A Population Survey and Resource Valuation of Soft-shell Clams (*Mya arenaria*) in the Annapolis Basin, NS

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Executive Summary

The Annapolis Basin in Nova Scotia has a very productive and potentially lucrative soft-shell clam industry. In recent years however, several factors have contributed to the decline of the clam populations as well as the increasing closure of clam harvesting areas. In the summer of 2006, Clean Annapolis River Project conducted a population survey and economic valuation of two priority clam growing areas.

Two beaches surveyed revealed relatively low clam densities, which did not meet the criteria for sustainable harvest used by Parks Canada. The mean densities of all clams at Deep Brook and Karsdale were 61 ± 12 clams/m^2 and 61 ± 9 clams/m^2, respectively. The mean densities of clams of commercial size at Deep Brook and Karsdale were 11 ± 2 clams/m^2 and 12 ± 2 clams/m^2, respectively. These findings support the anecdotal evidence of clam harvesters, which suggests clam densities are at critical levels.

Few clams in the smallest size categories ($\leq$25mm) were found at either beach surveyed. The majority of clams found were in the 25-45mm length category. As expected on heavily harvested beaches, numbers of clams dropped significantly in clams of commercial size. The length frequency distributions observed suggest that both beaches may be experiencing poor recruitment of smaller clams.

Based on weight measurements taken from clams at various locations in the Annapolis Basin and densities observed during the survey, mean biomass values for commercial size clams at Deep Brook and Karsdale were estimated at 27,200 kg and 70,125 kg, respectively.

Information provided by clam harvesters suggests that the actual level of harvesting in 2006 for all active clam harvesters neared 964,000 kg, which generated over $2.3 million in revenues for approximately 170 clam harvesters and their families. When compared to preliminary landings data provided by Fisheries and Oceans Canada through the dockside monitoring program, reported landings were significantly lower. The under representation of reported landings suggests that clam harvesters do not consistently provide landings reports and that the current dockside monitoring program may not be the most effective way of obtaining accurate landings data.

The economic and employment realities in rural Nova Scotia make a strong argument for the enhanced management and sustainability of the soft-shell clam harvest in Annapolis Basin. A variety of management options should be considered and may include increased conservation measures, enhancement activities, size and catch limits as well as increased enforcement.

Much of the responsibility ultimately rests with the clam harvesters to work together and ensure the long-term sustainability of their own industry. Such efforts must undoubtedly be coupled with cooperation from the proper regulatory agencies at all levels of government as well as the community as a whole.

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Introduction

Background

The intertidal zones of Nova Scotia's Annapolis Basin have a potentially very productive and lucrative soft-shell clam (*Mya arenaria*) industry. Historically, the area consistently produced over 30% of all the soft-shell clam landings in the Scotia-Fundy region and over 60% of all soft-shell clam landings in Nova Scotia (Angus *et al.*, 1985). Since the late 1970's however, several factors have contributed to the decline of clam populations as well as the increasing closure of beaches. The contributing factors include both environmental and biological as well as managerial factors (Rowell and Woo, 1990).

In response to the state of the fishery, local clam harvesters approached the Clean Annapolis River Project (CARP) and the Bay of Fundy Marine Resource Centre to work collaboratively to initiate projects that could enhance the soft-shell clam population and habitat in and around the Annapolis River Watershed. Initial efforts focused on creating a multi-stakeholder committee, the Annapolis Watershed Resource Committee (AWRC), completing a population survey and economic valuation of the present clam resource, as well as conducting water quality monitoring. This approach was modeled after a similar community based initiative underway in southern New Brunswick. The non-profit environmental organization Eastern Charlotte Waterways (ECW) in Charlotte County, New Brunswick, has been working closely, and with great success, with local stakeholders to improve the clam fishery in their area (Susan Farquharson, personal communication, November 2005). The approach was also influenced by lessons learned from a Gulf of Maine study tour, which enabled several Annapolis Basin clam diggers to visit communities along the coast of Maine to learn and share experiences in community based resource management (Sullivan, 2006).

Members of the AWRC include representatives from both the Digby County Clam Diggers Association and the Area II Clam Harvesters Association, Clean Annapolis River Project, Bay of Fundy Marine Resource Centre, Fisheries and Oceans Canada, Environment Canada, Canadian Food Inspection Agency, Nova Scotia Fisheries and Aquaculture, Nova Scotia Department of Environment and Labour, Bear River First Nations, municipal governments as well as clam buyers and processors. Since its creation, AWRC has initiated a number of projects related to the better management of soft-shell clam stocks in the Annapolis Basin. Further information on the water monitoring activities in closed areas and the management of a conditionally approved area in Annapolis Basin can be found in Appendix A.

The population survey conducted in the summer of 2006 was an initial assessment of the state of the clam resource on two beaches in the Annapolis Basin. Density, length frequency distribution as well as biomass of clams were measured. With this information, an economic valuation was conducted, which sought to give a dollar value to the clam resource based on the most accurate and up-to-date information obtained directly from clam harvesters.

The Soft-shell Clam

The soft-shell clam (*Mya arenaria*) is a thin-shelled bivalve found in subtidal and intertidal sediments from the subarctic to the Carolina's (Maine Department of Marine Resources, 1993). The shells vary in colour from white to dark grey and blue, depending on the sediment in which they live. Most of their life cycle is spent in a burrow, which they dig using their muscular foot. Their long "neck", shown in Figure 1, is composed of an incurrent and an excurrent siphon and extends near the surface. The incurrent siphon is used to draw in water on which the clam filter-feeds. This important characteristic makes them particularly sensitive to pollutants in water. Microscopic plant and animal matter that is suspended in the water, such as algae and diatoms, are their main source of food; however clams can also accumulate toxins such as bacteria and toxic algae, making them unsafe for human consumption. The excurrent siphon is used to release fecal material as well as sperm and eggs during external fertilization (DFO, 1933).

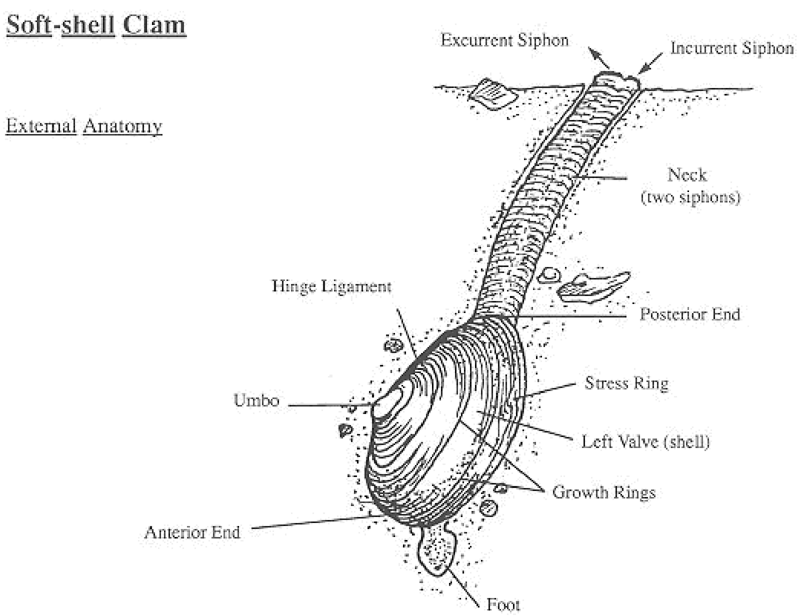

Figure 1: External anatomy of the soft-shell clam, *Mya arenaria*
(Source: Department of Fisheries and Oceans, 1993)

Spawning is onset by a combination of environmental factors, including the monthly tidal cycle and the water temperature. After the eggs are fertilized, larvae remain in the water for a period of approximately two weeks, after which they undergo a metamorphosis and settle on the bottom as juveniles. The clams then quickly begin to dig their burrow using their extensible foot. As juveniles age, they continue to dig deeper into their permanent burrow, usually to a depth of 10-15 mm (DFO, 1993). Previous studies in the Annapolis Basin have shown soft-shell clams to reach commercial size (44.5mm) in approximately 5½ to 6 years (Angus *et al*, 1985; Amaratunga, date unknown).

Soft-shell clams follow a Type III survivorship curve (Figure 2); life expectancy is low in juveniles, and increases as the clams age (Brousseau, 1978, Dame, 1996). In order to produce a sustainable adult population in the face of high mortality in early life, soft-shell clams must produce large numbers of juveniles.

