NUISANCE PROBLEMS ASSOCIATED WITH MASS EMERGENCES OF CHIRONOMIDAE (NON-BITING MIDGES) – WITH SPECIAL REFERENCE TO THE SITUATION AT MILLBROOK LAKE

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NUISANCE PROBLEMS ASSOCIATED WITH MASS EMERGENCES OF CHIRONOMIDAE (NON-BITING MIDGES) - WITH SPECIAL REFERENCE TO THE SITUATION AT MILLBROOK LAKE

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1. INTRODUCTION.

This report is based on a review of relevant literature and on many years experience of research on the biology of Chironomidae, which includes a limited amount of previous experience of nuisance problems associated with mass emergences of adult midges. Section 2 provides a brief overview of the biology of Chironomidae in general and Section 3 considers the biology of *Chironomus salinarius*, the species responsible for the local problem, more specifically. In Section 4 the management options for Millbrook Lake are discussed in relation to their likely impact on the midge problem. Some other possibilities for reducing the scale of the nuisance are discussed in Section 5 and the main points of the report are summarised in Section 6.

My familiarity with Millbrook Lake derives from a single visit in late January 1998 when, as would be anticipated, no midges were in evidence. The situation at Millbrook appears to be typical of this type of nuisance in the UK which generally results from periodic mass emergences of a single species from a waterbody close to a residential area. A number of species have been implicated in such cases but that suspected of causing the problem at

Millbrook, *Chironomus salinarius,* has been reported as a nuisance species on a number of occasions in other parts of the world, notably Venice and Orbotello in Italy. The problem in Venice has been the subject of a good deal of research but, short of the regular application of large amounts of insecticide, no practical solution to the problem is apparent in that situation.

Although chironomids are abundant virtually everywhere in fresh and in brackish water the adults generally do not constitute a nuisance, at least in the UK, except in situations where the bottom-dwelling community as a whole is depleted for some reason. This may arise where physical-habitat is very uniform and simple; examples are concrete reservoirs and slow sand filters. Some aspect of water quality may also make a water body unsuitable for most species, allowing tolerant species to develop much higher population densities than usual. Chironomid nuisance problems also sometimes develop following the creation of a new reservoir by flooding of agricultural land, after which chironomids often dominate the community for several years (because there is an abundant food supply and chironomids are adept at colonising new situations). In this case the problem usually abates after a few years when a more diverse and balanced community has had time to develop.

The magnitude of the problem in the UK is very small compared with those reported from some other parts of the world. In Japan for example, the dead insects sometimes accumulate on roads in such quantities that they make the roads slippery and are a hazard to traffic.

2. LIFE-CYCLE AND BIOLOGY OF CHIRONOMIDAE

2.1 Background

Chironomidae have a worldwide distribution and are abundant in virtually all freshwater habitats. Some species are physiologically adapted to life in brackish water and the family also includes some of the very few insects that are capable of living in a truly marine environment as well as a number of terrestrial species that live in damp soil. The vast majority of species, however spend their larval life in freshwater. These will be familiar to many people as bloodworms; which are often used as bait by anglers and are also marketed as food for aquarium-fish. These commonly grow to a length of 2 - 3 cm. Their bright red coloration is due to their haemoglobin content that enables them to survive periods of very low oxygen concentration. Such larvae may often be seen swimming with a figure-of-eight motion in water butts and garden ponds. However, they live most of the time in bottom sediments in which they construct tubes.

Worldwide there are several thousands of described species, and new species are frequently being discovered - even in Britain, where currently about 600 species are known to occur. Not all species of chironomid possess haemoglobin in the larval stage and consequently not all are bright red in colour. Some species are restricted to very specific habitats but many are capable of thriving in a wide range of environmental conditions.

2.2 The ecological role of Chironomidae

Some species of chironomid are predators but the main food sources for chironomids in freshwater habitats are decomposing organic matter (detritus) with associated micro-organisms, and / or algae. In contrast to the situation in terrestrial ecosystems, very few invertebrates in freshwater eat the healthy tissues of higher plants. Chironomid larvae frequently occur at high densities (they are often the most abundant macro-invertebrates in freshwater) and are a major food resource for fish; thus constituting an important part of the freshwater food-chain.

