NOVA SCOTIA BLOODWORM (*GLYCERA DIBRANCHIATA*) ASSESSMENT: A REVIEW OF METHODS AND HARVEST ADVICE

B. Semple

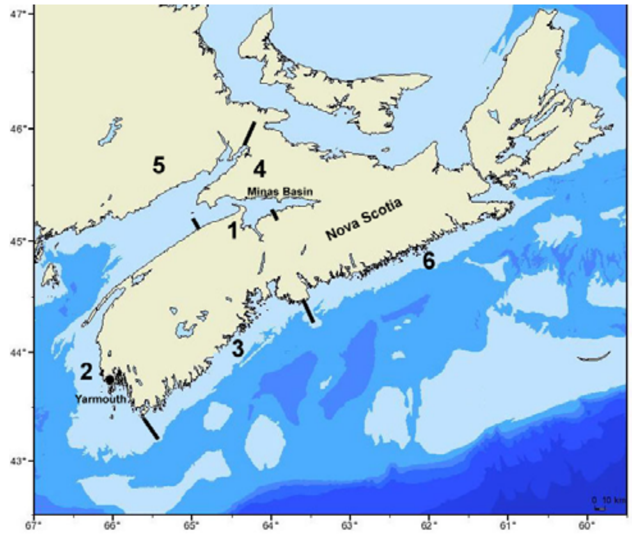

Figure 1. Location of Marine Worm Harvesting Areas 1-6.

Context:

Bloodworm (Glycera dibranchiata) is a marine polychaete harvested from intertidal mud flats and sold live to marine sport fishermen for bait. There has been a fishery for marine worms (primarily bloodworms) in the Maritimes Region since 1952, but it first became regulated in 2001. A Conservation Harvesting Plan was first developed in 2002. By 2008, regulation of an exploratory fishery had evolved to include licensing, reporting daily sales and fishing location, seasons, area closures, minimum legal size, and gear type. The recreational harvest also includes a possession limit and recreational harvesters are not allowed to sell their catch. At present, bloodworms are harvested primarily from the mud flats of the Minas Basin and in Southwest Nova Scotia (Figure 1), and this report focuses on these areas.

DFO Maritimes Science has not previously conducted a formal assessment of the status of bloodworms in this Region. In 2008, DFO Maritimes Science received a request by Fisheries and Aquaculture Management to review the scientific survey methods, stock assessment methods, and indicators required to monitor the future health of marine worm stocks for a sustainable fishery. A science peer-review meeting was held 9 February 2009, the results of which are presented in this Science Advisory Report. The focus of this assessment was on selected mud flats of the Minas Basin and Southwest Nova Scotia.

SUMMARY

- Harvesting can have measurable impacts on marine worm densities within a harvest area, although the sustainability of harvest appears to vary by location.

- Survey densities of commercial sized worms at Avonport, Walton, and Yarmouth Harbour dropped significantly after a few years of harvesting, and Yarmouth Harbour showed little evidence of recruitment in the 3 years after opening. Starrs Point and Kingsport have declined in importance as harvest areas over time. While these areas have not been surveyed, it is suspected that their bloodworm abundance has declined. Bloodworm densities in Cheverie remained relatively stable over 3 years with moderate harvest levels, and Goose Bay has remained an important harvest area since the 1950s.

- Mud flats should be managed independently because exchange of worms between flats is probably low and evidence suggests that harvesters can fish down individual flats to low levels. DFO resources are currently insufficient to manage harvest of bloodworms by flat without involving harvesters in surveys.

- A robust survey protocol was developed that harvesters can use to measure worm densities and size distributions.

- A number of management measures are currently in place to support a sustainable harvest of marine worms, including minimum legal size, possession limits for recreational harvesters, seasonal and year-round closures, gear restrictions, and licensing controls. Additional monitoring and enforcement would help to ensure the effectiveness of management controls, particularly minimum legal size.

- Additional measures that would support a sustainable harvest include: closing a flat when density falls below 0.6 worms/m^2 for worms over the minimum legal size (interim reference point until further evaluation), opening a closed flat when density exceeds 0.8 legal worms/m^2, and restricting harvesting during spawning. If regular monitoring of individual flats is not implemented then a cautious approach (based on less information) of rotating closures of flats should be substituted.

INTRODUCTION

Biology

Bloodworms *(Glycera dibranchiata)* belong to a phylum of animals known as Annelida. This group of organisms usually has an elongated, cylindrical-shaped body consisting of a series of similar segments. These worms inhabit the intertidal and subtidal regions of mud flats. They can survive in areas with low oxygen levels and have the ability to tolerate fluctuating salinity levels. They feed on invertebrates and other organic matter while burrowing through mud or sand.

