MIDGE MANAGEMENT RECOMMENDATIONS FOR STRAITS POND TOWNS OF HULL AND COHASSET, MASSACHUSETTS

Prepared For:	**Town of Hull** 253 Atlantic Avenue Hull, Massachusetts 02045
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Project No.:	**H114-000**
Date:	**February 22, 2002**

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1.0 INTRODUCTION

The Town of Hull, in partnership with The Town of Cohasset and a private organization, the Straits Pond Watershed Association (SPWA), and other local partners, has initiated a long-term watershed management planning effort at Straits Pond ("Pond"). This report specifically describes issues and recommendations involving the application of the pesticide temephos (trade name Abate) as a short-term measure for the control of non-biting midges (*Chironomys* sp.). Concern over midge infestation and increasing aquatic nuisance vegetation, primarily floating algal mats, and concerns about water quality prompted the initiation of a midge monitoring program and limnological investigation at Straits Pond located in the towns of Hull and Cohasset, Massachusetts. Environmental Science Services, Inc. (ESS) conducted the study during late spring, summer, and early fall of 2001. The investigation included an evaluation of watershed features as well as the physical, chemical, and biological features of the lake. The goals of the investigation were to:

- ?? Determine the effectiveness of Abate application through monitoring midge larvae distribution and population;
- ?? Assure that Abate is being applied appropriately so as to be both safe and effective;
- ?? evaluate the need for Abate application in general, as well as to evaluate options for algae control;
- ?? Evaluate water quality, aquatic vegetation, and watershed influences in relation to midge population and distribution; and
- ?? Develop a set of management recommendations based on the findings of this study.

The investigation of Straits Pond consisted of the following key components:

- ?? Pre- and Post-Abate Application Monitoring Program Design
- ?? Water Quality Monitoring
- ?? Sediment Midge Larvae Monitoring
- ?? Survey of Aquatic Vegetation
- ?? Definition of "Nuisance Conditions" and Adult Midge Monitoring Training and Guidance
- ?? Preparation of Management Recommendations Final Report

This report summarizes the approach and results for this monitoring program, discusses midge management feasibility of management alternatives, and provides midge management recommendations for Straits Pond and its watershed.

2.0 BACKGROUND

This section includes a history of Straits Pond and its management, a discussion of midge biology and population dynamics, and an overview of chemical treatment conducted at Straits Pond.

2.1 History of Straits Pond and Its Management

Like many hydrologically-restricted lakes and ponds across Massachusetts and elsewhere, Straits Pond has a serious eutrophication problem. Originally a salt marsh dammed in the late 1700s to support mill operations, Straits Pond has become progressively fresher and more phosphorus-limited over time. Until very recently, septage emptied directly into the Pond along with the unmitigated stormwater and landscape runoff that continues today, exacerbating this nutrient imbalance. Substantial amounts of phosphorus have accumulated in the Pond's organic sediments (IEP, 1980), creating a ready source of this nutrient that is released when dissolved oxygen (DO) drops sufficiently in the Pond's bottom waters.

Since the late 1800s, to varying degrees, Straits Pond watershed residents have endured the growth of nuisance aquatic weeds (e.g., algae blooms), fish kills, dense swarms of midges, and foul odors emanating from the Pond. Today, as the natural biodiversity of the Pond has been altered through increased pollution, sedimentation, and the spread of invasive species, these problems have grown exponentially. Every spring, as water temperatures rise in this shallow coastal pond, DO levels drop and swarms of non-biting adult midges emerge, impairing the quality of life – and in some cases, health – of local residents. As the spring turns to summer, the Pond's surface becomes covered in thick mats of algae, and its bottom is choked by widgeongrass (*Ruppia maritima*) and pondweed (*Potamageton pectinatus*). These rooted plants feed on nutrients in pond sediments, effectively recycling these nutrients to the pond bottom as they die and decompose in late summer-early fall. All of these conditions favor the hearty midge – an insect both tolerant of and a visible indicator of polluted, oxygen-starved environments – over more desirable finfish and benthic organisms, many of them midge predators.

Efforts to eradicate midges through the application of chemical pesticides have had limited success at achieving long-term insect control (MA DPH, 1953; Beres and Burbank, 1992; Beres et al., 1994) and have done nothing to address the root causes of midge infestation: nutrient enrichment and hydrologic restriction. However, significant strides have been made to reduce nutrient inputs to the Pond via both in-lake and watershed approaches.

A 2001 USGS topographic map was used to identify the watershed of Straits Pond (Figure 1). Although this is likely to be a very close approximation of the true watershed boundary, it is possible that the storm drainage systems in the watershed might not mirror surface topography.

Hull, Cohasset, and Hingham – the three towns containing the Strait's Pond watershed – continue to make significant investments in sewerage improvements, and have now sewered much of the watershed, with assistance from the DEP's State Revolving Fund (SRF). In 1999, Hull upgraded the derelict tide gate controlling the exchange of seawater to and from the Pond and hired a local resident to operate the gate in a manner that allows more flexibility in the management of tidal exchange and protects properties around the Pond from flooding. In 1986, Straits Pond and the Weir River Estuary became one of the Commonwealth's first Areas of Critical Environmental Concern (ACEC). In 1992 and 1994, teachers and students at Hull High School and South Shore Charter School conducted two extensive studies of midge populations in Straits Pond (Beres and Burbank, 1992 and Beres et al., 1994). These studies involved field sampling and laboratory investigations which found midges taken from the Pond ceased to pupate and often died at salinities greater than 18 ppt (Beres and Burbank, 1992 and Beres et al., 1994). Recent salinities measured in Straits Pond ranged from 10.26-11.43 ppt (ENSR, 2001). Beres and Burbank (1992) and Beres et al. (1994) also observed that fish such as mummichogs and striped killifish fed extensively on Straits Pond midges but ceased to prey and died off with increasing water temperatures (>80?F) and low oxygen conditions (typically < 6.0 mg/L).

