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History, assessment methods, and regulation of Nova Scotia's bloodworm (*Glycera dibranchiata*) harvest

Historique, méthodes d'évaluation et réglementation de la récolte du ver de vase de Nouvelle-Écosse (*Glycera dibranchiata*)

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TABLE OF CONTENTS

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ABSTRACT

The Nova Scotia commercial bloodworm harvest began with exports to the US in 1952; but was first regulated in 2002. By 2008, regulations included limited entry, reporting of daily sales and fishing location, seasons, area closures, and minimum legal size. The recreational harvest was regulated by seasons, minimum size, area closures, possession limit, and licenses. To aid in setting minimum legal sizes, size of maturity was measured in Southwest Nova Scotia and Minas Basin. DFO-directed and harvester-directed methods for surveying worm density and size distribution were developed and found to be robust. The effects of sample size on precision, time of air exposure of the mud, temperature of the mud surface, depth of digging, and variation among harvesters were measured. Depletion of 5 mud flats has been documented. Because of the risk of serial depletion and spawning failure, a precautionary management approach is recommended; this is in agreement with DFO's emerging species policy. Because interchange of worms between mud flats is probably small, flats should be managed individually. This requires the involvement of harvesters in surveys to determine mean densities relative to a reference point. Failing harvester participation, this recommendation includes alternating the closure of one-half the mud flats each year plus closure of depleted flats, as determined by occasional DFO surveys, until they recover.

RÉSUMÉ

La récolte commerciale du ver de vase de Nouvelle-Écosse a commencé par l'exportation de vers aux États-Unis en 1952, mais il a fallu attendre 2002 pour qu'elle soit réglementée. En 2008, la réglementation portait notamment sur la limitation de l'accès, la déclaration des ventes quotidiennes et des lieux de pêche, les saisons de pêche, la fermeture de zones et la taille légale minimale des vers. De son côté, la récolte à des fins récréatives était soumise à une réglementation incluant des saisons, une taille minimale, la fermeture de zones, une limite de possession et la délivrance de permis. Pour aider à fixer la taille minimale légale, on a mesuré la taille à la maturité dans le bassin Minas et le sud-ouest de la Nouvelle-Écosse. Avec l'aide du MPO et des pêcheurs, des méthodes destinées à mesurer la densité des vers et leur répartition par taille ont été élaborées et jugées pertinentes. On a mesuré les effets de la taille de l'échantillon sur la précision, la durée de l'exposition à l'air de la vase, la température de la surface de la vase, la profondeur de creusage et les variations entre les pêcheurs. On a également documenté l'épuisement de cinq vasières. Le risque d'épuisement continu et d'échec de la reproduction amène à recommander une approche préventive conforme à la politique du MPO pour les nouvelles pêches. Comme le déplacement des vers entre les vasières est probablement faible, il convient de gérer les vasières au cas par cas, ce qui requiert la participation des pêcheurs à des relevés visant à déterminer la densité moyenne à un point de référence. Si les pêcheurs ne participent pas à l'opération, nous recommandons entre autres d'alterner chaque année la fermeture de la moitié des vasières et de fermer les vasières dont l'épuisement a été confirmé par les relevés occasionnels du MPO, jusqu'à ce que leur population se régénère.

INTRODUCTION

Bloodworm (*Glycera dibranchiata*) is a marine polychaete harvested from intertidal mud flats and sold live to marine sport fishermen for bait. The North American harvest is principally in Maine and Nova Scotia, and markets are in the eastern US and western Europe (Creaser et al. 1983; Gerald Smith, buyer, Yarmouth, Nova Scotia, pers. comm.).

For Maine landings, Creaser et al. (1983) gave peaks in numbers sold at 25 million in 1948 and 31-37 million from 1963-75. From 2000-07, landings averaged 24 million (http://www.maine.gov/dmr/commercialfishing/historicaldata.htm) using a conversion of 44 worms per pound. Licensed diggers for both bloodworm and sand worm (*Nereis virens*) peaked at 1400 in the 1970s (Brown 1993).

When demand exceeded supply in the United States, the St. Andrews Biological Station was asked about supply from the Maritimes. After exploration and trial shipments, the Canadian fishery began commercial shipments from Yarmouth County in 1952 (MacPhail 1954) and reached 4 million worms by 1955 (Klawe and Dickie 1957). The fishery expanded to Minas Basin in 1985 (Mawhinney 1991, quoted in Shepherd 1994). In 1991, 49 harvesters were counted on 1 mud flat in Minas Basin (Mawhinney 1991). Reliable records of Canadian landings first became available in 2002 with the introduction of fishing logbooks; from 2002-08 landings ranged from 3.8 to 6.0 million worms, with distribution among areas shown in Table 1. Harvesters report landings without independent verification of accuracy. Value to harvesters is about $850,000 (Canadian) per year.

Table 1. Landings (000 worms) by area. See Fig. 1 for areas.

			Areas			
Year	1	2	3	5	6	Sum
2002	1956	2347	400	0	0	4703
2003	*	*	*	*	*	*
2004	2485	2592	128	*	*	5205
2005	1584	3929	79	416	*	6008
2006	993	4378	18	269	1	5658
2007	784	3635	8	126	6	4559
2008	735	2919	64	81	5	3804

*unknown

History of Fishery Management

In December 1994, Dr. J. Sherman Boates of the Nova Scotia Department of Natural Resources and members of the Kings County Bait Worm Harvesters Association presented the Department of Fisheries and Oceans (DFO) with a sound proposal for managing the bloodworm harvest in Minas Basin. Important elements were: limiting the number of harvesters, seasons matched to markets and avoidance of worm spawning times, a minimum size based on the size of maturity, rotation of harvest areas based on pre-season surveys, and longer closures of depleted flats. None of this proposal was accepted by DFO, probably because Minas Basin harvesters asked that Yarmouth area harvesters be excluded from Minas Basin. Thirteen years later, Yarmouth area harvesters were excluded, but important elements of the plan have yet to be adopted.

In 2001, violence between bloodworm harvesters from the Yarmouth area and Minas Basin and objections to commercial harvesting by residents of Hants County persuaded DFO to initiate management of this unregulated species. The largest buyer in Nova Scotia, Gerald Smith, stated that regulations were needed to save the worm fishery (The Vangard, Yarmouth, N.S., 29 May 2001).

In 2001, DFO hosted several public meetings for consultation. Subsequently, rules were written for access to licenses and a conservation harvesting plan (CHP) for the 2002 fishery. The Maritimes Region was divided into 6 areas (Fig. 1). Over 90% of the landings come from Areas 1 and 2, and the remainder come from Areas 3 and 5. Most of this report deals with Areas 1 and 2. The important beaches in Areas 1, 2, and 3 are mapped in Appendix 5.

License access for Area 1 required proof of selling $1,000 of worms in any of 1999, 2000, or 2001 or, for Areas 2-3, selling $2,000 of worms in 2 of these 3 years. This resulted in about 40 licenses in Area 1 and 90 in Areas 2-3. Area 2 harvesters were allowed access to Area 3, and up to 15 harvesters at a time were allowed in Area 1. Area 3 was also allowed up to 15 new licenses, and Areas 4 and 5 were allowed up to 10 each. Areas 1, 2, and 3 regulations included seasons, minimum worm sizes, and closed areas (Table 2). Harvesters were required to submit a monthly report of their daily harvest, the nearest port to harvest, price per worm, and buyer. These were submitted to a private monitoring company who entered the data into a DFO database. All harvesters were required to purchase a fisherman's registration ($30) and a worm harvesting license ($30) annually. All harvesting was limited to hand tools.

Table 2. Summary of the first bloodworm conservation harvesting plan, 2002.

	Area-1	Area-2	Area-3
license eligibility	$1000 landed value in 1 of 3 years	$2000 landed value in 2 of 3 years	no requirement
reporting	----------------------- monthly report of daily sales	--------------------------	
minimum legal size	1.6 g	3.0 g	3.0 g
season closures	Dec. 1-May 31	Dec. 1-Apr. 30	Dec. 1-Apr. 30
closed areas	Blomidon, Evangeline Beach, and Windsor Flats all year	Goose Bay Jan. 1-Aug. 2, Yarmouth all year	none

Recreational licenses were also issued in 2002 for a cost of $10. They had a season (not necessarily the same as the commercial harvest), possession limit, and the same minimum worm sizes as commercial harvesters.

By 2008, the CHP had evolved to the rules in Table 3. More areas were closed in Area 1 because of resource depletion and, in Hants County, perceived conflict with tourism. The later opening time in Area 1 was requested by harvesters to avoid spawning times. Forty-one harvest areas had been identified for reporting catch in Areas 1, 2, and 3. These were sometimes divided into even smaller areas (e.g., Yarmouth Harbour, Kingsport) for closures. Only Area 1 licensees were permitted to harvest in Area 1. License conditions for recreational fishers were well defined. Participation requirements were increased, and the number of licensed harvesters in Areas 1 and 2-3 combined were reduced to 77 from about 140 because of non-participation. Illegal effort by non-licensed harvesters was reduced when they were denied credit for unemployment benefits. Twenty-two licenses were added to Areas 4, 5, and 6.

Table 3. Summary of the 2008 bloodworm conservation harvesting plan.

	Area-1	Area-2	Area-3
license eligibility[1]	----------- $3400 landed value in 2007 -----------------		
reporting[2]	- monthly report of daily sales and identify daily harvest area -		
minimum legal size[3]	2.5 g	3.0 g	3.0 g
season closure[4]	Nov. 16-May 31	Nov. 16-Mar. 31	Nov. 16-Mar. 31
closed areas[5]	Blomidon, Evangeline, Avonport, Walton R., and part of Kingsport all year; Cheverie/Bramber and Mutton Cove Nov. 16-May 31 and July 1-Sept. 15	Yarmouth Hbr.	none

[1]Recreational harvesters must reside in the area for which they are applying for a license.
[2]No reporting requirement for recreational.
[3]The same for recreational and commercial.
[4]Open times for recreational harvesters correspond to common recreational use.
[5]Closed areas for recreational and commercial the same.

Regulations governing the Maine commercial harvest include: purchase of a harvester license, monthly reports of landings to the Department of Marine Resources by buyers, prohibition of harvesting on Sunday, a protected area of 0.6 ha used for research, recreational users possession limit of 125 worms, recreational users do not require a license. License fees sponsor research, fishery monitoring, and management (Peter Thayer, Maine Dept. of Marine Resources, West Boothbay Harbour, Maine, pers. comm.).

The objectives of this report are to review the development of a survey method used by DFO and another developed for use by harvesters, review time series of abundance on selected mud flats, and recommend a management regime.

ASSESSMENT METHODS

Size at Maturity

Dr. P. Pocklington of Arenicola Marine sexed worms in November-December 2002 and 2006. Only worms greater than 1.0 g were sexed because no mature worms were found in a sample of 100 smaller worms. Maturity was determined by the presence of eggs or sperm plates in the coelomic fluid (Klawe and Dickie 1957). A live worm was blotted and weighed to 0.1 g precision. A small amount of coelomic fluid was withdrawn with a syringe, placed on a depression slide, and viewed at 30 times magnification.

Dr. Pocklington also confirmed the species identification as *Glycera dibranchiata. G. capitata,* and *G. robusta* are other possibilities not seen among the worms sexed. DFO surveys did rarely encounter single specimens of very large worms that harvesters refer to as cannibals. These were probably *G. robusta*.

Perimeter of Mud Flats

The perimeter of spatially distinct mud flats were mapped in order to allocate survey locations within the flat and to obtain the approximate area of flats. A harvester familiar with the extent of a flat was given a Global Positioning System (GPS), instructed to walk the perimeter of the flat, and to mark a way point each time he changed direction. The marked locations were transferred from the GPS to a digitized map and a 100x100 or 200x200 m grid laid over the mapped areas.

