INNOVATIVE CHAIN DRAGGING METHOD CONTROLS MIDGES AT MĀNGERE WASTEWATER PLANT

Christopher Garton (Watercare Services Ltd)

ABSTRACT

An innovative chain dragging method invented by this author has been proven to be extremely successful at controlling nuisance *Chironomus zealandicus* midges at the Māngere Wastewater Treatment Plant (WWTP). This method replaced the use of a chemical called methoprene which was used as a larvicide. Since the new method was used there have been fewer midges and more importantly fewer public complaints. The new method has also led to a 75% reduction in the operational budget from approximately $300,000 per annum to approximately $75,000 per annum.

C. zealandicus midges have plagued the neighbouring community of Māngere Bridge since the Māngere WWTP was first built in 1960. Methoprene was used very effectively to control the adult midge population from 2008 onwards but the Māngere WWTP still received midge-related complaints from the public. In 2017, methoprene was successfully replaced as the primary form of midge control with the innovative chain dragging method. Between 2017 and 2019 there were multiple experiments and modifications to the method to refine its effectiveness. Since October 2019 there have been no complaints from the public and the number of midges each season has been the lowest since records began. Therefore, there is now strong evidence that this new chain dragging method is a success. In 2019 this method also successfully replaced methoprene on Pond 1 at the Rosedale WWTP in Auckland.

This paper discusses the success of the method over the seasons. It also details how the method works including the frequency of application so that others in the water industry may adapt this method for their sites. This paper also discusses lessons learnt by the author. This midge control method has been a successful innovation from Watercare Services Limited and is an idea worth sharing with the wider water industry.

KEYWORDS

Midge control, innovation, Māngere Wastewater Treatment Plant, wastewater, *Chironomus zealandicus*, methoprene

PRESENTER PROFILE

Christopher Garton works as an environmental scientist at Watercare Services Ltd and part of his role is to control nuisance midges across all Watercare sites. He has been controlling midges at the Māngere Wastewater Treatment Plant since 2014 and completed a Master of Science in this subject in 2020.

INTRODUCTION

Chironomus zealandicus midges are native to New Zealand and are in the family Chironomidae of the order Diptera. There are at least 121 chironomid species found in New Zealand with *C. zealandicus* being one of the most common and abundant. There are estimated to be over 5,000 species of chironomid midges worldwide and geographically they are the most widely distributed freshwater insects (Cranston, 1995; Oliver, 1971). They often perform important ecological functions as primary consumers processing organic matter (Benke, 1998) and as prey for aquatic and terrestrial predators (Crome, 1986).

They spend most of their life as larvae in freshwater bodies living in silk burrows either in the sediment or on surfaces such as rocks, logs, and filamentous algae (Forsyth, 1971; Robb, 1966). They feed on organic detritus floating in the water, algae, and other plant matter (Jeyasingham & Ling, 1997; Robb, 1966). *C. zealandicus* adult flies are non-biting as they have no mouth parts and only emerge to breed (Figure 1) (Forsyth, 1971). Despite only surviving as adult flies for 4-5 days they can emerge in very large numbers and create vast swarms. Female *C. zealandicus* lay approximately 1,000 eggs (Forsyth, 1971), and in water temperatures above 22 °C, these can emerge as adults in only 20 days (Robb, 1966). This fecundity enables the total population to rapidly increase rapidly from very few (hundreds and thousands) to billions in just a few months.

Figure 1: Male C. zealandicus at rest. Note: on the left photo one of the forward legs is absent and the other is shorter than usual. In the photo on the right, both forelegs can be seen raised. Photographs by Phil Bendle. Source: http://www.terrain.net.nz (website accessed: 21/4/2016).

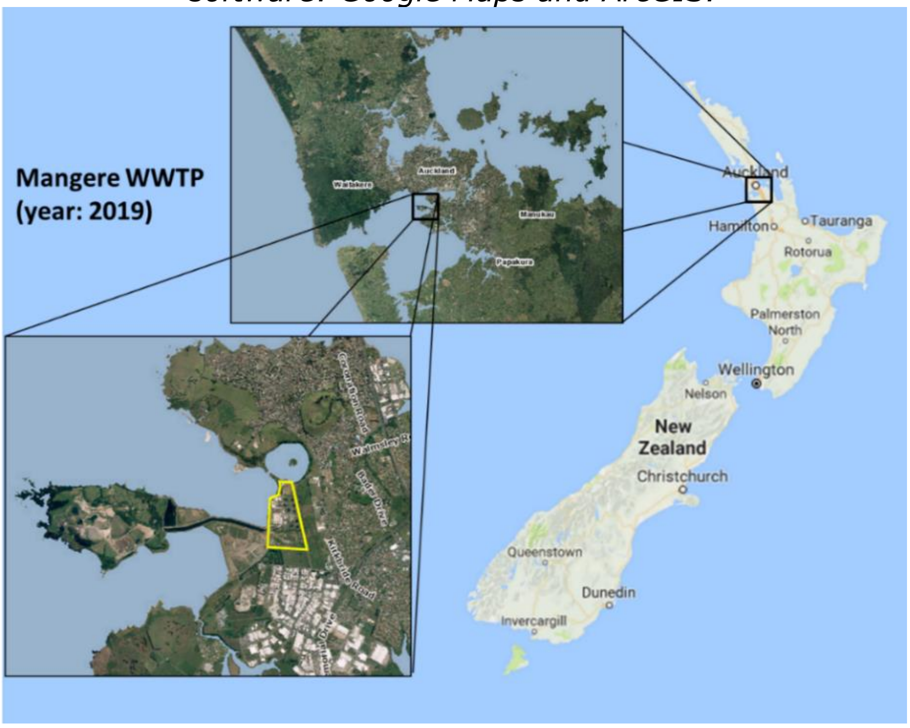
A minority of chironomid species can emerge in numbers so large that they become a serious public nuisance damaging property, disrupting economic activity, affecting people's health, and even becoming a navigational hazard (Ali, 1991a). They can emerge simultaneously to form vast mating swarms that are attracted to lights in residential and business areas and can disrupt outdoor and indoor activities by flying into ears, eyes, mouths, noses, and generally causing distress (Ali, 1991b). Their bodies can damage equipment such as air conditioners, automobile radiators, and industrial equipment and their eggs can cause staining on painted surfaces, clothing, and packaged goods (Ali, 1995). Dead chironomid bodies produce an unpleasant odour similar to rotting fish that can persist for several days (Ali, 1991b).