In Spring 2001, Hull and Cohasset teamed up to fund an assessment of the effectiveness of their chemical midge control strategy and produce the Pond's first full-fledged management plan (this document). Hull conservation officials have since characterized watershed sub-drainage areas in preparation for design of appropriate stormwater treatment measures. Hull recently received a Coastal Pollution Remediation Grant from Massachusetts Coastal Zone Management Program to begin implementation of these measures. Students from Wentworth Institute of Technology recently developed conceptual designs for specialized catch basins, constructed wetlands, detention facilities, and other stormwater treatment devices for the Pond.

SPWA, in partnership with the towns and state environmental agencies, has hosted two Biodiversity Days, organized Coast Sweep cleanups, led bird walks and coastal geology tours, and produced and circulated watershed management outreach brochures. SPWA and local municipal officials have worked closely with the Weir River Watershed Association

(WRWA) and the state environmental agencies to develop watershed plans for the Weymouth-Weir and Boston Harbor watersheds. The Hingham Selectmen appointed a Streamflow Task Force to coordinate with the EOEA, DEM, and their consultant, GZA, on a streamflow and water budget study for the Weir River watershed. The Task Force also supported fish passage and other habitat restoration projects at Foundry Pond and other sites in the watershed. Recently, at the behest of local environmentalists, the private company that supplies water to parts of Hull, Hingham, and Cohasset, the Massachusetts American Company, agreed to fund maintenance of a real-time streamflow monitoring gauge on the Weir River. SPWA and WRWA are also working with EOEA's Boston Harbor Watershed Team to implement water quality sampling and natural resource inventories in the Weir and Straits Pond watersheds.

To be sure, the active residents and officials of this watershed have done a lot toward restoring the environmental integrity and biodiversity of Straits Pond. Still, inhibited tidal flushing and poor water circulation limit the Pond's ability to clear itself of its legacy of nutrient enrichment. In the late 1940s, the footbridge leading out to the unnamed island on the northwestern side of the Pond (now part of the Coleman property) collapsed. The bridge was replaced with a fill causeway with undersized culverts to adequately circulate water. The culverts quickly filled in with sediment. The island is now a de facto peninsula into the center of the Pond, blocking water circulation and contributing to stagnation and invasive plant growth. The current landowner has submitted a letter to the SPWA expressing his interest in seeing the island become conservation land.

At about the same time the culverts were installed, as the first Straits Pond tide gate was being built to replace the old flashboard dam control structure at the outlet to the Weir River estuary, cobble fill was placed along a bedrock/ledge feature at the western end of the Pond creating a temporary impoundment to allow construction to take place in the dry. This cobble fill was never fully removed and, together with a portion of the ledge, the fill restricts tidal exchange and prevents complete flushing of the Pond at low tide.

2.2 Midge Biology and Population Dynamics

Larval growth rates of aquatic insects including midges are based largely on the total length of time available for growth and the biomass accumulation rate of the larvae. Temperature alone has not been found to be as important as degree-day accumulation in terms of larval development (Resh and Rosenberg, 1984). The degree-day accumulation for any given day is defined as the difference in degrees between the mean daily temperatures and the developmental threshold. The available scientific literature on this subject suggest that the number of degree days needed to complete development for a given species is constant (Resh and Rosenberg, 1984). However, only a few studies have been conducted to determine the number of degree-days needed to complete larval development for particular species or in particular habitats. Therefore, there is no specific degree-day development threshold available for midges in Straits Pond. However, the literature suggests that a warmer winter and early spring would result in an earlier emergence of midge pupae from Pond sediments and adults from the Pond. This is an important consideration in the design of future midge monitoring and management plans for the Pond.

Voltinism is the frequency with which aquatic insect life cycles are completed. Midges are known to complete more or less life cycles based on the climatic zone in which they live (Resh and Rosenberg, 1984). In the northeastern U.S., midges have generally been found to complete between two and three life-cycles per year. Beres and Burbank (1992) and Beres et al. (1994) found that an initial midge emergence from Straits Pond sediments occurred in approximately mid-April, with subsequent emergences in June and August, and a decline in midge populations in September. During peak emergence, large numbers of these midges inundate residential areas causing annoyance and public health risks due to inhalation and respiratory effects, according to Hull Board of Health declarations. Midge larvae growth and development may be enhanced in nutrient rich waters (PPCP, 2000), and the presence of certain midge species may be indicative of excessive organic and nutrient inputs in the Pond (Webb, 1999).

2.3 Abate Application at Straits Pond

Under Emergency Declarations issued by the Board of Health, the Town has applied insecticides to Straits Pond to control midge infestations and protect the public from associated inhalation and ingestion risks since the 1950s. Recent midge control efforts include the annual application of Abate, an agent which targets the larval stage of midge development. Abate is ideally applied in late March before the first generation of over-wintering larvae complete the maturation process and emerge from the Pond as adults, and Abate has been applied to Straits Pond in order to control midge populations for each of the past six years (Lee Lyman – pers. comm., 2001). In early 2001, members of the Hull Conservation Commission requested that the Town provide additional information on midge management and Abate application at the Pond. Given the absence of applicable long-term midge population density data from Straits Pond in relation to Abate application, the Abate application proposed by the Town and ESS for 2001 was a routine application based on past practice, data available in published literature, and the manufacturer's requirements. The Town and ESS recommended that Abate be applied in April just prior to the reported initial emergence period of adult flies from the Pond.