For bloodworms collected from the Minas Basin in 2002 and 2006, the size at 50% maturity was found to be approximately 2.5-2.9 g. For Southwest Nova Scotia (SWNS), the size at 50% maturity was found to be substantially larger (4.2 to 5.9 g) than in Minas Basin. These sizes at maturity are lower than earlier estimates from Maine, USA (Table 1). There appears to be some spatial variation in size at maturity in SWNS, and further investigation is required.

Table 1. Weight (g) of bloodworms at 25%, 50% and 75% maturity from different areas.

	Weight (g) at maturity			
Location	**25%**	**50%**	**75%**	**Source**
Wicasset Maine	4.3	5.4	6.0	Creaser (1973)
all Maine	4.4	6.2	7.2	Creaser et al. (1983)
SW Nova Scotia	3.0-4.1	4.2-5.9	6.0-6.9	Miller (2009)
Minas Basin	1.7	2.5-2.9	3.8	Miller (2009)

Klawe and Dickie (1957) suggested that spawning of bloodworms occurs during mid-May in Goose Bay. Creaser (1973) suggested a spawning time of mid to late June in central Maine. Nova Scotia harvesters believe spawning occurs in May-June, but it varies with year and location. Based on field observations, both Simpson (1962) and Creaser (1973) believed that individuals released all their gametes within minutes and that the seasonal spawning episode lasts only a few days. The current understanding is that bloodworms die after they spawn.

Klawe and Dickie (1957) concluded the larval stage of bloodworms was short because they failed to find larvae in the water column. Bristow and Vadas (1991) concluded larval exchange among areas was minimal because they found genetic differences between estuaries, within estuaries, and between intertidal and subtidal populations. Vadas and Bristow (1995) gave evidence that low population size could lead to low genetic diversity and postulated that this could leave populations unable to adapt to changing environments.

The Fishery

Marine worms (primarily bloodworms) are harvested from intertidal mud flats and sold live to marine sport fishermen for bait. Harvesting is conducted with the use of a handheld tool similar to a clam hack but modified slightly. The North American harvest is principally in Maine and Nova Scotia, and markets are in the eastern US and western Europe. After exploration and trial shipments, the Canadian fishery began commercial shipments from Yarmouth County in 1952 and reached 4 million worms by 1955. The fishery expanded to Minas Basin in 1985. In 1991, 49 harvesters were counted on one mud flat in Minas Basin. Reliable records of Canadian landings first became available in 2002 with the introduction of fishing logbooks; from 2002-07 landings ranged from 4.4 to 5.6 million worms (Table 2). In 2007, landings of close to 5 million worms were worth $900,000 to harvesters.

Table 2. Landings (000 worms) by Worm Harvesting Area from DFO's Commercial Data Division.

	Worm Harvesting Areas				
Year	**1**	**2**	**3**	**5**	**6**
2002	1956	2347	400	0	0
2003	*	*	*	*	*
2004	2485	2592	128	*	*
2005	1584	3929	79	416	*
2006	993	4378	18	269	1
2007	784	3635	8	126	6
2008	735	2919	64	81	5

*unknown

There are currently 6 marine worm harvesting areas (MWHA) in the Maritimes Region (Figure 1). The harvest season varies by area, as described in detail in the Maritimes Region Marine Worm Conservation Harvesting Plan. The minimum legal size for harvested worms in

MWHA 1 is 2.5 g. The minimum legal size in MWHA 2-6 is 3 g. In 2009, there were individual flat closures in Yarmouth Harbour and some areas in Minas Basin. Since 2004, there have been closures at Blomidan and Evangeline Beach to protect migratory birds.

ASSESSMENT AND ANALYSIS

Survey Methods

Surveys have been conducted using two methods. Method 1 involves direct involvement of science staff, while Method 2 can be conducted entirely by experienced harvesters using agreed to scientific protocols. Estimates of precision using these two methods were comparable and are considered acceptable for estimating abundance trends.

Method 1: Surveys using this method were conducted by experienced harvesters digging worms in a manner similar to commercial harvesting. An accompanying biologist determined the station locations and collected worm samples from each station. Survey locations were randomly selected at grid intersections (100x100m or 200x200m) on a bed map charted previously by an experienced harvester using a handheld Global Positioning System (GPS). At each station, the harvester dug 15 m^2 from three lines 0.7 x 7.1 m or two lines 0.7 x 10.7 m. Efforts were made to maintain a constant digging depth of about 12 cm.