As the number of people working and living in closer proximity to chironomid habitat (freshwater bodies) has increased, so has the number of complaints (Ali & Baggs, 1982). Ideal chironomid habitats have also been created as an unintended consequence of human activity by disrupting the ecological balance of existing freshwater bodies and by creating new habitats such as ponds and channels at wastewater treatment plants (Edwards et al., 1964; Spiller, 1964).

MĀNGERE WASTEWATER TREATMENT PLANT

The Māngere Wastewater Treatment Plant (WWTP) has been a habitat for chironomid midges since it was first built in 1960. The original design of the plant involved primary treatment followed by nutrient removal in four large oxidation ponds with a total area of 512 ha, (the largest system of its kind in the world at the time) (Watercare Services Ltd, 2005). Unfortunately, at the edge of the ponds, the biochemical oxygen demand (BOD) was low enough for multiple species of midges to thrive (Craggs & Duggan, 2001). These species were *C. zealandicus, Tanytarsus funebris, Paratrichocladius pluriserialis, and Polypedilum pavidus,* with the most abundant being *C. zealandicus* (Kingett Mitchell., 2003; Kingett Mitchell Ltd., 2006; Spiller, 1964). In 2003 the oxidation ponds were dismantled as part of Project Manukau and the Māngere WWTP was upgraded to a modern tertiary treatment plant using advanced biological nutrient removal technology and ultraviolet disinfection (Figure 2).

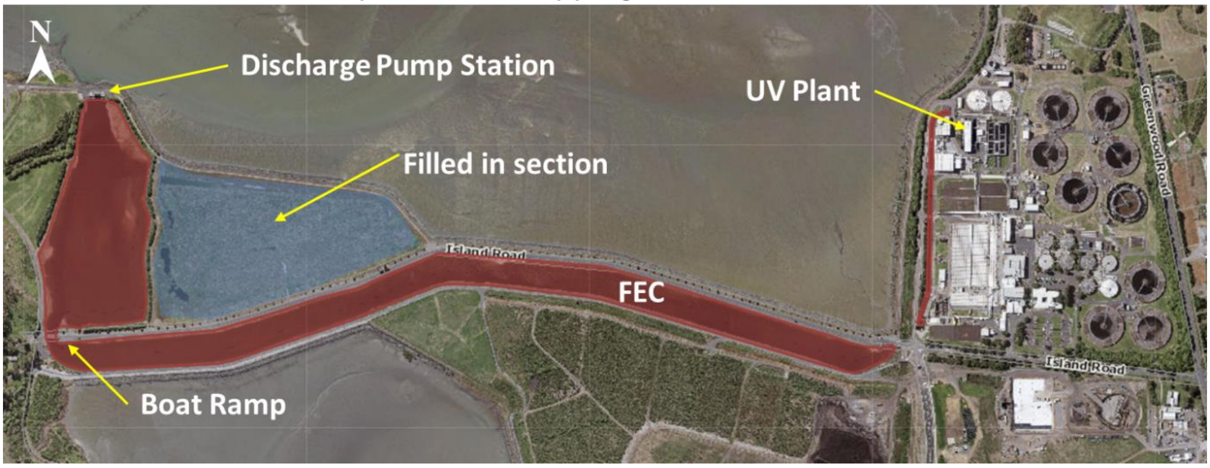
Figure 2: The location of the Māngere Wastewater Treatment Plant in Auckland, New Zealand. The treatment plant is shown with a yellow outline. Mapping software: Google Maps and ArcGIS.



The Project Manukau upgrade from 2002 to 2003 was the largest coastal restoration project in New Zealand's history with 13 kilometres of coastline restored when the oxidation ponds were dismantled (Watercare Services Ltd., 2005). The dismantling of the oxidation ponds removed most of the habitat for the midges, but not all of it. The fully treated wastewater from the WWTP is stored in the Final Effluent Channel (FEC) before being discharged into the Manukau

Harbour with the outgoing tide. Unfortunately, the FEC became 27.5 ha of prime habitat for *C. zealandicus* midges and they remained a substantial problem (Kingett Mitchell, 2006). In 2005 10.5 ha of the FEC was filled in which helped reduce midge numbers a little but the problem remained (Figure 3).

