Fisheries and Oceans Canada | Pêches et Océans Canada

Canadian Stock Assessment Secretariat
Research Document 98/54

Secrétariat canadien pour l'évaluation des stocks
Document de recherche 98/54

Not to be cited without
permission of the authors[1]

Ne pas citer sans
autorisation des auteurs[1]

PRELIMINARY STOCK SURVEY OF THE OCEAN QUAHOG (*ARCTICA ISLANDICA*) IN ST. MARY'S BAY, NOVA SCOTIA

R. Duggan[1], E. Kenchington[1], S. Smith[1] and J. T. McLane[2]

[1] Invertebrate Fisheries Division
Science Branch
Department of Fisheries and Oceans
P.O. Box 550, Halifax, N.S.
B3J 2S7

[2] Consultant
Halifax, Nova Scotia

[1] This series documents the scientific basis for the evaluation of fisheries resources in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

Research documents are produced in the official language in which they are provided to the Secretariat.

[1] La présente série documente les bases scientifiques des évaluations des ressources halieutiques du Canada. Elle traite des problèmes courants selon les échéanciers dictés. Les documents qu'elle contient ne doivent pas être considérés comme des énoncés définitifs sur les sujets traités, mais plutôt comme des rapports d'étape sur les études en cours.

Les documents de recherche sont publiés dans la langue officielle utilisée dans le manuscrit envoyé au secrétariat.

ISSN 1480-4883
Ottawa, 1998

Canada

Abstract

The fishery for Ocean Quahogs in Nova Scotia has been at best sporadic since a processing plant in Port Medway closed in 1971. Several surveys since the early 1950's have attempted to define the extent of this resource. Frequently there was difficulty in operating the sampling gear due to bottom conditions and strong tides which prevented accurate biomass estimates. A small commercial fishery has been operating in southwestern Nova Scotia for the past five years and landings approached 150 tonnes in 1996. Fishing experience has contributed to efficient harvesting techniques and the ability to work in areas where conditions prevented previous investigation. There is interest in setting up a plant to process and ship ocean quahog products. Industry is trying to determine if an adequate supply (6000 tonnes per year) of clams larger than 62 mm can be harvested. This report documents a 1997 industry funded survey which used commercial gear to survey an inshore bed of ocean quahogs. This bed had previously been identified but had never been harvested. The survey produced a biomass estimate of 59,500 tonnes of ocean quahogs.

Résumé

La pêche de la quahog nordique en Nouvelle-Écosse est au mieux sporadique depuis la fermeture en 1971 d'une usine de transformation située à Port Medway. Plusieurs relevés menés depuis le début des années 50 ont tenté de définir l'étendue de la ressource. Des difficultés se sont souvent posées dans l'utilisation du matériel d'échantillonnage à cause des conditions du fond et des fortes marées qui empêchaient d'estimer la biomasse avec précision. Une petite pêche commerciale existe dans le sud de la Nouvelle-Écosse depuis 5 ans, et les débarquements ont approché 150 tonnes en 1996. Cette expérience de pêche a permis d'améliorer l'efficacité des techniques de capture et ouvert la possibilité de travailler dans des zones où les conditions avaient jusque-là entravé les recherches. Un certain intérêt se manifeste pour la création d'une usine qui transformerait et expédierait les produits de la quahog nordique. L'industrie essaie de déterminer s'il est possible d'assurer un approvisionnement suffisant (6 000 tonnes par an) de quahog mesurant plus de 62 mm. Le rapport décrit un relevé, financé par l'industrie en 1997, qui faisait appel à des engins commerciaux pour prospecter une concentration côtière de quahog nordique qui avait été repérée mais jamais exploitée. Selon ce relevé, la biomasse exploitable serait de 59 500 tonnes de quahog nordique.

Introduction

The presence of ocean quahog, *Arctica islandica*, beds in coastal waters of the Maritime Provinces had been noted in the early 1950's. Several surveys (Medcof 1957; Chandler 1965; Medcof *et al.* 1971; Rowell and Chaisson 1983) have been conducted to assess biomass and economic viability. The fishery was greatly affected by the closure of the Triton Fisheries Ltd. clam processing plant in Port Medway, N. S. in 1971 (Hiltz 1977). Since then there have been sporadic attempts to create a commercial fishery (Bissel 1972). Presently, a small coastal fishery supplies a market for small ocean quahogs 45-60 mm in length known as "mahoganies". These are marketed live, without processing. Landings in 1996 were less than 150 tonnes.

Ocean quahog landings (mt)

1991	1992	1993	1994	1995	1996
17.9	29.1	11.2	29.6	78.8	142.0

This limited fishery has 3 license holders, of which only one accounts for the majority of the landings. These licenses are also allowed to land northern propellerclams, *Cyrtodaria siliqua,* Arctic surfclams, *Mactomeris polynyma,* and Atlantic surfclams, *Spisula solidissima,* which are targeted when the fisher has a specific order from a buyer. Size limits and a total allowable catch (TAC) have not been specified for this fishery. A new management plan to address these issues is currently being formulated..

Recent exploratory fishing has found several new ocean quahog beds and has also indicated that inshore biomass calculated from earlier scientific surveys may have been underestimated. Some beds that were identified in earlier studies were unable to be fully surveyed because of strong tides and inefficient gear (Rowell and Chaisson 1983). Experience gained in the commercial fishery has developed more efficient harvesting capability and therefore the ability to do more accurate surveys. A 1997 industry-funded survey of the central portion of a previously unsurveyed bed has provided a biomass estimate of 59,500 tonnes of shellstock, *i.e.*, whole animals.

The revised biomass estimates have kindled new interest in the fishery and one company is proposing to set up a plant to process and ship ocean quahog products. They would require a minimum of 6,000 tonnes shellstock per year and are requesting that further surveys be conducted to provide more accurate biomass estimates to formulate a management plan. This document addresses the results of an industry-sponsored survey in St. Mary's Bay and discusses the potential for this bed and others to provide sustainable harvests of 6,000 tonnes, as required by the investors for the processing equipment.