Harvest Efficiency

A small test of harvest efficiency was made in January 2009 by digging 5 lines 0.6 x 5 m in Goose Bay and 4 lines 0.6 x 10 m in the Tusket estuary. These lines were immediately dug a second time to search for worms missed in the first dig. The low temperatures resulted in little worm movement in the few minutes between the 2 digs. Goose Bay sediment was soft mud and Tusket sediment was harder sandy-silt.

Design for DFO Surveys

Surveys were conducted by an experienced harvester digging worms in a manner he would use for commercial harvesting. An accompanying biologist determined the station locations, pre-recorded on a GPS, and saved the worms from each station in separate bags. Certainly some worms were missed. The sampling method commonly used in benthic ecology, washing mud through a wire sieve, would have been cost prohibitive. Sampling during one low tide typically included turning over 16 mt of mud and walking 2 or more km over the flat between stations.

Survey locations were random selection of grid intersections on a map of the bed perimeter described above. If an intersection was located on rock or in water, the nearest location suitable for digging was chosen. At each station, the harvester dug 15 m^2 in 3 lines 0.7 x 7.1 m or 2 lines 0.7 x 10.7 m. The lines at a station were typically 2-6 m apart. A 7.1 m or 10.7 m rope laid out on the mud was a guide for line length, and the biologist carried a 0.7 m long stick to mark line width. Efforts were made to maintain a constant digging depth of about 12 cm or the bottom of the mud if that depth of mud was not found.

Variables tested for effect on mean worm density were: time the mud surface was exposed to air, the surface temperature of the mud, the depth of digging, variation among harvesters, and season. The effect of the number of stations on precision was also investigated.

Design for Harvester Directed Surveys

Using a GPS, randomized station locations, and the amount of digging used in the DFO survey is probably too onerous for harvester directed surveys. Instead, the harvester-surveyor first visually-determines the approximate perimeter of the bed to be surveyed, decides on the number of stations he will survey (12-20 for most flats, or more for the largest flats such as Goose Bay), decides on a fixed number of paces between stations that would allow the stations to be distributed over the bed (this may have to be adjusted during the survey), at each station lays out a rope guide 184 x 360 cm marking 2 sides, of a 6.6 m^2 rectangle to be dug.

Transfer Experiments

Harvesters believe stocking flats with worms can rehabilitate depleted flats. Stocking experiments were conducted on 4 mud flats, 2 in Area 1, 1 in Area 2, and 1 in Area 3. Three were closed to harvesting, and the fourth was difficult to reach and seldom harvested. In June 2002, worms were dug from a 5x5 m plot and all those greater than 1 g were distributed over a nearby 5x5 m plot. In some cases additional worms dug from another plot were added. A specified corner of the receiving plot was marked with a metal stake, and the position recorded with a GPS. In April 2003, the stakes were located using a metal detector, and worms were dug from a 3.6x3.6 m square in the center of the receiving plot. The 0.7 m band around the edge of the receiving plot was left as a buffer to reduce the impact of worms crawling into or out of the receiving plot. Also in April 2003, a nearby 5x5 m control plot was dug. This procedure was replicated 4 times in each area.

Length-weights

Repeatable measurements of lengths of live worms are difficult to obtain because the worms can make themselves short or long and twist into coils. To overcome this problem, investigators have used anaesthetics and reported relaxed lengths. However, results were variable. Klawe and Dickie (1957) used a 7.5% solution of magnesium chloride in fresh water. Creaser et al. (1983) used both 7.5% magnesium chloride and a 0.2% solution of poropylene phenoxytol, both in 31-33 ppt salinity. Creaser et al. report that lengths are 0.8-24% shorter in the magnesium chloride. A length-weight regression was generated from their data when poropylene phenoxytol was used (n=3364, 0.8-12 g, areas and sexes combined).

$$W=0.0023L^{2.322}$$

E. Sypitkowski and W. G. Ambrose of Bates College, kindly provided lengths and weights for worms from central Maine anesthetised in 7.5% magnesium chloride in sea water (n=1468, 0.2-14.3 g, R^2=0.81, sexes combined).

$$W=0.0166L^{1.670}$$

For this study, Dr. P. Pocklington produced a length-weight regression by using carbonated water for anaesthetic (n=114, R^2=0.73).

$$W=0.1003L^{1.265}$$

The first 2 regressions cross with the Creaser et al. (1983) regression giving a smaller weight at length for short worms and a larger weight at length for long worms. The last regression gives a larger weight at length at all lengths than the other two.

For all experiments and surveys in this study, worms larger than a pre-set size were blotted and weighed to the nearest 0.1 g. The harvesters were trained to retain worms to a little below the pre-set size. With the exception of 1 harvester who had gained considerable experience in surveying, a biologist accompanied all harvesters. Undersized worms were discarded during the weighing and not recorded.

RESULTS

Transfer Experiments

Worm densities from donor plots dug in 2002, receiving plots dug in 2003, and adjoining control plots dug at the same time as the receiving plots were compared using 2-way ANOVA (plots x treatments). The densities in all receiving plots were at least doubled. However, in L'Hebert an extra 25 worms were added, and in Evangeline an extra 75 worms were added to each plot. If the enhancements were successful, one would expect the receiving plots to have higher densities than both the donor and control plots. As seen in Table 4 and Appendix 1, worm densities in the receiving plots were not significantly the highest for either no./m^2 or g/m^2 at any of the 4 study locations. In Yarmouth, g/m^2 was higher in the receiving than source plots but not higher than the control plots. In L'Hebert no./m^2 was higher in the receiving than the control plots but not higher than the donor plots. For the final 2 areas, Blomidon and Evangeline, there was no significant difference among the 3 plot types.

Table 4. Summary of P values from comparing no./m^2 and g/m^2 among donor plots, receiving plots, and control plots for 4 study areas. Plots were compared with 2-way ANOVA (plots x treatments); if differences were significant ($P<0.05$) mean furthest from the receiving plot mean was removed and the analysis rerun.

Mud flat	no/m^2	g/m^2	comments
Yarmouth	0.56	0.03	
		0.84	when donor treatment weight density was removed from the analysis, receiving and control treatments did not differ
L'Hebert	0.03	0.09	
	0.60		when control treatment numerical density was removed from analysis, donor and receiving treatments did not differ
Blomidon	0.37	0.35	
Evangeline	0.62	0.65	

Size at Maturity

Size at maturity was measured as a guide for setting minimum legal size. The presence of eggs or sperm plates in the coelom was taken to indicate maturity.

For Minas Basin in 2002 and 2006 (Fig. 2), the size at 50% maturity was 2.5-2.9 g. For Southwest Nova Scotia (SWNS) the 50% size of maturity appears substantially larger, 3.5-4.2 g and 5.0-5.9 g for 2001-2 and 2006, respectively. However, the progression with size was not smooth and samples from the 2 times were not in agreement (Fig. 2). Looking at the area breakdown in Appendix 2, some large differences are seen among the areas that were combined in Fig. 2. The data were combined to overcome small sample sizes for some locations and sizes. The 1 sample from Barton in SWNS indicated a very small size at maturity, and these data were not grouped with either area. Although 1073 worms were sexed in SWNS, more work is needed to resolve spatial and perhaps temporal differences in size at maturity.

Perimeter of Mud Flats

Several of the flats were mapped to define their outline (Appendix 3) so random sampling locations could be allocated. Flats can be wide expanses as in Goose Bay or long and narrow river banks as for Chebogue River. The enclosed perimeter does not always represent the harvestable area. For example, Barton and Cheverie have many areas of bedrock outcrops too numerous to map and which move with erosion and deposition of mud. Also, drainage channels across the flats may never become dry enough to dig.

At a glance, the mud flats look expansive. However, when unsuitable harvest area is subtracted, the largest in Minas Basin are Houstins and Cheverie at about 1 km^2 each. In 2004, Avonport was about the same size, but exposure of underlying gravel and bedrock reduced its size. The largest in SWNS is Goose Bay at about 3 km^2.

Factors Affecting Survey Results

Survey Precision

Area expansion of worm density from dug plots to an entire flat was impractical because of the lack of measurement of the portion of the flat that could not be dug. Therefore, abundance is given as density per m^2.

To measure precision of sampling, 15 m^2 were dug at 32 stations at Avonport in June 2004. Usually, more small sampling units give better precision than fewer large dug areas (Vezina 1988). The choice of 15 m^2 per station was based on cost per replicate, i.e., the time spent digging versus the time to package the collection and walk to the next station.

The 15 m^2 was dug in two 0.7x10.7 m lines, and on this occasion collections for the 2 lines were kept separate. The variation between 7.5 m^2 lines at a station contributed 31% to the total variation, and variation among stations contributed the remaining 69%. The correlation coefficient between the 2 lines at a station was only 0.43.

The mud flat was divided into 3 sections with 10, 10, and 12 stations in each for boot-strapping. Either 1, 2, 3, 4, 5, 6, 7, or 8 stations were selected randomly from each section giving 3 to 24 stations per sample. This was repeated 200 times. There were 2 measures of precision: the 90% confidence interval as a percentage of the mean of the 200 means, and the standard deviation of the 200 standard deviations. The precision increased rapidly from 3 through 9 stations and more slowly from 12-24 stations (Fig. 3). Subsequently, for the large flats of Avonport and Cheverie, 16 or 17 stations were chosen; 8 stations could be comfortably sampled in 1 tide. For the small flat at Yarmouth with less distance between stations, 10 stations were chosen. Expected precision from Fig. 3 and observed values from 3 flats are compared in Table 5.

Table 5. Predicted precision (100[90% CI/mean]) from bootstrapping and observed precision.

Flat	Expected from bootstrapping (%)	observed (%)
Yarmouth (mean 6 dates)	31	31
Cheverie (mean 5 dates)	25	21
Avonport (mean 4 dates)	25	24

Harvest Efficiency

Of 90 worms collected from 39 m^2 in 2 locations, only 3 were taken on the second digs, and these 3 were smaller than 2.4 g (Fig. 4).

Change within One Year

The Blomidon flat has been closed for shore bird refuge since 2002. In 2003, it was sampled at 8 stations 4 times from April through December (Fig. 5). Total densities in May were significantly greater than in the other 3 months (2-way ANOVA, month x station, and Tukey's W, density of worms >1g, $P<0.05$). Repeating the analysis with only worm sizes greater than 2.0 g gave no difference among months ($P=0.09$). There was no obvious explanation for the difference in densities of small worms between months. The mud is thin over most of the beach and covers and uncovers bedrock regularly. The pre-selected stations often had to be moved because they fell on exposed rock.

Time of Exposure of the Mud Surface

Worm densities were compared immediately after the receding tide exposed the mud flat and about 130 min later before the tide returned (Fig. 6). In May 2004, Avonport beach was sampled at 8 locations from near high water neap tide to about mid-tide and on adjacent plots 2+ hours later. The horizontal distance between the highest and lowest sample was about 400 m.

Comparing the number of worms/15 m^2 with paired t-test, the mean densities did not differ for worm sizes 1-2 g (P=0.5) or >2 g (P=0.4). Densities for the 2 times were well correlated within stations for the larger worms (r=0.91), but less so for the smaller worms (r=0.47). Therefore, the hypothesis that the worm density is unaffected by the time of air exposure of the mud is not rejected.

Temperature of the Mud Surface

To compare the effect of mud temperature on worm density, sampling was conducted at the same stage of the tide in late afternoon of July 31 and early morning of August 2, 2007. Both times, 10 lines of 7.5 m^2 were distributed over a mud flat in Shelburne Harbour and dug to a depth of about 13 cm. Temperature (measured with a long-stem thermometer) was nearly isothermal with depth in the mud in early morning, but considerably warmer near the surface in late afternoon (Table 6).