Figure 3: The Final Effluent Channel (FEC) is coloured red. The blue section was closed and filled in 2005. The water flows from the UV Plant to the Discharge Pump Station. Mapping software: ArcGIS.



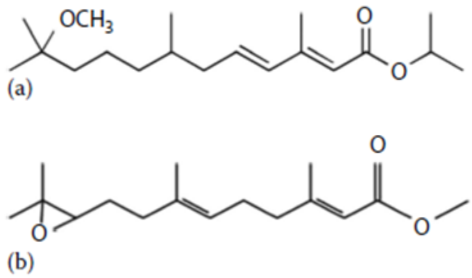
MIDGE CONTROL 2002 ONWARDS

Controlling midge numbers has been a major priority at the Māngere WWTP due to the high number of public complaints (Garton & Bickers, 2016; Watercare Services Ltd, 2005). In 2002 a surface film called Agnique MMF was trialled but abandoned in 2005 because strong winds at the site reduced its efficacy (Kingett Mitchell, 2006). In 2005 Dr Gene Brown developed the integrated pest management (IPM) strategy to control the midges and this strategy is still used today.

The first aspect of the IPM strategy is to closely monitor the midge numbers by using emergence and light traps as well as having an experienced entomologist sample specific trees for emerged adults. The second was planting additional native flax and trees adjacent to the FEC to create a vegetation barrier to help contain emerged adult midges (FBA Consulting Ltd., 2009). The third is to spray this vegetation barrier with a long-lasting contact insecticide every three weeks so that when the adult midges take shelter they succumb to the poison. The fourth and most important aspect of the strategy is to kill the larvae in the FEC (Kingett Mitchell Ltd., 2006). The implementation of this strategy in 2008 using methoprene to control the larvae in the FEC led to a large reduction in the number of midge-related complaints.

Methoprene was synthesised in March 1971 at Zoecon for use as a juvenile hormone (JH) mimicker for the control of mosquitoes (Devillers, 2013). JH is produced by the larva to grow them through their instar stages to pupation (Henrick, 2007). The larva must purge it from its body before pupation (Henrick, 2007). Methoprene closely mimics this JH (Figure 4) and only a little (1 part per billion) needs to be in the water with the larva for them to struggle to purge it from their body resulting in their death because they struggle to pupate properly (Henrick, 2007; Staal, 1975; Zhao, 2013).

Figure 4: Showing the similarities between methoprene and JH III. (a) is the chemical structure of Methoprene and (b) is the chemical structure of JH III (Zhao, 2013, p 85).



Methoprene is considered very safe for non-target organisms including humans because it is highly targeted for insect larvae (Glare & O'Callaghan, 1999). For this reason, it was used at the Māngere WWTP from 2008 to 2017. It was applied as slow-release pellets every three weeks from August to May and is still used successfully in this way at pond 2 at the Rosedale WWTP and the Omaha WWTP. Despite the success of methoprene, it is expensive and there is evidence that insect species can develop resistance to it (Cornel et al., 2002; Dame et al., 1998). For these reasons, in 2014 I started to develop an alternative to methoprene and by 2017 was able to replace methoprene use at the Māngere WWTP with the chain dragging method.

The chain dragging method scrapes the surface of the FEC with chains that have lateral spikes attached. The apparatus is towed by a jet ski because they are powerful and have a shallow draft. Between August 2017 and August 2019 version 1 of this method worked well. In September 2019 however, there was a spike in numbers because part of the FEC had been left untreated as part of a 12-month experiment that ended in August 2019. Also, the equipment used in version 1 was worn out and needed repairing. In October 2019 I redesigned the spikes on the chains and used this new version 2 equipment to bring the midge numbers under control. Version 2 has performed exceptionally well resulting in low midges numbers and no complaints since September 2019. The same equipment has also been successfully used at Watercare's second largest WWTP located at Rosedale on the North Shore of Auckland since September 2019.

The chain dragging method also reduced the cost of killing the larvae at the Māngere WWTP from approximately $300,000 per annum to $75,000 per annum. Similar savings have been made at the Rosedale WWTP as well. There is potential to reduce this further if the work was undertaken in-house instead of using a contractor.

The Māngere WWTP has now experienced five seasons using this new chain dragging method with the last two seasons recording the lowest midge numbers since records began in 2009. This record provides a high level of confidence in this method and therefore it is an appropriate time to share it with the wider water industry. The rest of this paper will detail how the chain dragging method works, how frequently it is used at the Māngere and Rosedale WWTPs in Auckland, and how effective it has been at controlling midges at Māngere WWTP. Midge data for Rosedale WWTP will not be presented in this paper because it is not yet as comprehensive as the data from the Māngere WWTP.