The survival of some species of duckling has been shown to be closely correlated with the abundance of emerging midges soon after hatching, when they are an important source of nutrition for the ducklings. Adult midges are also an important component of the food of aerial feeding birds such as swallows, martins and swifts.

2.3 The life cycle of Chironomidae

The length of adult life is only a matter of a few days, but since emergence may take place over several days the midges from a single emergence may well remain conspicuous for up to a couple of weeks. Adult chironomids do not have biting or piercing mouthparts and do not need to feed in order to mate and produce fertile eggs.

The males of most species form swarms usually above a prominent marker of some kind, such as a shrub or post. Such swarms are typical of warm summer evenings but there are species which emerge and swarm throughout the year if conditions are suitable. Swarming is inhibited by rain or anything more than a slight breeze. Swarming by males is an essential feature of the life cycle of most species since the female chironomids are attracted to the swarms by chemicals (pheromones) and by the sound, usually inaudible to the human ear, produced by the vibration of the wings of thousands of males. On entering the swarm a female is immediately seized by one of the males and the pair drops out of the swarm to continue mating on the ground or in vegetation.

The number of eggs laid by a single female varies enormously between species, from a hundred or so to three thousand or more. Usually the eggs are laid in a single batch but some females manage to produce one or two additional smaller batches. Each batch of eggs is laid in a gelatinous tube or ball, the elongate eggs usually being arranged in a spiral within the jelly. When first extruded the jelly is very sticky and adheres to any solid object with which it comes into contact, but soon expands and loses its stickiness in water. The egg ropes are either laid directly onto a stone, plant or other surface at the margin of a water body or else the mass is simply dropped onto the water surface where it either sinks to the bottom or becomes attached to a plant or other submerged object.

The time taken for eggs to hatch varies with temperature but at UK summer temperatures it is typically about 2 days. When the larvae hatch they are extremely small and colourless which makes them very difficult to see. They spend a short time feeding on the jelly of the egg mass, probably also deriving nutriment from associated micro-organisms, before swimming up into the water column. They are poor swimmers and dispersal is mainly due to water currents. Mortality during this stage is undoubtedly very high but ~~few~~ little good data exists.

Larvae go through 4 developmental stages (instars) separated by moults. The first larval stage (instar) typically lasts only for about 5 days, during which the larvae settle on a suitable substrate.This may be a plant, a rock, gravel, sand, organic silt, submerged wood or even the body of some other invertebrate; the choice varies according to species but particle size is one factor involved in substrate selection. Some predatory species remain free-living, burrowing in the sediment, but most construct some kind of tube or case in which they live. Many species construct their tubes in soft sediment and feed either by grazing an area around the end of the tube, or by filtering sediment particles using a net constructed within the tube. Water currents generated through undulatory movements of the body of the larva serve both to carry particles into the net and to maintain well oxygenated conditions in the immediate environment.

When the adult is ready to emerge the pupa swims to the surface and the adult emerges through a split in the pupal thorax. During this stage the insects are very vulnerable to predation but the whole process is completed very quickly, usually in a matter of seconds, after which the adult immediately flies to the shore where a short period is spent resting while the wings and body harden. Typically adults emerge in the evening or early morning.

The time to complete a whole cycle of development, from egg to adult varies with species and with environmental conditions (temperature, food supply, oxygen concentration). In summer, development of some species may take less than 3 weeks while in winter it may take several months. The number of generations produced in one year is also variable. In some species there is a fixed number of from 1 to 4 generations annually, while in others the number of generations is variable and mainly dependent on temperature. A few species can take more than one year to complete their life-cycle.

3.THE MIDGE PROBLEM AT MILLBROOK LAKE

3.1Chironomids associated with brackish or saline conditions

Numerous chironomid species are tolerant of a wide range of salinity and chironomids may be a major component of the fauna of brackish waters. (Pinder, 1995; Bervoets *et al.* 1996). Species characteristic of brackish waters include *Chironomus salinarius* Kieffer, *Chironomus aprilinus* Meigen and *Microchironomus deribae* (Kieffer) but Parma and Krebs (1977) reared 13 species from brackish ditches, including the typically freshwater species, *Chironomus riparius* Meigen. The species responsible for the problem associated with Millbrook Lake has been identified as *Chironomus salinarius*, one of the most tolerant species to saline conditions. I have not personally had the opportunity to examine any specimens but I believe this is likely to be correct.