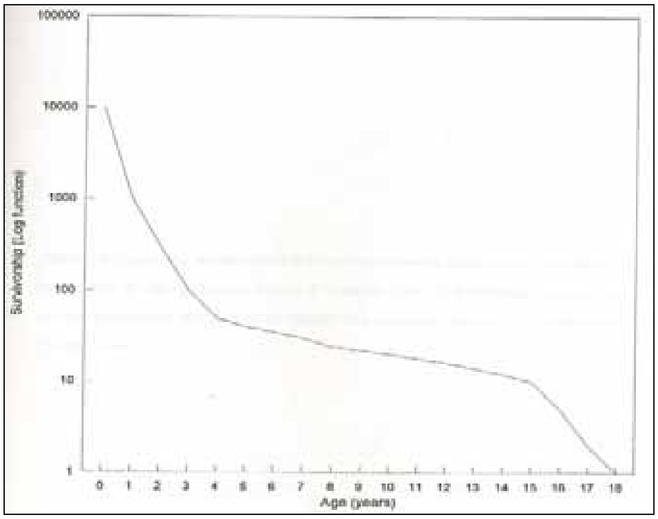

Figure 2: Survivorship Curve for *Mya arenaria*, Northeastern USA
(Source: Dame, 1996)

In Figure 2, survivorship represents the proportion of the base population that survives to the beginning on the next age category. The steep slope of the survivorship curve in earlier age categories is indicative of the low survivorship the clams experience. As clams age, the slope gradually flattens, demonstrating the increased survivorship in the remaining population of clams.

Materials and Methods

Study Sites

Based on consultation with local commercial clam harvesters, two priority beaches were identified for assessment: Deep Brook, and Karsdale. The clam harvesting area in Karsdale is considered one of the most important open areas remaining in the Annapolis Basin, second only to Thornes Cove (Personal communication, Kenneth Weir, February 8, 2007). The beach in Deep Brook is considered to be of less importance and is often only dug during spring tides when large clams in the lower intertidal area are accessible. Both beaches however, have been historically densely populated by soft-shell clams. Figure 3 shows a map of the Annapolis Basin with the two study sites: Karsdale and Deep Brook.

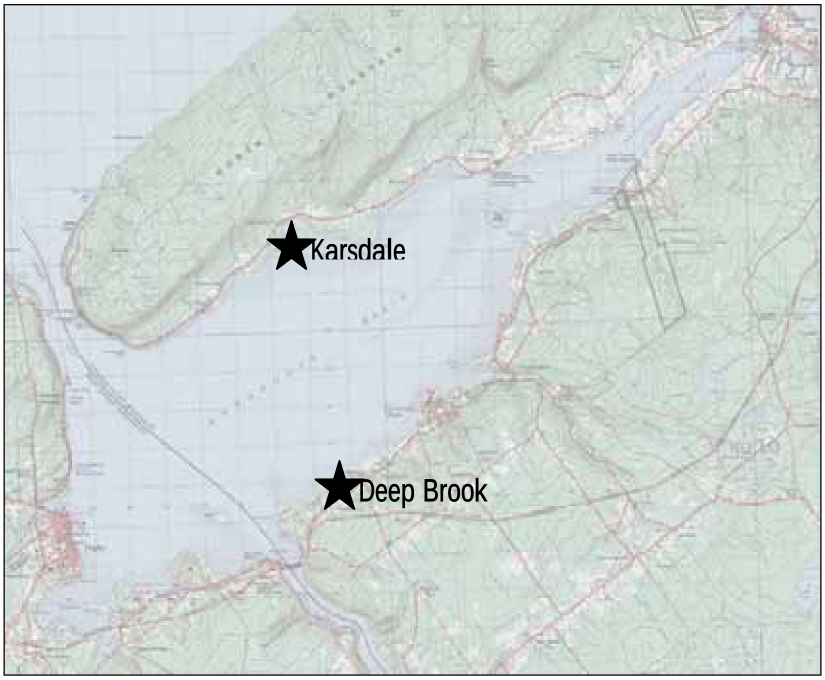

Figure 3: Annapolis Basin showing two study sites at Deep Brook and Karsdale

Clam harvesting areas are classified into four major categories according to their water quality: approved, conditionally approved, closed, and prohibited. Approved areas meet required water quality guidelines and can support an open clam harvest by recreational and commercial clam harvesters. Conditionally approved areas meet the approved criteria only for a predictable period (low precipitation, seasonal pollution source such as breeding bird populations, etc). Closed areas are subject to sources of contamination that render the clams unsafe to eat. In order to be harvested and sold on the market, they must go through a process known as depuration, or controlled purification, in a registered depuration plant. Clam harvesting is restricted at all times in prohibited areas due to high levels of contamination or the possibility of a large contamination event (ie: radius around sewage treatment plants, marinas, etc). The classification is part of the Canadian Shellfish Sanitation Program (CSSP), which is jointly managed by Fisheries and Oceans Canada, Canadian Food Inspection Agency, and Environment Canada (1992). The beaches at Deep Brook and Karsdale were classified as open at the time of sampling.

Population Survey

A literature review of past assessments conducted in the area as well as in New Brunswick was done in order to identify existing methodologies and to utilize existing standard methods. The review showed no consistent methodology for the assessment of clam stocks both within the Annapolis Basin and beyond. Methods varied widely in terms of the placement of a sampling grid, to the size of quadrat sampled as well as the mesh size used to sieve sediments (MacLeod and Hill, 1973; Angus *et al*., 1985; Rowell and Woo, 1990; Thorpe and Robinson, 1995; LeBlanc, 1997; LeBlanc, 2006). When no method could be obtained from Fisheries and Oceans Canada, the methodology used was based mainly on recent assessments by Parks Canada at Kouchibouguac National Park (KNP), New Brunswick (LeBlanc, 2006). KNP is responsible for the sustainable management of a commercial soft-shell clam fishery within the park, and conducts annual stock assessments. The KNP methodology has been tested and refined over several years.

The sampling methodology involved placing a square grid consisting of a baseline and perpendicular transects over the beach in question. The baseline was positioned approximately parallel to the coastline and was marked every 50m with polyvinyl chloride (PVC) posts. The posts were coloured with bright paint and a short description of their purpose was written on them in permanent marker. The locations of the posts were recorded with a handheld global positioning system (GPS).

Each post along the baseline marked the location of a perpendicular transect line, along which samples plots were located at 50m intervals. The first sample was collected 10m from the baseline in order to capture narrow clam beds along the shore. All other samples were collected at 50m intervals along the transect. Sample locations were also recorded using a GPS.

Due to the varying shape of the coastline, the baseline was a distance away from the shore in large coves. In these instances, the transect line continued toward the high water mark, starting at 40m and then every other 50m.

At each sample location, a $0.0625m^2$ quadrat was dug to a depth of 20cm. All contents within this area were placed in a bucket and carried to the water's edge. The contents were then sieved using a 5mm mesh. The number of clams was tallied on a data sheet (shown in Appendix B) and shell length was measured using a ruler. All clams were then returned to the beach. A diagram of the sampling grid is shown in Figure 4.

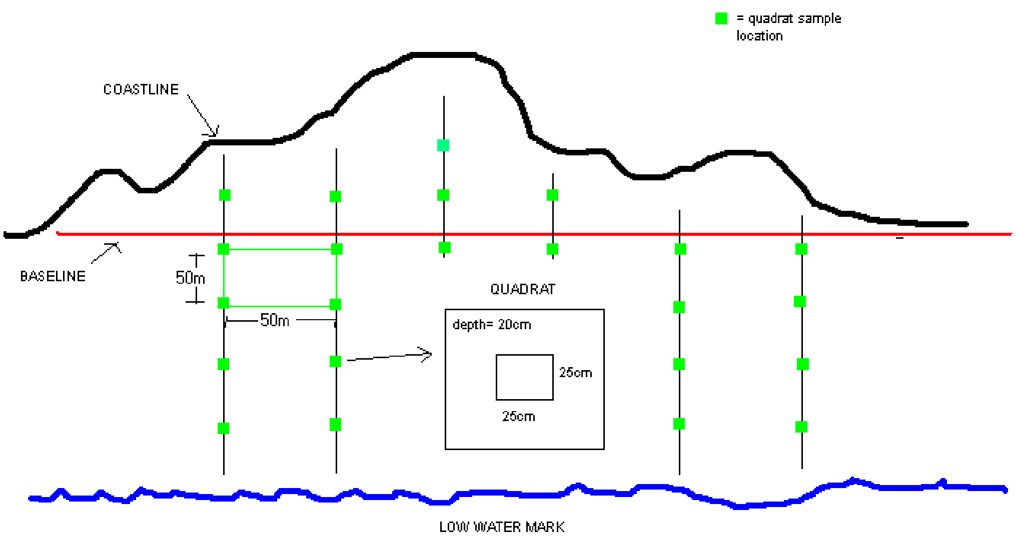

Figure 4: Sampling grid for soft-shell clam stock assessment

The sampling at Deep Brook took place from July 20-28, 2006, while the survey at Karsdale occurred August 2-29, 2006. The sampling covered an area of approximately 67 hectares, included 244 plots and over 900 clams were counted and measured.