CHAIN DRAGGING METHOD

It is known that frequent disturbances of freshwater habitats can lead to a decrease in the diversity and abundance of macroinvertebrates (Reice, 1985). The chain dragging method uses a jetski to tow wires connected to lengths of chains with lateral spikes attached to disturb the habitat of *C. zealandicus* (Figures 5 and 6). The chains kill the larvae in two ways. One is by physically damaging their bodies, and the other is through the redeposition of fine sediments that smother larvae burrows either killing them directly because they are unable to burrow free or causing stress which may kill them indirectly. The chains also detach any filamentous algae from the channel floor. Filamentous algae are very common in the FEC and provide food and sanctuary for *C. zealandicus* larva (pers. observ.). Preventing the growth of filamentous algae reduces the amount of available habitat and food.

Figure 5: Diagram describing the chain dragging method. The wires are attached via sacrificial links in case the chains become snared on obstacles in the FEC and the floats allow them to be retrieved afterwards.

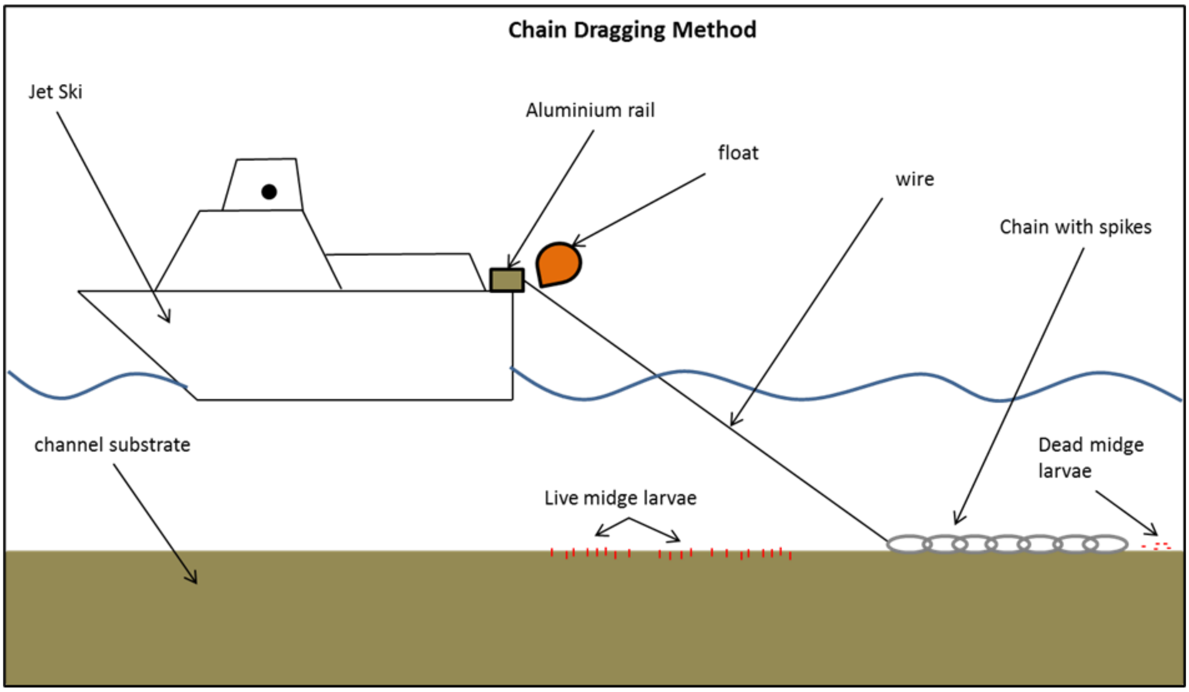


Figure 6: The contractor on his jetski towing the chains along the FEC. Photo taken by the author on 5/12/2018.

There are many large boulders, pieces of concrete and other inorganic debris in the FEC that are relicts of past construction activities and illegal dumping by the public. Individual chains had to be used so that they could flow freely over this debris and each wire is attached to the boat via a sacrificial link to prevent damage to the boat in case a wire becomes stuck. The chains have lateral spikes attached (80 cm long 12 mm diameter nylon plastic rods) to extend the total area disturbed and to cut through the surface layer of the sediment where the larvae have their burrows (Figure 7). Version 2 with the nylon rods can be seen in Figure 7 below as well as the remnants of other lateral spikes (made from cable ties and modified brushes) that comprised version 1. The chains are dragged in a systematic way working from the banks of the FEC towards the centre of the channel ensuring that all surfaces of the channel have had the chains dragged over them.

Figure 7: Modified chains version 2 with nylon rods attached as spikes. Photo taken by the author on 13/12/2019.

TREATMENT FREQUENCY

The frequency of the chain dragging method treatment is based on the seasonal growth time of *C. zealandicus*. Robb (1966) showed that water temperature affects the time required for *C. zealandicus* larvae to grow into an adult. Robb (1966) discovered that this relationship is non-linear with expected growth times being 20 days at 22 °C, 35 days at 20 °C and 40 days at 15 °C. Most of the water in the FEC is discharged daily with the outgoing tide and the water in the FEC is warm from the treatment processes. In the winter the water temperature usually does not drop below 17 °C and remains above 20 °C between September and June and above 22 °C from October to May. These water temperatures make the FEC viable midge habitat all year round. As a consequence, the chain method is used all year as well but with a reduced frequency in the winter months.