Industry-Funded Survey of St. Mary's Bay

An industry-funded exploratory survey was carried out by J. T. McLane (consultant) in July, 1997. The survey vessel was a 45' commercial fishing boat "Just For Fun II" operated by Mr. Cameron Widrig. It was equipped with a 36" (0.81 m) wide hydraulic dredge with a variable angle cutting blade and water pressure manifold. Depending on type of bottom, the angle and water pressure of the manifold can be adjusted to control the depth of sediment displaced to expose the targeted species. Similarly, the blade is appropriately adjusted.The colecting bag is made from 40mm shrimp net. Water is delivered through a 4" flexible hose from a pump on deck to the dredge which is towed across the bottom. Vessel speed, usually less than 1 knot, is also used to control harvesting efficiency. Vessel speed could not be recorded accurately, however tow speed was estimated as 0.4 knots.

Sample stations for the survey area (Fig. 1) were located at the intersections of the (X and Y, 5930 chain) Loran C lines of position on Canadian hydrographic chart number 4118. Tow duration was three minutes. Tow length was caculated by an in house computer program (ACON developed by Gerry Black, DFO Halifax, 426-3845) from beginning and end readings from the onboard global positioning system (GPS) receiver

Dredge contents from each tow were washed down and sorted by 1) live species, and 2) trash. Quahogs were placed in plastic milk boxes, level with the top, and weighed to the nearest kg. The scale broke at station 10, and no further weights could be recorded. The average weight of boxes from the first 10 stations, (24 kg) was used to calculate weight from volume for the remaining stations (volume was recorded at all stations). Trash was negligible in all tows except station 10 where 3 boxes of shell weighing 42 kg were discarded. Bycatch was also small; the entire survey yielding only a handful of Greenland cockles (Serripes groenlandicus), and a few razor clams (Ensis directus). Clams were immediately dumped after each tow and animals from station 30 only (Fig. 1) were kept for meat yield analysis and for PSP and ASP testing.

Survey Results

Thirty stations were completed on July 27, 1997. Tow depths ranged from 32-49 m. Bottom type was primarily sand with occasional patches of clay. The strong tidal conditions in the Bay of Fundy are well known. It was suggested by the survey crew that tidal changes during the survey probably caused variability in dredge efficiency as all tows were made in the same direction.

Mean number of animals per level milk box was calculated from 19 level boxes. The mean was 255 with a standard deviation of 53. The range was 163 to 353 indicating that a considerable size range exists on the beds. However length frequency measurements from all stations indicate that 76% of all clams caught were >62mm in length.

Weight of quahogs per tow (Table 1) ranged from 5 to 156 kg with a mean of 87.3 kg. Stations 5, 6, 28 and 30 were excluded from the definition of the bed because of low catches and their proximity to what appeared to be the outer edge of a bed of densely concentrated quahogs. An area of bottom believed to be a subset of the commercial bed (Fig. 1) was used to provide an estimate of survey biomass.

The estimate of biomass from the survey requires knowing the area covered by each tow and the total area the survey results would be applied to. We assumed that the area of a standard tow was defined in terms of a constant tow length (say 38.58 m) and the width of the dredge (0.8128 m), that is, an area of 31.36 m². The total survey area was given as 17.32 km² which implies that the area potentially contained 552,296 standard tows. The total weight caught in each tow is converted to the catch per standard tow by multiplying the former by the ratio of the area of the standard tow to the actual area of the tow. The mean of all of the catches per standard tow was multiplied by the total number of standard tows in the survey area to calculate biomass over the survey area.

The actual area for each tow would be calculated by assuming a constant tow width and then determining the actual distance the gear was towed over the bottom. The general procedure during each tow in the survey was to try and maintain a towing speed of 0.4 knots for three minutes. This would result in an expected tow distance of 37.06 metres. The average tow distance for the survey was 38.58 metres but ranged from 12.79 to 79.14 metres. The distance towed was estimated using the begin and end positions from the onboard global positioning system (GPS) receiver. Our understanding of the situation was the readings from this receiver were only recorded to the 100th of a decimal degree. For such short tows, this implies a possible maximum error of ±37.0 m depending upon how close the third decimal place was to 0 or 9.

If we assume that the possible error on the true tow distance was symmetric and random then given how close the actual mean distance was to the expected distance we might assume that the best estimate of tow distance is the mean tow distance. Therefore each tow would be assumed to have covered the same distance. However, this approach also assumes that there was no systematic change in tow distance. This is unlikely given tidal influences in this area combined with the slow speed of the tow. A plot of tow distance against time (Figure 2) shows that there was a temporal trend in the data which appears to coincide with the tidal cycle.

The following regression model was used to investigate for the presence of a tidal pattern in the tow distance data (P.C. Smith, BIO, pers. comm.).

$$\text{Tow Distance} = \beta_0 + \beta_1\cos\left(\tfrac{2\pi}{12.42}\times\text{Time}\right) + \beta_2\sin\left(\tfrac{2\pi}{12.42}\times\text{Time}\right)$$

The fit of the regression model was significant (p-value = 0.007) with an R^2 of 0.354. The predicted curve from this model is given on Figure 2. Note that the predicted minimum and maximum tow durations occurred at the tows made at 0951h and 1556 h, respectively. The tide tables give 1000h and 1600 h as the times for the low and high tide respectively in this area for 27 July, 1997. With the exception of the first tow, all the residuals fit well within the ±37.0 m predicted above. The residual for the first tow was 39.73 which wasn't too far off of the mark.

These results leave us with three ways of estimating the distance towed for each set. That is, using the distances as recorded, taking the mean distance or using the fit from the above model. Biomass estimates for the three ways of estimating distance towed are presented in the following text table.