Weight measurements were taken for different length categories of clams using a ruler and a Pelouze digital scale. A regression analysis was then done, which allows the weight of any given clam from the flats to be estimated (Appendix C). Using the formula generated in the analysis, the biomass of different size categories could then be determined. The methodology used for the statistical analyses and biomass calculations was taken from LeBlanc (1997).

Economic Valuation

The methodology used to conduct the economic valuation was based on the guidebook developed by Eastern Charlotte Waterways Inc. (ECW *et al*., 1995). Resource valuations conducted by ECW and others (Lipton *et al*., 1995; LeBlanc, 1997; LeBlanc, 1999) were used as guides in the valuation for the Annapolis Basin.

The economic valuation was conducted using biomass data obtained from the population survey. Total available harvestable area was estimated from coastal maps and traditional knowledge of local clam diggers. Harvest estimates as well as both variable and fixed costs were also obtained via personal communications with local diggers. These values were then compared against preliminary landings and value data from Fisheries and Oceans Canada. Sustainable harvest was defined as 10% of total biomass, based on estimates by DFO and harvest rates used in other clam resource valuations in the Bay of Fundy (LeBlanc, 1997; LeBlanc, 1999). This is considered a modest estimate for sustainable harvest, with a total possible range from 10-15%. The spreadsheet template and mathematical calculations also followed studies done by Kevin LeBlanc at ECW.

Results

Population Survey

Density

The density of clams varied within areas on the same beach as well as between beaches. The mean density of all clams at Deep Brook was 61 ± 12 clams/m^2. The mean density of all clams at Karsdale was 61 ± 9 clams/m^2. The total number of clams measured and the mean density with standard error of each size category of clams at Deep Brook and Karsdale is shown in Table 1.

Table 1: Total Number, Density and Standard Error of Clams at Karsdale and Deep Brook, Annapolis Basin

Size Category (mm)	Deep Brook (n = 86)			Karsdale (n = 158)		
	# Clams Measured	Mean Density (clams/m2)	SE	# Clams Measured	Mean Density (clams/m2)	SE
5	4	0.74	0.5	4	0.41	0.2
10	12	2.23	1.2	25	2.53	0.8
15	10	1.86	0.9	36	3.65	0.9
20	9	1.67	0.7	60	6.08	1.6
25	27	5.02	1.5	60	6.08	1.3
30	65	12.09	3.5	101	10.23	1.8
35	86	16.00	3.5	110	11.14	2.1
40	57	10.60	3.0	95	9.62	1.5
45	35	6.51	1.5	72	7.29	1.5
50	12	2.23	1.0	29	2.94	0.6
55	4	0.74	0.4	7	0.71	0.3
60	4	0.74	0.4	3	0.30	0.2
65	0	0.00	0.0	2	0.20	0.1
> 69	2	0.37	0.3	1	0.10	0.1
Total Commercial Size (> 45mm)	57	10.60	2.0	114	11.54	1.9
Total	327	60.84	12.1	605	61.27	8.8

The total mean density for clams of commercial size was 10.6 ± 2 clams/m^2 at Deep Brook and 11.5 ± 2 clams/m^2 at Karsdale. The densities of clams in the different commercial size categories (45mm > 69mm) with standard error bars at Deep Brook and Karsdale are shown in Figure 5.

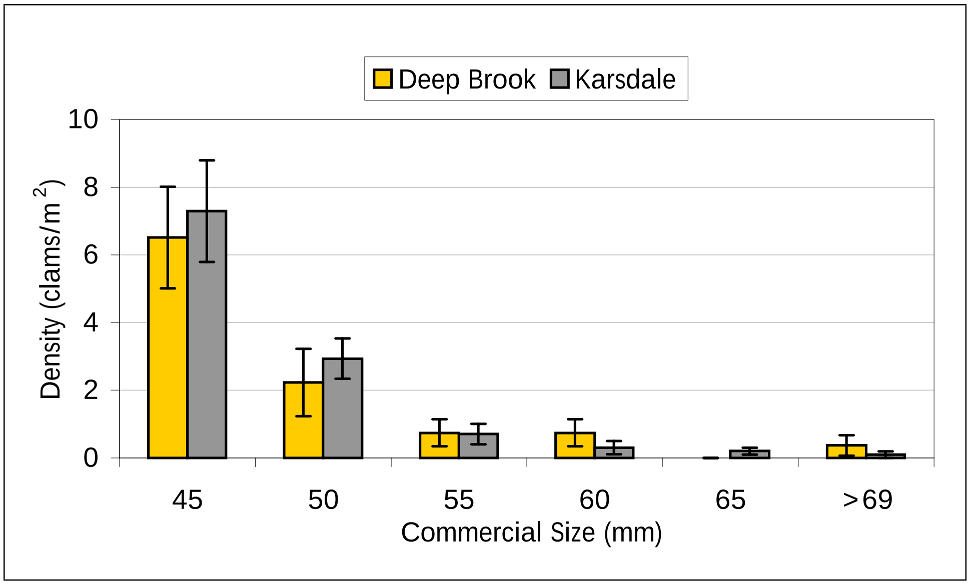

Figure 5: Density of Commercial Size Clams With Standard Error Bars at Deep Brook and Karsdale

The length category with the highest density of commercially harvestable clams at both Deep Brook and Karsdale was the 45-49mm category, with respective densities of 6.5 ± 1.5 clams/m^2 and 7.3 ± 1.5 clams/m^2.

Length Frequency Distribution

Few clams in the smallest size categories (≤ 25mm) were collected during the survey at Deep Brook (Figure 6). The majority of clams occurred in the 30-45mm size category, after which fewer clams were found. A total of 324 clams of all sizes were found in 86 plots at Deep Brook.

A similar length frequency distribution was found at the beach in Karsdale; however more clams were found over a larger area. Few clams were found in either side of the distribution, with the majority of clams falling in the 20-45mm category (Figure 6). A total of 605 clams of all sizes were found in 158 plots.

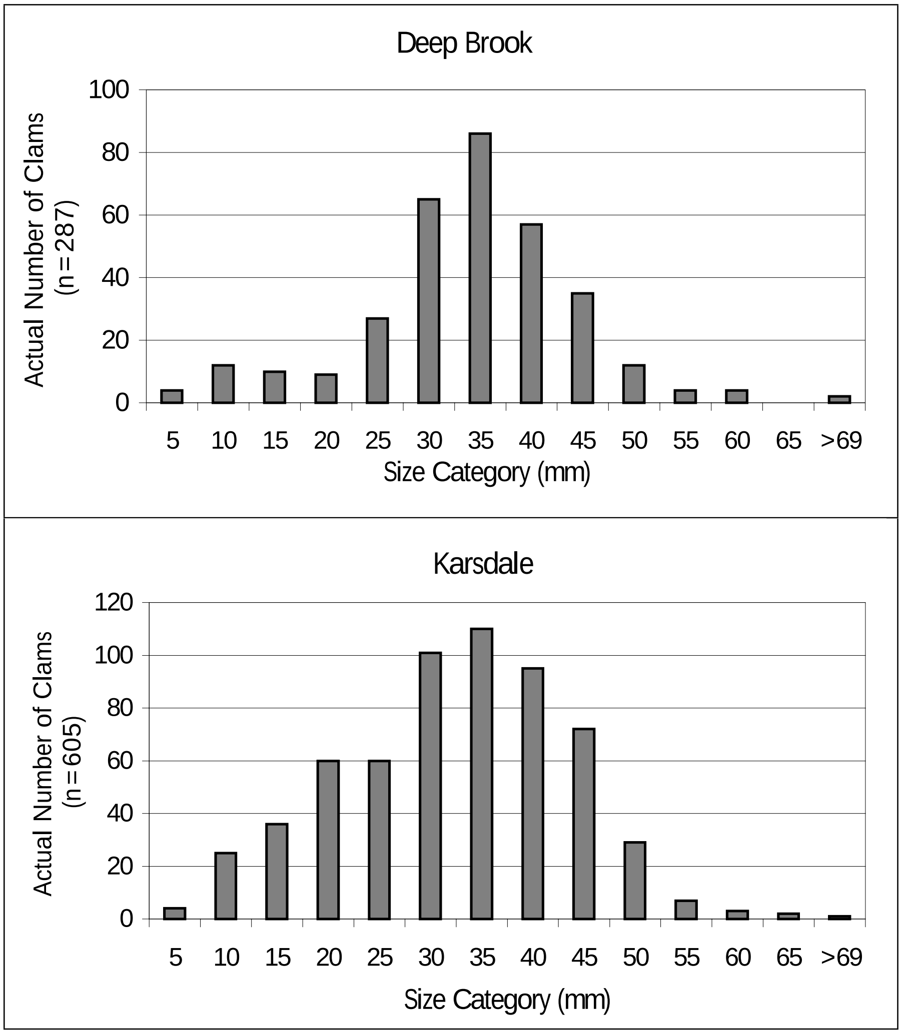

Figure 6: Length Frequency Distribution of Clams at Deep Brook and Karsdale, Annapolis Basin, Summer 2006

Biomass

The total mean biomass for commercially harvestable clams at Deep Brook is estimated at 27,200 kg, with a range of approximately 17,000-37,000 kg (Table 2).