Table 6. Temperature with depth in mud in early morning and late afternoon.

	Temperature (^oC)	
Depth (cm)	Morning	Afternoon
2	17	26-28
12	18	22-23
20	18	20-21

Although the morning densities were higher for each of 3 size intervals (Fig. 7), the differences were not statistically significant (paired t-tests). They were near significant for worms of 1.0-1.9 g (P=0.06), but not for the other 2 sizes (P>0.5). Therefore, the hypothesis that worm density is unaffected by the temperature of the surface mud is not rejected.

Depth of Digging

Does the depth of digging affect density estimates, and if so, is the effect the same for all worm sizes? On 4 September 2007, 10 lines of 4.2 m^2 each (0.7x6 m) were dug on a mud flat in Shelburne Harbour. Each line was first dug to 10 cm deep and then immediately from 10-20 cm deep. Worms were retained to a minimum size of 0.7g.

Fig. 8 clearly shows an abundance of worms at 10-20 cm. Therefore, the hypothesis that depth of digging does not affect density estimates is rejected. To test whether the density with depth was the same for all sizes, sizes for each line were grouped into 0.7-1.4 g, 1.5-2.4 g, and ≥2.5 g. Significantly more of the smallest worms were in 0-10 cm (P=0.01); the number for the middle size class did not differ with depth (P=0.49); and the number in the large size class did not differ with depth (P=0.32) (paired t tests). The hypothesis that worms of each size grouping was equally abundant at 0-10 cm and 10-20 cm was also rejected**.**

Variation among Harvesters

Four harvesters participated in a survey of Sandy Cove in September 2008. Each was asked to make 200 digs with their forks at 12 stations distributed over the harvestable area. Before beginning the survey, each harvester made 200 digs and the area dug was measured. The size of digs was adjusted until each dug about 10 m^2 in 200 digs. However, because the areas dug began to vary as the survey progressed, areas of 10 m^2 were marked on the mud surface for the remainder of the survey. The areas were placed immediately adjacent to one another to reduce spatial variability and to test whether harvesters were digging with the same efficiency.

The mean density per station for worms $\geq$2 g was 8.0, 7.6, 7.2, and 7.7 for the 4 harvesters and found not to differ (P=0.8, 2-way ANOVA, station x harvester). The size distribution of worms collected is shown in Fig. 9 and also was not significantly different (chi-square contingency table, P>0.5). Therefore, the hypotheses that 4 harvesters could obtain similar mean densities and size frequencies of worms when surveying adjacent areas was not rejected.

Harvester Directed Survey Design

In October 2008, 2 of the harvesters who participated in the above survey of Sandy Cove surveyed that mud flat again. They were asked to sample 6.6m^2 at 15 stations instead of 10 m^2 at 12 station as before. They were to distribute their sampling stations over the flat, but unlike the first time, select the sites themselves and independently. They jointly decided on the perimeter of the harvestable area and, given the size of the area, decided they should take about 150 paces between stations.

Their mean catches for worms >2 g were 0.98 and 1.03/m^2 compared to 0.76 and 0.77/m^2 in the September survey. These 4 means did not differ (1-way ANOVA, P=0.4). The size distributions obtained in October (Fig. 10) also did not differ (chi-square, P=0.4).

Two additional harvesters surveyed part of the Sissiboo River mud flat in October with the same instructions, 15 stations of 6.6 m^2 and independent selection of the station locations. Their mean collections were 1.23 and 1.12 worms >2 g/m^2. Size distributions are shown in Fig. 10. Neither the mean densities (unpaired t-tests, P=0.6) nor the size distribution (chi-square, P=0.7) differed. The precision for the 4 harvesters in October as measured by the 90% CI as a percent of their respective means were 26, 26, 18, and 22%

From these results, it is evident that 2 harvesters can choose survey locations, survey a mud flat independently, and obtain very similar results. Their levels of precision were reasonable. An incidental result for Sandy Cove was a 25% lower density estimate in September than October. This hints at a difference between times, but the means did not differ statistically.

Abundance over Time

For even the few years for which survey results are available, large changes in abundance can be seen. Given the above tests of the robustness of the survey method, the survey results should reflect population changes.

In Yarmouth Harbour, there were 4 stations in 2002, 8 stations for the 4 sampling dates in 2003, and then 10 stations for the final 6 sampling dates. The harbour was closed to fishing from 2002 through August 2004, then opened for the month of September 2004. It was also open for all or part of the years 2005 through 2007. Density increased from 2002 until the opening in 2004 (Fig. 11). This was especially true for the larger worms over 3 g. By the time of opening, the population was 90% large worms. The 1-month season in 2004 reduced abundance by one-half and it has continued decreasing. There was little evidence of recruitment through 2007 as the population was still nearly all large worms.

Avonport was sampled at 8 stations in 2002-03 and 16 stations for 2004-05. It has been closed since the beginning of the 2004 season. The larger size is given as >2g as this was the minimum legal size at the time. Although not part of the survey, a large loss of mud depth and the area covered was apparent in 2004. The mud loss plus heavy fishing in 2002 and 2003 probably lead to the decline in abundance (Fig. 12).

Cheverie is a large beach and was sampled at 16 or 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 here, and there was no marked change in abundance during the 3 years surveyed (Fig. 13). In 2006, most of the harvesting occurred inshore of the surveyed area (harvesters, pers. comm.).

A small mud flat on the west bank of the Walton River was sampled only twice, at 6 stations both times. The decrease in abundance and size of worms from October 2002 to May 2005 is striking (Fig. 14). The area was fished heavily prior to 2005 and residents have reported a loss of mud from the flat.

DISCUSSION

Transfer Experiments

Worm density was artificially increased by 2 to 3.7 times in four 5x5 m plots on each of 4 mud flats. The flats were dug 10 months later and the density compared to that in nearby plots dug at the beginning and the end of the experiment. There were no clear increases in abundance in the enhanced plots.

This could have resulted from the worms dying or moving out of the receiving plots. Klawe and Dickie (1957) added 210 marked worms of $\geq$5 g to 5 m^2 plots and dug the plots 20-30 days later. Sixty percent of the worms were not recovered. Of those recovered, 57% were within the plots, 16% were within 2 m of the plots, and another 16% were 2-10 m from the plots. These authors suspect swimming is rare except at spawning time. However, Dean (1978) caught 15 large bloodworms not in spawning condition swimming on the surface in Maine. He also recovered 19 non-reproductive worms from plankton collections using meter nets. Abundance of these swimming worms was low as the former was from 33 nights of observation and the latter from 1,050 collections. In a different trial, Klawe and Dickie (1957) dug the same 10 m^2 plots 6 weeks apart. Although they estimated that about 90% of the commercial catch was removed by the first digging, the second digging yielded 80% of the first. These results indicate that movement from our 5x5 m plots over 10 months was likely.

Size at Maturity

Two studies from Maine are in fair agreement (Table 7). The SWNS results are roughly similar to the Maine results, but sizes differ between 2 years of sampling. Klawe and Dickie (1957) gave a length frequency of mature animals for Goose Bay, SWNS, but they did not give the numbers of immature animals at the same sizes. They reported substantial numbers of mature worms from 2.5-4.5 g. Minas Basin worms mature at smaller sizes than those from SWNS and Maine.

Table 7. Weight (g) of bloodworms at 25%, 50% and 75% maturity.

	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	3.2-4.5	4.5-5.5	?	this study
Minas Basin	1.7	2.6	3.8	this study

Klawe and Dickie (1957) and Creaser (1973) were firm in the conviction that both sexes die after reproduction. However, in the 5 sampling periods in the summer or autumn in Yarmouth Harbour (this study), after spawning that probably occurs in May (Klawe and Dickie 1957), 29-59% were larger than 6 g. For SWNS as a whole, worms larger than 6 g were 63% mature in 2001-02 and 85% mature in 2006 (Appendix 2). Why were these large worms still living? In an unfished flat in Maine, Creaser (1973) showed 15% of the total size frequency to be larger than 34 cm, with 11% mature and 4% immature, during the 4 months prior to spawning. In the 2 months following spawning, 13% of the frequency were still greater than 34 cm and all immature. How did this group of large immatures grow from 4 to 13% of the population? Simpson (1962) speculated some spawners may be able to recover based on the variable degree of atrophy she observed at spawning.

Time of Spawning

Klawe and Dickie (1957) dated spawning as mid-May in Goose Bay and Creaser (1973) during mid to late June in central Maine. Nova Scotia harvesters (pers. comm.) believe spawning occurs in May-June but varies with year and location. Simpson (1962) observed surface swarming and spawning in November in Maryland. Based on anecdotal reports, she expected it also occurred sometime during May-July. Based on field observations, she and Creaser (1973) believed that individuals released all their gametes within minutes and that the seasonal spawning episode lasted only a few days.

Harvest Efficiency

In this study, 87 worms >1 g were found on the first dig of 39 m^2 and only 3 were found on the second dig; 70% were smaller than 3 g. Klawe and Dickie (1957) released 941 dyed bloodworms from 2-36 cm relaxed length and re-dug the release areas 1-hour later. Converting lengths (cm) to weights (g) using the

$$W = 0.0166L^{1.670} \quad (R^2=0.81)$$

regression from E. Sypitkowski and W.G. Ambrose (Bates College, Lewiston, Maine, pers. comm.) capture efficiencies were: 1 g - 35%, 1.5 g - 52%, 2 g - 67%, $\geq$3 g - >80%. Sypitkowski et al. (2008) tagged bloodworms with coded wire tags and released 100 worms in each of five 20 m^2 plots. A professional digger dug the plots a few hours later. The mean size of the released and recovered worms were 2.3 and 2.4 g, respectively. After correcting for tag loss, recovery over multiple diggers and locations averaged 45% with about a 25% increase in efficiency from 1-2 g to 3-6 g worms. Blake (1979) buried another large polychaete (*Arenicola* *marina*) to 30 cm depth and dug the release area the next day. Recoveries ranged from <5% for worms <4 cm to >80% for worms >18 cm.

Our small test resulted in much higher efficiency than the other studies. Our harvester (Brian Thompson) pointed out that the second dig would be marginally less efficient than the first because he would be unable to follow tracks in the mud to search for worms. This could also be the case in the above studies where tagged worms were buried and re-dug on the same tide.

Survey Methods

Having an experienced harvester map the perimeter of the harvestable portion of mud flats was useful for allocating sampling stations. However, mud-flats move, especially those most exposed to wave action, and this would need to be repeated every few years. Estimating population size for an entire flat or comparing yield/ km^2 among flats would be difficult if rock outcrops and meandering streams render a large portion unharvestable.

Measures of bias and precision in estimating mean densities/m^2 of worms gives the author confidence in the validity of survey results. For the DFO survey method, precision (100[90% CI of mean]) averaged 21-24% for 2 large flats sampled at 16 stations and 31% for a small flat sampled at 10 stations. For the survey design developed for harvesters, precision was also high at 18-26% for 4 harvesters on 1 flat. Neither time of air exposure of the flat (0.2 vs. 2.2 h), surface temperature of the flat (17^o vs. $26\text{-}28^oC$), nor choice of 4 experienced diggers had significant effect on density. Depth of digging would affect density estimates since nearly as many worms were found from 10-20 cm as from 0-10 cm depth.

Although abundance changed over time, erratic shifts were not seen at Yarmouth, Avonport, or Cheverie (Figs. 11, 12, 13), the flats with the longest time series. The ratios of large to small worms were also regular. There is no explanation for the decrease of small worms within 1 year at Blomodon, but the change was unidirectional (Fig. 5). Klawe and Dickie's (1957) percentage length frequency distributions for June, July, and August samples from Goose Bay were good agreement.