In March 2001, the Town received approval from the Hull Conservation Commission to apply a pelletized form of Abate containing 1% temephos (active ingredient) for one year subject to renewal for years two and three based on the Commission's review of monitoring data. The following is an excerpt from that Order:

> "The treatment to control the population of non-biting midges is limited to the use of Abate™ 1-SG (active ingredient, Temephos). This approval is limited to one year (2001), subject to renewal for the remaining two years (2002 & 2003) of this order. Following the first year application and prior to December 31, 2001, the applicant shall present to the Commission the results of their work to develop a threshold larvae density to govern future applications. This report shall be the precursor for a renewal request and no guarantee is made that subsequent approvals will be granted by the Commission."

The application was contracted to a licensed commercial applicator who applied the material in concentrations required by the manufacturer for control of mosquitoes and midge larvae in "shallow ponds and lakes." This concentration, as specified by the manufacturer, was 5-10 lbs. of formulated product per acre, resulting in the application of 0.05 – 0.1 pounds of temephos per acre. Abate is applied directly to the water column and acts on organisms both in the water column and in surface sediments. According to the manufacturers description of the product, Abate is generally not persistent in the environment and dissipates relatively soon after application. Therefore, the effect of the chemical is to kill midges present at the time of application but not for any considerable period thereafter.

3.0 STUDY APPROACH

Monitoring midge larvae populations, the efficacy of Abate applications, aquatic vegetation, and water quality will provide essential baseline information for the development of the Long-Term midge Management Plan.

3.1 Study Methods and Implementation

3.1.1 Sample Site Selection

Based on discussions with the Hull Conservation Agent and SPWA as well as observations of Pond conditions such as water circulation patterns and watershed land use and topography, 10 midge sampling transects were selected. Transects were also sited to provide thorough coverage of the Pond and coverage of a variety of habitat conditions. Habitat conditions observed at these sites are presented in Attachment A. Sediment grab samples were collected along each of the 10 transects within three discrete pond zones: 1) nearshore areas, 2) mid-depth/offshore areas, and 3) deepwater areas. These zones were selected in order to determine if there were any significant differences in the effectiveness of current Abate application protocols with water depth and distance from shore. Hull officials who had observed the Abate application process hypothesized that the Abate application vessel (an airboat) was applying the chemical in higher concentrations in deeper portions of the Pond because the vessel could not access shallower areas due to its draft requirements, particularly when fully loaded with Abate. In order to test this hypothesis, nearshore areas were located at an approximate water depth of 2 feet and at an approximate distance from shore of 10 feet, offshore areas were located at an approximate water depth of 3 feet and an approximate distance from shore of 100 feet, and deepwater areas were located at an approximate water depth of 4 feet and an approximate distance from shore of 500 feet, with sample locations sited in each area. In total, three grab samples were sampled each round along the 10 transects, for a total of 30 samples per round.

3.1.2 Sample Site and Bathymetric Mapping

Pond sampling locations were recorded and accurately transcribed onto a Pond locus map (Figure 2). In addition, water depth measurements were collected at each midge sampling location and depth contours were developed and incorporated into the locus map. The Town and/or its consultant may use this locational information to return to the same sample locations for future rounds of midge larvae population monitoring, should additional sampling be necessary.

3.1.3 Midge Larvae Sampling Methodology

Midge sampling was performed using an 6" x 6" Ekman dredge from an ESS motorized boat along the 10 predefined transects. At each sampling location, a pre-cleaned Ekman dredge was used to retrieve one grab sample. Grab samples are preferred over cores for most invertebrate sampling studies since this method preferentially collects the upper oxygenated layers of the pond's substrate where biologic activity is typically greatest. Upon retrieval, excess water and fine sediment were drained out of the sample by placing the grab sample into a 3 gallon bucket sieve with a 541 µm (#30 mesh) bottom. Extraneous debris remaining in the bucket was removed by hand or was removed by repeated washings. After each sample had been adequately washed, all residual material remaining in the bucket was transferred to a 10 inch x 14 inch plastic gridlined tray with two delineated sections. Residual material was then evenly distributed along bottom of tray, and ESS personnel counted the number of midge larvae present in one randomly selected quadrat per sample. Only 3 dead midge larvae were identified in samples collected during the 4/19/01 post-Abate sampling effort. All midge larvae counted were alive (i.e., red and wriggling) at the time of sampling. The number of midges counted in the quadrat was then multiplied by two (the total number of sections in the tray) and then divided by the surface collecting area of the dredge. The dredge surface area (36 square inches) was then multiplied by a conversion factor of 50 in order to provide the number of midges per square meter. Several voucher specimens of midges were collected and preserved in ethyl alcohol for future reference. Dredge and bucket sieve were thoroughly washed immediately following each grab sample enumeration.

3.1.4 Midge Sampling Schedule

A total of six rounds of field sampling (midge monitoring) and investigation were conducted at Straits Pond. ESS personnel conducted initial field sampling (midge monitoring) and investigation efforts on 3/28/01 and 4/19/01. The pesticide Abate was applied to the Pond by Lycott Environmental on 4/11/01 in between these two rounds of sampling. An additional four (4) rounds of monitoring were conducted on 6/4/01, 7/6/01, 8/13/01, and 9/28/01. The results of the 2001 ESS midge enumeration are presented in Tables 1 and 2.