Table 2: Biomass Calculations for clams of commercial size at Deep Brook

Calculation	Size 45-49mm Regression X=47.5	Size 50-54mm Regression X=52.5	Size 55-59mm Regression X=57.5	Size 60-64mm Regression X=62.5	Size 65-69mm Regression X=67.5	Size >69mm Regression X=70	Total
Mean Mass / Plot (g)	4.15	1.92	0.84	1.08	0.00	0.76	-
Standard Error (g)	0.96	0.83	0.41	0.53	0.00	0.53	-
Lower Confidence Interval (g)	3.19	1.09	0.43	0.55	0.00	0.22	-
Upper Confidence Interval (g)	5.11	2.74	1.25	1.61	0.00	1.29	-
Biomass (kg) (lower CI)	9,929	3,403	1,329	1,705	0	698	17,065
Biomass (kg) (upper CI)	15,903	8,539	3,895	4,996	0	4,003	37,336
Mean Biomass (kg)	12,916	5,971	2,612	3,351	0	2,350	27,200

The total mean biomass for commercially harvestable clams at Karsdale is estimated at 70,125 kg, with a range of approximately 50,000-90,000 kg (Table 3).

Table 3: Biomass Calculations for clams of commercial size at Karsdale

Calculation	Size 45-49mm Regression X = 47.5	Size 50-54mm Regression X = 52.5	Size 55-59mm Regression X = 57.5	Size 60-64mm Regression X = 62.5	Size 65-69mm Regression X = 67.5	Size > 69mm Regression X = 70	Total
Mean Mass / Plot (g)	4.65	2.52	0.80	0.44	0.37	0.21	-
Standard Error (g)	0.95	0.54	0.34	0.25	0.26	0.21	-
Lower Confidence Interval (g)	3.70	1.99	0.46	0.19	0.11	0.00	-
Upper Confidence Interval (g)	5.59	3.06	1.14	0.69	0.63	0.41	-
Biomass (kg) (lower CI)	28,892	15,517	3,604	1,463	850	0	50,326
Biomass (kg) (upper CI)	43,650	23,883	8,876	5,399	4,907	3,209	89,924
Mean Biomass (kg)	36,271	19,700	6,240	3,431	2,878	1,604	70,125

Economic Valuation

The net harvest revenue of all active clam diggers in Annapolis Basin for 2006 was estimated at $2,376,073 (Table 4). The total yearly costs for all clam diggers were estimated at $390,320. The total number of active clam diggers was estimated at 170 for 2006 out of 279 license holders in clam harvesting area II (CHA2). The total harvestable area for the Annapolis Basin calculated from maps was 24, 890,000 m². The estimate was based on historical clam harvesting areas (ie: last 20 years), as opposed to the areas currently supporting an intense commercial harvest. The preliminary landings data for 2006 provided by Fisheries and Oceans Canada was estimated at 56,206kg, for all of CHA2 with a total value of $110,055. These data were reported two and half months after the December seasonal closure and are preliminary and subject to change. Refer to Appendix D for detailed calculations and sources of data on the financial analyses.

Based on biomass calculations of the two study sites at Deep Brook and Karsdale, the total biomass estimate for the Annapolis Basin was 3,484,600kg, with a direct market value of over $10 million. The information provided by harvesters suggests the actual level of harvesting in 2006 was 5,670kg per digger per year, or 963,900kg for all active diggers in 2006.

Table 4: Resource Valuation for Soft-shell Clams, Annapolis Basin 2006

PARAMETERS	Active Digger
CALCULATION OF HARVESTING COSTS	
I. FINANCIAL ANALYSES	
Available Harvested Area per year (m^2)	24,890,000
2006 Annapolis Basin Clam Landings (kg)*	54,206
Average number of flats a digger works per year	5
Average number of diggers per flat	30
average flat size/area (m^2)	341,073
Equivalent harvested areas per year (m^2)	51,160,950
VARIABLE COSTS	
Average amount harvested per digger (kg/day)	27
Number of tides worked daily (1-2 tides daily)	1
Number of working days per year	210
Average number of working days per year	210
Actual level of harvesting per digger per year (kg)	5,670
Average distance travelled by digger (km/day)	60
Travel cost ($/km)	0.39
Number of diggers per vehicle	3
Average ATV costs per year	270
Average cost of ATV fuel per year	150
Average number of ATV's per digger	0.5
Transportation cost per year ($)	1,848.00
FIXED COSTS	
Licensing fees ($)	80.00
Number of hacks utilized by digger per year	0.5
Unit price for hack ($)	90.00
Average cost of other materials per year ($)	323.00
Total annual fixed cost per digger ($)	448.00
Total yearly costs of harvesting per digger ($)	2,296.00
Total yearly revenues harvested per digger ($)	16,272.90
Total yearly net profit per digger ($)	13,976.90
II. ECONOMIC ANALYSES	
Total number of active diggers	170
Total yearly costs of clam diggers ($)	390,320.00
Total harvest revenues of clam diggers ($)	2,766,393.00
Net harvest revenues of clam diggers ($)	2,376,073.00
2006 Annapolis Basin clam value ($)*	110,055.00

* Source: Fisheries and Oceans Canada; Data preliminary and subject to change.

Discussion

Density

Population surveys at both Deep Brook and Karsdale revealed relatively low clam densities, which did not meet the criteria for sustainable harvest used by KNP. KNP requires a minimum mean density of 12 clams/m^2 in commercial size classes for harvesting to occur. The mean densities of commercial size classes at both Deep Brook and Karsdale were below this guideline, with densities of 10.6 ± 2 and 11.5 ± 2 clams/m^2, respectively. In addition, KNP requires a minimum mean density of 100 clams/m2 of all clams to allow harvesting at any particular beach. This guideline ensures that there is a healthy population of recruits for future harvesting. The beaches at Deep Brook and Karsdale were also below this guideline, with respective densities of all clams as low as 61 ± 12 and 61 ± 9 clams/m^2.

It is important to note that the guideline for clams of commercial size at KNP assumes a minimum length for harvest of 50mm. Given that the minimum length for harvesting in the Annapolis Basin is only 45mm, an even higher density of clams would be required to ensure the sustainability of the fishery. Table 5 below compares the minimum densities for sustainable harvest of commercial size clams (50mm) at KNP against those observed at Deep Brook and Karsdale.

Table 5: Mean densities and standard error of clams at Deep Brook and Karsdale, Annapolis Basin, compared against minimum required densities for sustainable harvest at KNP

Area	Commercial Size Clams (clams/m^2) 50mm	Total Clams (clams/m^2)
KNP	12	100
Deep Brook	4.1 ± 1.4	60.8 ± 12.1
Karsdale	4.3 ± 0.8	61.3 ± 8.8

It is also important to note that the commercial fishery had been open since April (surveys conducted approximately mid-season). The beaches surveyed, particularly at Karsdale, are considered some of the most productive beaches by local clam harvesters and are therefore under intense harvesting pressure. The harvesting season in the Annapolis Basin is open until the end of December; therefore the observed densities were expected to support another 4-5 months of commercial harvesting.

The distribution of clams at both beaches also appeared very patchy, with some areas supporting denser patches and other areas almost completely devoid of clams. The methodology did not focus sampling in dense patches, but rather the clam harvesting area as a whole. Anecdotal evidence from clam harvesters suggests that the distribution of clams on the beaches have not historically been so patchy and that, in the past, clams were available over a much larger area (Kenneth Weir, personal communication, February 8, 2007). Focusing sampling within the denser patches would increase overall measures of density and better represent the reality of where harvesting occurs; however, it would not capture the historical changes that have occurred on the flats.

Length Frequency Distribution

The distribution of clams at Deep Brook and Karsdale at the time of sampling appears to be spread out over the range of length categories; however the frequency of recruitment sizes are lower than what a Type III survivorship curve would predict, particularly at Deep Brook. As shown in Figure 2, the survivorship curve of *Mya arenaria* predicts large numbers of smaller clams with high mortality in early life followed by fewer numbers of adult clams with lower mortality later in life. Figure 6 shows how the frequency of juvenile clams observed at both beaches does not correspond with this curve.