Harvesters have been sceptical that surveys give a meaningful index of abundance. They believe harvest rates change at short time intervals depending on many variables. However, their decisions on whether to harvest a particular flat are based on their, or a colleagues', catch rates. This is a survey result. The methods described here extend this ad hoc approach by standardising procedures to make them repeatable in time and space and with acceptable confidence limits.

Serial Depletion

Flats are vulnerable to serial depletion leading to the Allee effect. Serial depletion occurs when harvesters harvest flats one after another until no worm concentrations of acceptable density can be found. The Allee effect occurs when the density of spawners decreases to the level that egg fertilization is unsuccessful. Because dilution of eggs and sperm occurs in 3 dimensions and could be very rapid, spawner density on a very local scale could be important to successful egg fertilization. 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 Star's Point, Shepherd (1994) collected only 49 mature worms (19 females) in 30 hours of digging. Bloodworms with apparently local recruitment, and from which harvesters can find and remove small aggregations of potential spawners, appear vulnerable. These problems have been researched for abalone (Prince and Hilborn 1998), queen conch (Stoner and Ray-Culp 2000), and sea urchins (Gaudette et al. 2006).

Management Advice

The first "guiding principle" of DFO's New Emerging Fisheries Policy (DFO 2001) is, "Conservation will not be compromised – a precautionary approach will guide decision making. Information on the abundance, distribution, and productivity of the target species is identified as the key scientific requirement for development of precautionary management strategies." To be precautionary, the less knowledge there is about a stock, the more conservative the management of that stock should be. The following advice adopts this precautionary approach.

Manage by Mud Flat

Flats should be managed separately. Klawe and Dickie (1957) concluded the larval stage was short because they failed to find larvae in the water column. Bristow and Vadas (1991) concluded larval exchange among areas was slight 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.

Sustainability of flats to harvest vary considerably. Commercial sized worms at Avonport and Walton nearly disappeared (Figs. 12 and 14). Yarmouth Harbour sustained very heavy harvest for 2 years after 2.5 years of closure, but had little recruitment in the 4 years after it reopened. Stars Point 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 1993; Minas Basin harvesters, pers. comm.). From 2004-07, it provided only 4% of the Minas Basin harvest. Kingsport flat is a priority harvest area because it is easy to access and the surface is easy to walk on and easy to dig. The portion of the Minas Basis harvest taken from this flat changed from 56% to 77% to 26% to 14% from 2004-07. The number of worms taken decreased by 92% over the same period. Goose Bay 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 Area 2.

Flats should be surveyed regularly. Closed flats need surveying before re-opening. Flats supplying a large portion of the harvest should be surveyed at least biannually. Small flats may be vulnerable to over-harvesting by small effort so also need periodic surveys.

Bloodworms are very fragile near the time of spawning. Handling can cause them to burst and leave their gametes on the mud. Areas 2 and 3 are now open to harvest during the spawning season, and some Area 1 harvesters have requested opening during the spawning season. Accurate times when spawning occurs at any location, and variation among locations and years is lacking. Avoiding spawning would require attention to spawning during surveys and/or harvesting.

Rational for Harvester Surveys

DFO has not surveyed all the approximately 40 flats in Areas 1-3 even once. DFO Science has dedicated limited resources to this small fishery to date, and it is expected that these resources will be reduced in the future. Governments are not equipped to manage fish stocks on a scale of kilometers.

Harvesters are able to survey flats. The names, locations, and boundaries of flats are known to most experienced harvesters. Since 2003, most harvesters have reported landings by flat. The survey method described in this report has been field tested by harvesters and has given acceptable results of mean densities and size distributions. Precision is acceptable and the method is robust to changing environmental variables. In the summer of 2009, harvesters surveyed 3 closed flats. They recommended opening a portion of the Avonport flat and keeping Yarmouth Harbour closed. Both results were accepted and the management change made for Avonport. Kingsport worms were abundant but small. This flat may be surveyed later in the summer of 2009 to see if sufficient growth has occurred.

Adherence to Regulations

Current management measures are presented on pages 2-3. Minimum legal size has not been enforced on the fishing grounds or at buying stations. Buyers (pers. com.) claim they can only enforce the minimum size that markets will accept, because if they attempt a larger minimum they risk loosing their harvesters to another buyer. In a 2006 sample of catches of 4 harvesters in Minas Basin, 79% of their worms were below the 2.5 g minimum size. Licenses, seasons, and closed areas are better enforced, but the author has seen violations of each of these. Limited licenses, seasons, and beach closures are required for the recommendations below. Enforcement of minimum size to protect spawners would be beneficial but not essential.

Recommended Management for 2009

- While a target minimum density for successful spawning is arbitrary, it is more precautionary than no target. It is recommended that a flat be closed if the mean density of worms over the legal minimum size reaches $0.6/m^2$. A closed flat can be opened if the mean density of worms over the legal minimum size reaches $0.8/m^2$. The record of mean densities from all surveys through 2008 are given in Appendix 5. The survey depth would be 12.5 cm (5 in.) or the mud depth if it is less. The mean density would be based on harvester directed surveys as described in the Results section. When harvesting, harvesters will usually obtain higher catch rates than the average density because they search out the high density areas.

- Areas now closed, and any new closed areas, should remain closed until the above survey density is reached. In the first year of this plan, it is recommend that at least 4 flats in Area 1 and at least 6 flats in Area 2 be surveyed before they are opened to harvest.

- The season opening date in Areas 2 and 3 should be moved from April 1 to June 1. However, if a method of surveying for spawners can be agreed upon and carried out by harvesters, the season could be open from April 1 until spawning occurred. If a method for avoiding spawners was adopted in Area 1, they could open selected flats before the present June 1 opening.

- If harvesters do not agree to conducting surveys as described here, then all closed flats should remain closed, 50% of all open flats (chosen by DFO) should be closed on alternate years as a precautionary measure, and all seasons should open June 1.

- Upper Yarmouth Harbour east of the channel and north of 43°50’25” should be permanently closed for research and for seeding the remainder of the harbour with larvae.

ACKNOWLEDGEMENTS

Harvesters Brian Thompson, Paul Barkhouse, Jerimiah Robinson, Larry Langthorne, Arthur Scoville, Leonard Angell, and Warren O'Connell, and others did the harvesting for surveys under contract. Brian Thompson was especially helpful in mapping mud flats, conducting surveys, and providing worms for size of maturity. Alan Reeves transferred the mud flat locations from a GPS to digitized maps, and accompanied harvesters for some of the stock surveys. Francis Kelly created the maps in Appendix 5; Robert Mohn completed the bootstrapping analysis; and T. Worcester and D. Roddick provided helpful comments on the manuscript. E. Sypitkowski, J. Soles, and W. Ambrose provided information on Maine landings and length-weights.

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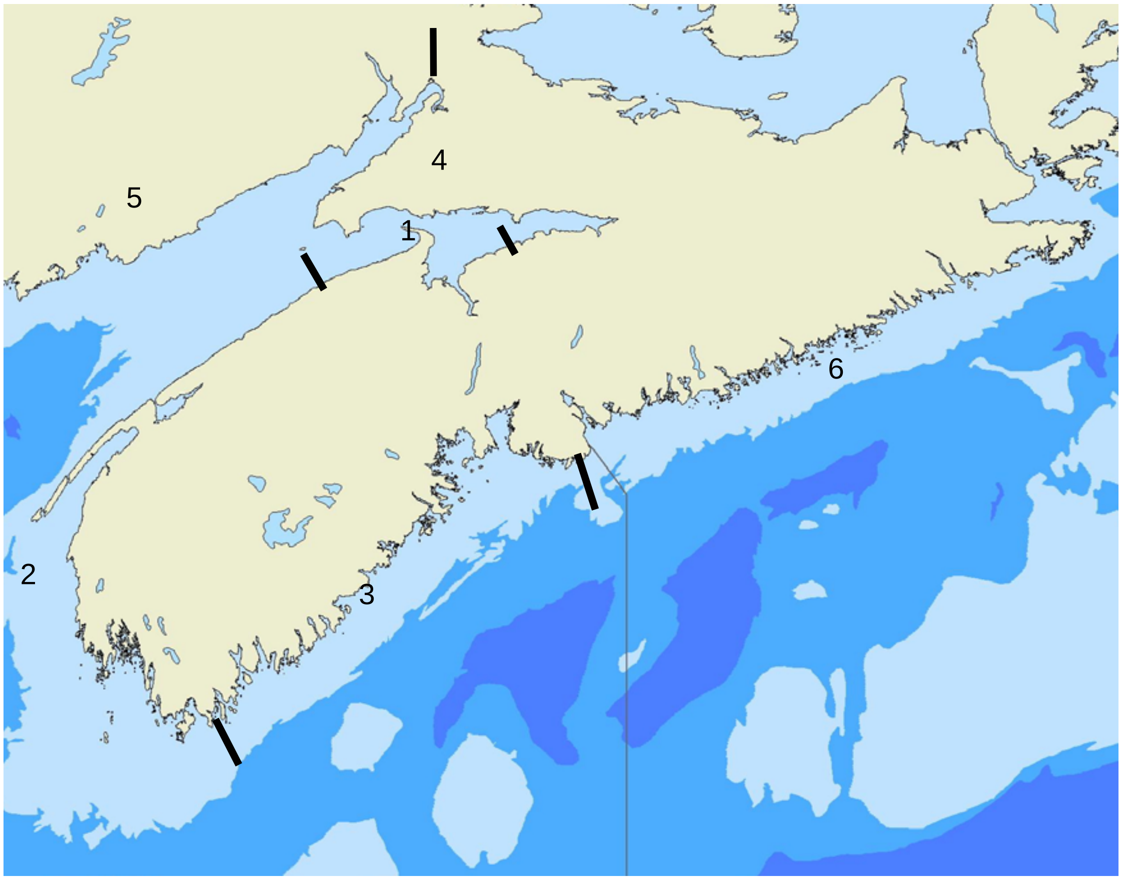


Fig. 1. Marine worm harvesting areas.

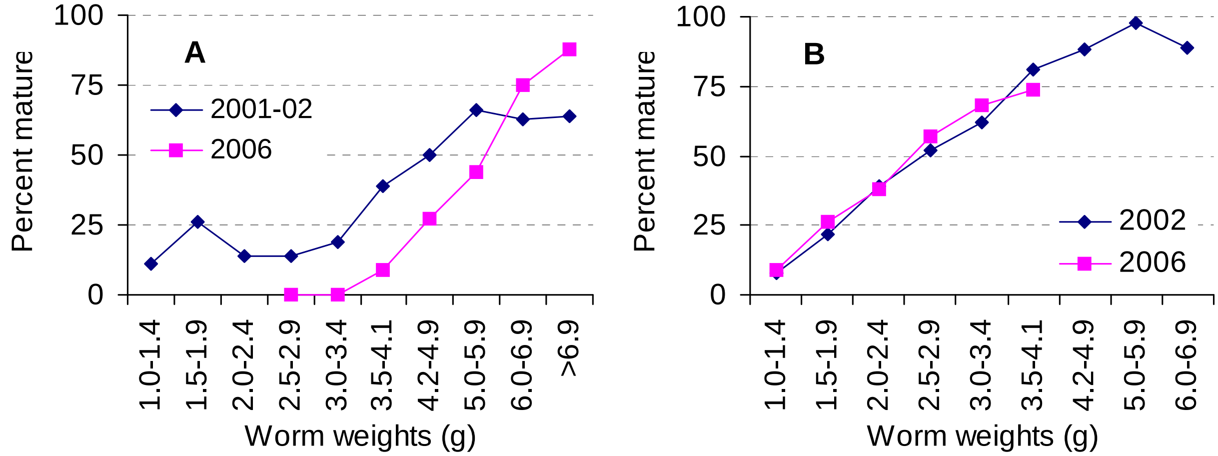


Fig. 2. Percent mature versus worm size in 2 areas; A – Southwest Nova Scotia, B – Minas Basin. Data for several mud flats were combined, see Appendix 2.