3.1.5 Water Quality Monitoring

ESS personnel measured water temperature, DO, pH, salinity, and conductivity along sample transects during each sample round. In addition, ESS sampled water quality at two locations in Straits Pond on 9/28/01 in order to characterize existing water quality conditions in the Pond. Water quality was sampled at one appropriate deep-water location (SP-1), both at the surface and bottom (to differentiate any potential salt-wedge related issues), and at one location near the outlet of the pond (SP-2) for a total of three samples (see Figure 2). These samples were analyzed for fecal coliform, E. coli, total phosphorus, dissolved phosphorus, total Kjeldahl nitrogen, total suspended solids (TSS), DO, temperature, pH, salinity, and conductivity. Sampling, analysis, and reporting protocols accepted by MADEP and USEPA were followed, and a MADEP certified laboratory was used to analyze samples. A discussion of results from this sampling is presented in Section 4.2.

At each location, ESS personnel collected surface water samples in laboratory cleaned and labeled sample bottles from just beneath the water surface at an appropriate distance from the bank or submerged obstacles via the direct grab method. Bottom water samples were collected via a van dorn bottle. A summary of water quality sampling/laboratory parameters is provided in Table 3.

Additional water quality measurements were collected in the field by ESS using instrumentation according to ESS' MADEP approved Standard Operating Guidelines. Measurements at each sampling site included pH, specific conductance, temperature, and DO. Field measurements were taken directly in the water column. A summary of water quality parameters that were measured in the field is provided in Table 4.

3.1 6 Aquatic Vegetation Survey

ESS conducted a survey of aquatic vegetation, and macroscopic algae at the Pond on 8/13/01. Transects were established relative to in-pond conditions such as water depth, cove isolation, length of littoral zone, and past observation of aquatic plants. At regularly-spaced sample stations along the transects, observed aquatic plant species were listed and prioritized by dominance. Measurements of percent cover and bio-volume (a volumetric measure which varies by depth of vegetative material in a pre-defined sample area) of aquatic vegetation were also be made, and samples were categorized at each station for both cover and bio-volume as follows: 0-25%, 26-50%, 51-75%, or 76-100%.

A map of aquatic plant distribution at the time of sampling is included as Figure 3. In addition, a plant species list and percent cover and bio-volume measures conducted along transects are presented in Tables 5 and 6, respectively.

3.1.7 Adult Midge Monitoring Training and Guidance

In Spring 2001, ESS conducted a training session for SPWA members and others interested in monitoring adult midges. ESS recommended appropriate sampling protocols and provided implementation guidance. The population of post-emergent adult midges was sampled at least weekly using light traps set at 10 locations (each associated with a transect) along the Pond shore for an established period during April through September. These samplers were checked, and captured adult midges were enumerated. Unfortunately, this method of monitoring proved unsuccessful due to weather and Pond conditions experienced at Straits Pond during the study period.

3.1.8 Establishment of Definition of "Nuisance Conditions"

The Town has proposed applications of Abate in 2002 and 2003 as part of an Integrated Pest Management (IPM) concept, applications triggered by the results of site-specific monitoring of midge larvae population density. The Town has also stated that Abate applications proposed for 2002 and 2003 will only be made when midge larvae population density exceeds threshold values developed through the monitoring of the 2001 Abate application.

In general, IPM suggests that chemical treatments not be applied as a matter of routine, but only when specific site monitoring indicates that pest density is above a certain "trigger" threshold. Depending on the pest vector to be controlled, threshold values may be reported in larvae per square meter, insects per unit volume, rodents per acre, or other density measure. There is no trigger threshold value for nuisance midge populations reported in the available literature. Specific discussions with both Norfolk County and Plymouth County Mosquito Control Districts, both the Northeastern and Southeastern Regional Offices of the Department of Environmental Protection, the MA Office of Coastal Zone Management, and Town of Scituate Conservation Commission staff (regarding midge control as Musquashcut Pond) also disclosed no specific trigger threshold value for midge control.

Without any pre-existing IPM threshold upon which to rely, ESS proposed to develop threshold midge larvae densities by sampling the pre-application midge larvae population and monitoring the concentration of adult midges and midge larvae at one-month intervals throughout the 2001 midge season. This information has generated data on the overall efficiency of Abate as a short-term control agent, the re-growth of the midge population following control efforts, and provided a basis for use of a threshold larvae density for potential Abate applications in 2002 and 2003. In addition to field monitoring data, literature research on midges was conducted via both library and internet searches and through dialogue with participants on the "midge listserve," a web-based clearinghouse of current midge information, and informal interviews were conducted with Town officials and local residents. Results of this research are presented in Section 4.5.

4.0 STUDY RESULTS

An analysis of potential trends and issues of concern was performed based on pre- (3/28/01) and post- (4/19/01) Abate application midge larvae monitoring in Straits Pond as well as overall midge monitoring results. Summary data collected and analyzed by ESS are presented in Tables 1, 2, and 5 through 16 and Figures 4 through 8. Key findings of this analysis are presented below.

4.1 Pre- to Post-Abate Application Midge Monitoring Results

ESS staff analyzed midge concentration data using Analysis of Variance (ANOVA) statistical tests to determine if midge concentrations varied significantly between pre- and post-Abate application sample dates (Table 7). Means of pre-Abate application samples vs. post-Abate application samples were compared for 3/28/01 (pre-) vs. 4/19/01 (post-) as well as for 3/28/01 (pre-) vs. the mean of 6/4/01, 7/6/01, 8/13/01, and 9/28/01 (all post-). Overall pre- and post-Abate application transect means were compared as well as means of samples collected in the nearshore, offshore, and deepwater zones (Tables 8-10; Figures 6-8).