Definition of Standard Tow	Mean weight (kg)	Biomass (t)	Standard error (biomass)
No correction	96.45	53,271	3,309
Distance as recorded	138.80	76,661	10,766
Distance from Tidal model	107.74	59,505	5,779

The standard error estimates were made assuming a random assignment of stations and may not be appropriate for this survey given the systematic design. An alternative approach for estimating the standard error would be to fit a spatial model to the data and use the model to estimate the standard error.

A geostatistical model was applied to the catch data for each of the standard tow options above. The geostatistical spatial model implies that catches made in tows close together will be more similar than tows made at a greater distance apart. There was no evidence for any spatial patterns in the data (Fig. 3) and therefore fitting a spatial model to these data will give results little different from those in the table above.

Given the evidence of a tidal effect on the distance towed, the biomass estimate of 59,505 t was preferred here. An estimate of the survey biomass of clams over 62 mm was calculated by determining a length-weight regression for 200 clams.

$$\text{weight (g)} = 4.619\, e^{0.0413\,(\text{shell length mm})}$$

The weight of clams >62 mm as a percentage of the total was extrapolated to the total biomass to calculate an estimate of 45,223 t of > 62mm shellstock. Rough 95% confidence intervals calculated using a bootstrap method (Bca, see Efron and Tibshirani 1993) for this estimate were 37,510 to 53,882 t. Without accounting for growth, recruitment or natural mortality (M= 0.015 to 0.05), a fishery with an annual removal rate of 6,000 t would be sustained for 7-8 years at which point the bed would be fished down (landings would fall dramatically thereafter).

Estimates of population biomass require knowledge of the efficiency of the gear. The efficiency of the gear is not well understood in this area, and so extrapolation of population biomass is problematic. The gear is normally thought to be highly efficient (95% on sand bottom; Medcof and Caddy 1971) in recruited size classes. In this analysis we will assume that the gear is 100% efficient for the selected sizes (above 38 mm) and thus provide a slightly conservative estimate of biomass. Under this assumption, the population biomass will be approximately equal to the survey biomass and using the estimates from the model adjusted for the tides, ~59,500 t above 38 mm (recruitment to the gear) with 45,223 t of > 62mm shellstock. Removal of 6,000 t would represent 13.3% of the population in the first year, 15.3% in the second year, 18% in the third year etc.

Estimates of maximum sustainable yield (MSY) were calculated from the estimate of 62 mm + biomass and, for comparison with Rowell and Chaisson's (1983) results, from the estimated total biomass. The natural mortality rate (*M*) of *Arctica islandica* has been reported as 0.015 to 0.05 (cf. Rowell and Chaisson 1983). Using Gulland's (1971) $0.5*M*B_0$ model which assumes that maximum surplus production occurs when the stock is reduced to 50% of the virgin level (X=0.5) and that the fishing mortality rate at MSY (F_{MSY}) is equal to *M*, MSY for the St. Mary's Bay bed is estimated at 339 t to 1131 t. These numbers would increase to 446 t to 1488 t if the estimated total biomass were used in Gulland's (1971) equation. However, it would be unrealistic to assume that F_{MSY}, averaged across both recruited and pre-recruit year-classes was approximately equal to *M*. Rowell and Chaisson (1983), who did make that assumption, estimated MSY for the inshore zone excluding St. Mary's Bay at 426 to 1421 t (using an inshore biomass estimate of 56,833 t and the same values of *M* as used here).

The applicability of Gulland's (1971) equation to long-lived unexploited species is questionable (Kenchington 1987). It can produce grossly optimistic estimates of MSY. However, in the present case, with MSY estimates of perhaps 700 to 2,200 t for the total inshore zone including St. Mary's Bay, it is sufficient to show that an annual removal of 6,000 t would not be sustainable in the long term.

Shell Length Frequencies and Condition Index

Lengths of quahogs as determined from the maximum shell measurement (Fig. 3), measured at 21 stations, ranged from 38 to 95 mm. It should be noted that the dredge was not lined and that some smaller animals could have passed through the mesh of the collecting bag. Time constraints and the probability that fishing characteristics of the dredge would be altered prevented experimenting with liners. The average size was 66.0 mm with a standard deviation of 9.1 mm. Length frequency distributions of stations 3 and 30 are shown in figure 5. There appears to be a shift in the size distribution moving from east to west. The western stations have smaller clams (e.g., station 3 mean 62.6 mm), than the eastern stations (e.g., station 27 mean 74.9 mm). This may be due to different year classes present in the population, to differing growth rates or to both.

A sample of 100 clams was processed for condition index (Table 2). Meat yield (whole tissue) as a function of length is presented in figure 6. The correlation was highly significant (r^2= 0.91) and produced the following yield equation:

$$\text{Meat Weight (g)} = 0.8322\ (\text{Shell Length mm}) - 40.994$$

Meat weight was determined to be approximately 19% of the total weight (s.d. 8.6%). The percentage water was determined to be approximately 26% (s.d. 12.8%). PSP and ASP analyses of clams from station 30 were negative (pers. comm., K.A. White, Canadian Food Inspection Agency, Yarmouth, N.S.).

Discussion

Careful attention will have to be given to the formation of a management plan for an expanded fishery. Ocean quahogs are a slow growing species which can live more than 200 years. (Ropes 1985). Size and age-at- maturity for this species varies throughout its distribution (Table 3), but locally is about 48 mm and 13 years respectively (Rowell et al. 1990). Similar estimates are found in the U.S.A. (Ropes and Murawski 1980, Thompson *et al.* 1980) but size-at-maturity in Iceland is slightly larger at 55 mm and age is much greater at ~50 years (Steingrimsson and Thorarinsdottir 1995).