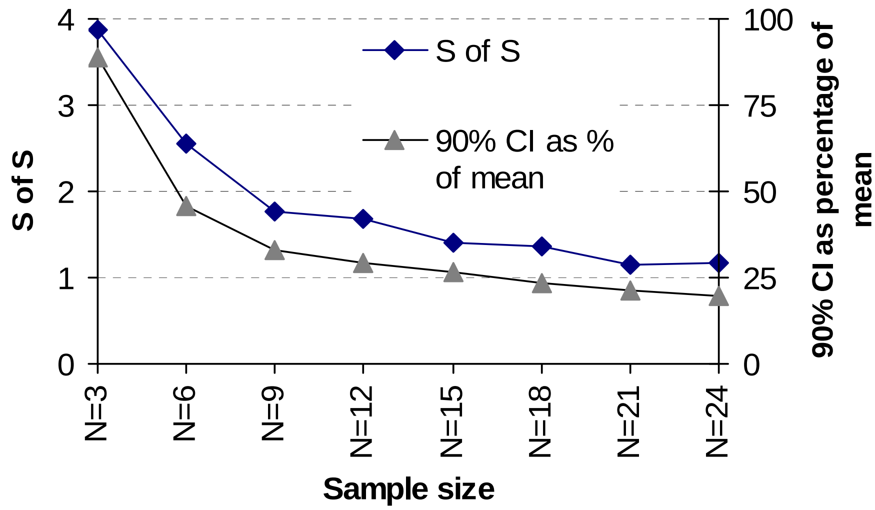


Fig. 3. Bootstrapping results for Avonport. There were 32 stations dug, and 3 to 24 stations were randomly selected 200 times. S of S is the standard deviation of the standard deviation for each of the 200 samples. The 90% confidence interval as a percentage of the mean was averaged for the 200 samples.

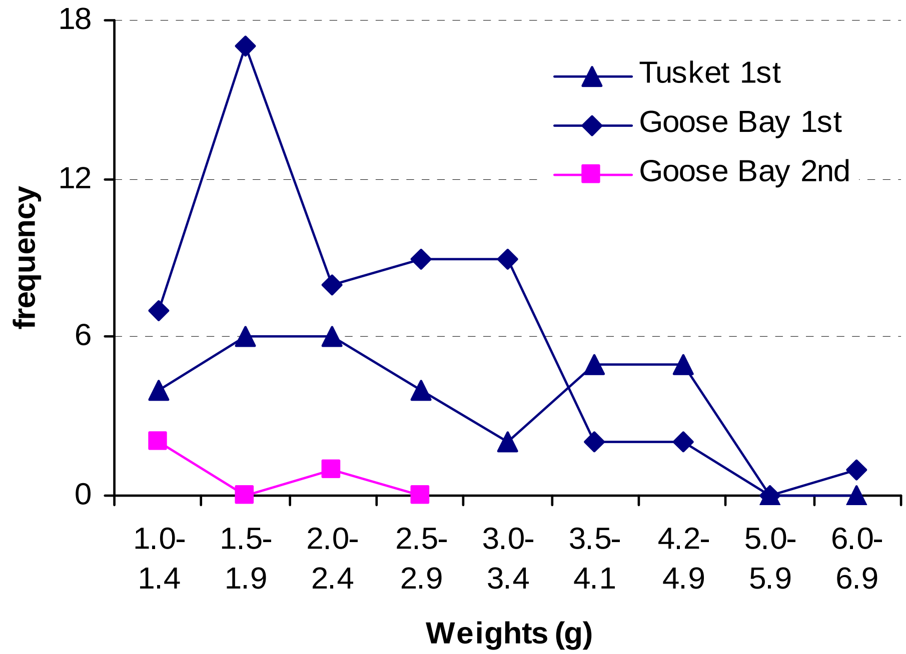


Fig. 4. Test of harvest efficiency. Size frequency of worms from the first digs in Goose Bay and Tusket and from the second dig in Goose Bay. No worms were taken in the second dig in Tusket.

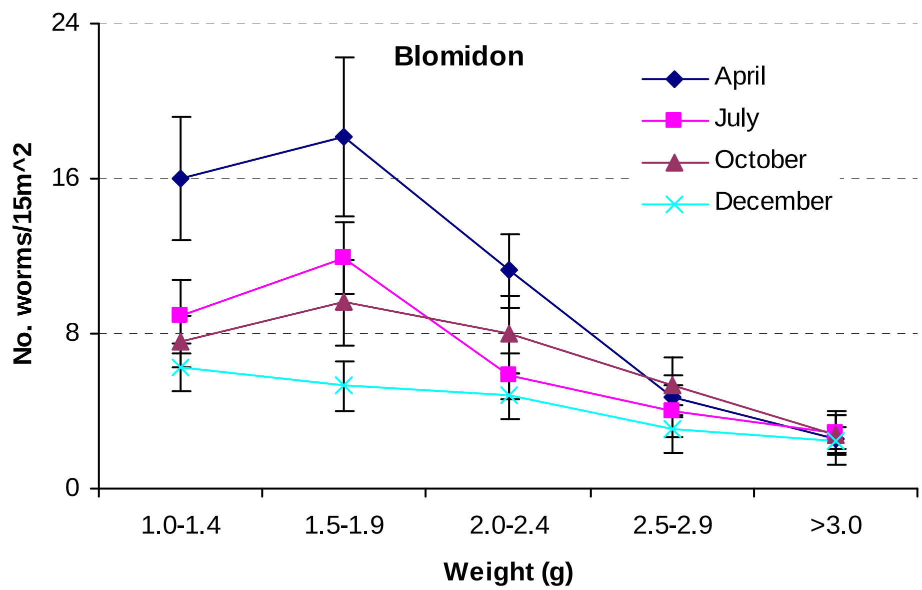


Fig. 5. Mean worm densities (+/- 1 SE) at 8 stations in 4 months on Blomidon mud flat.

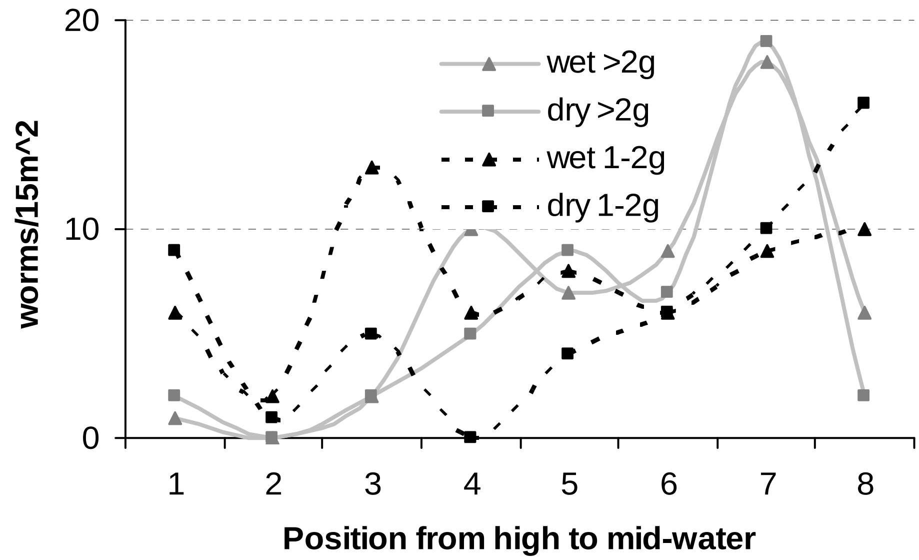


Fig. 6. Worm densities compared after tide had receded for 1-15 min (wet) and for 125-140 min (dry).

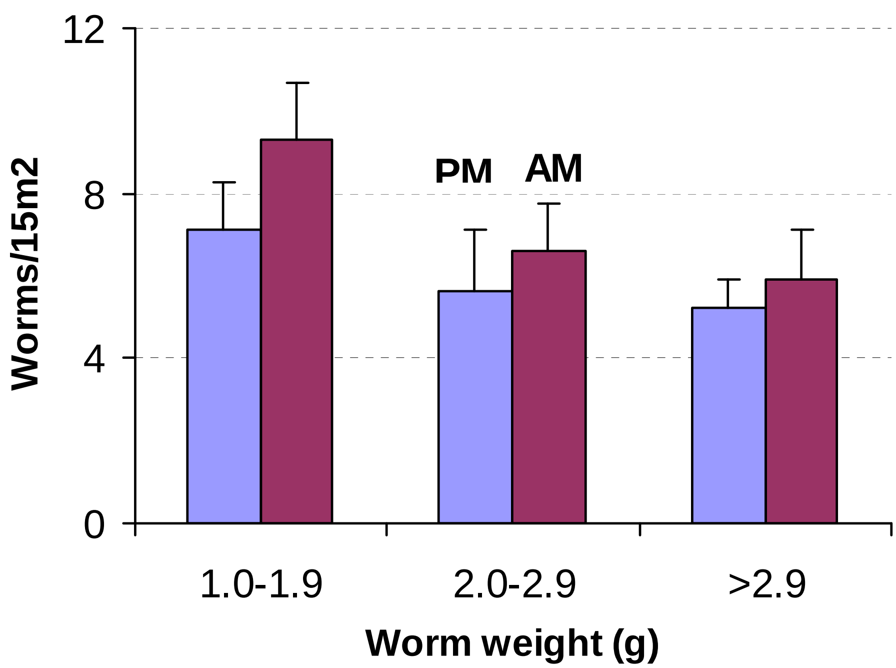


Fig. 7. Worm density (+ 1 SE) in early morning when mud surface was cool and in late afternoon when mud surface was warm.

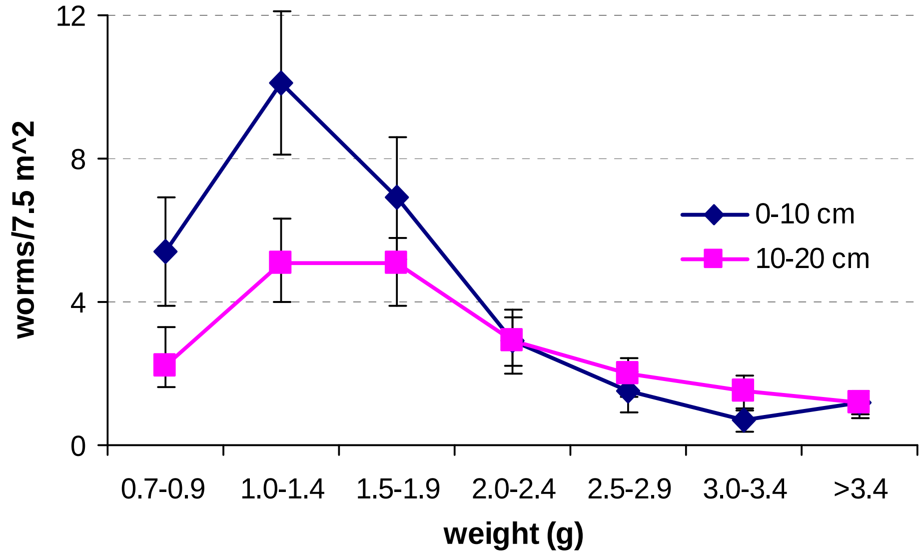


Fig. 8. Worm density (+/- 1 SE) at 0-10 cm and 10-20 cm depth in the sediment.