The results of this analysis varied based on the water depth (distance-from-shore) zone. When the means of all sites and zones (combined) were compared for pre- vs. post- and for pre- vs. all post-, no significant differences were found between the means (? < 0.05, see Table 7). However, a significant decrease in midge concentrations was found between the deepwater pre- and post- means, while the offshore mean increased slightly from pre- to post- but did not increase significantly (Table 9). No significant difference was found for nearshore means. However, mean midge populations were found to increase most in samples collected in the nearshore zone. These results indicate that Abate may have been more effective – or more effectively applied – in the offshore and deepwater zones than in the nearshore zone.

ESS also examined midge concentration results found by Beres et al. (1994). The midge larvae sampling methodology used by Beres et al. (1994) was essentially the same as that used by ESS, and the findings of the 1992-1994 study are reported in the same units used by ESS. ESS ran an ANOVA test for the means of all sites sampled on 6/12/94 (pre-) vs. 7/1/94 (post-) and found a significant decrease in mean midge concentrations between 6/12/94 and 7/1/94 (? < 0.05, see Table 11). Abate was applied to the Pond during this interim period on 6/23/94. However, midge concentration data from 1992-1994 (Beres et al., 1994) and data from the present study indicate that midge concentrations in the Pond also experience a natural decline during this time of year (Figure 4 & 5), so some of this variance may be explained by these natural changes in the midge life cycle. Beres et al. (1994) did not sample in different water depth (distance-from-shore) zones, instead one sample was collected at each sample location to represent that portion of the Pond. In addition, ESS compared the means of historic midge data (1992-1994) to the 2001 data for similar seasonal sampling periods and these data suggest that there are significantly more midges reported in the present study than in the 1992 and Beres et al. (1994; Table12).

Of the 30 locations sampled by ESS, results at 13 of these indicated an increase in midge concentrations from pre- (3/28/01) to post- (4/19/01) Abate application, with 14 showing an apparent decrease, and 3 showing no change (Tables 1 & 2; Figure 5). Sample T4-1, located on the south shore of the Pond in Cohasset, had the highest midge larvae density of the samples taken on both 3/28/01 and 4/19/01. The midge larvae density at this site more than doubled from the first to the second sample round and was a full order of magnitude greater on 4/19/01 than any of the other sites sampled that day. This may indicate a source of pollution in the vicinity of this site, potentially related to septic or stormwater discharge. Site T1-1 had the highest midge concentration for any sample date with 40,000 midge larva per square meter on 6/4/01. T1-2 and T1-3 also had relatively high concentrations that day. Several other sites (e.g., T1-2, T2-2, T5-3, T6-1 and T7-2) had high midge larvae densities relative to the other sites sampled on 4/19/01, and site T6-1 had a relatively high concentration on 6/4/01.

An analysis of potential trends and issues of concern was performed based on overall 2001 midge larvae monitoring. The following findings are worth considering:

?? Midge population densities generally appeared to increase just after Abate application in April, with populations remaining at or near April post-application levels into June and July. This increase was found to be statistically significant using an ANOVA test (? < 0.05; see Table 7).

?? Midge population densities generally appeared to decrease substantially from March (3/28/01) to August (8/13/01) and to September (9/28/01). These decreases were found to be statistically significant using an ANOVA test (? < 0.05; see Table 7).

?? Midge population densities generally appeared to decrease substantially from July to August, remaining at or near August (8/13/01) levels into September (9/28/01).

?? A statistically significant (? < 0.05) increase in mean annual midge concentrations can be seen in the ESS 2001 data as compared to data collected during both the 1992 and 1994 sampling seasons of the Beres et al. (1994) study (see Table 12).

4.2 Water Quality and Aquatic Vegetation Results

In general, nutrient rich waters and reportedly poor water circulation have resulted in depressed DO levels in the deeper waters of the Pond during summer months. These conditions are favorable to midge growth and would not be conducive to a healthy predator base. Therefore, midges thrive during low DO conditions, which is evidenced by the peak in midge concentrations during the lowest DO period which was found to be June-August (Tables 1-2,13-14). It should also be noted that the Pond stratifies from approximately early June through late August, as indicated by the DO profiles for these months in Table 15. This stratification further creates conditions at the sediment water interface that favor midges, as few predators such as killifish can tolerate these low DO conditions. Furthermore, the poor DO levels would reduce the likelihood for success of a pond management strategy relying on increasing the predator base alone. Even with more predators having access to the Pond, these fish would not tend to utilize the deeper areas of the Pond as well as the shallow areas found to be extremely low in DO. The Massachusetts Surface Water Quality Standards (MADEP, 1998) establish a standard for DO in waterbodies of equal or greater than 5.0 mg/L and greater than 60% saturation for Class B warmwater fisheries (BWWF) waters, the classification for Straits Pond (314 CMR, 1997). DO levels in Straits Pond were found to fall below this level in deeper water samples in July and August but remained above 8.0 mg/L in surface waters sampled during the study period (Table 15). Before a strategy can be developed to help the Pond achieve this standard, better understanding of Pond water quality under various mixing conditions (e.g., well-mixed, early stratification, stratified) and the typical seasonal mixing cycles is required. A recommended monitoring strategy that would become part of the Pond's IPM approach is provided in Section 6.