It is simply not reasonable to assume that each treatment would cover the whole channel bed and kill all of the midges in the FEC every time. With this in mind, as well as the non-linear relationship the larvae have with water temperature, I designed the treatment frequency so that each larva has the potential to be run over by the chains at least twice during their short lives. The current frequency for the FEC is fortnightly treatments from May to August and weekly treatments from September to April.

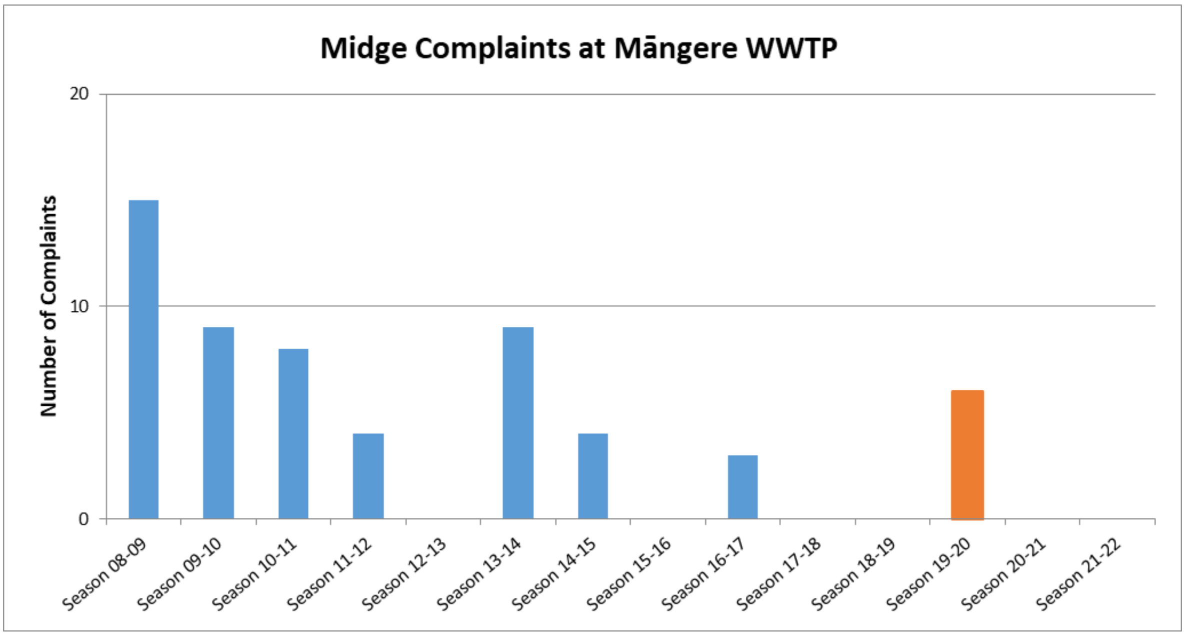
At the Rosedale WWTP, the chain dragging method is used on the large Pond 1 which has a wastewater retention time of several weeks. The depth of the water and the longer retention time mean that water temperatures remain much lower there with September water temperatures being between 10 °C and 15 °C and generally not rising above 20 °C until December, peaking between 23 – 25 °C in February and then usually falling below 20 °C by April. With these lower water temperatures in mind, I designed the current frequency to be fortnightly treatments for April and August, weekly treatments from September to March, and no treatments from May to July.

RESULTS

PUBLIC COMPLAINTS

The most important outcome for Watercare is whether our neighbours in the local community are disturbed by the midges. Watercare strives to be a good neighbour and takes full responsibility for the creation of prime midge habitat close to where people live in the Māngere area. Figure 8 shows the complaints received from July 2008 until June 2022. Methoprene was officially used as the prime treatment solution for killing larvae in the FEC from 2008 until August 2017 when it was replaced with the chain method. Each season is counted from the 1st of July until the 30th of June the following year. Before the use of methoprene, there were 110 complaints recorded in the 2003 - 04 season, and 47 in the 2004 - 05 season. Using methoprene in 2008 brought the number of midges under control and vastly reduced the number of complaints received.

Figure 8: Midge complaints per season (July – June) from July 2008 to June 2022. The blue columns are from seasons with methoprene and the orange is from a season with the chain method version 1. The chain method was used from season 2017-18 onwards.



DISCUSSION OF PUBLIC COMPLAINTS RESULTS

The chain dragging method was used from the 2017-18 season onwards and during that time there have only been six complaints, all received during September 2019. Aside from that month, the midges have not been a nuisance to the local community for five years. This is a great result for the local community. Watercare Services Limited strives to be a good neighbour and have a positive impact in the Māngere area.

The September 2019 spike in midge numbers had several causes. The first being that 5% of the FEC had been left untreated as part of a year-long Before After Control Impact (BACI) experiment I conducted from August 2018 until August 2019. I did not realise it at the time but leaving this small section untreated over winter and in the early spring of 2019 was enough to allow the total midge population of the 2019-20 season to reach high numbers by September. Combined with a strong southwesterly wind these midges were blown to the local neighbourhood and became a nuisance. In addition, the chain dragging equipment had become a little worn out and was less effective in 2019 than it was when first used in 2017. This motivated me to redesign the chains and spikes to make them more durable and this resulted in a much-improved version 2 which has been used since October 2019.

