing in Squibnocket Pond. In principle it could reduce residence time of seawater in the Pond from about half a year to about a week. Tidal flushing similar to that of Menemsha Pond would result in a residence time of less than four days. In this hypothetical example the salinity of the Pond would be about 0.1 o/oo lower than undiluted seawater of 31 o/oo.

The site of an artificial inlet would have a major effect on its stability, and hence on the maintenance needed to keep it open. An unstructured inlet at the site of the historical inlet at Squibnocket Beach would most probably be unstable and require repeated opening, like other artificial inlets to coastal ponds on the south shore of Martha's Vineyard. An unstructured inlet in the barrier spit could also be subject to horizontal migration, a process that would destroy the dunes presently located there. An inlet located near Nashaquitsa Cove at the east end of the Pond would probably be partially cut in glacial deposits and may be more resistent to migration. It would be exposed to storm waves of infinite fetch, however, and shoaling would most likely occur near the mouth.

An alternative site for an artificial inlet would be at Herring Creek, presently connecting Squibnocket Pond to Menemsha Pond through a restricted channel. At this site glacial and wetland deposits would be encountered, and the state highway would need to be crossed. However, inlet migration and sediment transport would probably pose little problem in the sheltered waters of the Ponds. An inlet at this site would affect and be affected by the fact that Menemsha Pond itself has an inlet. The need for increased flow at this inlet may necessitate modifications to the artificial structures that currently stabilize it. Increased flow could also affect sediment transport at Menemsha inlet.

The effect of an inlet of natural dimensions on salinity of the Pond would be expressed rapidly--perhaps a matter of several days. The response of organisms to the change would begin within a period of days and major changes directly associated with the opening would probably be complete in a few years. For example, the effect on alewives may not be evident in less than 3 to 6 years.

Controlled exchange with the sea at intermediate levels

It may be desirable to have the capability of managing exchange with the sea at intermediate levels. For example, in the event of an oil spill it would be useful to be able to close the Pond entirely for several days. If it is considered desirable to increase the salinity of the Pond to the range where commercial shellfish (except scallops) might grow, this may be possible with only minor modification to the existing Herring Creek. For example, if the amount of seawater entering the Pond could be doubled, from about 11,500 m^3/day to 23,000 m^3/day, the salinity of the Pond would rise from 10 o/oo to approximately 20 o/oo, which is well within the range for oysters and clams. The required 23,000 m^3/day is less than currently leaves the Pond on average with ebb tide, and it is less than 1% of the likely exchange through a natural inlet.

The present cross sectional area of Herring Creek where it enters Squibnocket Pond is about 1.7 m^2 (18 ft^2). The culvert that conducts Herring Creek under the state highway, and associated concrete structure, is only one of the sites that may provide an opportunity to regulate flow.

Salinity changes in the Pond accompanying doubled flood tide input of seawater would occur most rapidly over the first several months; in about six months, one half of the total expected salinity change would likely occur. Half of the remaining expected change would occur over the next six months. Little cumulative change in salinity would be expected after three years. The direct biological response could be in a state of flux for several years beyond that.

Management of Nutrients

The growth and abundance of plants depends upon numerous conditions, of which one set involves the availability of adequate nutrients. In many naturally occurring situations a limited supply of certain nutrients is responsible, in turn, for limiting the abundance and/or productivity of plants. Under these circumstances plant growth may be artificially stimulated by adding the nutrient(s) responsible for limiting growth, often nitrogen or phosphorus. Growth may be stimulated intentionally through fertilization (as any gardener or aquaculturist knows) or inadvertently through unintended enrichment associated with various human activities. In either case, it is in principle possible to manage plant growth through management of limiting nutrients.

Before attempting to do this for a water body, it is necessary to have some idea of the existing status of plant growth as well as the natural and human sources of nutrients. It is also prudent to decide what uses are intended for the water body or what condition is regarded as desirable.

The very low nitrogen concentration in samples collected in the Pond on September 2 suggests that plant growth can at some times be limited by nitrogen (phosphorus was high in all our samples). Under these conditions it would generally be assumed, therefore, that restricting additions of nitrogen-containing nutrients would prevent further plant growth. It should be noted that seasonal data of Walsh et al (1979; Table 6), and our own data for samples collected on October 9 (Table 9) suggest the periods of nitrogen limitation in Squibnocket Pond may be brief.

This study of Squibnocket Pond produced results we find quite surprising and informative. As expected, we found nitrogen loading is much less than for developed areas of southern Massachusetts--an estimated 20-25% (Table 12). The nitrogen concentration in entering groundwater also appears to be very low compared with more developed areas--an estimated 10-50% (Table 12). However, more than one source of data suggests Squibnocket Pond is highly productive (eutrophic): the abundance of submerged aquatic vegetation in the coves; the high turbidity of the water; high oxygen concentration during daylight hours; and high chlorophyll a concentrations (Table 6). Our suspicion is that this results from the nature of existing exchange with

Table 11. Calculated equilibrium cross-sectional areas (A_c) at MSL versus tidal prism (T_p) for a hypothetical inlet at Squibnocket Pond based on existing empirical models (modified from Kana and Mason, 1988). A_c in ft.^{2} and (m^2).

