CASCO BAY REGIONAL SHELLFISH WORKING GROUP

A Guidance Document for Municipalities in Maine

Photo by Sarah Randall , DEI, 2017.

Milky Ribbon Worm (*Cerebratulus lacteus*) Predation and Mitigation: A Review

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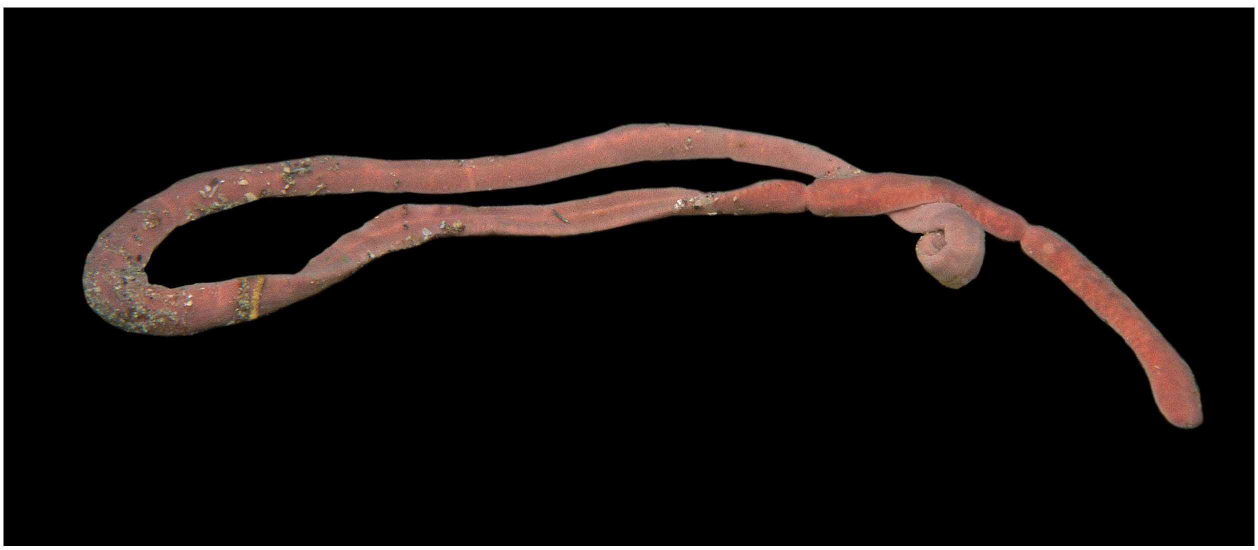
Purpose

Members of the Casco Bay Regional Shellfish Working Group[1], including shellfish harvesters, expressed interest in compiling a document about milky ribbon worms (*Cerebratulus lacteus*)(MRW), a significant clam predator. This document serves as a resource for municipalities to better understand MRW predation of soft-shell clam populations, as well potential predator control strategies.

Background Information

MRW present a large threat to the survival of soft-shell clam populations throughout the intertidal along the coast of Maine. This document presents a summary of all scholarly literature, unpublished research, and white papers currently available on the MRW.

The Gulf of Maine is one of the fastest-warming bodies of water in the world (Pershing et al., 2015). Warming seawater temperatures have the biological effect of increasing invertebrate predation rates. Summertime temperatures now last until mid-fall, which elongates the time period that predators feed maximally. Thus, as climate change continues to increase the temperature of the Atlantic Ocean, there will be a decreased chance for clams to survive to reach a harvestable size because of the high rates of predation (currently over >99%) by clam predators, including the MRW and green crabs (Beal et al. 2018).



https://www.barnegatbaypartnership.org/species/milky-ribbon-worm/

Life History

Milky ribbon worms can be found along the entire Atlantic coast ranging from Florida into Atlantic Canada (McDermott, 2001). This species is one of the largest nemerteans[2] and possesses characteristics such as the absence of external appendages, a lack of visible segmentation, and the ability to survive without feeding for extended periods of time (Wilson, 1900; Thiel & Kruse, 2001). MRW are nocturnal or-

1 www.tidalbayconsulting.com/cbrswg

2 Nemertea is a phylum of invertebrate animals also known as ribbon worms or proboscis worms.

ganisms, coming out of their burrows mainly during night tides (Wilson, 1900). In Maine specifically, the reproductive season for MRW occurs between July and August (McDermott, 2001). When it comes to sediment preference and depth, these worms can be found within 6-8 inches from the surface (Wilson, 1900). Additionally, MRW are sulfide tolerant and therefore can survive in sediments composed of 50% or more organic content (Visel, 2020).[3] Lastly, MRW are regenerative, meaning that cutting them into pieces does not kill them, but instead increases their overall population and therefore shows that they should be handled carefully (Kohl Kanwit, personal email message, June 17, 2020).