A combination of factors may contribute to the observed length frequency distribution. Firstly, the methodology used in the surveys was not designed to examine the recruitment population specifically. When studying clam recruitment, the methodology often involves a more in-depth survey of the first few centimetres of sediment with a very fine mesh sieve (Thorpe and Robinson, 1995; LeBlanc *et al*, 2005 [B]). In the current study, all the sediment within the plot area was sieved at the same time using the same mesh size (5mm). Some of the smaller clams may have slipped through the mesh during the vigorous sieving that was needed to remove the often thick mud and clay in the plots. It is important to note however that the purpose of this study was not specifically to examine clam recruitment.

The intense harvesting pressure at these beaches may also influence the observed length frequency distribution. The clam fishery in the Annapolis Basin has gone through cycles of high landings and harvesting effort followed by a period of depressed landings and harvesting effort. Anecdotal evidence from commercial clam harvesters and landings data (Figure 7) suggests that the fishery is currently in a depressed period. The peak in the frequency distribution of clams in the 25-45mm category could be a result of higher densities of spawning clams 4-5 years ago. The recent decline in available mature spawning clams, as a result of increased harvesting pressure, may have contributed to the poor recruitment at both Deep Brook and Karsdale in the last 2-3 years.

Similar length frequency distributions have been observed in other populations of commercially harvested clams and other molluscs. A study done on the Northern Quahog (*Mercenaria mercenaria*) population in St. Mary's Bay displayed a similar distribution of clams, with a peak frequency in the 30-50mm length category and lower frequencies in both the smaller and larger clams (LeBlanc *et al*, 2005 [B]). A study of the American Oyster (*Crassostrea virginica*) in the Miramichi estuary also showed a similar distribution, with few juveniles (5-55mm) and larger adult ($\geq$75mm) oysters (LeBlanc *et al*, 2005 [A]).

Biomass and Economic Valuation

The estimated clam landings based on harvester information for 2006 was approximately 963,900 kg for all active diggers. The landings data for 2006 provided by Fisheries and Oceans Canada was 56,206 kg. Although the DFO landings data are preliminary and subject to change, these values represent a seventeen-fold difference in landings. Using average digging capacity and the actual numbers of active diggers on the ground should be a more accurate measure of landings than using the analyses of landed clams from dockside monitoring companies. It is well known that not all clam diggers report their landings to the dockside monitoring program, resulting in significant underestimates of landings for the area.

This tendency can have serious implications for the clam fishery. DFO determines what proportion of its resources is allocated to a given fishery based on landings data and the associated value of the fishery. Locally, the lobster fishery generally receives the largest proportion of resources, while the clam fishery receives significantly less. It is therefore in the best interest of clam harvesters to consistently report their landings to dockside monitoring companies, in order to provide a more accurate account of both the resource being harvested as well as its associated value in dollars.

The way landings data are reported does not necessarily reflect where the majority of soft-shell clams are harvested. The preliminary landings presented here are for Clam Harvesting Area 2 (CHA2), which includes Digby, Annapolis and Kings counties. The majority of soft-shell clam harvest in CHA2 occurs in the Annapolis Basin. The CHA2 landings may therefore overestimate the total harvest of soft-shell clams as they include the harvest of other clam species, such as quahogs in other areas of CHA2 such as St. Mary's Bay.

The biomass data used in the economic analysis was assumed to be average of most clam harvesting areas in 2006. The two study sites were deemed by harvesters to be typical of clam harvesting areas, with some beaches having slightly higher densities (ie: Thornes Cove) and others having slightly lower densities (ie: Twin Cove). Qualitative observations by local clam harvesters suggested that both open and closed clam harvesting areas had similar densities in 2006. The low availability of the resource in the last few years resulted in every beach being harvested to the greatest extent. Given that fishing regulations differ in closed areas, surveys should also be conducted in important closed clam beaches in order to get a more thorough understanding of biomass in those areas.

The implementation of stock assessments on clam beaches prior to the harvesting season could be part of a long-term management plan. This would provide an estimate of biomass before the resource is put under harvesting pressure. In 2006, the most intense harvesting occurred during June, July and August, which corresponded to the time of the population survey. If biomass estimates were taken prior to the commencement of the harvest, a sustainable limit on harvesting at a particular beach could be determined. Such a program would be similar to the annual stock assessment program in place at KNP in New Brunswick. Securing funds to support such projects is an ongoing challenge.

The number of diggers was divided between active and non-active to reflect the cyclical trend in harvesters responding to the state of the resource. In recent years, the clam fishery in the Annapolis Basin has gone through cycles of high landings and harvesting effort followed by a period of depressed landings and effort. This is in large part due to the high number of harvesting licenses available in CHA2 (279 total), the highest number of all clam harvesting areas in Nova Scotia (Fisheries and Oceans Canada, 2006). The large number of available licenses is indicative of the lucrative fishery that once existed in the Annapolis Basin, however this level of harvesting, coupled with other environmental and managerial considerations, has proven to be unsustainable and continues to impact the fishery today. When clam densities are thriving, there is an influx of the "non-active" clam diggers who profit from the clams on a short-term basis. The resource is therefore put under immense harvesting pressure, which results in significant reductions in densities. The non-active or part-time clam diggers then move on to other forms of employment (ie: other fisheries, forestry, etc), leaving the full time harvesters to struggle while the clam stocks gradually rebuild. The cycle then repeats itself. This trend is represented in the landings data reported over the past decade in the Annapolis Basin (Figure 7). Although the actual numbers of clams landed may be under estimated in Figure 7, the overall trend reflects the cycle described by the diggers.

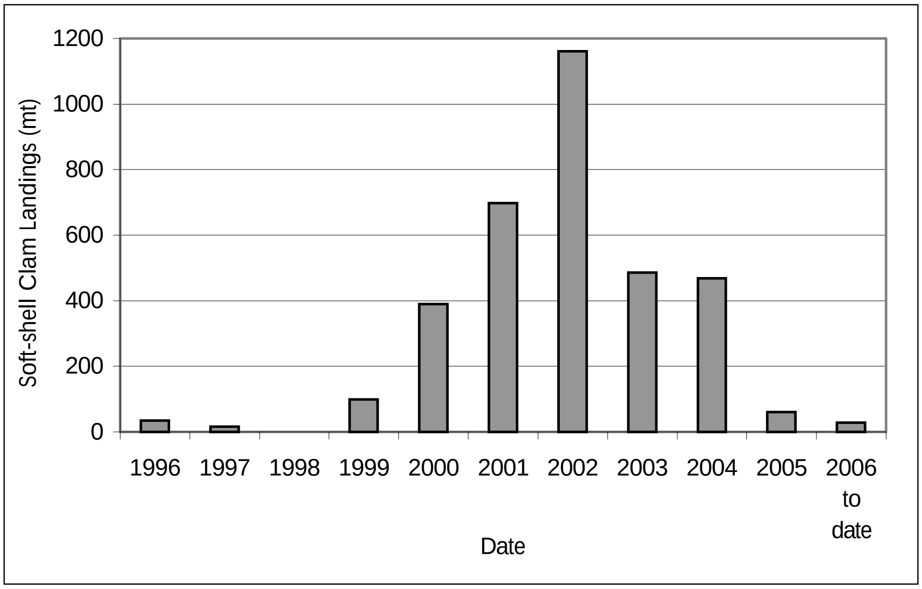

Figure 7: Soft-shell Clam Landings Data For Annapolis Basin, 1996-2006
Source: Fisheries and Oceans Canada (no data for 1998)

Any efforts to enhance the clam populations in the Annapolis Basin will be frustrated by this recurring cycle. It is therefore imperative that clam harvesters explore options to reduce the number of licenses to a more sustainable level, based on a combination of science and clammers' traditional knowledge. One option being explored in CHA3 is a temporary freeze on the transfer of licenses. Other innovative solutions should also be considered. The results of the study suggest a strong need for stricter management guidelines as well as both increased compliance with and enforcement of the guidelines.

The economic and employment realities of rural Nova Scotia also suggest a strong need for the better management of the clam resource, which has the potential to provide a significant number of well paying jobs. However, with the decreasing trend in clam biomass and the limited opportunities for alternative employment, an increasing number of harvesters are being forced to leave their communities in search of more lucrative employment in the booming oil and gas sector in western Canada. This downward trend has rippling effects to all others who are impacted by the fishery including the clam buyers, processors, truck drivers, etc. While other large employers in the area are closing and downsizing (ie: closure of Shaw Wood in Cornwallis, which employed approximately 200 people), it is critical at this time for the clam fishery to recover.