It is possible that changes in the way the lake is managed could lead to *Chironomus salinarius* being supplanted by some other, potential "nuisance species". For example management to encourage the development of a less saline lake could lead to conditions conducive to the development of high densities of the closely related, *Chironomus riparius*. Bervoets *et al.* (1996) found no effect on survival or emergence among larvae of *Chironomus riparius* exposed to salinity of up to 10 ppt (parts per thousand) in the laboratory (seawater typically has a salinity of about 34 ppt). In experiments, larvae were transferred directly from freshwater to high salinity, probably causing a salinity shock, whereas gradual acclimatization would probably have induced greater tolerance. However, in nature, other factors would also influence salinity tolerance, including temperature, pollution and temporal changes in salinity. Furthermore the laboratory experiments were only concerned with fourth instar larvae whereas earlier instars may well be less tolerant. Nevertheless, Bervoets *et al.* (1996) also found populations of *Chironomus riparius* in watercourses with salinity of up to 7.5 ppt. .

Other species are capable of tolerating much higher salinity; *Tanytarsus barbitarsis* Freeman exploits waters with salinity in excess of 20 ppt and *Microchironomus deribae* has been found in salinity as high as 42 ppt (Bervoets *et al.*, 1996). *Chironomus salinarius* is one of the most tolerant chironomids in respect of salinity and can thrive in salinity equivalent, at least, to normal seawater .

3.2 Chironomus salinarius

Evidence indicates that the number of annual generations produced by *C. salinarius* is largely dependent on temperature. In Norway *Chironomus salinarius* has only one generation per year (Koskinen, 1968) whereas in the lagoon of Venice there are probably 5 annual periods of emergence, between March and October (Ferrarese & Geretti,1989). There is little direct information concerning the life-cycle of this species in southern England, but by analogy with closely related species I would expect that 3 or 4 generations are likely with a first emergence probably in April or early May and a final period of emergence in September. Research in both Norway (Koskinen, 1968) and Italy (Ferrarese & Geretti, 1989) indicates that the main period of emergence is in the first hour or so after sunset and is initiated primarily by falling light intensity.

Chironomus salinarius appears to be particularly abundant where there is a degree of organic pollution in addition to high salinity. For example, Thienemann (1954) reported a massive rise in numbers of *Chironomus salinarius* in a Scottish sea loch during a period of intense eutrophication during the second world war, which was reversed following the elimination of the cause of the eutrophication after 1946. In a shallow, coastal-lagoon, fish-pond system in the Bay of Cadiz *Chironomus salinarius* larvae were most abundant in areas where there was the slowest rate of water renewal (and presumably therefore highest accumulation of nutrients and organic matter) and densities were positively correlated with the biomass of benthic macroalgae (*Ulva lactuca* and *Cladophora*) (Drake and Arias, 1995; Arias and Drake, 1994).

In the lakes near Orbotello in Italy where this species regularly causes a nuisance problem, larval population densities of up to 33,000 per square metre of lake bed were recorded by Majori *et al.* (1984). A study (unpublished) of the fauna of the Fleet Lagoon, in Dorset, in 1983 revealed population densities of between 16,000 and 26,000 per square metre during April to June, falling to about 6000 during the period from July to September and to 1000 or less for the remainder of the year. Lower populations later in the year may be attributable to increased predation by the fry of fish (e.g. Bass), although this is speculative.

Chironomus salinarius has been implicated in nuisance problems associated with mass emergence of adults in several parts of the world of which the most famous example is the Venice Lagoon where nutrient enrichment has led to an increase in algal biomass and a consequent increase in the abundance of larvae of this species (e.g. Ali *et al.*, 1994). Attempts at controlling this problem so far appear to have been unsuccessful.

3.2.1 Attraction to light

The city of Orbotello in west-central Italy also has a problem with large numbers of *Chironomus salinarius* that swarm around lights in the lake-front area of the city (Majori *et al.*, 1984). Swarms were densest at night around fluorescent and incandescent white lights as compared with similar types of blue, green or red lights. Ali *et al.* (1994) also investigated the attractiveness of light of different wavelengths to adult *Chironomus salinarius* on an island in the Lagoon of Venice. They used incandescent, lights of 7 colours. The white light attracted most midges with yellow being the second most effective colour and red the least effective, but there was also a strong relationship between light intensity and numbers caught. They concluded that manipulating light intensity and colour could be useful to divert adult *Chironomus salinarius* populations away from areas where they create a nuisance problem.