This survey was put together on short notice to provide some estimate of biomass for an Industry / DFO meeting to discuss the feasibility of expanding the present fishery. There is interest in setting up a plant to process and ship quahog products from southwest Nova Scotia. If industry was to proceed they wanted assurance of an adequate supply (6000 t / yr, >62 mm min. size) in proximity to their proposed site. This bed in St. Mary's Bay, although previously located, had not been surveyed and was suspected to contain a large resource. The current survey estimates a total biomass of 59,500 t and a biomass of 45,200 t of >62 mm clams. The present survey, conducted in a single day, appears to be incomplete in that catch rates for stations on the northern and southern perimeter of the study area indicate that the bed might extend beyond the area examined. An expanded survey of this area plus additional surveys of previously identified beds is recommended. Surveys using commercial gear operated by experienced fishers will in all probability increase the original crude estimates of biomass and enhance the feasibility of expanding the present fishery. Disregarding additional growth and recruitment, which is not well understood, a fishery which removes 6,000 t per year would be sustained for 7-8 years from this single bed. However, fishing at this level of removal is not sustainable.

The United States ocean quahog fishery, which has operated for 25-30 years, indicates recruitment is variable with infrequent strong year classes. Their approach is to limit catches to about 3% of biomass. This would equate to a TAC of only 1,785 t for all sizes, or 1,357 t for the 62 mm + stock, from the portion of the bed surveyed in St. Mary's Bay.

On the west coast, the Geoduck fishery (Hand and Waddell 1996) is in some respects comparable to that of the ocean quahog. This species is also long lived, with animals aged at 140 years. There, 55 licences pursue what is considered to be a lucrative fishery. The Geoduck fishery is divided into three management zones. These areas are further divided into smaller regions so quotas can be specific to inlets, bays or islands. In general, there is a three year rotation so that areas harvested one year are given time to recuperate between harvests. Industry is currently funding an enhancement project for this species in the Gulf of Georgia.

With respect to a quahog fishery, a plan for individual bed management, incorporating minimum size limits, TACs, and exclusion of portions of the bed from harvesting is recommended to preserve a spawning biomass. Where size at maturity is 48mm, caution would suggest a minimum harvesting size of approximately 55mm. It may be necessary to rotate harvesting areas on a yearly basis as with the Geoduck fishery. Alternately, a system of strip harvesting beds on an annual basis may promote recruitment (Rowell and Chaisson 1983).

References

Bissel, G.E. 1972. *Review of the East Coast Quahog Fishery* (Guidelines for Development). Prepared by Western Consultants for Resource Development Branch, 96 p.

Chandler, R. A. 1965. Ocean quahog resources of Southwestern Northumberland Strait. *Fish. Res. Board Can., MS Rept.* No. 828: 22 p.

Efron, B and R. J. Tibshirani. 1993. An Introduction to the Bootstrap. Chapman & Hall, London.

Gulland, J.A. 1971. *The Fish Resources of the Ocean.* Fishing News (Books) Ltd., Surrey, England, 255 p.

Hand, C. M. and B. J. Waddell. 1996. Invertebrate working papers reviewed by the Pacific Stock Assessment Review Committee (PSARC) in 1993 and 1994. *Can. Tech. Rep. Fish. Aquat. Sci.* 2089.

Hiltz, L. L. 1977. The ocean clam, (*Arctica islandica*). A literature review. G. E. Mack, Ed. *Can. Fish. Mar. Service Tech. Rept.* 720: 117 p.

Kenchington, T. J. 1987. Management of newly-exploited fish resources. *Oceans '87 Proceedings, Fifth Symposium on Oceanographic Data Systems*, Vol. 3: 956-961.

Medcof, J. C. 1957. Search for ocean quahogs in Port Medway Harbour. *N.S. Fish. Res. Board Can., MS Rept.* No. 1002: 7 p.

Medcof, J.C. and J. F. Caddy. 1971. Underwater observations on the performance of clam dredges of three types. *ICES CM 1971/* B:10, 5 p.

Medcof, J. C., D. F. Alexander, and R. A. Chandler. 1971. Promising places to look for ocean quahogs and bar clams, and trial fishing with a rocker dredge off Richibucto, N. B. and Clark's Harbour, N.S. *Fish. Res. Board Can., MS Rept.* No. 1068: 38 p.

Ropes, J. W., and S. A. Murawski. 1980. Size and age at sexual maturity of ocean quahogs, *Arctica islandica* Linné, from a deep oceanic site. *I.C.E.S. Shellfish Com. K*: 26. 7p.

Ropes, J. W. 1985. Modern methods used to age oceanic bivalves. *Nautilis* 99: 53-57.

Rowell, T. W., and D. R. Chaisson. 1983. Distribution and abundance of the ocean quahog (*Arctica islandica)* and Stimpson's Surf Clam (*Spisula polynyma*) resource on the Scotian Shelf. *Can. Ind. Rept. Fish. and Aquat. Sci.* No. 142: 69 p.

Rowell, T. W., D. R. Chaisson, and J. T. McLane. 1990. Size and age at sexual maturity and annual gametogenic cycle in the ocean quahog *Arctica islandica* (Linnaeus, 1767), from coastal waters in Nova Scotia, Canada. *J. Shellfish Res.* Vol. 9, No. 1, 195-203.

Steingrimsson, S. A., and G. Thorarinsdottir. 1995. Age structure, growth and size at sexual maturity in ocean quahog, *Arctica islandica* (Mollusca: Bivalvia), off NW Iceland. *ICES CM 1995/K*: 54

Thompson, I., D. S. Jones, and J. W. Ropes. 1980. Advanced age for sexual maturity in the ocean quahog *Arctica islandica* (Mollusca: Bivalvia). *Mar. Biol.* 57: 35-39.

Table 1. St. Mary's Bay ocean quahog Survey. Set Locations, Volume and Weight of Catch, Distance and Area per Tow. Weights estimated from volume for stations 11-30.