Method 2: Surveys using this method were also conducted by experienced harvesters. In this method, however, the harvesters would visually determine the approximate perimeter of the bed to be surveyed, decide on the number of stations (12-20 for most flats, but more for the largest flats such as Goose Bay), and decide on a fixed number of paces between stations that would allow the stations to be distributed over the bed. At each station, the harvester used a rope guide 184 x 360 cm marking two sides of a 6.6 m^2 rectangle to be dug.

Abundance Trends of Marine Worms on Selected Mud Flats

The abundance of marine worms over time was assessed for selected mud flats in the Maritimes Region using survey Method 1.

In **Yarmouth Harbour** (MWHA 1), 4 stations were sampled in July 2002, 8 stations were sampled in May, July, October and November 2003, and then 10 stations were sampled on the final six sampling dates (2004-2007). The harbour was closed to fishing from 2002 through August 2004, and then it opened for the month of September in 2004. Some of the area was open for all or part of the years 2005-2007. Densities of bloodworms increased from 2002 until the opening in 2004 (Figure 2). This was especially true for the larger worms over 3 g. At the time of opening, the population was 90% large worms. The one-month season in 2004 reduced abundance by half and it continues to decrease. There is little evidence of recruitment as the population was still nearly all large worms in 2007.

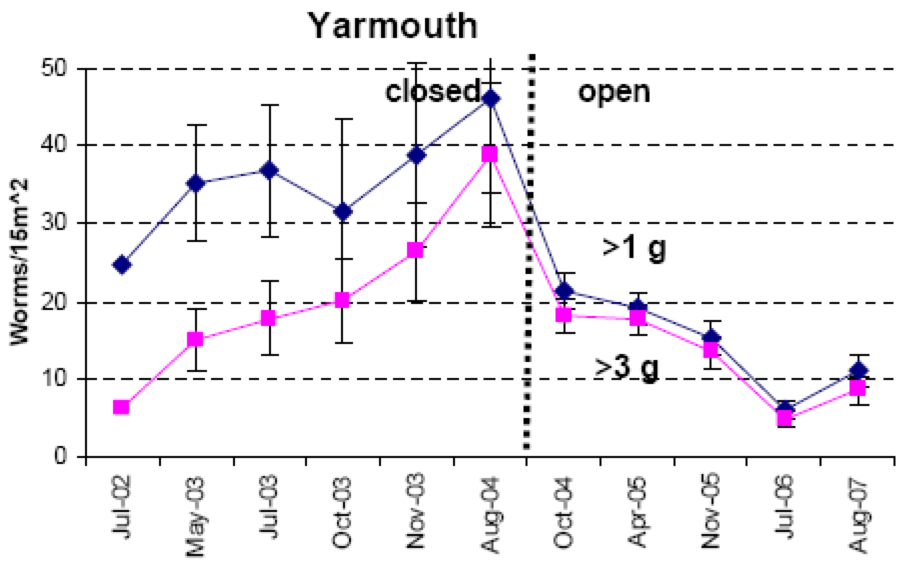

Figure 2. Mean densities of bloodworms >1 g and >3 g ± 1 standard error for 11 sampling dates at Yarmouth Harbour. The area was closed to harvesting before September 2004, then open September 2004 and parts of 2005-2007.

Avonport (MWHA 1) was sampled at 8 stations in 2002-03. As the survey method was refined, station number was increased to 16 for 2004-2005. The area has been closed since the beginning of the 2004 season. The larger size is given as >2 g as this was the minimum legal size at the time. Although not part of the survey, a large loss of the area covered by mud and a reduction in mud depth was apparent in 2004. The mud loss and/or heavy fishing in 2002 and 2003 probably lead to the decline in bloodworm abundance (Figure 3).