Soft-Shell Clam Predation

Studies have found that clam mortality increases with higher densities of MRW, suggesting that MRW are a serious and formidable predator for soft-shell clams. In the lab, 100% of soft-shell clams died when MRW were present, and 0% died in their absence (Bourque et al., 2001). MRW have been found to have a strong preference for soft-shell clams, even when other species of shellfish are present. Field experiments in the Annapolis Basin, Nova Scotia, resulted in 100% mortality of clams (25-32 mm in shell length) between May-August 1987 due to MRW (Rowell and Woo, 1990). Furthermore, they appear not to have a size preference and will prey on clams of all sizes in laboratory trials (Rowell and Woo, 1990; Bourque et al., 2001; Bourque et al., 2002). However, field trials in Freeport, Maine found that MRW seemed to have a preference for clams larger than 40 mm (DEI, 2020).[4] Through observation, researchers have found that MRW actively seek prey during low tide (Bourque et al., 2002). MRW exhibit a sit-and-wait predation strategy in areas with a high abundance of soft-shell clams. MRW wait until they receive a stimulus (chemical cues from prey), then follow the prey in pursuit (Thiel & Kruse, 2001).

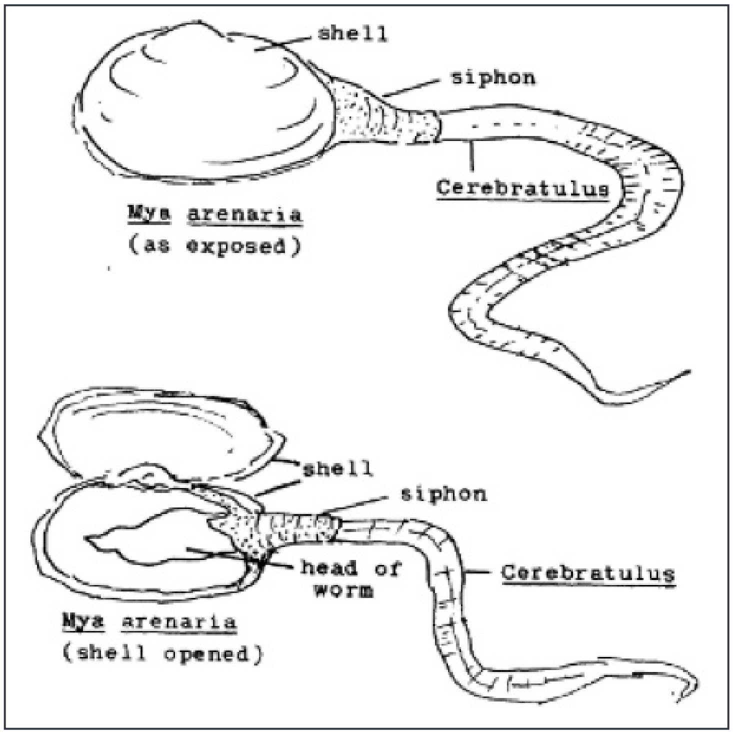


Figure 1. Diagram of a MRW preying on a soft-shell clam.

Nemerteans such as *Cerebratulus* possess potent neurotoxins (Kem, 1985) that can kill their prey within just a few seconds (Thiel & Kruse, 2001). Once an MRW encounters a clam, it delivers immobilizing toxins into the bivalve's mantle cavity by inserting its proboscis through the clam's posterior region through its incurrent or excurrent siphons or the anterior end through the pedal opening, or gape (Figure 1). The toxins act to dissolve all tissues that subsequently are ingested by the worm (Göransson et al., 2019).

3 Statements from Visel, 2020 are not peer reviewed but rather fall under grey literature.

4 Statements from the DEI are unpublished research findings. FMI: https://downeastinstitute.org/research/milky-ribbon-worms/

In some cases, attacks by a worm can occur without everting the proboscis. A MRW can insert its head into the clam's mantle cavity via the siphons and begin to consume the clam, starting with the viscera, then mantle, and sometimes the siphon (Bourque et al., 2002). Because of this unique method, it is possible to visibly distinguish the difference between green crab and MRW predation on clams. Green crab attacks are typically associated with crushed or chipped valves (but see Tan & Beal, 2015), whereas MRW predation leaves no visible damage to the shells that are left intact (Figure 2).