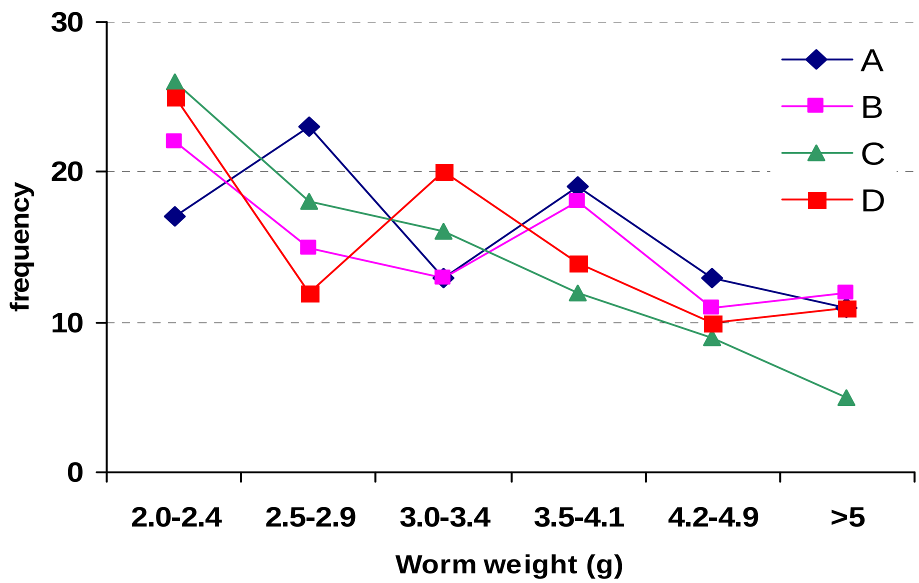


Fig. 9. Number of worms taken by 4 harvesters, each sampling adjacent quadrats at 12 stations.

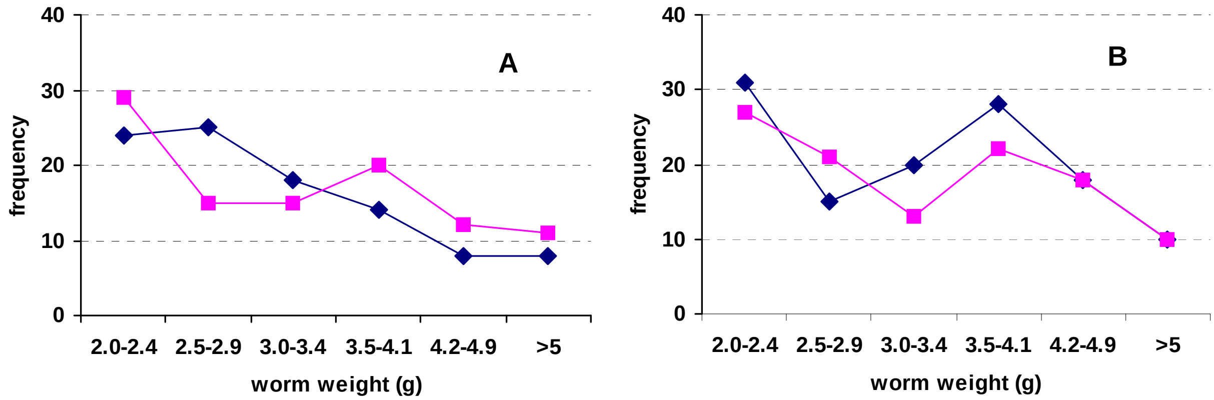


Fig. 10. Number of worms taken by 2 harvesters in Sandy Cove (A) and 2 in the Sissiboo River (B). Each harvester selected 15 stations independently.

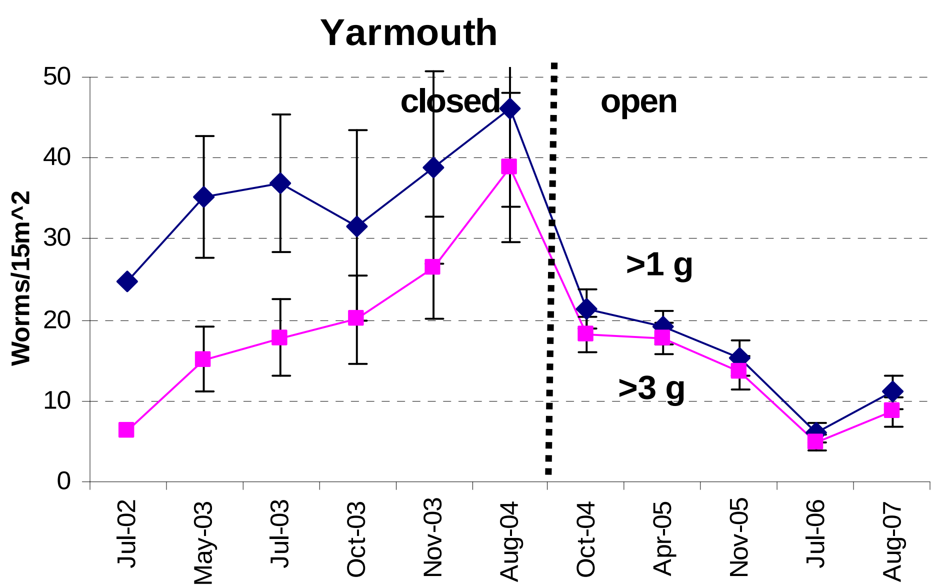


Fig. 11. Mean densities (+/- 1 SE) for 9 sampling dates in Yarmouth Harbour. The harbour was closed to harvesting before September 2004 and open for parts of each of 2005-07.

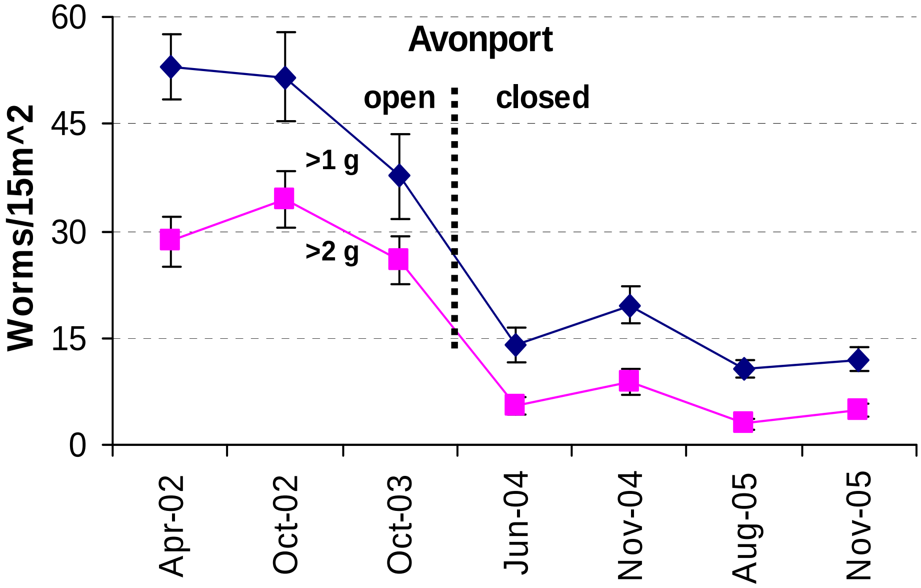


Fig. 12. Mean densities (+/- 1 SE) for 7 sampling dates in Avonport. The flat was open through October 2003 and closed during 2004 and 2005.

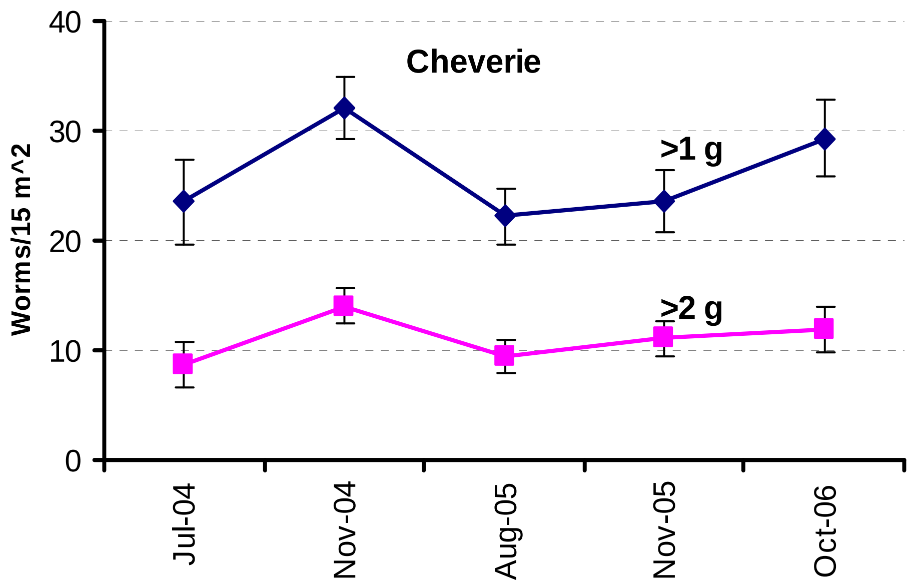


Fig. 13. Mean densities (+/- 1 SE) for 5 sampling dates in Cheverie. Harvest occurred for short seasons each year.

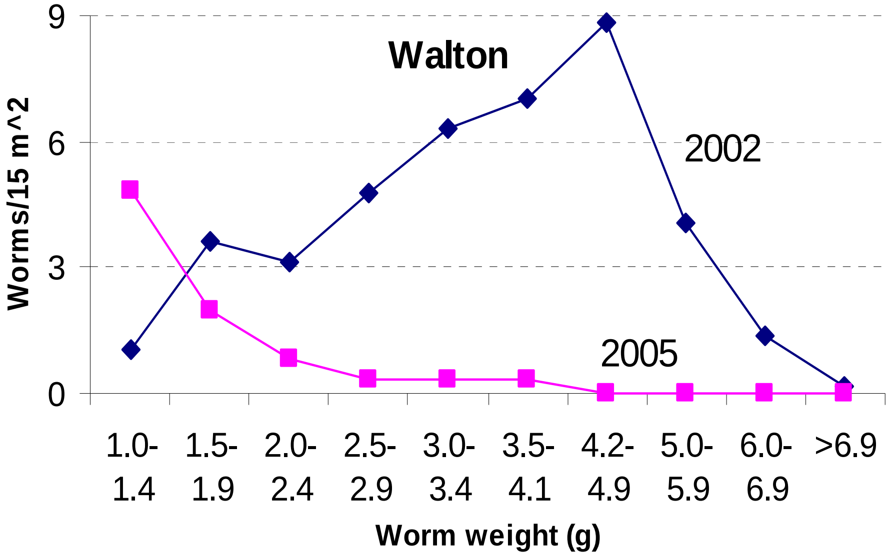


Fig. 14. Mean densities for 2 sampling dates on the west side of the Walton River.