Set No.	Latitude	Longitude	No. Boxes	Catch Wt.(kg.)	Tow Dist.(m)	Area (m2)	kg./m2
1	441230	661762	4	96	78.58	63.87	1.50
2	441229	661836	4.5	108	13.14	10.68	10.11
3	441235	661912	3.3	79.2	33.16	26.95	2.94
4	441248	662002	2.25	54	21.96	17.85	3.03
5	441259	662078	0.41	10	27.32	22.21	
6	441296	662057	0.21	5	56.64	46.04	
7	441293	661980	2.1	51	26.28	21.36	2.39
8	441280	661900	5.7	137	21.96	17.85	7.68
9	441271	661817	4.5	110	25.93	21.08	5.22
10	441260	661748	4.8	115	13.83	11.24	10.23
11	441245	661678	5	120	33.16	26.95	4.45
12	441293	661648	5	120	14.18	11.53	10.41
13	441316	661704	4	96	12.79	10.40	9.23
14	441317	661792	4.5	108	65.68	53.38	2.02
15	441322	661872	4.6	110	31.75	25.81	4.26
16	441198	661950	1	24	32.89	26.73	0.90
17	441181	661888	2	48	13.49	10.96	4.38
18	441171	661796	4.7	112.8	45.11	36.67	3.08
19	441206	661703	4	96	13.83	11.24	8.54
20	441195	661603	5.75	138	61.38	49.89	2.77
21	441186	661531	4.2	102	57.09	46.40	2.20
22	441132	661479	3.5	84	79.14	64.32	1.31
23	441151	661626	4.5	108	55.96	45.48	2.37
24	441161	661696	6.5	156	62.27	50.61	3.08
25	441110	661668	4	96	47.1	38.28	2.51
26	441097	661588	4.2	100.8	44.12	35.86	2.81
27	441086	661514	2.25	54	54.84	44.57	1.21
28	441080	661430	2	48	61.24	49.78	
29	441246	661560	3.5	84	43.47	35.33	2.38
30	441239	661509	2	48	61.38	49.89	
				Mean Wt.	Mean Dist.		Mean kg./m2
				87.29	40.32		4.27

Table 2. Weight and Length Data on ocean quahogs Sampled from Station30.

Length(mm)	Total Wt.(g)	Meat Wt.(g)	Shell Wt.(g)	Water (g)
77	130.25	24.8	80.49	24.96
74	90.74	23.79	64.91	2.04
78	126.23	26.61	67.54	32.08
73	88.36	13.66	52.84	21.86
88	145.84	32.72	74.96	38.16
70	99.27	19.6	60.11	19.56
74	103.56	22.51	53.3	27.75
83	140.75	27.29	76.6	36.86
69	75.31	14.77	40.56	19.98
59	42.73	9.69	31.86	1.18
80	133.55	24.8	broken	
87	166.55	34.52	89.33	42.7
78	117.27	23.93	61.46	31.88
53	34.51	4.08	17.76	12.67
68	78.42	14.09	43.72	14.25
92	197.45	35.99	111.38	50.08
56	47.01	7.89	25.84	13.28
74	97.91	20.47	54.9	22.54
79	135.63	26.83	69.05	39.75
68	88.22	16.42	50.72	21.08
66	78.8	14.7	43.75	20.35
86	167.06	32.06	80.46	54.54
74	91.2	18.45	44.6	28.15
76	114.49	25.01	62.01	27.47
72	94.08	19.04	55.08	19.96
50	31.99	5.55	18.68	7.76
78	117.35	22.04	66.65	28.66
80	141.87	29.3	77.27	35.3
75	107.41	19.59	62.27	25.55
73	105.39	21.96	55.73	27.7
79	128.99	25.91	65.32	37.76
76	126.6	24	69.5	33.1
76	114.16	18.63	61.45	34.08
78	127.76	23.52	70.07	34.17
78	120.97	25.27	60.38	35.32
70	91.54	17.61	51.58	22.35
91	202.21	40.08	110.05	52.08
84	151.47	24.73	89.39	37.35
81	122.58	24.32	61.5	36.76
81	148.84	29.82	91.73	27.29
82	146.31	26.21	79.2	40.9
65	63.71	10.78	33.35	19.58
83	156.57	28.97	88.62	38.98
91	183.95	34.82	100.92	48.21
91	182.92	37.02	84.84	61.06

Table 2. Cont'd

Length(mm)	Total Wt.(g)	Meat Wt.(g)	Shell Wt.(g)	Water (g)
83	136.23	27.17	66.06	43
66	80.68	13.45	45.86	21.37
70	85.21	16.23	44.21	24.77
53	39.51	6.57	21.67	11.27
68	94.19	17.72	54.02	22.45
73	104.56	14.26	52.19	38.11
70	110.18	18.78	65.01	26.39
66	69.55	13.48	35.62	20.45
88	156.77	31.88	84.92	39.97
73	100.52	17.58	53.61	29.33
65	63.23	7.82	33.18	22.23
59	47.62	8.08	25.51	14.03
76	116.58	23.03	63.87	29.68
66	73.28	13.52	38.08	21.68
77	119.13	22.68	61.75	34.7
69	76.71	15.29	36.77	24.65
62	66.47	12.91	37.77	15.79
60	62.02	11.83	34.04	16.15
58	49.8	6.08	26.92	16.8
64	71.47	11.1	41.55	18.82
59	51.21	8.08	25.15	17.98
64	63.91	10.74	35.14	18.03
79	121.86	23.61	69.2	29.05
87	183.6	28.99	97.99	56.62
87	158.36	33.5	88.74	36.12
92	199.25	29.62	95.01	74.62
85	173.01	39.79	98.69	34.53
89	216.66	32.69	132.98	50.99
86	160.5	31.44	78.36	50.7
83	149.97	26.85	83.48	39.64
65	69.11	9.24	broken	
75	112.4	19.69	60.01	32.7
63	64.04	11.7	37.82	14.52
56	53.82	8.65	32.51	12.66
77	119.17	25.11	66.29	27.77
63	68.18	12.78	30.92	24.48
76	109.24	21.99	34.12	53.13
62	62.38	9.18	38.9	14.3
72	89.04	18.17	44.55	26.32
75	101.24	20.55	49.98	30.71
77	109.04	17.96	56.05	35.03
79	136.18	26.68	76.98	32.52
67	85.47	14.31	46.92	24.24
78	121.87	22.66	69.87	29.34
87	165.73	29.72	94.73	41.28
74	100.5	17.32	49.91	33.27
82	135.69	25.18	63.96	46.55

Table 2. Cont'd.