4. THE MANAGEMENT OPTIONS FOR MILLBROOK LAKE AND LIKELY IMPACT ON THE MIDGE PROBLEM

Operational controls on the lake consist of:

- a tidal flap allowing flow out but not in, which can be winched up to admit sea water
- a weir penstock over which surplus flow drains through the tide flap, which can be raised to drain the lake.

These allow the following management options:

Option 1- Periodically drain the lake and refill with sea water, as at present.

Option 2- Have the tidal flap operating, with the penstock down, thus establishing a "fresh" water lake

Option 3- Hold the tidal flap open with the penstock closed, (except during spring tides when it must be closed for flood defence) thus establishing a lake predominantly of sea water

Option 4- Have the tidal flap operating with the penstock raised, resulting in a small river channel flowing through a large area of exposed mud.

Option 5- Hold the tidal flap open (except during spring tides) with the penstock raised, returning the lake to an estuarine regime.

These options will now be considered in respect of their predicted impact on the midge problem

Option 1

The current practice is to drain and refill the lake on a fortnightly cycle from about March to October. I would expect this to cover adequately the periods of emergence by *Chironomus salinarius*. However, The changes in salinity which this regime produces are unlikely to affect *Chironomus salinarius* adversely. If anything I would expect that periods of higher salinity might encourage the development of larger populations of this species, at the expense of species that are less tolerant of high salinity. However, I am told that this regime is an effective method of controlling the problem and the benefit therefore probably results from erosion of the bed of the lake during draining and consequent flushing of the immature stages, into the estuary. Since the midges are likely to complete a generation in about 4 weeks or less during summer, flushing on each spring tide, as at present, is advisable to prevent numbers building up to nuisance levels.

Advantages:

- •Continuation with the present regime involves no cost over and above those currently incurred
- •The regime is known to be effective in containing the problem (according to my information).

Disadvantages:

- •Drawing down the lake every 2 weeks is very disruptive to populations of other organisms inhabiting the lake, including fish and other predators that would assist in natural control of the midges.

•The lake bed is exposed during the period of drainage which may be considered to be undesirable on aesthetic grounds

Conclusion: This appears to be a viable means of control and continuation with the present management regime is therefore an option that should be considered.

Option 2

There is an argument that allowing a freshwater lake to develop would, over a number of years, allow the establishment of a diverse and balanced freshwater community which would prevent the development of large populations of nuisance species. Although this has proved to be the case in some reservoir developments which have produced semi-natural lakes, it has not been so with very artificial reservoirs such as the one at Farmoor, near Oxford, where habitat diversity remains low and the midge problem persists after many years. I think it is also unlikely to be the case at Millbrook, where the habitat is very uniform and it is difficult to see how habitat diversity, in and around the lake could be significantly enhanced.

Advantages: •If this method were successful it would provide a long term solution requiring relatively little ongoing management.

•The lake would be a permanent feature, attractive to wildfowl in winter and to a very limited range of breeding species

Disadvantages: •It is unlikely to succeed because of the lack of habitat diversity within and adjacent to the lake

•With relatively long retention times in the lake, water quality may become a problem. This could result in the developmental of nuisance algal problems as well as the replacement of the present midge problem by a similar one attributable to a pollution tolerant midge, such as *Chironomus riparius.*

•Even if a stable and balanced community could be achieved in the long term this would take several years during which time the problem would be ongoing. Any management intervention to control outbreaks of midges would be precluded by the need to allow the progression to equilibrium to proceed without interruption

Conclusion: This approach would be very unlikely to succeed and for reasons already stated I do not consider it to be a sensible or viable solution to the problem.

Option 3 -

This option would result in a permanent lake with high salinity maintained through a limited daily exchange of water with the estuary and it would provide ready access for fish. Conditions would continue to be suitable for the development of large populations of *Chironomus salinarius* and the only potential advantage in respect of this problem would be increased fish predation on larvae and pupae.

Advantages: •The maintenance of a permanent lake could be considered desirable

•Increased predation by fish MIGHT lead to a reduction in the scale of the problem

Disadvantages: •Water quality problems could result from relatively long retention times in the lake.