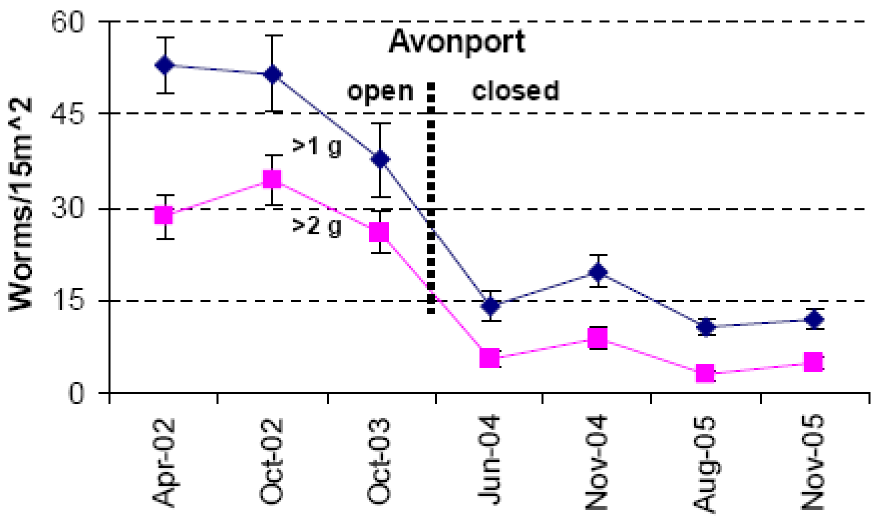

Figure 3. Mean densities of bloodworms >1 g and >2 g ± 1 standard error for 7 sampling dates at Avonport. The beach was closed to harvesting after 2003.

Cheverie (MWHA 1) is a large beach that was sampled at 16-17 stations from 2004 through 2006. The beach has been open to fishing for a shortened season every year since 2003. Fishing effort was not heavy, and there was no marked change in abundance during the 3 years surveyed (Figure 4). In 2006 most of the harvesting occurred inshore of the surveyed area (harvesters, *pers. comm.*).

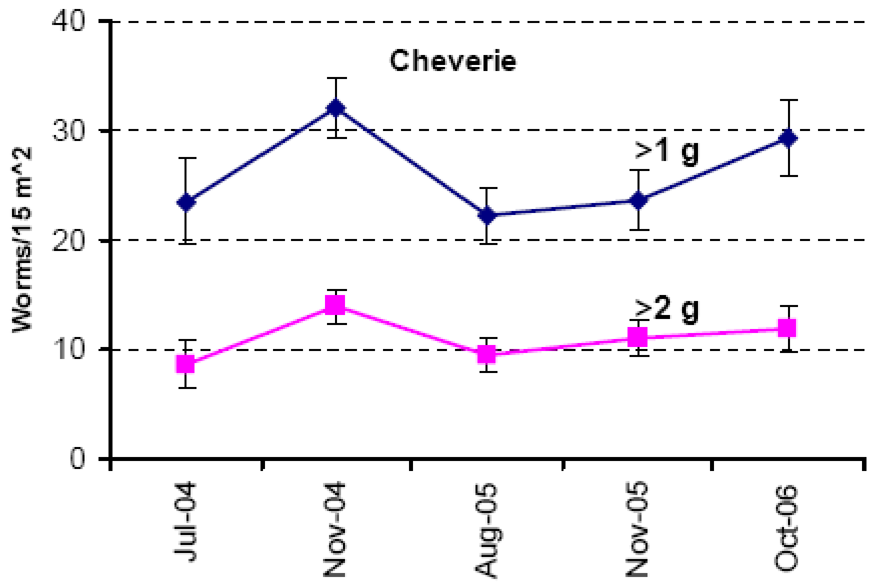

Figure 4. Mean densities of bloodworms >1 g and >2 g ± 1 standard error for 5 sampling dates at Cheverie.

A small mud flat on the west bank of the **Walton River** (MWHA 1) was sampled only twice at 6 stations. The decrease in abundance and size of worms from October 2002 to May 2005 is striking (Figure 5). The area was fished heavily prior to 2005 and residents have reported a loss of mud from the flat.

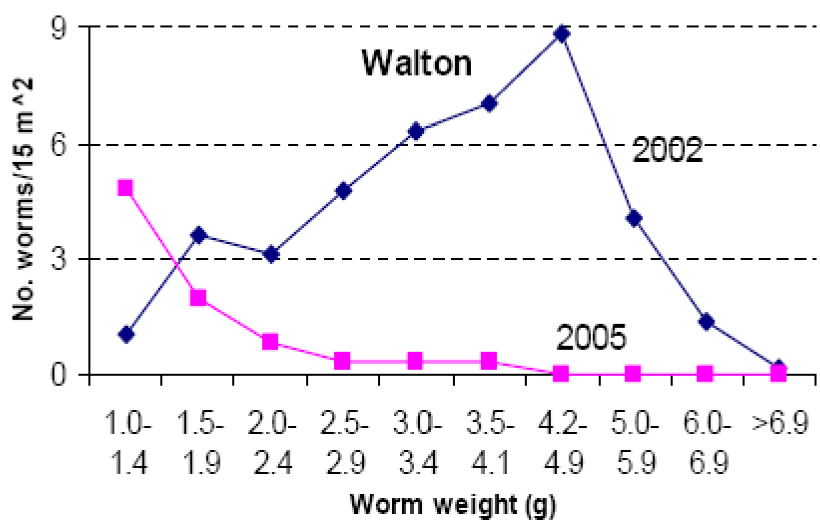

Figure 5. Mean densities by size for 2 sampling dates on the west side of the Walton River.