Recommendations

The current population survey and economic valuation should be viewed as a preliminary assessment of the current clam resource in the Annapolis Basin. Based on the results of the study, several recommendations can be made for future consideration, including:

1. Continued involvement and increased role of Annapolis Watershed Resource Committee (AWRC)

Given the multi-stakeholder nature of the AWRC and its long-term goals for sustainability, the committee should continue to be involved, and be given an increased role, in management decisions relating to soft-shell clams in the Annapolis Watershed. The committee has strived to be inclusive of all stakeholders despite often conflicting interests and opinions among its members. Case studies throughout the Gulf of Maine have shown community-based resource management programs inclusive of all stakeholders to be very effective (Sullivan, 2006).

2. Enhancement of clam populations on depleted beaches

Using lessons learned from other areas throughout the Bay of Fundy and Gulf of Maine, engage all clam harvesters in an intense re-seeding program to increase biomass of clams on depleted beaches.

3. Consideration of management options

Any enhancement efforts must be coupled with management guidelines and a commitment to compliance from all harvesters. Some management options include increasing the size limit of commercial size clams to 50 mm (2 inches), imposing a catch limit per tide (ie: 68kg, 150lbs of clams per digger per tide), considering the pros and cons of both winter and summer conservation closures, reducing the number of licensed diggers in the area, imposing mandatory memberships and conservation time for all licensed diggers with a recognized clammers association, etc.

4. Increased involvement of local municipalities in clam industry

Given the economic and social implications of the fishery, it is in the best interest of local municipalities to get involved and work toward ensuring the stability of this important source of employment for their rural communities.

5. More frequent stock assessment on all harvested beaches

Prior to this study, the last stock assessment of this type in the Annapolis Basin was conducted over ten years ago. More frequent population surveys should be conducted on a regular basis in order to track the state of the resource in both open and closed clam harvesting areas.

6. Further study to look at economic implications for the rest of the industry

The economic analysis presented here is preliminary and only provides a portion of the complete economic implications of the clam fishery in the Annapolis Basin. Although the current study focused on the harvesters, future analyses should investigate the ripple effects that a decline and/or improvement in clam stocks would have to all sectors including clam buyers, processors, truck drivers, etc.

7. Continued efforts to identify and remediate land-based sources of contamination in the watershed

Work should continue with CARP and all stakeholders in the Annapolis River Watershed to increase awareness of the impacts that land-based sources of contamination can have on clam beds and the livelihoods of clam harvesters. Water quality monitoring as well as sanitary surveys of shorelines should continue in an effort to identify and, where possible, remediate the sources of contamination.

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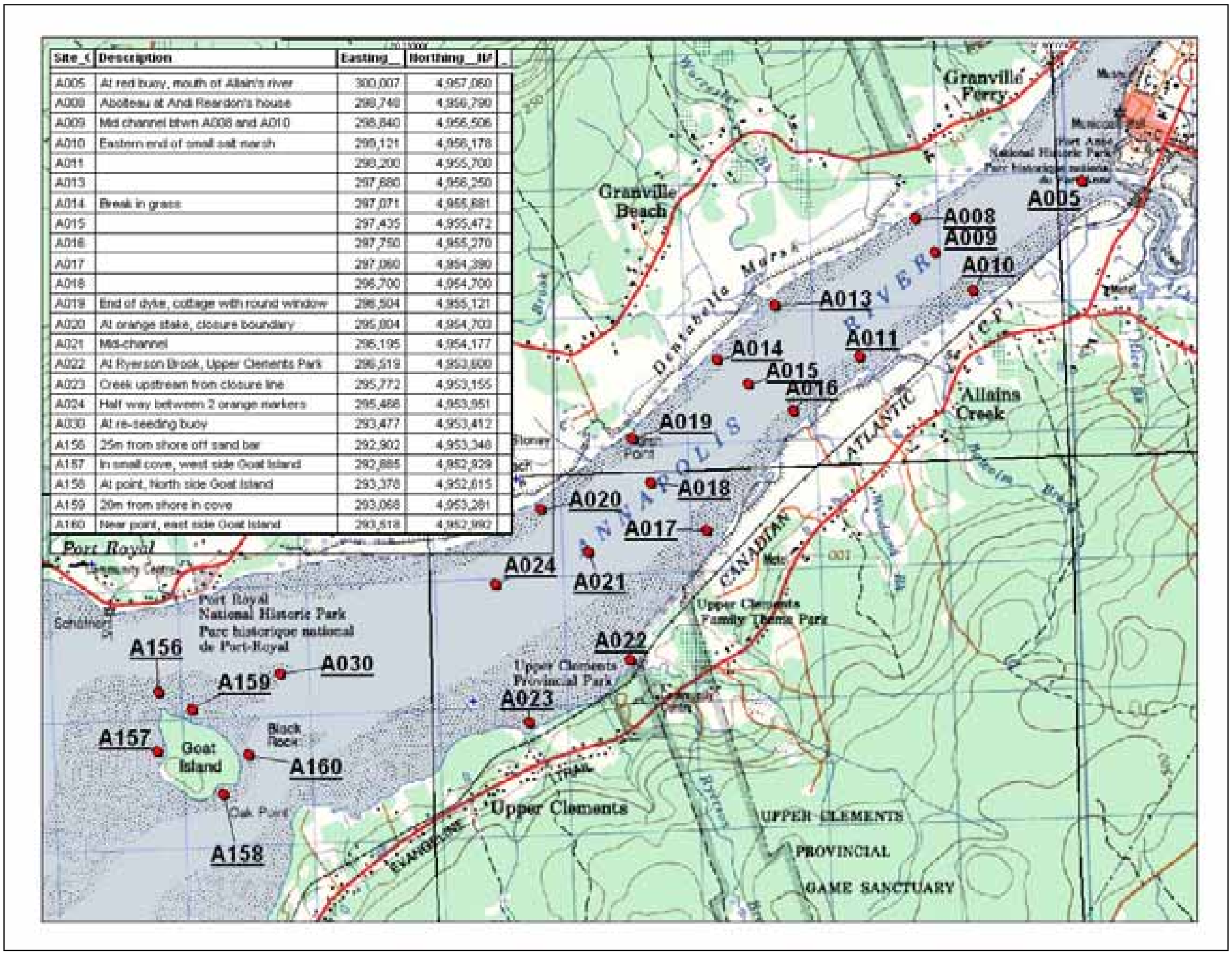
Appendices

Appendix A – Water Quality Monitoring and Conditional Opening at Goat Island

In cooperation with Environment Canada (EC) and others, CARP staff collected water samples in the closed area east of Goat Island and around Goat Island biweekly from June through November 2006. The purpose of the monitoring was to gain a better understanding of fecal coliform contamination in the closed area and to investigate any opportunities for conditional openings. Samples were collected from sites predetermined by EC and were located along the north and south shores of the Basin, in the centre of the Basin, as well as around Goat Island. Sample sites were selected to monitor potential input sources of bacteria, such as small streams. Figure 8 shows a map with a description and location of all the sample locations.



Site_	Description	Easting_	Northing_
A005	At red buoy, mouth of Allain's river	300,007	4,957,060
A008	Aboiteau at Andi Reardon's house	298,740	4,956,790
A009	Mid channel btwn A008 and A010	298,840	4,956,506
A010	Eastern end of small salt marsh	299,121	4,956,178
A011		298,200	4,955,700
A013		297,880	4,956,250
A014	Break in grass	297,071	4,955,881
A015		297,435	4,955,472
A016		297,750	4,955,270
A017		297,060	4,954,390
A018		296,700	4,954,700
A019	End of dyke, cottage with round window	296,504	4,955,121
A020	At orange stake, closure boundary	295,804	4,954,703
A021	Mid-channel	296,195	4,954,177
A022	At Ryerson Brook, Upper Clements Park	296,519	4,953,600
A023	Creek upstream from closure line	295,772	4,953,155
A024	Half way between 2 orange markers	295,486	4,953,951
A030	At re-seeding buoy	293,477	4,953,412
A156	25m from shore off sand bar	292,902	4,953,348
A157	In small cove, west side Goat Island	292,885	4,952,929
A158	At point, North side Goat Island	293,378	4,952,615
A159	20m from shore in cove	293,068	4,953,281
A160	Near point, east side Goat Island	293,518	4,952,992

Figure 8: Water quality sampling locations, Annapolis Basin, 2006

Analysis of the data indicated that the levels of fecal coliforms continue to exceed Canadian Shellfish Sanitation Program (CSSP) guidelines for an approved area. The data did not suggest a particular point source of contamination, but rather the overall background level of bacteria originated from various sources in the upstream stretches of the Annapolis River. Similarly, based on available precipitation data, spikes in fecal coliform concentrations did not appear to necessarily coincide with incidences of high precipitation. 23 sites were monitored, totaling over 200 water samples collected for fecal coliform analysis. The results of the 2006 water sampling are shown in Table 6.