•Some studies indicate that production of *C. salinarius* is greater in polluted saline sites and any reduction in water quality could exacerbate the problem

•High salinity with little flushing would continue to provide ideal conditions for *Chironomus salinarius*, with no guarantee that predation would have any significant impact.

Conclusion: Such a management regime is unlikely to significantly improve the situation in respect of the midge problem and could conceivably aggravate it. It is not therefore recommended.

Option 4

This would result in the lake being reduced to a large area of permanent mud around a small meandering river channel.

Advantages: •This would eliminate the current non-biting midge problem.

Disadvantages: •The large area of, possibly unpleasant smelling, mud would be aesthetically unacceptable.

•Other, potentially more unpleasant insect problems might develop as a result of the large area of permanently wet mud. One possibility might be the development of large populations of biting midges (*Culicoides*), while stagnant pools within the area of mud would be excellent sites for mosquitos to breed.

Conclusion: This option is unacceptable on aesthetic grounds and because of the possibility of exchanging one insect problem for another, potentially more unpleasant one.

Option 5:

This would effectively return the lake to an estuarine regime which should result in the elimination of the problem as a result of :

(a) development of an estuarine community, with increased competition and predation, including by birds at low tide and fish at high tide;

(b) regular flushing of the lake bed which would prevent the development of a significant midge population through physical disruption of their habitats and removal of juvenile stages.

Advantages: •This would be an effective and permanent solution to the problem, with little likelihood of alternative problems of a similar nature developing subsequently.

Depending on the perspective of the individual other perceived advantages might be seen as:

(1) enhanced visual amenity in that the estuary presents an ever-changing and arguably more interesting aspect

(2) the estuarine environment would be attractive to migrating and overwintering populations of wildfowl, such as shelduck, mallard and teal, and waders, such as godwit, curlew and redshank.

Disadvantages: *Depending on the perspective of the individual these might be perceived as:*

(1) loss of the permanent lake as an amenity and replacement by estuary, *may* be regarded as visually less attractive.

(2) loss of wildlife associated with the permanent lake, such as breeding mute swans and some overwintering wildfowl.

(3) Additional management would be needed to ensure that the tidal flap is closed during spring tides to prevent the possibility of flooding. However it does not appear that this would be more onerous or expensive than the present regime of regularly draining and refilling the lake.

Conclusions: To my mind this is the best of the available options. However, before recommending it I would like to see some sampling of the estuarine mud below the dam, to ensure that the midges do not develop significant populations in this habitat. I think this is unlikely but if they do, the matter of whether the lake itself is the primary source of the infestations will need to be investigated in more detail.

I also anticipate that residents will have differing perception and priorities. Those badly affected by the "plagues" of midges will no doubt see their elimination as the first priority and will perhaps be less concerned with other effects of management. Among others, who may be more concerned with the visual and appearance of the area , there may be differing opinions as to the desirability of retaining the lake as a permanent feature. In my view the natural estuary is far preferable to the existing artificial and featureless lake - but I do not live there and my opinion in this respect is irrelevant..

From October to March, when the midges are not breeding, it would be possible to close the penstock and restore the lake over winter to encourage overwintering wildfowl. This would reduce the management requirement over the winter but otherwise seems a matter of personal preference.

5. OTHER POTENTIAL METHODS FOR ALLEVIATING THE PROBLEM

Possible measures to control the extent of the problem fall into 3 broad categories

1. Reducing the size of the larval population
2. Preventing emergence of the adults
3. Preventing the adults from encroaching on residential areas

5.1. Reducing the size of the larval population

Consideration of the options for management of the lake as a whole have focused on the impact that they are likely to have on the populations of midge larvae on the lake bed, as the only long-term solution to the problem. However, before departing from consideration of controlling larval numbers it is worthwhile to reiterate that other studies have indicated that *Chironomus salinarius* is more abundant in areas where there is significant organic pollution, and in areas where there a relatively slow exchange of water.. Without the advantage of a detailed study of conditions within Millbrook Lake and of the distribution and abundance of the midge larvae in this situation it is impossible to say whether these observations are relevant to the situation here. It is possible though, that the problem is being generated by high densities in a restricted area, or areas, of the lake bed which could be tackled by means other than major changes in hydrological management.