Source	Equation	Application	Predicted Ac* A	B	C
O'Brien (1969)	$A_c = 2.0 \times 10^{-5} T_p$	General	1770 (164)	1180 (110)	591 (55)
Nayak (1971)	$A_c = 1.89 \times 10^{-5} T_p$	Unjettied	1680 (156)	1120 (104)	560 (52)
Jarrett (1976)	$A_c = 7.75 \times 10^{-6} T_p^{1.05}$	Atlantic Coast	1720 (160)	1120 (107)	540 (53)
Jarrett (1976)	$Ac = 5.37 \times 10^{-6} T_p^{1.07}$	1 or no jetties	1710 (160)	1110 (107)	530 (53)

* Estimated for tidal range in Squibnocket Pond of ca.:

A - 3 feet (1 m); $T_p = 2.51 \times 10^6$ m^3;
B - 2 feet (0.66 m); $T_p = 1.67 \times 10^6$ m^3;
C - 1 foot (0.33 m); $T_p = 8.37 \times 10^5$ m^3.

the sea which causes the Pond to act as a trap for incoming materials. We also suspect that eutrophication has been a natural process in Squibnocket Pond, although it is estimated that present human sources of nitrogen have doubled the natural loading rate (Table 12).

What is the likelihood, from a practical viewpoint, that future nutrient input could be effectively managed? The Squibnocket Pond watershed is not extraordinarily large (i.e., in contrast with that of Lagoon Pond; Table 12) and involves only a small portion of the two Towns involved. The Pond itself occupies a larger portion of its catchment area than the others listed in Table 12. All of these attributes are favorable to nutrient management. Furthermore, the high proportion of wetland within the watershed implies existing legal restrictions on watershed modification, and provides a potentially effective nutrient trap. Finally, large portions of the watershed are presently undeveloped, and land owners here have in the past demonstrated an uncommon sensitivity and commitment to preservation of the land and Pond. These factors also could be favorable to nutrient management.

The results of our study can be used for a first estimate on the importance of various areal sources of nutrients to Squibnocket Pond. From data in Table 10 it is concluded that groundwater discharge is probably the most important vehicle for nitrogen loading. For this assessment it is assumed that no human intervention will occur in the beach/wetland sector of the watershed, which falls under conservation use restrictions; our assessment is limited to the remaining three watershed sectors. Table 13 summarizes the calculations. Nitrogen loading was calculated from total nitrogen groundwater concentrations (Table 10) for each sector, and the groundwater discharge from that sector assuming it is directly proportional to the area of the sector and given a total discharge of 13,900 m^3/day. The results (Table 13 column A) indicate that the Nashaquitsa sector is responsible for nearly 60 % of present loading, even though it occupies only 18% of the watershed.

We then calculated hypothetical nitrogen loading for other sectors if future land use resulted in groundwater nitrogen concentrations equal to that of the present Nashaquitsa sector (Table 13 columns B and C). The results indicate the Squibnocket Ridge sector could provide an increase over present loading by about 40% [(187-27)/392 = 0.40); Black Brook sector could increase loading by 173% [(815-135)/392 = 1.73]. If both sectors delivered groundwater at the concentration presently delivered by Nashaquitsa sector, nitrogen loading would increase by a factor of over 3 (Table 13 column C; 1230/392 = 3.14).

Table 12. Data and calculations for groundwater discharge and other characteristics of coastal ponds in southern Massachusetts: Lagoon Pond (Martha's Vineyard), Green Pond (Falmouth), Town Cove (Orleans), and Squibnocket Pond (Martha's Vineyard).

	LP	GP	TC	SP
Shoreline Length (Km)	11.6	9.3	11.5	9.47
Coastal Pond Area (km^2)	2.18	0.63	1.63	2.51
Groundwater Recharge Area (km^2)	13.5[a/] 19.7	4.3 7.6	4.6	5.41
Total Catchment Area (km^2)	15.7 21.9	4.9 8.2	6.2	7.86
Recharge Area/Pond Area	6.2 9.0	6.7 12.1	2.8	2.2
Groundwater Recharge (M^3/day)				
@ 16.1 in./yr (=0.41m/yr.)	17,600 24,600	5,500 9,200	7,000	8,800
@ 22 in/yr. (=0.55m/yr)	23,700 33,000	7,400 12,400	9,300	11,800
field estimate[b/] (m^3/day)	30,000 60,000	7,900 11,600	2,000 100,000	13,900
calc (@ Q_{sqb}/A_d) rate[c/]	29,400	10,500	8,100	13,900
Estimated N-loading (M/day)				
anthropogenic	1,560	2,100	1,400	194[d/]
total	-	-	1,800	392
Est. N concentration (uM/l)	53	200	220	28

a/ Range given where two methods for estimating recharge area gave different results.

b/ Estimated from salinity time series for LP, GP and TC; estimated from velocity time series for SP.

c/ Based on measured discharge rate for Squibnocket Pond/catchment area, applied to recharge areas for other ponds.

d/ Natural loading estimated by applying average N concentration of Squibnocket Ridge and Black Brook sectors to entire watershed. Anthropogenic = Total - Natural.