Figure 2. Damage by MRW (Photo: Brian Beal/DEI, 2015)

Milky Ribbon Worms as a Prey Species

A literature review by McDermott in 2001 showed that MRW serve as prey for a variety of consumers. MRW were recovered from the stomachs of 85,454 fish, 26,642 of which were examined in the lab and 58,812 of which were examined in the field, along with the digestive tracts from a few other organisms such as birds. It was found that nemerteans, including MRW, are preyed on by a number of fish, birds, other nemerteans, arthropods, a squid, and invertebrates. Of the fish stomachs examined, winter flounder and yellowtail flounder contained the most nemerteans in their stomachs. Observations of birds feeding on MRW are rare; however, the review found that MRW compromised 20% of the gut volume of black-bellied plovers, and were only recovered from the digestive tracts of this particular bird species. Because MRW are rarely encountered by birds and fish, they may have difficulty learning that MRW are distasteful and therefore continue to prey on the species (McDermott 2001).

Control Methods

INTRODUCTION OF CLAM WORMS

A laboratory study introduced clam worms (*Nereis virens*) to aquariums containing soft-shell clams and MRW. Researchers found no significant reduction in soft-shell clam mortality when clam worms were introduced, demonstrating their ineffectiveness in controlling MRW predation (Bourque et al., 2001).

INTRODUCTION OF BLOODWORMS

The same laboratory study also introduced bloodworms (*Glycera dibranchiata*) to aquariums containing soft-shell clams and MRW. Researchers found that MRW predation of soft-shells was significantly reduced when bloodworms were present. However, a 9% mortality rate was observed when bloodworms were placed alone with clams (Bourque et al., 2001).

In 2016, DEI conducted an intertidal field experiment in Freeport, Maine to determine if the results of Bourque et al. (2001) could be successfully duplicated in the wild (i.e., whether the presence of bloodworms can reduce MRW predation on juvenile soft-shell clams) (Bioremediation, DEI). The study excluded predators by planting clams, along with different densities of bloodworms in sediments that were taken from the adjacent sediments (mudflats) in wooden boxes. The boxes were protected by different types of mesh screening bottom (half of which had a Pet Screen®[5] bottom that MRW cannot penetrate while the other half had a 4.2 mm flexible net bottom that they can penetrate) and covered with a 3.2 mm aperture netting. Unfortunately, the use of sediments from the mudflats introduced tiny green crabs to the experimental units (EUs), which feasted on the clams in the boxes through the field season (May- October). Thus, researchers were unable to determine the impact bloodworms had on decreasing clam mortality by MRW (Bioremediation, DEI).

DEI conducted the study again in 2017 with an attempt to limit the introduction of green crabs into the EUs by filling them instead with terrestrial sediments from a local gravel pit. Those results should be available by the fall of 2020.

PLASTIC NETTING

In 2014, DEI conducted a field study in Freeport, Maine placing flexible plastic netting with 4.2 mm aperture over four 18 m^2 plots in the intertidal, and netting with 6.4 mm aperture over four more plots. Researchers found that while netting was effective in deterring green crab predation on juvenile clams, it was ineffective in reducing MRW predation. MRW are able to burrow beneath the netting and crawl through it to access clams. The authors also argue that flexible plastic netting is not a practical solution on a large scale to combat MRW predation because covering large stretches of the intertidal is too expensive, difficult, and time-consuming (Beal et al., 2016). In conjunction, another DEI field study in 2014 also noted that nets that cover the top of the flats were ineffective at controlling MRW predatory activity (Gregarious Clam Experiments, DEI).

SCREENS

Understanding that netting applied to the top of flats is not effective in deterring MRW, DEI built wooden boxes (2-ft x 4-ft; 1-ft x 2-ft) to contain juvenile clams with several densities. Those boxes that were lined on both the top and bottom with Pet Screen®[6] were effective in reducing MRW predation, but clam growth rates were not as fast when that screening was used on top of the box compared with larger aperture netting.

DEI also conducted a field study in Freeport, Maine in 2017 to examine whether the presence of adult soft-shell clams attract settling juvenile clams (i.e., causing gregarious clam settlement). They used 8-inch diameter x 6-inch deep plastic plant pots containing 0-16 adults with a small circle of Pet Screen® placed in the bottom of half of the pots to keep MRW from entering the bottom of the pots through the small drainage holes associated with the pots. Researchers found that the circles of Pet Screen® placed at the bottom of the plant pots were ineffective in stopping MRW from reaching the adult clams inside. Apparently, the worms entered the pots through the drainage holes, and then pushed enough of the screening aside to reach and attack the adult clams. The same experiment was conducted in 2018, with the only difference being that the circles of Pet Screen® were hot-glued to the bottom of the pot. While the hot-glued screens did deter MRW predation, and therefore increased

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5 A description of Pet Screen® can be found at this link: https://www.phifer.com/product/petscreen-pet-proof-screens-pp/

6 This has not been tested at a commercial scale. Additionally, aquaculture using Pet Screen® is not financially viable given the current conditions as it would need to be applied to both the top and bottom.

the rate of adult clam survival, it was not 100% effective. Results from this 2018 study are still being processed (Gregarious Clam Experiments & Protecting Clams, DEI).