Length(mm)	Total Wt.(g)	Meat Wt.(g)	Shell Wt.(g)	Water (g)
91	172.61	37.61	117.36	17.64
69	71.71	11.8	40.23	19.68
77	144	22.9	86.68	34.42
78	118.83	23.37	61.99	33.47
73	108.52	21.25	58.37	28.9
62	59.97	9.92	29.32	33.86
58	51.58	7.05	28.34	16.19
66	73.63	11.39	40.93	21.31

Table 3. Size and age-at-maturity of ocean quahogs from three regions.

	Mean Size (mm) and Age (yrs) at-Sexual-Maturity				Sex Ratio	Reference
Location	Male		Female		M:F	
S.W. Nova Scotia	47.1	(13.1)	49.2	(12.5)	2:1	Rowell et al. (1990)
Eastern U.S.A.	47.1	(9.8)	55.0	(13.2)	4:1 immature 2:1 mature	Ropes & Murawski (1980)
Iceland	55.0	(49.0)	55.0	(56.0)	larger animals all female	Steingrimsson & Thorarinsdottir (1995)

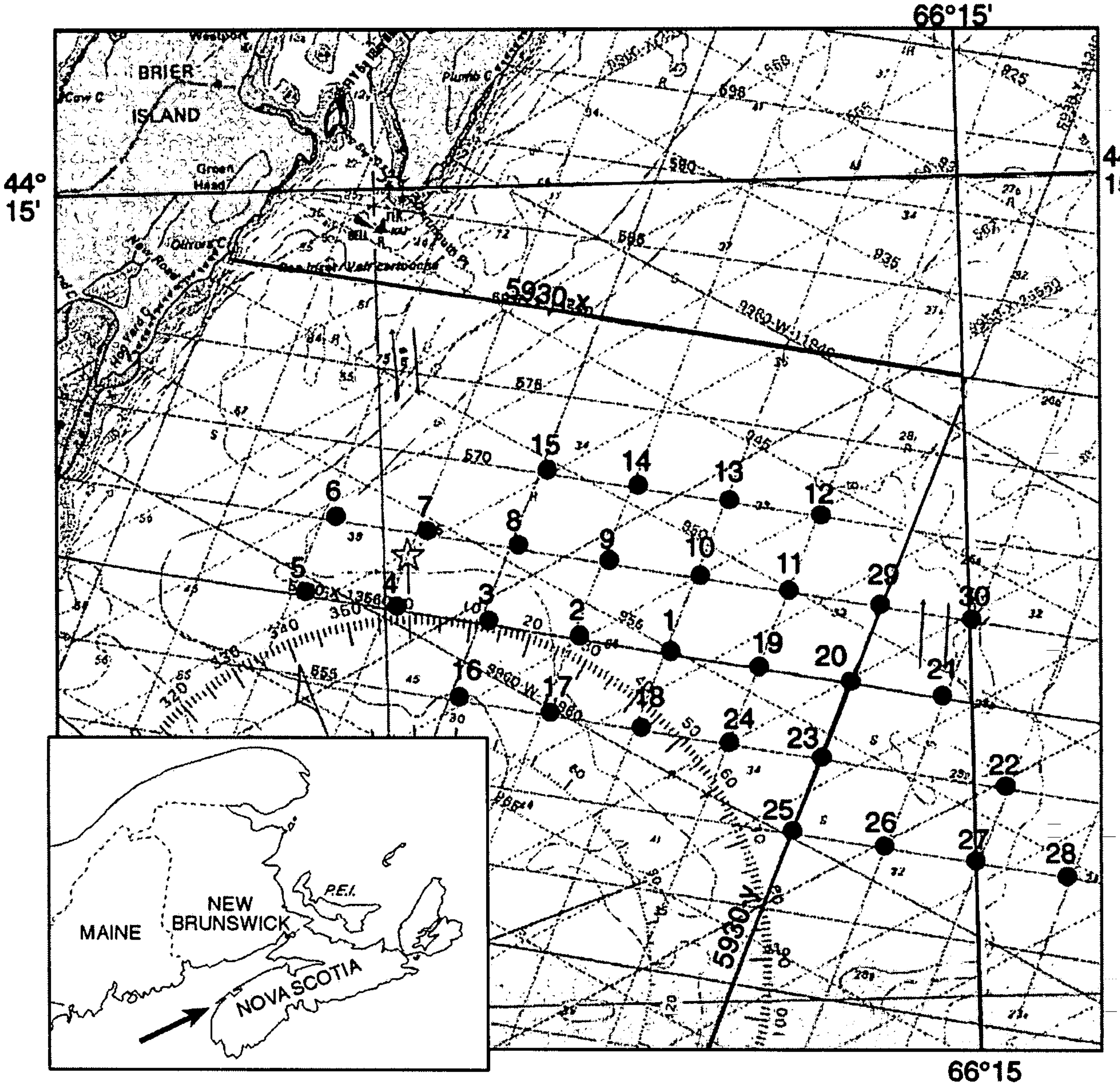

Figure 1. St Mary's Bay Ocean Quahaug Survey. Location of stations and station numbers.