Appendix 1. Worm transfer experiments. In 2002, worms from 25 m^2 source plots were distributed over 25 m^2 receiving plots. At L'Hebert and Evangeline, extra worms from other sources were added to the receiving plots. In 2003, the middle 13 m^2 of the receiving plots and the 25 m^2 control plots were dug.

		no./m^2 >1g			**g/m^2 >1g**		
		source	receiv. plot		source	receiv. plot	
Area	Station	plot	mid 13m^2	control	plot	mid 13m^2	control
Yarmouth	2	2.2	3.77	5.12	4.7	9.0	11.3
	4	0.88	0.85	0.56	2.2	6.4	5.1
	5	0.60	0.85	1.20	2.9	6.1	6.2
	6	1.44	1.69	0.72	4.8	11.0	5.2
	mean	1.28	1.79	1.90	3.7	8.1	6.9
		no extra worms released					
L'Hebert	1	0.68	1.0	0.68	3.1	5.0	3.4
	4	2.0	2.08	1.44	8.9	9.2	6.1
	5	1.76	1.46	1.32	7.4	5.6	5.7
	6	1.4	1.62	0.96	6.8	6.9	4.4
	mean	1.46	1.54	1.10	6.6	6.7	4.9
		25 extra worms releasd in each receiving plot					
Blomidon	1	2.56	5.23	4.56	4.2	9.0	9.3
	2	2.92	3.23	2.2	4.5	5.5	3.3
	3	3.04	2.69	1.8	4.9	4.0	3.3
	5	2.88	3.69	3.36	4.4	6.8	6.6
	6	2.00	2.23	3.00	2.6	2.2	4.9
	mean	2.68	3.41	2.98	4.1	5.5	5.5
		no extra worms released					
Evangeline	1	1.2	1.38	1	1.8	1.1	1.5
Beach	2	1.56	1.46	1.24	2.1	2.5	1.7
	3	0.8	0.76	1.76	1.1	1.0	2.7
	4	0.88	2.08	1.48	1.3	3.7	2.5
	mean	1.11	1.42	1.37	1.6	2.1	2.1
		75 extra worms released in each receiving plot					

Appendix 2. Bloodworm maturities for indicated dates and locations.

Minas Basin - 2002

mud flat **m^2 sampled** **date**		Size class (g) 1.0-1.4	1.5-1.9	2.0-2.4	2.5-2.9	3.0-3.4	3.5-4.1	4.2-4.9	5.0-5.9	6.0-6.9	>6.9	Total
Walton-west	No. sexed	6	22	19	29	38	42	53	24	8	1	242
90 m^2	mature m	0	3	3	12	10	19	23	11	5	0	86
25/10/02	mature fe	0	4	3	6	14	16	23	13	3	1	83
	% mature		32	32	62	63	83	87	100			
Walton-east	No. sexed	2	5	6	12	10	23	23	16	5	2	104
30 m^2	mature m	0	0	1	2	3	9	11	7	4	1	38
25/10/02	mature fe	0	0	0	2	3	8	10	9	1	1	34
	% mature				33	60	74	91	100			
Ocean Beach	No. sexed	24	35	30	22	12	17	11	3	4	1	159
105m^2	mature m	0	5	5	7	0	4	5	2	1	0	29
31/10/02	mature fe	0	0	6	2	5	7	5	1	1	1	28
	% mature	0	14	37	41	42	65	91				
Cheverie	No. sexed	61	98	94	57	48	31	28	5	1	0	423
120m^2	mature m	1	3	14	11	11	13	12	3	1	0	69
24/10/02	mature fe	1	4	15	17	21	12	12	1	0	0	83
	% mature	3	7	31	49	67	81	86				
Avonport	No. sexed	65	55	61	56	39	31	10	3	0	0	320
75 m^2	mature m	4	4	10	12	13	16	5	2	0	0	66
23/10/02	mature fe	5	9	12	15	9	12	4	1	0	0	67
	% mature	14	24	36	48	56	90	90				
Houstins	No. sexed	243	102	37	12	4	3	0	0	0	0	401
120m^2	mature m	8	16	11	6	1	2	0	0	0	0	44
30/10/02	mature fe	14	23	13	5	3	1	0	0	0	0	59
	% mature	9	38	65	92							
	total N	401	317	247	188	151	147	125	51	18	4	1649
	Total % mature	8	22	39	52	62	81	88	98	89		

Minas Basin - 2006

		Size class (g) 1.0-1.4	1.5-1.9	2.0-2.4	2.5-2.9	3.0-3.4	3.5-4.1	4.2-4.9	5.0-5.9	6.0-6.9	>6.9	Total
Cheverie	No. sexed	63	64	40	30	12	9	6	2	0	0	226
14/11/06	mature m	2	9	8	9	4	2	3	0	0	0	37
	mature fe	4	8	4	10	6	6	1	2	0	0	41
	% mature	9	27	30	63	83						
Kingsport	No. sexed	37	24	21	14	13	10	3	0	0	0	122
13/11/06	mature m	3	3	5	2	3	5	3	0	0	0	24
	mature fe	0	3	6	4	4	1	0	0	0	0	18
	% mature	8	25	52	43	54	60					
	Total N	100	88	61	44	25	19	9	2	0	0	348
	Total % mature	9	26	38	57	68	74					

Appendix 2 continued.

Southwest Nova - 2001-2

Mud flat		Size class (g)										
Date		1.0-1.4	1.5-1.9	2.0-2.4	2.5-2.9	3.0-3.4	3.5-4.1	4.2-4.9	5.0-5.9	6.0-6.9	>6.9	Total
L'Hebert	No. sexed	12	6	10	6	11	17	17	26	16	11	132
1/02	mature m	0	0	0	0	0	0	3	9	3	5	20
	mature fe	0	0	0	1	0	3	3	10	6	2	25
	% mature	0		0		0	18	35	73	56	64	
Clyde R.	No. sexed	31	24	13	10	5	3	6	3	2	0	97
12/01	mature m	1	1	1	0	1	1	1	1	1	0	8
	mature fe	5	4	5	0	1	0	1	1	1	0	18
	% mature	19	21	46	0							
Barrington	No. sexed	39	35	14	7	1	7	1	1	0	0	105
12/01	mature m	4	1	1	1	0	3	0	0	0	0	10
	mature fe	2	6	3	3	0	3	0	1	0	0	18
	% mature	15	20	29								
Pubnico	No. sexed	20	21	12	10	7	7	7	9	1		94
12/01	mature m	0	1	1	1	1	2	0	1	0		7
	mature fe	0	2	2	0	1	0	4	2	0		11
	% mature	0	14	25	10							
Tusket	No. sexed	47	33	14	24	17	24	19	12	4	11	205
12/01	mature m	5	1	0	1	2	2	7	5	2	3	28
	mature fe	3	0	1	1	4	9	5	5	1	4	33
	% mature	17	3	7	8	35	46	63	83		64	
Wedgeport	No. sexed	34	37	22	29	18	16	6	2	1	0	165
12/01	mature m	0	0	0	1	0	2	2	0	0	0	5
	mature fe	0	0	0	3	2	4	2	0	1	0	12
	% mature	0	0	0	14	11	38					
	Total N	183	156	85	86	59	74	56	53	24	22	798
	Total % mature	11	10	16	14	20	39	50	66	63	64	
Barton[1]	No. sexed	64	25	12	10	2	1	0	0	0	0	114
1/02	mature m	1	6	8	3	0	0					18
	mature fe	7	4	4	5	1	1					22
	% mature	13	40	100	80							

Southwest Nova - 2006

		Size class (g)										
		1.0-1.4	1.5-1.9	2.0-2.4	2.5-2.9	3.0-3.4	3.5-4.1	4.2-4.9	5.0-5.9	6.0-6.9	>6.9	Total
Wedgeport	No. sexed	0	0	8	16	20	45	24	16	19	53	201
17/11/06	mature m			0	0	0	2	6	3	11	18	40
	mature fe			0	0	0	2	4	5	4	33	48
	% mature				0	0	9	42	50	79	96	
Yarmouth	No. sexed							20	9	5	20	54
17/11/06	mature m							1	2	0	8	11
	mature fe							1	1	3	5	10
	% mature							10			65	
	Total N	0	0	8	16	20	45	44	25	24	73	
	Total % mature				0	0	9	27	44	75	88	

[1]Barton not included with 2001-2 means because size at maturity conspicuously smaller than other areas.

Appendix 2 continued.

Southwest Nova - 2001-2

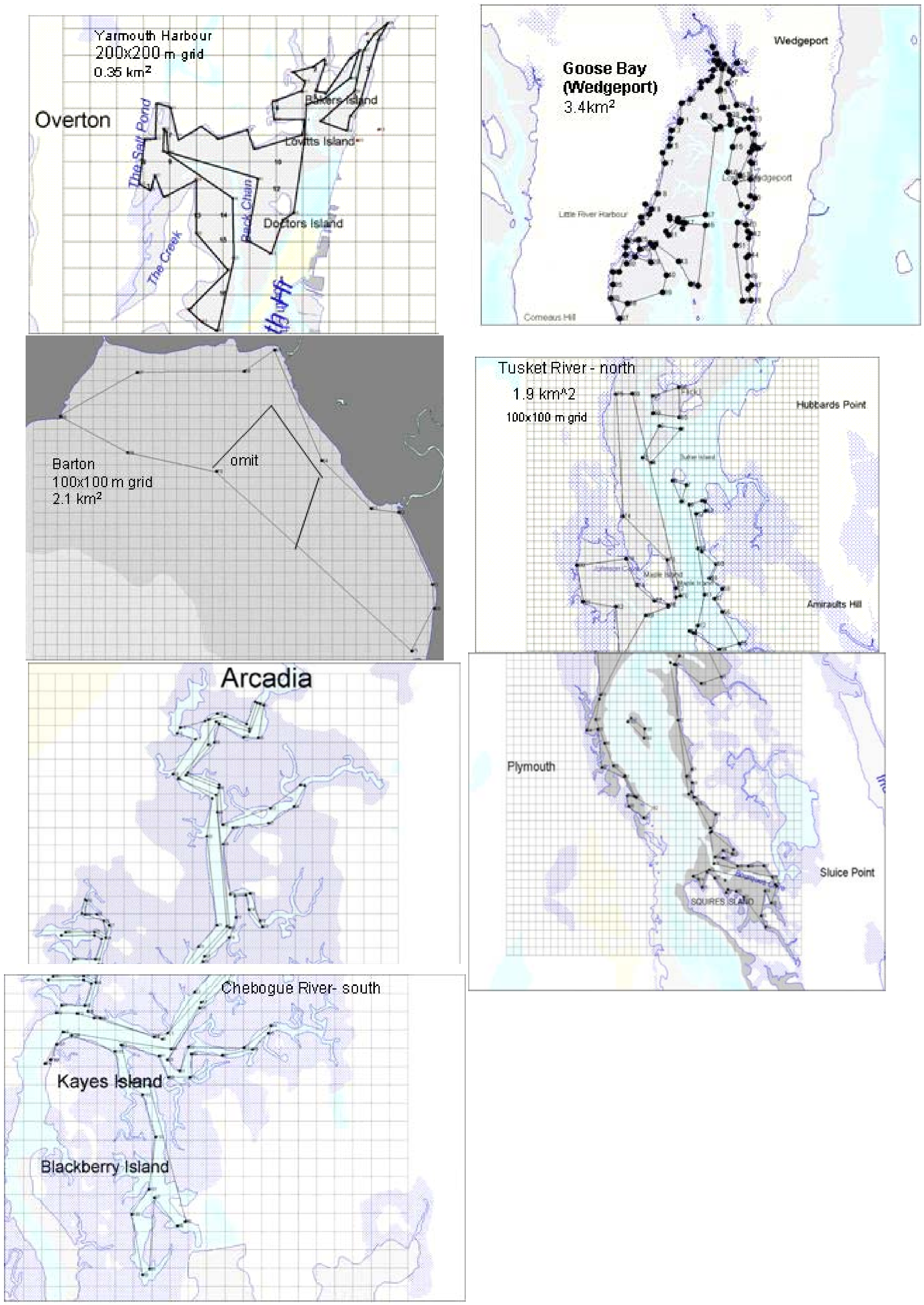
Mud flat		Size class (g)										
Date		1.0-1.4	1.5-1.9	2.0-2.4	2.5-2.9	3.0-3.4	3.5-4.1	4.2-4.9	5.0-5.9	6.0-6.9	>6.9	Total
L'Hebert	No. sexed	12	6	10	6	11	17	17	26	16	11	132
1/02	mature m	0	0	0	0	0	0	3	9	3	5	20
	mature fe	0	0	0	1	0	3	3	10	6	2	25
	% mature	0		0		0	18	35	73	56	64	
Clyde R.	No. sexed	31	24	13	10	5	3	6	3	2	0	97
12/01	mature m	1	1	1	0	1	1	1	1	1	0	8
	mature fe	5	4	5	0	1	0	1	1	1	0	18
	% mature	19	21	46	0							
Barrington	No. sexed	39	35	14	7	1	7	1	1	0	0	105
12/01	mature m	4	1	1	1	0	3	0	0	0	0	10
	mature fe	2	6	3	3	0	3	0	1	0	0	18
	% mature	15	20	29								
Pubnico	No. sexed	20	21	12	10	7	7	7	9	1		94
12/01	mature m	0	1	1	1	1	2	0	1	0		7
	mature fe	0	2	2	0	1	0	4	2	0		11
	% mature	0	14	25	10							
Tusket	No. sexed	47	33	14	24	17	24	19	12	4	11	205
12/01	mature m	5	1	0	1	2	2	7	5	2	3	28
	mature fe	3	0	1	1	4	9	5	5	1	4	33
	% mature	17	3	7	8	35	46	63	83		64	
Wedgeport	No. sexed	34	37	22	29	18	16	6	2	1	0	165
12/01	mature m	0	0	0	1	0	2	2	0	0	0	5
	mature fe	0	0	0	3	2	4	2	0	1	0	12
	% mature	0	0	0	14	11	38					
	Total N	183	156	85	86	59	74	56	53	24	22	798
	Total % mature	11	10	16	14	20	39	50	66	63	64	
Barton[1]	No. sexed	64	25	12	10	2	1	0	0	0	0	114
1/02	mature m	1	6	8	3	0	0					18
	mature fe	7	4	4	5	1	1					22
	% mature	13	40	100	80							