CLAM AQUACULTURE

A field study in Maine examined potential management efforts to increase soft-shell clam populations. From this study, it was concluded that there are no large-scale direct management efforts that are effective in protecting soft-shell clam populations. However, increasing clam aquaculture (i.e. enabling concentrated efforts by motivated individuals to exclude predators from clams) may be a solution to replace stocks lost to MRW predation. Beal et al. (2016) suggests that because predator mitigation can be more closely undertaken and monitored in a controlled aquaculture setting, soft-shell clam populations have the potential to grow while excluding MRW (Beal et al., 2016). However, installing Pet Screen® over the top and bottom of a farm plot would be difficult, expensive, and likely to restrict water flow. Predator deterrent boxes with appropriately sized mesh are more effective in excluding MRWs, but can also be expensive. Beal's work suggests there may be opportunities for preventing MRW through dedicated predator protection efforts that may be easier to undertake on aquaculture sites, but more applied research is needed (Hagan & Wilkerson, 2018).

BAIT TRAPS

Due to the fact that MRW prey heavily on soft-shell clams, Bourque et al. (2002) suggested that clam flesh could be used as bait in traps placed on the sediment surface to catch MRW and lower their overall population density in the particular area. However, this approach has not been critically tested and requires more research to determine its potential effectiveness.

KEY CONCLUSIONS

While there are some methods that provide limited protection from MRW, an effective, large- scale mitigation method has yet to be discovered. This table summarizes potential control methods, and their efficacy based on current information.

CONTROL METHOD	KEY COMPONENTS	MATERIALS NEEDED	COST	EFFECTIVENESS
Clam Worms	Introduce clam worms into an area where MRW and soft-shells are present	Clam worms	Ranges from $60 for 5 dozen to $275 for 20 dozen *(depends on size of worms)*	Ineffective
Bloodworms	Introduce bloodworms into an area where MRW and soft-shells are present	Bloodworms	Retail bait prices- Ranges from $60 for 5 dozen to $275 for 20 dozen (depends on size of worms) *(Possibility to get cheaper prices from a wholesaler or directly from a wormer)*	Shown to reduce MRW predation in the lab, but not in the field; more research is necessary
Plastic Netting (applied on the surface)	Place plastic netting over plots in the intertidal to protect soft-shells from predation	Flexible plastic netting, floats, and zip ties	• 14' x 20' net- $10 • 10 floats- $20 • 10 zip ties- $2 • Total- $32	Flexible netting with an aperture greater than 4.2 mm is ineffective in protecting clams from MRW (it is somewhat effective to reduce green crab predation)
Screens (applied to both the top and bottom of the plot)	Attach Pet Screen® to the top and bottom of experimental units to protect soft-shells from predation	Pet Screen®, experimental units (such as plant pots), hot glue gun + glue	Pet Screen®- Range of different sizes • $17 for (36" x 7')- $164 (36" x 100') • 8x6 plant pots- $20 for 50 • Hot glue + glue- $15	Pet Screen® was effective to some degree in controlling MRW in the field, but may reduce clam growth rates
Clam Aquaculture	Intertidal shellfish aquaculture lease *(Requires a lease from the state or municipality if they have an aquaculture ordinance)*	Seed, Pet Screen®, floats and zip ties ; wooden boxes- 2-ft x 4-ft, 4-ft x 8-ft	• 10,000 seed clams at $25/1000- $250 • Pet Screen®- $17-164 • 10 floats- $20 • 10 zip ties- $2 • Total- $282	Effective when used in small areas with netting and carefully monitored
Bait Traps	Clam flesh could be used as bait in traps placed on the sediment surface to catch MRW	Clam flesh and bait trap	Varies significantly *(Depends on trap)*	More research needed

CONSIDERATIONS

As there are no large-scale mitigation methods as of yet, this section summarizes a few considerations for municipalities as they site conservation projects.

What do we know about MRW populations and how do we survey them?