The history of landings and anecdotal evidence from harvesters have been used to evaluate trends at the following locations.

Starrs Point (MWHA 1) was the principal harvest area in Minas Basin from the late 1980s through the early 1990s when it was abandoned for lack of worms (Shepherd 1994; Minas Basin harvesters, *pers. comm.*). From 2004-2007, it provided only 4% of the Minas Basin harvest.

Kingsport (MWHA 1) flat was a priority harvest area because it is near a parking area, close to Kentville, the residence of most area harvesters, and the surface is easy to walk on and easy to dig. Based on reported landings information, the portion of the Minas Basin harvest taken from this flat changed from 56% to 77% to 26% to 14% from 2004-07. The total landings of worms from this flat decreased by 92% over the same period.

Goose Bay (MWHA 2), on the other hand, has been relatively stable. It was the most important harvest area in the 1950s (Klawe and Dickie 1957), and from 2004-07 supplied 31% to 73% of the catch from MWHA 2. Further investigation of this area is warranted.

Indicators of Stock Status and Ecosystem Health

Bloodworm populations on mud flats may be vulnerable to serial depletion followed by reduced fertilization success. Serial depletion occurs when harvesters harvest a mud flat until no worm concentrations of acceptable density can be found and then move on to harvest a new area. Reduced fertilization success may occur when the density of spawners decreases to the level that egg fertilization is unsuccessful. Because dilution of eggs and sperm in three dimensions would be very rapid, spawner density on a very local scale could be important to successful egg fertilization. Bloodworm density on a commercial bed in Maine before and after stock collapse was 4 and 0.9 worms/m^2 (Vadas and Bristow 1985). The year harvesters quit harvesting at Starrs Point, Shepherd (1994) collected only 49 mature worms (19 females) in 30 hours of digging. Mud flats with apparently local bloodworm recruitment and from which harvesters can find and remove small aggregations of potential spawners appear vulnerable. These problems have been well researched for other species, such as abalone, queen conch, and sea urchins.

The potential impact of marine worm harvesting activity on mud flat habitat characteristics was investigated using a study of the differences between sites in the Minas Basin that had been actively harvested or disturbed in a manner similar to marine worm harvesting (11 sites) and 50 undisturbed reference sites (Westhead 2005). In this study, it was found that disturbed sites tended to have generally higher overall organism densities, capitellids, nematodes, and *Corophium*. Tube building spionids and maldanids were in lower densities. This suggests a mud flat community shift from sedentary tube dwellers to a more mobile and opportunistic community (*Corophium*, capetellids and nematodes that more easily colonize the disturbed habitats). This is further supported by a higher dominance of amphipods in test sites (60%) than reference sites (48%). The duration of this potential community shift was not investigated.

The impact of marine worms harvest on other ecosystem components (e.g., migrating birds and groundfish), was not assessed at this meeting; however, these would be important considerations to investigate in future assessments.

Sources of Uncertainty

Sources of uncertainty that may influence the assessment of surveyed mud flats include the influence of mud loss and other environmental changes on population abundance.

The size at maturity for bloodworms in southwestern Nova Scotia is larger than in Minas Basin, but should be investigated further because the variability in estimates is high.

Site-specific spawning times are not well known.

CONCLUSIONS AND ADVICE

Experimental evidence indicates that harvesting can have measurable impacts on marine worm densities, although the sustainability of harvest appears to vary by location. For example, survey densities of commercial sized worms at Avonport, Walton and Yarmouth Harbour dropped significantly after a few years of harvesting, and Yarmouth Harbour showed little evidence of recruitment in the 3 years after opening. Starrs Point and Kingsport have declined in importance as harvest areas over time. While these areas have not been surveyed, it is suspected that their bloodworm abundance has declined. Bloodworm densities in Cheverie remained relatively stable over 3 years with moderate harvest levels, and Goose Bay has remained an important harvest area since the 1950s.