The issue of how nutrient concentrations influence both midge and aquatic plant populations in the Pond is somewhat complex in coastal ponds like Straits Pond which receive substantial freshwater inputs from their watersheds as well as regular salt water inputs from adjacent estuaries. These factors as well as the configuration of the Pond may limit the ability of pond management techniques to completely eliminate midge populations from the Pond, although the management goal expressed by local residents is to reduce the midge population below nuisance levels which may be achievable through a combination of short- and long-term measures. The key to understanding this issue and designing an appropriate management program is to develop a monitoring program targeted to the management goals. The water quality discussion below is meant to provide a basis for management program development discussions among local residents and Town officials.

Waterbodies with salinities greater than 10 ppt generally tend to be nitrogen limited, meaning that any available nitrogen is almost immediately utilized by aquatic vegetation to fuel growth and that without sufficient nitrogen additional growth is limited. In freshwater systems, phosphorus tends to be limiting. Clearly, nutrient limitation goes to the heart of residents' concerns about the overabundance of both aquatic vegetation and midges. The aquatic plant community, including macroscopic algae, retains and cycles nutrients through the Pond during the year. As these plants die and decompose, DO is used up and DO levels fall, creating conditions favorable to midges as described above. Warmer water temperatures during the summer months accelerate plant growth and death rates as well as decomposition rates, leading to lower DO levels in the warmest months. However, the reduction in nutrient inputs to the Pond from watershed sources can only go so far toward reducing aquatic vegetation and increasing DO levels. Once a pond has a high level of aquatic vegetation, the aquatic plant community can cycle and effectively recycle nutrients from the atmosphere and stored in pond sediments to fuel growth year after year. In these cases, it is often better to seek an in-pond solution such as aquatic vegetation harvesting or, in some cases, dredging in conjunction with watershed source reduction to control the long-term aquatic vegetation problem and the associated DO and midge problems. Presently, there are no Massachusetts standards for nutrients. However, USEPA guidance suggests that in many cases phosphorus levels exceeding 0.03-0.05 mg/l and nitrogen levels exceeding 0.1 mg/l may lead to accelerated waterbody eutrophication.

Salinity levels in the Pond were in most cases greater than 20 ppt (Table 13 & 14), indicating a strong saltwater influence. While data from water quality samples collected and analyzed for nutrients during this study did not indicate a definitive nitrogen or phosphorus limitation (Table 16), it is difficult to make such a determination based on the relatively small number of water quality samples collected during the study. A long-term monitoring program is needed to better understand this important issue.

Based on discussion with Town officials and local residents, aquatic vegetation is currently at nuisance levels in Straits Pond in the summer months. Active management, primarily through in-pond measures, will be required to bring vegetation levels into check. See Sections 5 and 6 and Table 17 and 18 for more information on potential in-pond measures.

4.3 Discussion of Abate Efficacy

The increase in midge larvae densities from pre- to post-Abate application may be related to midge population dynamics, Abate efficacy, some combination of both, or other factors such as seasonal or annual temperature variations tide gate management/tidal exchange. The findings of this study did not show a significant reduction in midge concentrations after the application of Abate in 2001.

As no other analogous published studies were available for comparison, ESS compared the 2001 midge population density data to data collected during the Beres et al. (1994) study to better understand whether these April midge larvae densities would have been less, equal to, or greater if Abate had not been applied. ESS understands that Abate was not applied to Straits Pond during the 1992 and 1993 sampling seasons during the Beres et al. (1994) study, however, in-pond water levels were manipulated as a part of a pond management experiment during that period. Abate was applied (although the dosage and form of application are not known) during the 1994 season of the study on 6/23/94 (Beres et al., 1994). Mean midge concentration data from both the ESS 2001 and 1992-1994 are presented in Figure 4.

Although the Beres et al. (1994) study had several inconsistencies in its experimental design and some of the conclusions included in the study's reports are not fully supported by the data collected, the midge concentration data were collected in a scientifically sound and valid manner and provide the best available historic information on midge concentrations related to Abate application in Massachusetts ponds.

4.4 Definition of "Nuisance Conditions" and Midge Management Threshold

No threshold midge management thresholds or reference values appropriate for application to the Straits Pond situation were found in published literature and internet sites researched by ESS staff and through interviews with key pest management and local officials. Homeowners around Straits Pond were interviewed in 1992 (Beres and Burbank, 1992) to determine the level of awareness and interest in the midge issue and to characterize public opinion on the extent and duration of midge infestation. The results of that survey suggest that the level of "nuisance" varied among respondents, some saying they considering midges a serious health risk and others saying they did not find midges to be much of a problem. The results of the survey also indicate that respondents considered the months of June, July, August the months when midges (the adult flies) were the greatest nuisance. Some respondents also mentioned that May and September were periods of some level of nuisance from midges (Beres and Burbank, 1992).

Due to the inconclusive nature of findings relative to Abate application, a threshold density value to govern the application of Abate in years 2002 and 2003 cannot be developed at this time. In place of such a threshold, ESS recommends that a performance-based approach be considered that is integrated with other Pond assessment and management measures, as discussed in Sections 5 and 6. These findings may also indicate that a more targeted approach to Abate application may be more effective at controlling midge larvae populations in Straits Pond or that other management methods may be more effective.

5.0 MANAGEMENT FEASIBILITY ASSESSMENT FOR STRAITS POND

This section presents a discussion of the feasibility of selected management options for Straits Pond as well as the basis used for selecting these alternatives.

5.1 Management Objectives

Based on interviews with SPWA members and local officials, the primary management objectives for Straits Pond can be stated as follows:

?? Reduce the population density of midges in and around the Pond;

?? Increase the Pond's ability to clear itself of nutrient enrichment;

?? Reduce the extent and bio-volume of nuisance aquatic plants in the Pond; and

?? Reduce the frequency and severity of algal blooms in the Pond.