Southwest Nova - 2006

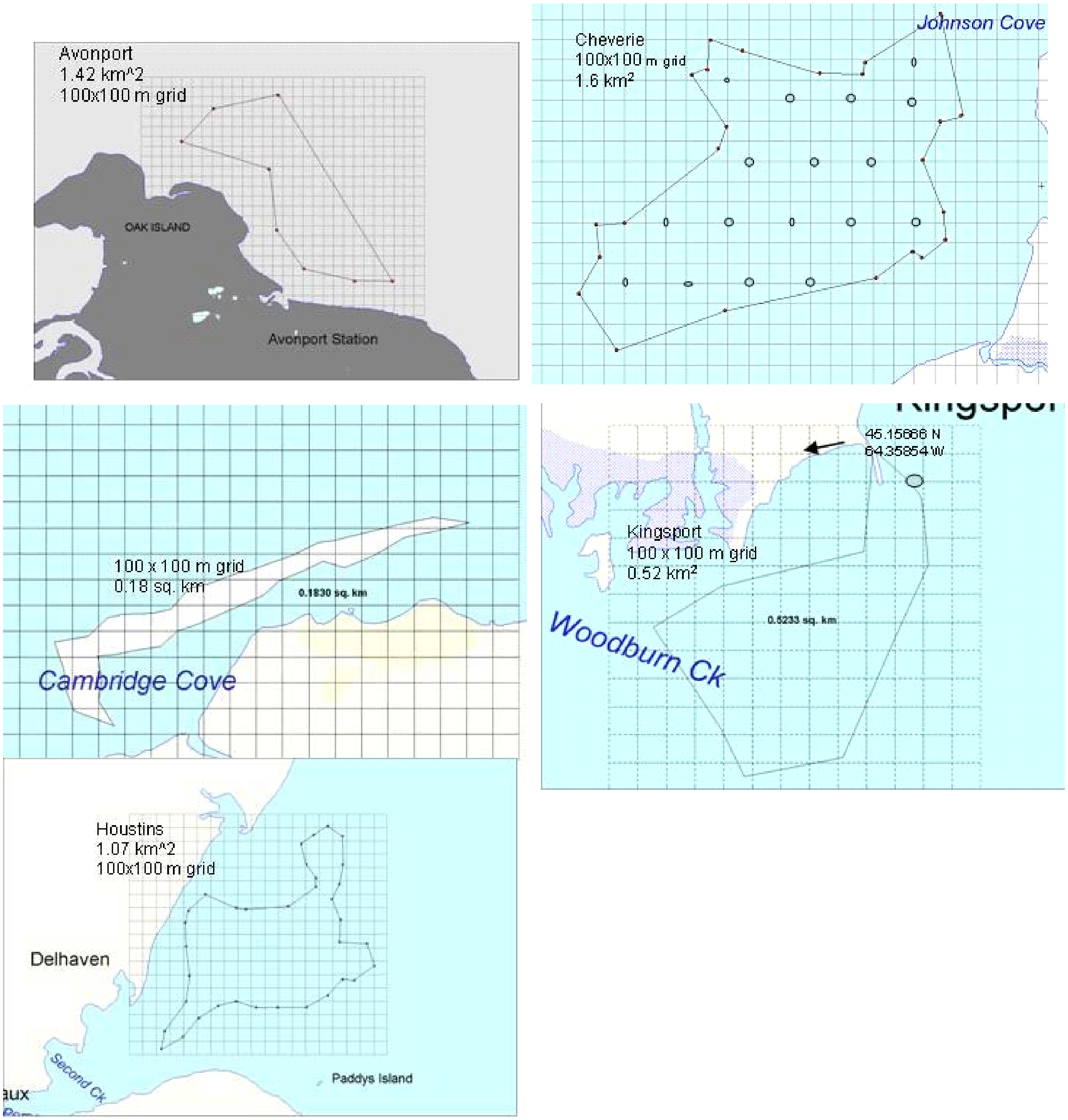
		Size class (g)										
		1.0-1.4	1.5-1.9	2.0-2.4	2.5-2.9	3.0-3.4	3.5-4.1	4.2-4.9	5.0-5.9	6.0-6.9	>6.9	Total
Wedgeport	No. sexed	0	0	8	16	20	45	24	16	19	53	201
17/11/06	mature m			0	0	0	2	6	3	11	18	40
	mature fe			0	0	0	2	4	5	4	33	48
	% mature				0	0	9	42	50	79	96	
Yarmouth	No. sexed							20	9	5	20	54
17/11/06	mature m							1	2	0	8	11
	mature fe							1	1	3	5	10
	% mature							10			65	
	Total N	0	0	8	16	20	45	44	25	24	73	
	Total % mature				0	0	9	27	44	75	88	

[1]Barton not included with 2001-2 means because size at maturity conspicuously smaller than other areas.

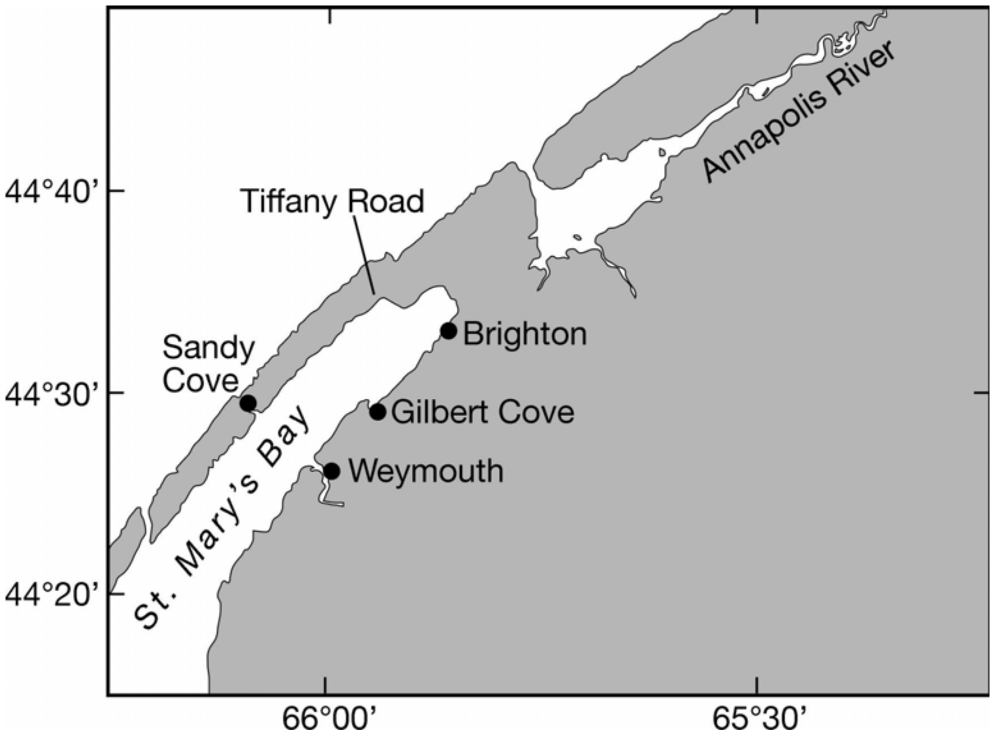
Appendix 3. Mapped mud flats in Southwest Nova. See Appendix 5 for locations.

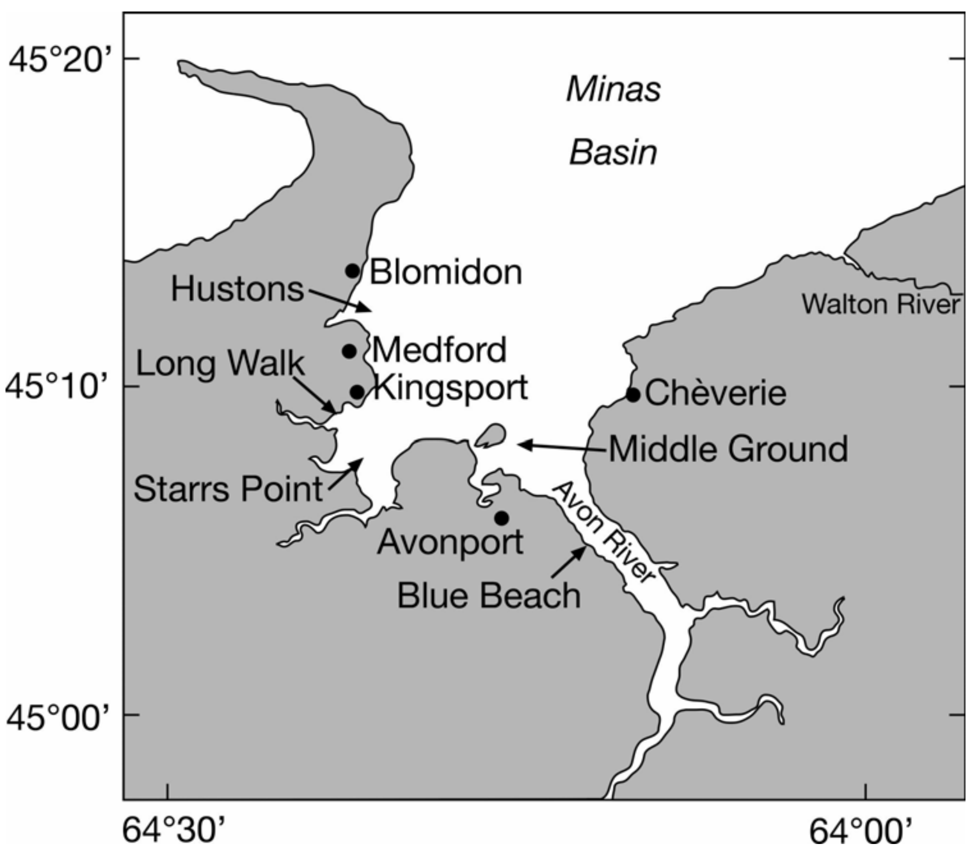


Appendix 4. Mapped mud flats in Minas Basin. See Appendix 5 for locations.



Appendix 5. Principal harvest beaches.





Appendix 5 continued.