Table 6: Fecal coliform densities (MPN/100ml) for Annapolis Basin, 2006

Station	14 Jun	29 Jun	02 Aug	17 Aug	31 Aug	19 Sep	27 Sep	03 Oct	18 Oct	08 Nov	20 Nov
5	33	17	13	2	1.9	1.9	5	4	1.9	33	130
8	13	23	13	17	2	8	5	33	5	26	79
9	12	79	13	1.9	1.9	2	8	9	2	33	33
10	17	5	11	2	2	13	2	240	5	17	13
11	27	13	5	5	1.9	8	1.9	49	1.9	13	79
13	13	33	4	2	1.9	23	5	17	2	13	33
14	33	23	13	2	23	5	5	14	1.9	17	7
15	23	5	8	5	1.9	2	2	8	6	8	49
16	22	46	5	8	1.9	4	2	79	8	17	23
17	13	4	11	2	2	5	2	70	1.9	8	13
18	5	2	8	2	2	2	2	17	2	8	7
19	17	13	11	2	2	13	2	11	5	5	5
20	13	7	8	2	8	13	2	17	5	17	8
21	17	5	11	1.9	1.9	2	5	4	1.9	4	5
22	8	33	11	5	2	5	1.9	13	7	13	79
23	5	49	5	5	5	1.9	2	33	1.9	6	11
24	22	5	8	1.9	1.9	2	2	46	2	1.9	1.9
30	13	4	5	2	1.9	1.9	2	13	2	5	11
156	33	23	13	2	2	2	2	8	5	2	17
157	70	1600	79	1.9	1.9	1.9	2		2	5	
158	9	26	8	2	2	2	2	13	17	8	13
159	79	7	8	2	1.9	2	1.9	11	2	17	17
160	79	5	2	1.9	1.9	2	1.9	13	11	13	5
Tide	MR-MR	MF-MF	HF-HF	HF-HF	MF-MF	MR-HR	LT-LR	HR-HT	HT-HF	LR-LR	HR-HR
CARP Info		Wet	Wet	Dry	Dry	Dry	Dry	Wet	Dry	Dry	
Lawerencetown —	Rain (mm)										
0-24h	0.0	2.2	29.0	0.0	0.0	0.0	0.0	9.0	N/A	N/A	N/A
24-48h	0.0	0.0	0.0	1.2	0.8	0.0	0.0	39.0	N/A	N/A	N/A
48-72h	2.1	0.0	0.0	2.2	0.0	0.0	0.9	0.0	N/A	N/A	N/A
Total	2.1	2.2	29.0	3.4	0.8	0.0	0.9	48.0	0.0	0.0	0.0
Lake Joli —	Rain (mm)										
0-24h	0.0	0.5	13.0	0.0	0.0	0.0	0.1	4.8	N/A	N/A	N/A
24-48h	0.1	0.0	0.0	3.8	0.8	0.0	3.8	25.0	N/A	N/A	N/A
48-72h	2.8	0.0	0.0	9.0	3.0	0.0	4.0	0.0	N/A	N/A	N/A
Total	2.9	0.5	13.0	12.8	3.8	0.0	7.9	29.8	0.0	0.0	0.0
Greenwood —	Rain (mm)										
0-24h	2.8	1.6	13.6	0.0	0.0	0.0	0.0	0.0	8.2	22.6	0.2
24-48h	5.8	0.4	8.8	0.0	0.0	0.0	0.8	28.4	0.0	0.0	0.4
48-72h	0.0	0.0	0.0	0.8	0.0	0.0	0.0	5.6	0.0	2.0	0.0
Total	8.6	2.0	22.4	0.8	0.0	0.0	0.8	34.0	8.2	24.6	0.6
0-24 tot	2.8	1.6	13.6	0.0	0.0	0.0	0.0	0.0	8.2	22.6	0.2
0-48 tot	8.6	2.0	22.4	0.0	0.0	0.0	0.8	28.4	8.2	22.6	0.6
0-72 tot	8.6	2.0	22.4	0.8	0.0	0.0	0.8	34.0	8.2	24.6	0.6

The water quality guidelines of an approved area as per the CSSP Manual of Operations are the following:
"the median or geometric mean faecal coliform Most Probable Number (MPN) of the water does not exceed 14/100 mL, and not more than 10% of the samples exceed a faecal coliform MPN of 43/100 mL, for a five-tube decimal dilution test" (Fisheries and Oceans Canada, Canadian Food Inspection Agency, and Environment Canada, 1992).

Water quality monitoring may continue in Spring 2007 in a closed area that has and will continue to see considerable improvements in shoreline sanitary conditions. The Municipality of Digby recently installed a new sewage treatment plant in the community of Smith's Cove and residents in the community have one year to connect. Future water quality monitoring may therefore focus on the clam harvesting areas of Smith's Cove and the Joggins in Digby. A map of all the closed areas as of 2006 is shown in Figure 9.

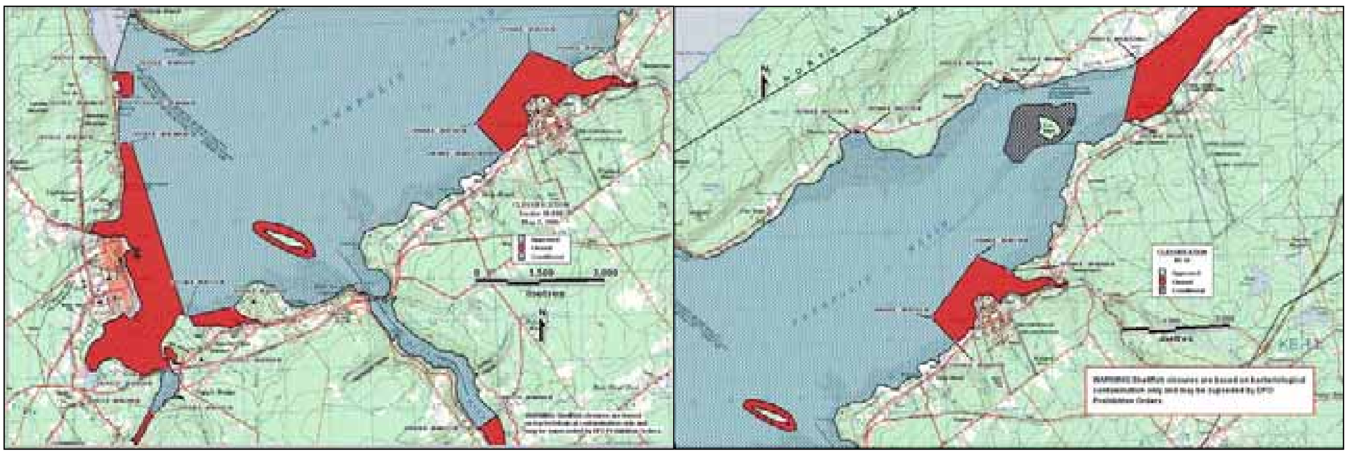


Figure 9: Clam Harvesting Area Classification Maps for Annapolis Basin, 2006
Source: http://www.atl.ec.gc.ca/epb/sfish/maps/ns/area18.html

Goat Island Conditional Opening
Goat Island is an important clam harvesting area in the Annapolis Basin that offers over 200 ha of harvestable beach (Figure 10). Breeding populations of birds that nest on the island in the spring and summer are suspected to cause high counts of fecal coliform bacteria in the water and shellstock. When birds are no longer nesting on the island in the fall however, water quality meets the guidelines of an approved area.

A Memorandum of Agreement (MOA) was signed between Fisheries and Oceans Canada, Canadian Food Inspection Agency, Environment Canada, Clean Annapolis River Project, Digby County Clam Diggers Association and the Area II Clam Harvesters Association, for a conditional opening of Goat Island during the months of October and November. CARP staff were responsible for conducting the shellstock and water testing both prior to and during the conditional opening.

Sampling done for two consecutive weeks from mid to late September of both water and shellstock showed levels of fecal coliforms within the guidelines of an approved area. Water samples were taken from sites around the island previously established by EC. Shellstock samples were taken from both sides of the island with assistance from CFIA. The pre-opening shellstock sampling consisted of intensive 'beach sweeps' with 10 samples being taken from each side of the island, for a total of 20 samples.

The area opened on October 2, 2006. As per the guidelines in the MOA, water and shellstock were to be re-sampled every two weeks for the duration of the opening. However, upon re-sampling, shellstock showed marginal contamination, forcing a closure until further testing could be done. Due to a combination of heavy rain, high winds, and tide schedules, re-sampling was delayed until mid November. Once re-sampled however, two shellstock samples continued to show marginally high fecal coliform counts and the island was closed for the remainder of the season.