5.2 Management Alternatives

Several management options were evaluated based on field observations, an analysis of available data, and a review of previous Straits Pond studies. Alternatives analyzed included chemical treatment, other in-pond management measures, and watershed management measures. A discussion of these alternatives is presented below and recommended alternatives are presented in Section 6.0.

5.2.1 Chemical Application Alternatives

While numerous approaches to midge management could be tested for Straits Pond, Based on midge monitoring for Straits Pond conducted by ESS (2001) and other studies (i.e., Beres et al., 1994), there appears to be some uncertainty as to the effectiveness of applying the chemical pesticide Abate to Straits Pond for midge control, at least under the current protocol. Specifically, mean midge concentrations were found to increase after Abate application on 4/11/01 in nearshore and offshore zones and decrease in the deepwater zone, and the ability to attribute midge concentration reductions found in 1994 to Abate application may be confounded by what appear to be natural cycles in midge populations in the Pond. Given this situation and the lack of other analogous midge monitoring data in relation to Abate application, ESS recommends that the following subset of management approaches be considered by the Town, SPWA, and other interested parties:

Please Note: These alternatives are _not_ *presented in order of priority.*

1. **Continue Current Abate Application Protocol –** Abate would be applied as it has been over the entire Pond by a licensed pesticide applicator.

2. **Continue Current Abate Application Protocol with Monitoring –** Abate would be applied as it has been over the entire Pond by a licensed pesticide applicator. The Town or its consultant would monitor midge populations over several rounds both pre- and post-Abate application. This may be done for one or more years. The data would be reviewed at the end of each study season to refine the understanding of Abate effectiveness.

3. **Temporally Targeted Abate Application –** Under this alternative, Abate would be applied either once or twice during the spring-summer during periods of highest midge concentrations found during 2001 and 1992-1994 monitoring and/or prior to initial adult fly emergence.

4. **Spatially Targeted Abate Application –** Under this alternative, Abate would be applied to those areas of the Pond that demonstrated higher midge concentrations during 2001 monitoring.

5. **Experimental Abate Application –**

   5a. Under this alternative, two coves of known high midge concentrations and of similar environmental, geomorphic, and areal character would be selected for study. In one cove, a silt curtain would be hung to isolate the cove from the rest of the Pond. Abate would be applied in this cove only. No Abate would be applied to the other cove *or to the rest of the Pond*. Both coves would be monitored for midge concentrations over several rounds both pre- and post-Abate application.

   5b. Under this alternative, two coves of known high midge concentrations and of similar environmental, geomorphic, and areal character would be selected for study. Silt curtains would be hung to isolate *both* coves from the rest of the Pond. Abate would be applied in one cove only. No Abate would be applied to the other cove. Both coves would be monitored for midge concentrations over several rounds both pre- and post-Abate application.

6. **Apply No Abate in 2002 with Monitoring –** This alternative would apply no Abate to the Pond in 2002. The Town or its consultant would monitor midge populations over several rounds. Data from 2002 would be compared to data from 2001 and 1994 to refine the understanding of Abate effectiveness.

7. **Increased Dose Abate Application –** Abate would be applied over the entire Pond by a licensed pesticide applicator using a higher dose of the chemical in accordance with rules and regulations on Abate use.

5.2.2 Other In-Pond Management Alternatives

Other in-pond management alternatives include the following:

?? Dredging

?? Nutrient inactivation in in-flowing waters and bottom sediments

?? Mechanical harvesting of aquatic vegetation

?? Herbicide application

?? Biological controls

?? Benthic Barriers

?? Drawdowns

5.2.3 Watershed Management Alternatives

Watershed management measures focus on identifying sources of water quality impairment in the drainage area of the study waterbody. In the case of Straits Pond, a major goal of the Towns which share the Pond and SPWA has been to prevent nutrients from entering the Pond which fuel the growth of nuisance aquatic vegetation and create conditions favorable to midges as discussed in Section 2. Based on field observations and extensive discussions with Town officials and SPWA members, the following watershed management alternatives were considered:

?? Stormwater management (e.g., specialized catch basins, constructed wetlands, detention/recharge);

?? Groundwater quality improvements (e.g., sewer extensions, septic system upgrades); and

?? Flow improvements (e.g., modifications to the tide gate at the Route 228 bridge, ledge notching near the inlet/outlet to allow increased tidal exchange, and dredging).

6.0 RECOMMENDED POND AND WATERSHED MANAGEMENT PROGRAM

Based on field observations, an analysis of available data, a review of previous Straits Pond studies, discussions with Town officials and SPWA members, and professional judgment, the following recommendations were developed for short- and long-term midge control and water quality management at Straits Pond:

6.1 Recommended Chemical Application Approach for Midge Control

Based on the research and analysis conducted under this study, ESS recommends that the following management measures be implemented under an adaptive Integrated Pest Management (IPM) approach tied to future midge monitoring results:

Temporally Targeted Abate Application – Abate would be applied either once or twice during the spring-summer during periods of highest midge concentrations found during 2001 and 1992-1994 monitoring and/or prior to initial adult fly emergence. Application would be based in part on degree-day monitoring, as discussed in the ESS draft report.

Spatially Targeted Abate Application – Abate would be specifically targeted to those areas of the Pond that demonstrated higher midge concentrations during 2001 monitoring.