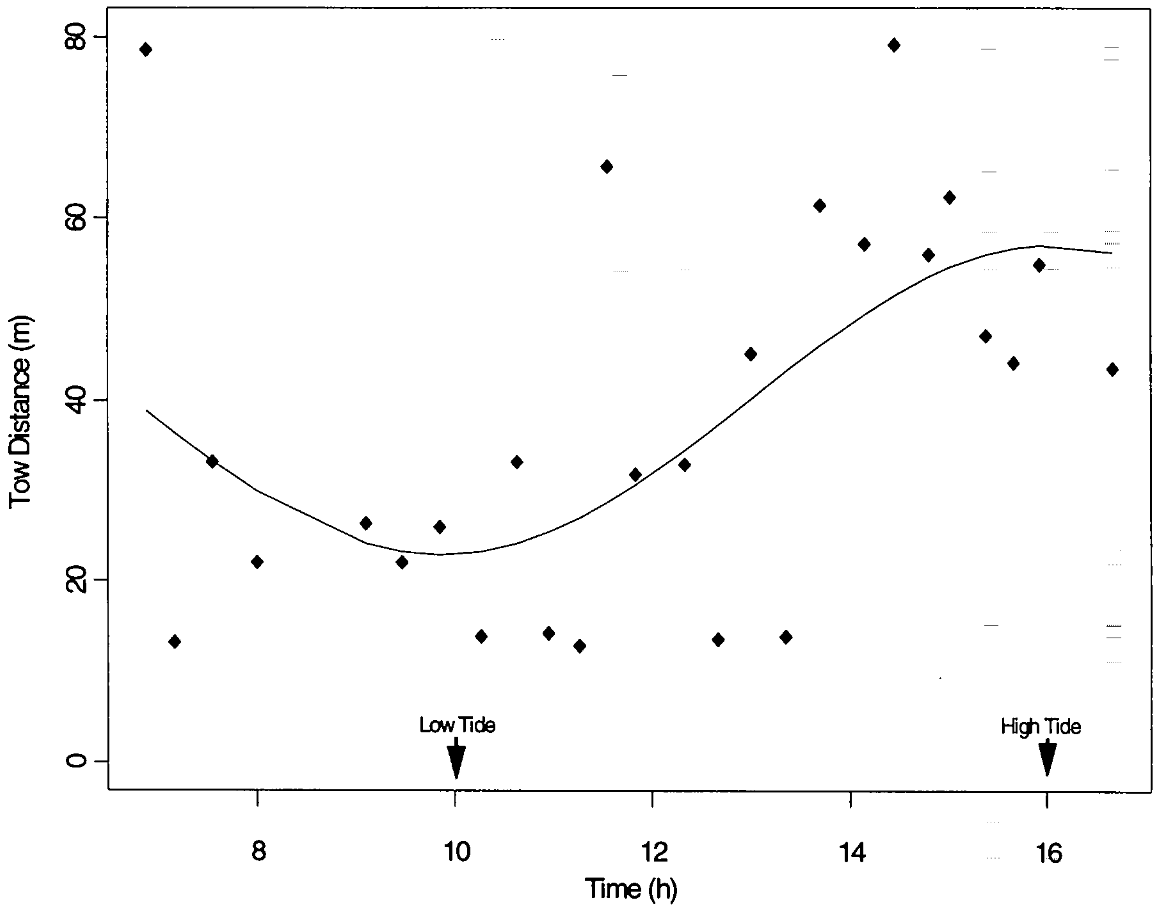

Figure 2. Distance towed as a function of time of day from 27 July survey in St. Mary's Bay. Fitted line is from the tidal model described in the text. Times for low and high tide are indicated.