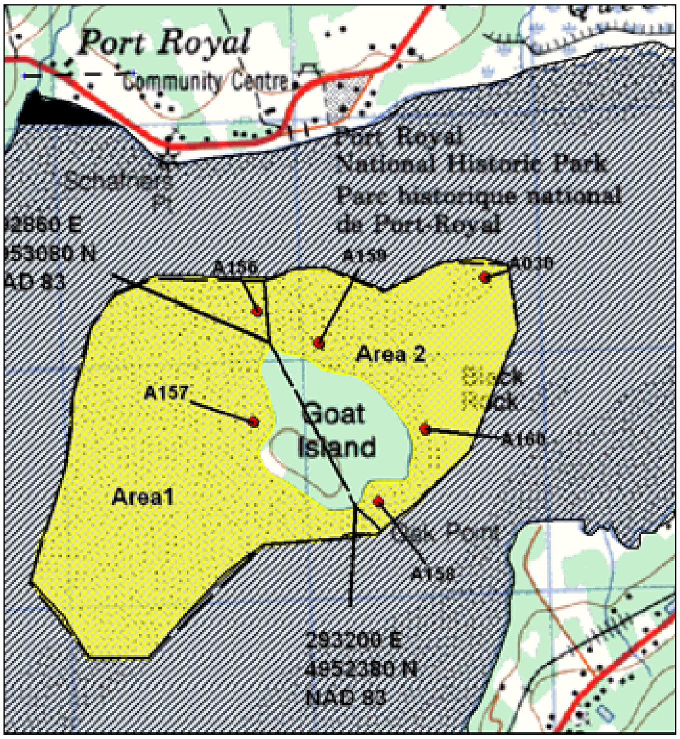


Figure 10: Map showing Conditionally Approved Area at Goat Island, 2006

If reviewed favourably by Fisheries and Oceans Canada, Canadian Food Inspection Agency, and Environment Canada, the MOA will be effective until 2008. At the time of writing, plans for continued monitoring around Goat Island in 2007 remained.

Appendix B – Stock Assessment Data Sheet

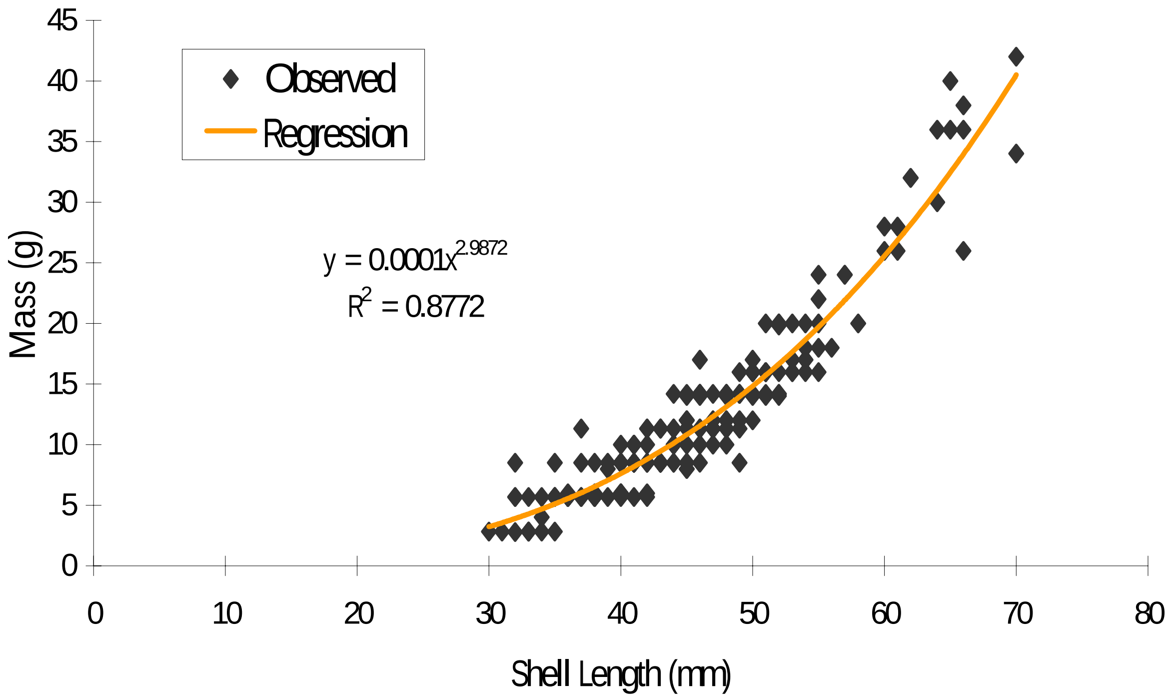
Name of clam flat: ______________________ Survey Crew: ______________________

Date of Survey: ______________________ Plot Size: ______________________

Time of Survey: ______________________ Mesh Size: ______________________

Tran #	Plot #	Sediment	Broken	5-9mm	10-14mm	15-19mm	20-24mm	25-29mm	30-34mm	35-39mm	40-44mm	45-49mm	50-54mm	55-59mm	60-64mm	65-69mm	> 69mm

Appendix C – Regression Analysis of Length/Weight Ratio of Soft-shell Clams, Annapolis Basin



Appendix D — Economic Valuation of Soft-shell Clams, Annapolis Basin 2006

	A	B	C	D	E	F
1	DATA	STUDY SITES				
2		Karsdale	Deep Brook	Total	Average	
3	Harvestable Area (m^2)	487,695	194,450	682,145	341,073	
4	Sustainable Harvest (%)	10	10	20	10	
5	Annual Average Price ($/kg)	2.87	2.87	5.74	2.87	
6	Biomass of Clams (kg)	70,125	27,200	97,325	48,663	
7	Sustainable Level (Kg)	7,012.50	2,720.00	9,733	4,866	
8	Gross Harvesting Benefit ($)	20,125.88	7,806.40	27,932.28	13,966.14	
9	Number of Harvesting Days: 210					
10	shell stock (estimated at 27 kg/day)	259.7	100.7	360.5	180.2	
11	Total Number of diggers: 279 licenses					
12	Active:170					
13	Non-Active:109					
14	Harvesting Benefits ($/$m^2$)	0.041	0.040	0.081	0.041	
15	kg/m^2	0.014	0.014	0.028	0.014	
16						
17	CALCULATION OF HARVESTING COSTS	Active Digger		Source		
18	FINANCIAL ANALYSES					
19	Available Harvested Area per year (m^2)	24,890,000		Topographic map, local clam harvesters		
20	10% Sustainable Harvesting (kg)	348,460		E15 x B19		
21	2006 Annapolis Basin Clam Landings (kg)	54,206		Fisheries and Oceans Canada *landings data preliminary and subject to change		
22	Average number of flats a digger works per year	5		Local clam harvesters		
23	Average number of diggers per flat	30		Local clam harvesters		
24	average flat size/area (m^2)	341,073		E3		
25	Equivalent harvested areas per year (m^2)	51,160,950		B22 x B23 x B24		
26						
27	VARIABLE COSTS					
28	Average amount harvested per digger (kg/day)	27		Local clam harvesters		
29	Number of tides worked daily (1-2 tides daily)	1		Local clam harvesters		
30	Number of working days per year	210		Local clam harvesters		
31	Average number of working days per year	210		B29 x B30		
32	Actual level of harvesting per digger (kg)	5,670		B28 x B31		
33						
34	Average distance travelled by digger (km/day)	60		Local clam harvesters		
35	Travel cost ($/km)	0.39		Local clam harvesters		
36	Number of diggers per vehicle	3		Local clam harvesters		
37	Average ATV costs per year	270		Local clam harvesters		
38	Average cost of ATV fuel per year	150		Local clam harvesters		
39	Average number of ATV's per digger	0.5				
40	Transportation cost per year ($)	1,848.00		[31 x B34 x B35 / B36] + [(B37 + B38) / 2]		
41						
42	FIXED COSTS					
43	Licensing fees ($)	80.00		Local clam harvesters		
44	Number of hacks utilized by digger per year	0.5		Local clam harvesters		
45	Unit price for hack ($)	90.00		Local clam harvesters		
46	Average cost of other materials per year ($)	323.00		Local clam harvesters		
47	Total annual fixed cost per digger ($)	448.00		B43 + (B44 x B45) + B46		
48						
49	Total yearly costs of harvesting per digger ($)	2,296.00		B40 + B47		
50	Total yearly revenues harvested per digger ($)	16,272.90		B5 x B28 x B31		
51	Total yearly net profit per digger ($)	13,976.90		B50 — B49		
52						
53	ECONOMIC ANALYSES					
54	Total number of active diggers	170		Local clam harvesters		
55	Total yearly costs of clam diggers ($)	390,320.00		B49 x B54		
56	Total harvest revenues of clam diggers ($)	2,766,393.00		B50 x B54		
57	Net harvest revenues of clam diggers ($)	2,376,073.00		B56 - B55		
58	2006 Annapolis Basin clam value ($)	110,055.00		Fisheries and Oceans Canada *data preliminary and subject to change		