MIDGE NUMBERS

Midge numbers at the Māngere WWTP are closely monitored every week of the year using three different methods. The three methods are sampling trees near the FEC and in the community, emergence traps, and light traps. Of these, only the community sampling and the emergence traps will be discussed in this paper as the data from the light traps is not as accurate.

COMMUNITY MIDGE RESULTS

Every week an experienced entomologist counts the number of adults at 14 specific locations near the FEC and in the local community (Figure 9). This data has been collected every week since 2005. However, an undocumented method change in February 2009 makes data obtained before this incomparable and for this reason, only data from 1/7/2009 onwards will be used in this paper.

Figure 9: The 14 locations sampled once per week for the community midge monitoring data set.

The results from the community data set show that midge numbers during the seasons when the chain method version 1 was used were relatively comparable to the years that methoprene was used (Figure 10). It also shows a dramatic drop in numbers after version 2 was used. In Figure 11 the 2019-20 season is allocated to the chain method version 1 because the high midge numbers occurred while using version 1 (most of the column) and these were brought down after version 2 was used from October 2019.

Figure 10: Community midge sampling data set from 1/7/2009 until 30/6/2022 and colour coded for each treatment.

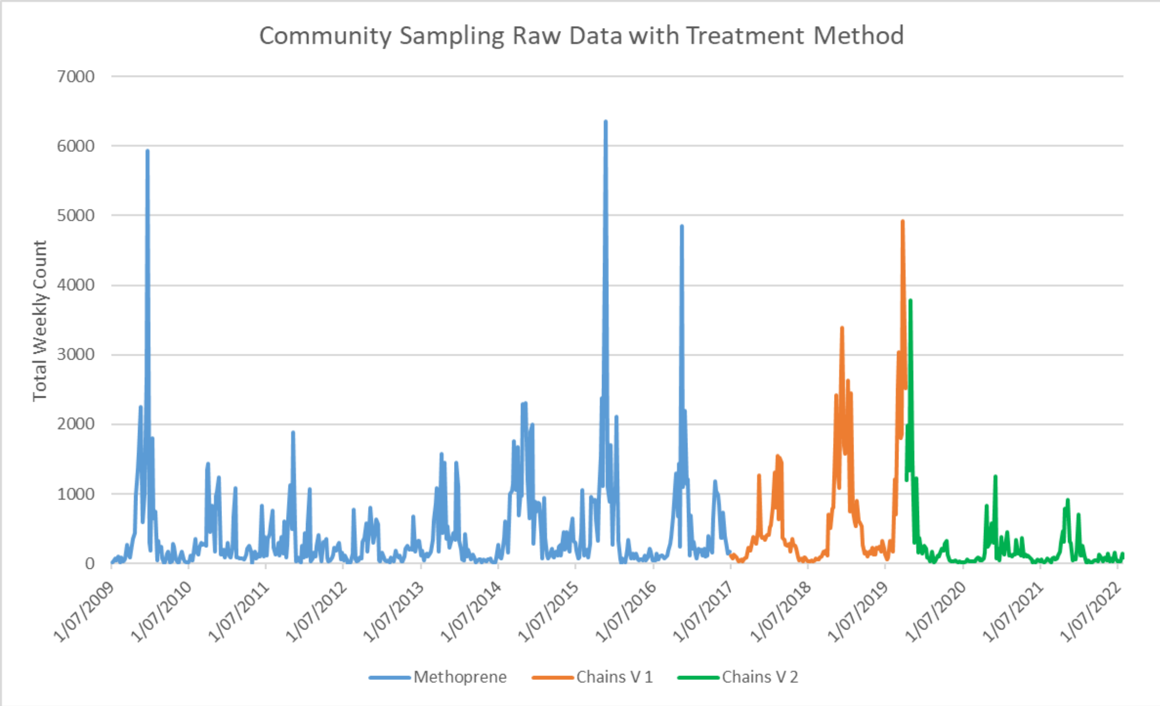
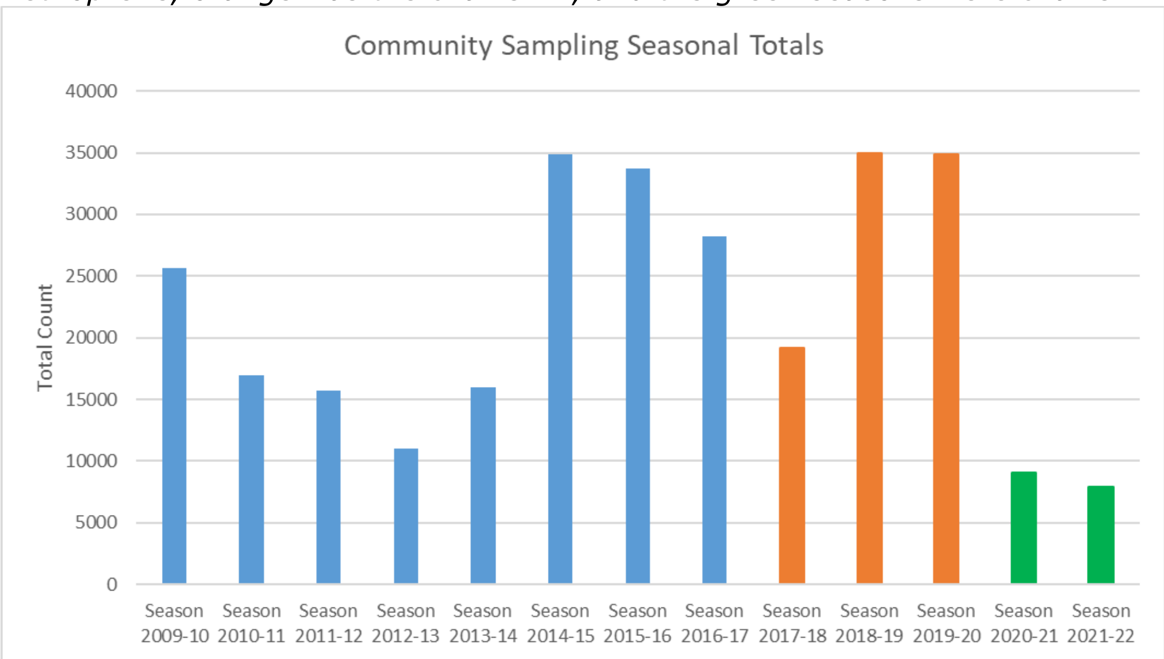