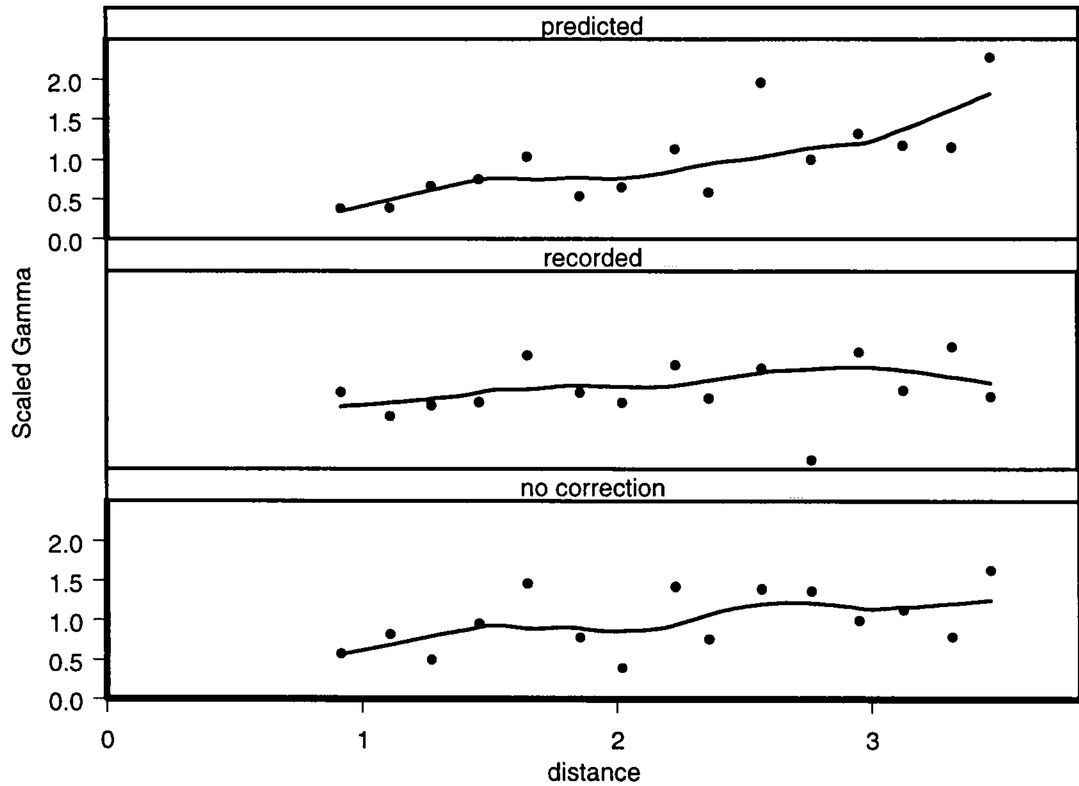

Figure 3. Scaled variograms for weight of quahaugs per standard tow where standard tow was defined as, a) a constant distance towed (no correction), b) the distance recorded from the GPS receiver, or c) the distance predicted from the tidal model in the text.

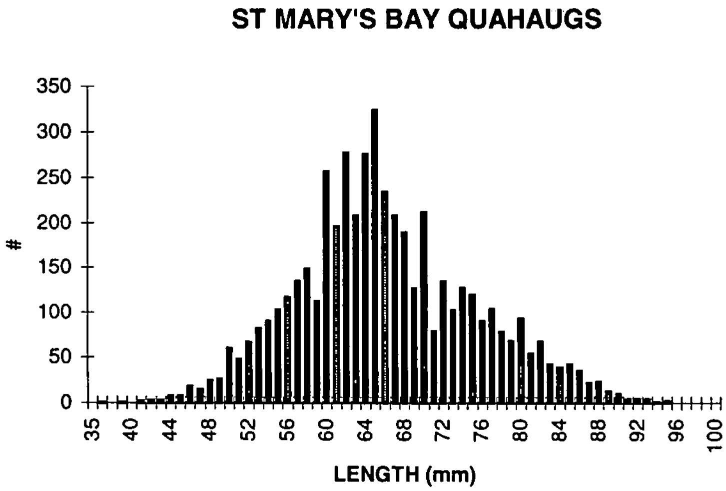

Figure 4. Size frequency St. Mary's Bay quahogs.

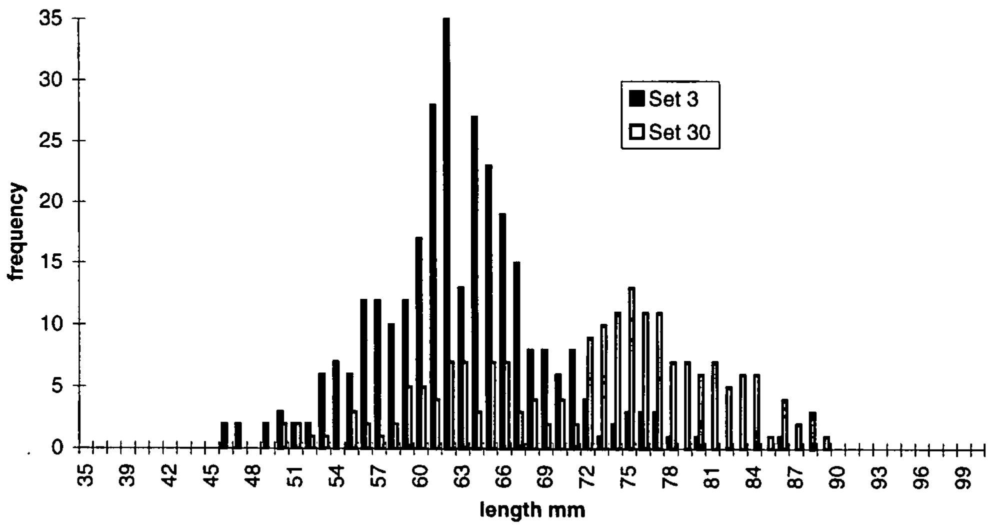

Figure 5. Size frequencies station # 3 (n=304), station # 30 (n=164).

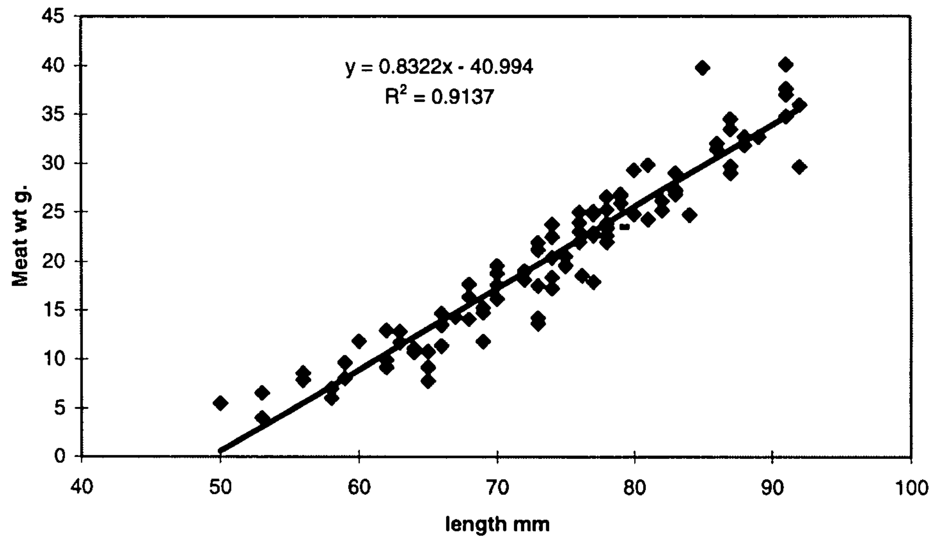

Figure 6. Meat yield as a function of length for St. Mary's Bay quahogs.