Table 13. Estimated nitrogen loading (nitrate, nitrite and ammonia) to Squibnocket Pond (Martha's Vineyard) via groundwater discharge.

		$NO_3+NO_2+NH_4$ (uM/l)	Q_{gw} a/ (m^3/day)	N-Loading (M-N/day)		
				A	B b/	C c/
Groundwater Sec.						
Squibnocket R.		12.6	2,120	27 (7%)	187 (34)	187 (15)
Nashaquitsa		88.4	2,540	230 (59%)	230 (42)	230 (17)
Black Brook		14.7	9,230	135 (34%)	135 (24)	815 (66)
				392	552	1230
Flowing Steams		2.88	?			
Ponds/Wetlands		3.72	-			
Brackish Ponds						
Squib. Pond d/	out	1.00	-26,500	-26.8		
	in	1.10	11,500	12.7		
	net			-14.1 (-4%)		

a/ Assumes groundwater discharge is the only significant source of freshwater to the Pond

b/ Calculated assuming Squibnocket Ridge sector discharged groundwater with nitrogen concentration equal to present Nashaquitsa estimated value.

c/ Calculated assuming Squibnocket Ridge and Black Brook sectors discharged groundwater with nitrogen concentration equal to present Nashaquitsa estimated value.

d/ Average nitrogen concentrations from data of Walsh et al (1979); see Table 6.

For perspective, EPA estimates indicate nitrogen loading associated with a typical U.S. household, including inputs from the septic system (1.2) and use of lawn fertilizer (0.8), is about 2 M/house/day. Thus the current loading from each sector in EPA house-equivalents is: Nashaquitsa, 100; Squibnocket Ridge, 12; and Black Brook, 60 houses.

The flux of nitrogen resulting from tidal exchange was also estimated. This amounted to a loss of only about 4% of current loading by groundwater (Table 13 column A, bottom). Hence, unless other mechanisms for large losses can be identified, the results suggest most nitrogen entering the Pond is trapped there in the biota and sediments. Other mechanisms that should be evaluated are denitrification and movements associated with migration of animals, such as fish and birds. Under conditions of nitrogen limitation, which we believe prevail for some periods in Squibnocket Pond, it is possible nitrogen is imported by tidal exchange.

Management tools that have been used to reduce nitrogen loading are: reduced lawn fertilizer application; upgraded zoning for residential construction; and innovative denitrifying septic systems, to name a few. Further assessment should also be given removal of nitrogen after it has already entered the Pond, such as by shellfish aquaculture, and fisheries development. Greatly increased exchange with the sea could also serve to remove nitrogen. All of these mechanisms should be quantitatively assessed before they are implemented.

Management of Wildlife Habitat and Fisheries Resources

Management of the alewife resource has been assessed by Bourne (1989; Appendix 1) as part of this study. The conclusions and recommendations of that study are given in his self-standing report. As mentioned earlier, shellfish of potential commercial value are at or near their lower limit of salinity tolerance in Squibnocket Pond. Management steps to enhance the environment for shellfish may reduce its value for alewives. Attempts to manage the Pond for shellfish may also lead to conflict with its use by natural predators of shellfish, such as waterfowl and aquatic mammals. The opportunities and tradeoffs associated with integrated management of fish and wildlife make management of these resources a challenging and worthwhile endeavour. The basic environmental information provided in this report provides a strong basis on which to begin a discussion of management.

Recreational Uses

Active and passive recreational use of the Pond has been limited by its remote location and restricted public access. This has effectively limited the use of boats and motors, and of recreational vehicles on adjacent lands. The low level of active recreational use is assumed to have a positive effect on the value of this area to wildlife, and on its wilderness ambience and value for passive recreation. The decision by private landowners to preserve the shoreline in its natural state has also served to enhance the value of the Pond for passive recreation and wildlife use.

Management of the Vista

The value and sensitivity of the natural vista at Squibnocket are subject to individual assessment and caprice. Our subjective belief (not entirely appropriate in this report) is that they are of great and unique value and of great vulnerability to human modifications. This area of management is most difficult and important, and it bears on fundamental rights of citizens under our system of government. The visual impacts associated with modification of the vista are difficult to assess quantitatively or objectively. Past management in this area has been most effectively practiced by the private land owner or conservation organization, and through public land acquisition.

Protection of Archaeological Sites

The abundant native American archaeological sites at Squibnocket are of particular interest and relevance, given that members of the Wampanoag Tribe continue to live in this area. The sites have added interest because of the undeveloped nature of lands around the Pond. Although several laws bear on preservation of these sites, ignorance of their location may be equally important for their survival. From a philosophical viewpoint, however, it would seem inappropriate to base a management plan for the sites on ignorance, given that their alleged presence is offered as justification for land preservation.

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