Experimental Abate Application – Two coves, a test cove and a control cove, of known high midge concentrations and of similar environmental, geomorphic, and areal character would be selected for study. Silt curtains would be hung to isolate the control cove from the rest of the Pond, and no Abate would be applied to this cove. Abate would be applied in the test cove only. No Abate would be applied to the other cove. Both coves would be monitored for midge concentrations over several rounds both pre- and post-Abate application.

As discussed in Section 2.2 of the draft report, the literature on aquatic insect development suggests that a warmer winter and early spring would result in an earlier emergence of midge pupae from Pond sediments and adults from the Pond. To account for this, ESS recommends that air temperature data be monitored (or that NOAA or other local monitoring data be tracked) throughout the year and used to determine the most appropriate application time for Abate each spring that Abate is to be applied.

More complete tracking and reporting of Abate application concentrations and methods is also recommended. Based on monitoring results that indicated reduced effectiveness of Abate as applied to the Pond in nearshore and/or shallow areas, ESS recommends applying Abate in these areas of the Pond when the Abate application vessel is not fully loaded so that these areas can be better accessed and Abate can be applied in an appropriate concentration. ESS recommends that the Town work with its licensed pesticide applicator to revise the application protocols based on the findings of the ESS study – and in future based on an adaptive IPM approach tied to midge monitoring results – in order to implement the recommendations listed herein most effectively.

ESS also recommends that the Town consider using a slow release tablet form of Abate rather than the granular form used presently. Tablet form Abate has been shown in at least one scientific study to be more effective at controlling midges than the granular form.

6.2 Algae Management Measures

Control of algae blooms in Straits Pond can be accomplished over the long-term by improving the quality of water entering the pond and/or increasing the flushing of the Pond by seawater. In the short-term however, it may be desirable to control algae blooms through the use of in-lake management actions such as mechanical removal or chemical application.

Mechanical techniques that may be employed would depend on the nature of the algae bloom. For blooms that form algal mats or floating colonies, a weed harvester could be employed. If mats are sufficiently dense a hydro-rake could also be utilized. The cost for these approaches would range from a minimum of $350/acre for harvesting up to a maximum of $2,500/acre for hydro-raking plus additional cost for trucking and disposal of the material removed. Typically, mechanical removal techniques work best after substantial mat formation has occurred and conditions in the pond are at peak nuisance levels. Ultimately, the success of either of these approaches will be dependant on the nature of the algae bloom and the level of effort expended.

Chemical control is likely to be the most effective and the most economical short-term approach for algae control. Algae treatments in Straits Pond would likely be performed using Captain™ or KT® algicide (both copper based compounds) or Hydrothol® 191 (see

Attachment B). Hydrothol® 191 is a broad-spectrum organic aquatic algicide. The most appropriate choice will need to be determined by a licensed commercial applicator and is likely to be based on the specific type of algae present, pond salinity, dissolved oxygen, and potentially other physical or chemical factors at the time of treatment. Whichever chemical is selected, it will be important to treat the algae before they are allowed to develop into a noxious algal bloom. To track algal growth may require water clarity monitoring with a Secchi disk or other method. Treating algae chemically before major noxious bloom outbreaks or mechanically will substantially minimize the potential for fish kills associated with low oxygen levels created by decaying algae following treatment. Similarly, it may be advisable to treat the pond in sections over time (stepwise treatments) to further reduce the risk of oxygen problems.

6.3 Other Recommended In-Pond and Watershed Management Measures

The following watershed management measures are recommended based on field observations, an analysis of available data, and a review of previous Straits Pond studies[1]. These are long-term measures that could be pursued by watershed partners through grant and other funding programs over time. A list of specific implementation projects based on these measures and cost estimates for these projects is included as Attachment A.

1. **Tidal Exchange and Water Circulation Improvements –** Proposed measures include removal of the fill causeway to the island (or replacement of undersized culverts with appropriately sized culverts) and removal of cobble fill and, as necessary, ledge outcrop to allow increased tidal exchange. Such improvements are expected to improve benthic and fisheries habitat and passage by increasing tidal exchange, flushing nutrients, increasing DO and salinity, and reducing water temperatures. This includes final design and permitting of these measures.
2. **Tide Gate Management Planning –** After Strategy 1 is implemented, a tide gate management program will be developed based on new flow regimes in order to manage toward desired biological, ecosystem, and other endpoints. Strategy 1 will allow more complete cold-weather drawdowns and improve the likelihood of success of other proposed aquatic weed control strategies.
3. **Mechanical Harvest of Algae and Pondweeds –** Mechanical harvest and off-site composting of algae and pondweeds will be scheduled once a year for each of the three years of the grant in order to remove nutrients, reduce plant densities, improve habitat, and supplement other management activities.

[1] Diagnostic/feasibility studies conducted since 1953 support and recommend these approaches (MA DPH, 1953; IEP, 1980; Beres et al., 1992 and 1994).

4. **Integrated Pest Management (IPM) –** This approach will involve local resident volunteer monitors, local officials, and technical advisors in the application of targeted biological and, as necessary, chemical controls to control midges and restore ecological balance to the pond ecosystem. A carefully crafted monitoring and associated management communication program will be the basis for a dynamic management system supported by local data collected on a regular basis to support day-to-day management decisions. Midge predators such as mummichogs and killifish will be viewed as "keystone" species for the Straits Pond ecosystem. Numeric population (minimum) targets will be established by species for midges and selected "desirable" fish and macroinvertebrate species, and a set of management protocols will be tied to tide gate operation and biological/chemical control strategies.
5. **Watershed Outreach and Involvement** (see Outreach and Technology Transfer section below).

7.0 REFERENCES

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