Figure 11: Community midge sampling data set from 1/7/2009 until 30/6/2022 divided into seasons (1/7 – 30/6 the following year). The blue seasons were methoprene, orange was the chains V1, and the green seasons were chains V2.



DISCUSSION OF COMMUNITY MIDGE RESULTS

Although it is tempting to use the community midge data to compare the efficacy of the different treatment methods, this would not be statistically appropriate because unquantifiable external factors can impact the midge populations differently each season. It is not the purpose of this paper to quantifiably compare the use of methoprene to the chain method in an attempt to assess which method is better. This data does not facilitate that kind of questioning. That comparison was done in a BACI experiment I conducted on the FEC between August 2018 to August 2019 and the evidence from that experiment was inconclusive (Garton, 2020).

The community midge sampling data shows that the chain dragging method was successfully used as a replacement for methoprene on the FEC from August 2017 onwards. Both the number of complaints and the number of midges remained low. In addition, when version 2 of the chain dragging method was used, those seasons (2020-21 and 2021-22) had the lowest midge numbers on record. This evidence shows that the chain dragging method has been a success.

EMERGENCE TRAP RESULTS

The emergence traps are pyramid-shaped net traps that float on the surface of the water and capture adult midges immediately after they eclose (emerge) from their pupal husks (Figure 12). In September 2015 I modified the design of the emergence traps at Māngere WWTP to include a sticky card in the bottle at the apex of the trap. This made the traps substantially more accurate but meant that emergence trap data gathered before this is not comparable. For the regular midge monitoring programme on the FEC, nine emergence traps are checked at least once a week (Figure 13). The total number of midges on each card is counted and fresh cards are placed into the bottles to reset the trap.

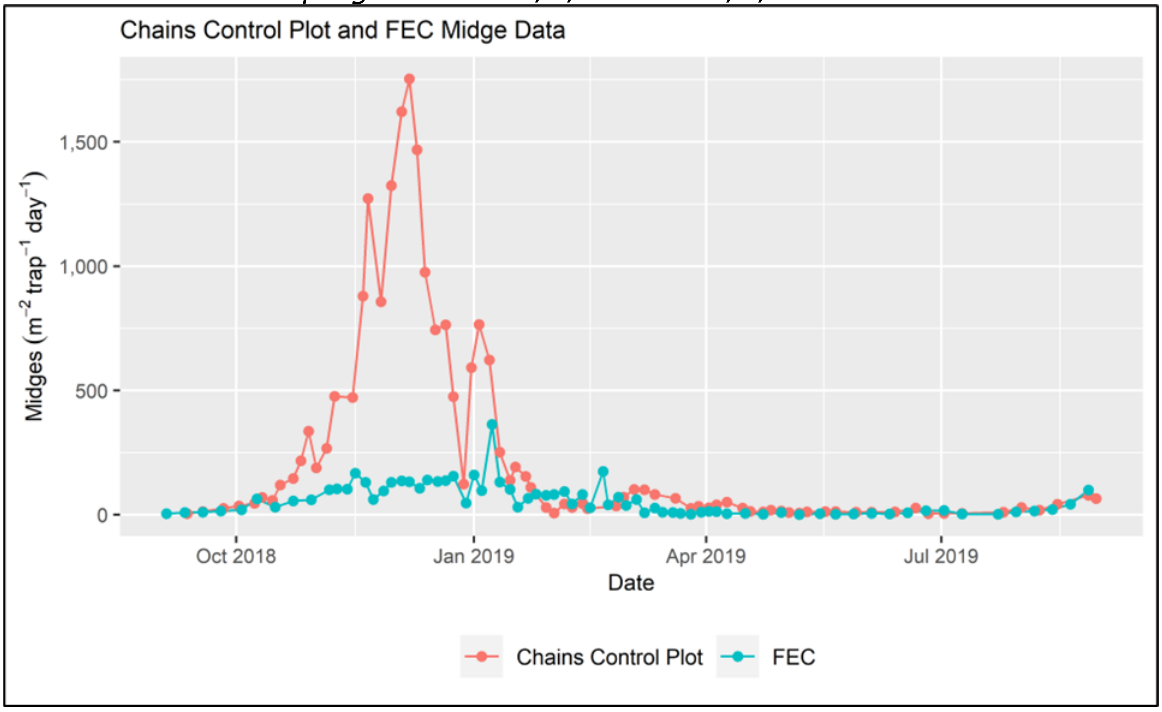
Figure 12: Left: an emergence trap used on the FEC. Right: a sticky card from the apex of a trap with adult midges stuck to it. Photos taken by the author on 26/10/2018 (left) and 15/10/2018 (right).