Though little information on MRW surveys and population assessments is currently available, there are two promising starts. The University of New England conducted detailed population surveys of clams and known predators in Scarborough, ME with five main objectives in mind:

1. Establishing baseline data for Scarborough's shellfish management program;
2. Quantifying predator density on clam flats;
3. Analyzing trends in distribution;
4. Analyzing trends in sediment preference; and
5. Designing mitigation efforts. The results from this study have not been made available.

Researchers at Bates College and Manomet are currently developing a survey technique for MRW.

What can towns do if MRW are an issue in a particular cove?

If the town has enough people available for regular maintenance and monitoring, installing Pet Screen® on the top and bottom may be a viable mitigation method for certain conservation areas (e.g., reseeding/transplanting) or aquaculture sites (Bioremediation, DEI). It is important to recognize that this method would require significant upkeep. In addition, permitting may be required from the state and Army Corps of Engineers, and municipal conservation closures are necessary during the growing season. Netting also has to be removed before ice may build up in a cove.

The town may also consider using bait traps in the cove, in which clam flesh is put into traps to control MRW predation. Additional research is needed on this mitigation method, so the town may want to conduct their own experimental trials to determine its effectiveness.

What mitigation methods are worthwhile?

Although more information and research are needed, the presence of bloodworms in the same area as MRW may deter MRW from eating clams in a laboratory, though results have not been proven in the field. Unfortunately, bloodworm and sandworm landings are currently declining[7], which may have an effect on MRW populations. If this trend continues, then the bloodworm mitigation method may not be an option. Setting aside up to 25% of the intertidal for clam aquaculture has been suggested as a potential measure to control MRW populations (Beal et al., 2016). However, this effort requires riparian landowner approval, permitting[8], significant upkeep, and consistent monitoring.

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7 https://www.maine.gov/dmr/commercial-fishing/landings/documents/bloodworms.graph.pdf, https://www.maine.gov/dmr/commercial-fishing/landings/documents/sandworm.graph.pdf

8 More information on the aquaculture permitting process and required forms can be found here: https://www.maine.gov/dmr/aquaculture/forms/lpa.html

What might happen if MRW predators, such as flatfish/flounder rebound?

Certain flatfish landings have been declining in Maine for decades. For example, 131,540 thousand pounds of witch flounder were landed in 2019, which is approximately 7% of the witch flounder landed in 1999 (1,979,699 million pounds).[9] Additionally, even though the most recent state landings data for yellowtail flounder are available through 2009, landings in 2009 were a fraction of the several millions of pounds landed on average in the late 1980s.[10] Although no scientific literature exists to support this hypothesis, if MRW predators were to rebound, we can assume this would decrease MRW numbers, and hopefully reduce soft-shell clam mortality. This question and hypothesis would be interesting to test in the future if flatfish populations rebuild.

What if a bait market were started for MRW?

Although no bait market currently exists for MRW, an individual from a local tackle shop in Maine stated that MRWs work great for catching fish. However, unlike bloodworms and sandworms, MRW break apart easily (creating even more MRWs) and may not stay on a hook as well. Using the bait trap mitigation method to catch MRW could reduce the total population of MRW in the intertidal and in turn be used to start a bait market.

Why is it not in the best interest of clammers to remove MRW from the mudflats while they are clamming?

Unless clammers are careful to remove all pieces of the MRW from the mud, the removal efforts may inadvertently create more MRWs.

Is there a best mesh size to deter MRW predation?

According to the Downeast Institute experiments from 2014-2018, 2.1 mm mesh, either net or Pet Screen® applied to the top and bottom of wooden boxes (2-ft x 4-ft; 1-ft x 2-ft), is the best as it deters MRW predation while at the same time allowing for clam growth (Protecting Clams, DEI).

Does using a hydraulic rake to harvest clams affect MRW densities?

A hydraulic rake is a device pulled by hand to harvest clams in states where this type of harvest is permissible by regulation[11]. This device is attached by a hose to a pump engine that sends jets of water directly into the sediment, causing the sediment to become less compact (Virginia Marine Resources Commission; Bourque et al., 2001). A field study was conducted to address concerns that use of hydraulic rakes could increase the number of MRW locally. However, it was found that the use of a hydraulic rake itself did not increase MRW densities and thus can continue to be used as a cultivation method without the fear of increasing MRW densities (Bourque et al., 2001).

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9 Witch Flounder Landings Graph: https://www.maine.gov/dmr/commercial-fishing/landings/documents/witchflounder.graph.pdf

10 Yellowtail Flounder Landings Graph: https://www.maine.gov/dmr/commercial-fishing/landings/documents/yellowtail.graph.pdf

11 The use of hydraulic rakes for harvesting is not legal in Maine.

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