A thorough and probably expensive investigation would be required to determine whether this is the case and there is no guarantee that it would produce a satisfactory solution to the problem. A useful first step however, would be to carry out a structured survey to determine the relative abundance of the larvae in different parts of the lake to determine whether there are any obvious "hot-spots". If there are, then it would be worthwhile to carry out further research to determine the environmental conditions that make these areas particularly suitable for colonisation and to consider the potential methods for their elimination.

5.2 Preventing emergence of the adults

The only practical means of reducing adult emergence (other than reducing the size of the larval population) is to encourage, or introduce populations of fish that would feed on the pupae as they make their way to the surface for emergence. It is highly unlikely that, in isolation, this would exert sufficient control on midge numbers to be acceptable.

5.3 Preventing adults from encroaching on residential areas.

The midges, which emerge around dusk, are attracted to the affected residential areas by street and domestic lighting. The location of street lights and the colour of the houses (white will be especially attractive in combination with street lights) are likely to be important factors determining which will be the most affected areas; wind direction at the time of emergence will also have an influence. Screening of the houses from the lake with trees and tall shrubs would probably be effective but does not seem to be a practical option in this case. Altering the colour of the street lights to a less attractive colour might be helpful but does not solve the problem of domestic lights or reflective white surfaces.

Establishing attractive lights away from the residential area to attract the midges, to the north side of the lake, away from the houses, could be helpful, but a brightly lit area close to the lake would probably be too intrusive to be acceptable and would inevitably be subject to vandalism.

Clearly extensive use of insecticides is not an option that should be given serious consideration but very localised use of non-persistent insecticides with low vertebrate toxicity might be a possibility, if adults could be encouraged to aggregate in specific areas. This might be achieved using attractive lights (see above) away from the houses, in conjunction with the establishment of vegetation, long grass and dense shrubbery, that is suitable for the insects to rest in during the periods when they are not active. Research is currently being carried out to develop chemical and sonic attractants for midges as a solution to this type of problem. These are possibilities for the future but I cannot say how soon the technology will become available or how effective it is likely to be in practice.

6. SUMMARY.

The present nuisance is created by the presence of a substantial population of larvae of the salt tolerant, non-biting midge, *Chironomus salinarius* in the bed of the lake. This is based on information from other sources, since I have not been able to see any specimens, but it is highly likely that this is the case.

The best way to tackle the problem is to manage the affected area so as to eliminate the population of *Chironomus salinarius* or to reduce the size of the population to an acceptable level. Alternative methods, designed to prevent the adults, once emerged, from encroaching on areas where they cause nuisance are unlikely to be sufficiently effective, or otherwise acceptable, in this situation.

In managing the area to eliminate the problem caused by *Chironomus salinarius* it is vital to avoid creating conditions that are conducive to the build up of large numbers of alternative species that are equally likely to cause a problem. This includes the possibility of creating conditions suitable for insects such as biting midges (Ceratopogonidae) and mosquitoes as well as alternative species of non-biting midge.

The current regime of draining and refilling the lake with sea water on a fortnightly basis during the period from March to October appears to be effective in controlling the problem. Continuation with this regime is clearly an option that residents will want to consider. However, it is a means of containing the situation, rather than eliminating the underlying cause of the problem.

It is most unlikely that allowing the lake to develop as a predominantly freshwater environment would be an effective solution because the lack of habitat diversity within the lake and its surroundings is not conducive to the development of a balanced and stable ecosystem. Even if this were to be achievable it would take a several, at least ten and probably more, years during which management of the lake to control midge numbers as at present would not be an option. An additional concern is that the relatively long retention time of water in the lake would lead to a deterioration in water quality that would be liable to lead to the emergence of large numbers of pollution tolerant midges, such as *Chironomus riparius*.

Of the alternative options for management that are considered in this report, that which would effectively return the area to estuarine habitat is the one most likely to eliminate the midge nuisance without creating habitat that could encourage the development of large populations of alternative nuisance species.

All of the management options discussed in this report are deemed to have advantages as well as disadvantages. The perception of these is to a large extent subjective and inevitably opinions as to the desirability of one course of action over another will vary among residents.

It is possible that a detailed study of the biology of Chironomus salinarius and the physical and chemical conditions within the lake would lead to a solution that would allow the permanent retention of the lake as it is at present without the accompanying midge problem. This would be expensive and there could be no guarantee of success. In any event, it would be a matter of several years before the necessary research could be completed, a plan of action formulated and the necessary changes implemented.

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