Figure 13: Location of the 9 emergence traps on the FEC. Mapping software: ArcGIS.

The results from the emergence traps are averaged by the number of traps and the number of days between sampling to obtain a single 'per trap per day' emergence value. Averaging the data in this way allows the data to be comparable even if there is variability in the number of days between samples or the number of traps functioning properly that week. The traps have a contact surface area of 0.2025 m^2. Emergence data is usually presented in scientific papers as 'emergence per m^2' and so the data from the FEC is multiplied by 4.94 to obtain 'per trap per day per m^2' results.

During the BACI experiment conducted from August 2018 to August 2019, there was a 2,500 m^2 section near the eastern end of the FEC that remained untreated and closely monitored. This untreated section was called the 'Chains Control Plot'. This section was monitored with six emergence traps of the same specifications as those used on the FEC for the regular midge monitoring programme. Comparing data from the treated FEC and the untreated section provides an estimate of how effective the treatment is (Figure 14).

Figure 14: Results from the emergence traps on the untreated chains control plot and the 9 FEC emergence traps from the Māngere WWTP midge monitoring program from 1/9/2018 - 31/8/2019.



DISCUSSION OF EMERGENCE TRAP MIDGE RESULTS

The difference in the number of midges that emerged from the untreated plot and the rest of the FEC between October 2018 to February 2019 is substantial. This shows that the chain dragging method version 1 was very effective at controlling midges in the FEC.

The chains control plot may slightly underrepresent the rest of the FEC due to the slightly coarser particles of the channel substrate at the eastern end of the FEC (where the chains control plot was located) compared to the finer particles in the western end of the FEC where emergence numbers are historically higher (unpublished emergence trap data from the midge control program). Finer particles tend to allow for higher population densities as the midge larvae can form more vertical burrows that are more tightly packed together. However, for this paper, it can be safely assumed to be a representative sample for the whole FEC.

The FEC is 16.4 ha which means that multiplying the results from the controlled plot by 164,000 would give an approximate idea of the number of midges that could emerge across the FEC if it was left untreated. The peak result of 1,754 midges per m^2 per day obtained on 7/12/2018 from the control section gives a peak total of 287,656,000 midges emerging from the FEC per day. This is a high number and would certainly have the potential to cause a public nuisance in the local community if allowed to occur.

LESSONS LEARNED

The high number of midges that occurred in September 2019 taught me several lessons that I would like to share. In that incident, the small section of the FEC that was left untreated allowed the total population of midges to snowball and gain momentum into August and September and cause public complaints. It took several months of treatment with an improved equipment design to bring the situation back under control. I learnt that it was important not to leave sections untreated, especially at the end of winter and early spring because the population of one of their natural predators in the channel (mosquito fish) is low at that time of year giving the midge population the potential to grow very large. In addition, I learnt that it is important at the Māngere WWTP to keep the treatment occurring throughout the winter and to increase the frequency in September as a way of preventing any population snowball effect from occurring. At the Rosedale WWTP, due to the lower water temperatures, it is not necessary to treat through the winter months. However, treatments are started in August before any noticeable increase in midge emergence occurs as a way to prevent population momentum from occurring.

It is very important to monitor the midge population. The data that has been collected has been vital in understanding whether the treatment is working well and how to optimise its frequency to avoid unnecessary treatments.

The chain dragging method is designed to disturb the habitat of the midge larvae and is ecologically destructive. The FEC is an artificially engineered channel with high operational value but little ecological value. For this reason, it is acceptable to use a destructive method of midge control in the FEC. However, I would like to emphasise that this method would be highly inappropriate for use on natural waterbodies such as streams, rivers and lakes.

CONCLUSIONS

The chain dragging method has been proven to be effective at controlling the population of nuisance midge species *C. zealandicus* at the Māngere WWTP for five seasons and the Rosedale WWTP for two seasons. Data from public complaints and the community midge sampling programme show that the number of midges remained low and swapping the treatment of methoprene with the chain dragging method has been successful. Improvements in the design of the equipment (version 2) appear to have made a noticeable difference to the performance with the 2020-21 and 2021-22 seasons at the Māngere WWTP being the best on record. Financially, the switch from using methoprene to using the chain dragging method reduced the operating costs of killing the larvae in the FEC from approximately $300,000 to $75,000, saving Watercare approximately $225,000 per annum. Similar savings were made at the Rosedale WWTP as well.

Important lessons learned from using the chain dragging method are to start early in the season to prevent momentum building in the midge population and to ensure that as much of the midge habitat is treated as possible. It is also important to monitor the midge population to optimise the timing and frequency of treatments.

It is hoped that the information in this paper will be helpful to others in the water and wastewater industry who may have similar issues with nuisance midges.

ACKNOWLEDGEMENTS

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