A robust survey protocol was developed that harvesters can use to measure worm densities and size distributions. Surveying of closed flats prior to re-opening can be used to establish baseline conditions and ensure a minimum population size. Annual surveying of mud flats that supply a large portion of the harvest should occur. Small flats that may be vulnerable to over-harvesting by small effort also require periodic surveys. Unharvested flats that could relieve pressure from heavily harvested flats should be surveyed before harvest begins.

A number of management measures are currently in place to support a sustainable harvest of marine worms, including minimum legal size, possession limits for recreational harvesters, seasonal and year-round closures, gear restrictions, and licensing controls. Additional monitoring and enforcement would help to ensure the effectiveness of management controls, particularly minimum legal size.

Additional measures that would support a sustainable harvest include: closing a flat when density falls below 0.6 worms/m^2 for worms over the minimum legal size (an interim limit reference point until further evaluation), opening a closed flat when density exceeds 0.8 legal worms/m^2, and restricting harvesting during spawning. If regular monitoring of individual flats is not implemented then a cautious approach (based on less information) of rotating closures of flats should be substituted.

Mud flats should be managed independently because exchange of worms between flats is probably low and evidence suggests that harvesters can fish down individual flats to low levels. DFO resources are insufficient to manage the harvest of bloodworms by flat without involving harvesters in surveys.

OTHER CONSIDERATIONS

Monitoring Considerations

Based on experimental evidence, worm densities determined using the survey methods described above were not significantly affected by the duration of air exposure of the mud (0.2 vs. 2.2 hours) or the temperature of the mud surface (17ºC vs. 26-28ºC). However, surface temperature did tend to have a greater influence on small worms than on large worms. Digging depths in the survey needs to be standardized since worms are found at all depths from 0-20 cm. Experienced harvesters obtained similar mean densities and size frequencies of worms when surveying adjacent areas.

Having an experienced harvester map the perimeter of the harvestable portion of mud flats may be useful for allocating sampling stations. However, mud flats move, especially those most exposed to wave action, and this mapping would need to be repeated every few years.

Estimating population size for an entire mud flat or comparing yield/km^2 among mud flats would be difficult if rock outcrops and meandering streams render a large portion unharvestable.

Management Considerations

A **minimum legal harvest size** is currently in place, which can be useful to protect spawners and ensure future recruitment. However, in a 2006 sample of catches of four harvesters in Minas Basin, 79% of worms were below the 2.5 g minimum size. Enhanced enforcement may help to ensure the minimum harvest size is respected.

Efforts to maintain a **minimum density** of bloodworms may reduce the risk of unsuccessful fertilization. A minimum survey density of 0.6 worms/m^2 for worms over the legal minimum size (based on Figures 2-5 as an interim **reference point** until further evaluation), may be appropriate. Surveys using methods described previously and a survey depth of 12.5 cm (5 in.) or the depth of the mud, whichever is less, are expected to provide the most reliable results. It is recommended that flats open to harvesting that are found to be under the minimum survey density of 0.6 worms/m^2 be closed, while closed flats found to be 0.8 worms/m^2 could be opened to harvesting. In the first year, it is recommended that a minimum of four flats be surveyed in MWHA 1 and at least six flats be surveyed in MWHA 2 before they are opened to harvest.

Managing mud flats as if they were separate stocks may decrease the risk of eliminating population components. Studies of diversity in marine worms indicate that there can be genetic differences between estuaries, within estuaries, and between intertidal and subtidal populations.

Minimizing harvesting of bloodworms during spawning may reduce gamete mortality and risk of unsuccessful fertilization. Bloodworms are very fragile near the time of spawning and handling can cause them to burst and leave their gametes on the mud. Precise spawning times for each mud flat are not known, and it is not known whether spawning time varies among locations and years. Avoiding spawning would require attention to spawning times during surveys and/or harvesting. A season opening date of June 1 in MWHA 2 and 3 could help to avoid harvesting during spawning in these areas. However, if a method of surveying for spawners can be agreed upon and carried out by harvesters, an opening date of April 1 until spawning occurred may also be effective.

Upper Yarmouth Harbour east of the channel and north of 43º50’25” would be a suitable location for a **permanent research closure**, and a closure in this area may also contribute larvae to the remainder of the harbour.

Based on experimental evidence, transfer of marine worms to a survey plot does not appear to significantly increase the density of worms at that location after 10 months. Worms may not survive the transfer or may move away from the receiving location.

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