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Assessment Protocol for the Commercial Harvest of Pacific Oysters (*Crassostrea gigas)* in British Columbia

Tammy C. Norgard, Graham E. Gillespie and Michelle I. Bigg

Fisheries and Oceans Canada
3190 Hammond Bay Road
Nanaimo, BC V9T 6N7

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems 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.

Fisheries and Oceans Canada
Canadian Science Advisory Secretariat
200 Kent Street
Ottawa ON K1A 0E6

http://www.dfo-mpo.gc.ca/csas-sccs/
csas-sccs@dfo-mpo.gc.ca

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ABSTRACT

This document evaluates the assessment and management frameworks utilized by the BC Ministry of Agriculture (BC MoA) for the commercial harvest of wild Pacific Oyster (*Crassostrea gigas*) in B.C. and proposes an assessment protocol for use by Fisheries and Oceans Canada (DFO) and Industry to guide DFOs management and regulation of the fishery which was delegated in 2012. The primary results of the study include the recommendation to utilize a stratified random sampling survey design on high density discrete Pacific Oyster beds using a square quadrat size of 75 cm x 75 cm or greater. The recommended sampling intensity is 10 quadrats per hectare with a minimum sample size of 5 quadrats per stratum.

Protocole d'évaluation visant la pêche commerciale de l'huître du Pacifique (*Crassostrea gigas*) en Colombie-Britannique

RÉSUMÉ

Ce document évalue les cadres de gestion et d'évaluation utilisés par le ministère de l'Agriculture de la C.-B. pour la récolte commerciale d'huîtres du Pacifique (*Crassostrea gigas*) sauvages dans la province et propose un protocole d'évaluation que Pêches et Océans Canada (MPO) et l'industrie pourront utiliser afin de guider la gestion et la réglementation de la pêche par le MPO, responsabilité qui lui a été déléguée en 2012. Les résultats primaires de l'étude sont notamment la recommandation d'utiliser pour les relevés des bancs d'huîtres individuels à haute densité une conception d'échantillonnage aléatoire stratifié en utilisant un quadrat carré de 75 cm sur 75 cm ou plus. L'intensité recommandée de l'échantillonnage est de 10 quadrats par hectare, avec une taille d'échantillon minimale de 5 quadrats par strate.

INTRODUCTION

Legislative rights to Canada's inland and coastal fisheries were initially vested in the Federal Government by the British North America Act of 1867, which provided jurisdiction over all tidal and non-tidal fisheries except those in Quebec (Quayle 1969, 1988; Parisien 1972). Through a series of petitions, legal decisions and agreements, jurisdiction over tidal fisheries came to rest with the Federal Government (they are also responsible for anadromous species) and jurisdiction over non-tidal fisheries with the Provincial Government (Parisien 1972). The sole tidal fishery exception was oysters; an agreement between British Columbia (BC) and the Dominion of Canada in 1912 delegated responsibility for oyster harvests to the Province (Appendix Figure 1).

In December 2010, Justice C.E. Hinkson ruled on a petition before the BC Supreme Court, thereafter referred to as the Hinkson decision[1]. The ruling concluded that aquaculture (with the exception of marine plant cultivation) was, by definition, a fishery rather than agriculture and therefore management and regulation fell under Federal rather than Provincial jurisdiction.

In addition to shellfish aquaculture, the Province also managed and regulated the harvest of "wild" Pacific Oysters from Crown foreshore[2]. This fishery may have its roots in the recovery of stock washed outside of lease boundaries prior to successful recruitment and establishment of Pacific Oyster stocks beyond aquaculture tenures. Although not explicitly addressed in the Hinkson decision, this endeavor is also clearly a fishery and thus belongs under Federal jurisdiction as per the pith and substance of the Hinkson decision.

This document evaluates the assessment and management frameworks utilized by the BC Ministry of Agriculture (BC MoA) for the wild oyster harvest and proposes Pacific Oyster assessment protocol for use by the Fisheries and Oceans Canada (DFO) and Industry as DFO assumes responsibility for management and regulation of the fishery.

PACIFIC OYSTER

The Pacific Oyster, *Crassostrea gigas* (Thunberg 1793) is a non-indigenous species introduced to BC for aquaculture (Quayle 1964, 1969, 1988; Gillespie *et al*. 2012). Its native range is from Sakhalin Island and coastal Russia through Japan to Kyushu, China, Korea, Southeast Asia and Pakistan (Coan *et al*. 2000). They have been introduced and have established populations in many countries worldwide (Ruesink *et al*. 2005, Gillespie *et al*. 2012).

The Pacific Oyster was introduced extensively on the west coast of North America in the early 1900s, and was first brought into BC in 1912 or 1913 (Bourne 1979, Gillespie *et al*. 2012). Small scale introductions continued and large scale importation of seed oysters began in 1925. Successful reproduction was reported in Ladysmith Harbour in 1925, 1926 and 1932, followed by successful dispersal beyond the harbour in 1936 (Elsey 1932, 1934; Elsey and Quayle 1939; Quayle 1964, 1969, 1988; Bourne 1979). Widespread reproductive success was reported in 1942, 1958 and 1961 resulting in the establishment of Pacific Oysters throughout the Strait of Georgia. They were transplanted to the west coast of Vancouver Island (Esperanza Inlet; Barkley, Clayoquot and Kyuquot Sounds) in 1937; they are now established in suitable habitats

[1] *Morton v. British Columbia (Agriculture and Lands)*, 2009 BCSC 136, Docket S083198.

[2] Oyster aquaculture primarily occurs on Crown foreshore tenured from the Province of BC. Pacific oyster stocks on untenured foreshore are considered "wild" (Bourne 1979, IEC International 2006).

on the west coast of Vancouver Island south of Brooks Peninsula (Gillespie 2007; Gillespie *et al*. 2012). There is also confirmed reproductive success of Pacific Oysters in Skidegate Inlet, Haida Gwaii (Sloan *et al*. 2001; Gillespie *et al*. 2012) and reported occurrence of natural-set Pacific Oysters from Tasu Sound on the west coast of Haida Gwaii (Gillespie, unpublished data).

BIOLOGY

Pacific Oysters are protandric hermaphrodites, initially spawning as males and then may become females during the winter season (Gillespie *et al*. 2012). They are broadcast spawners with a pelagic larval period of 3-4 weeks depending on temperature (Gillespie *et al*. 2012). Their natural distribution in BC is limited to locations with warmer water temperatures that are required to stimulate gonadal development, spawning and the metamorphosis of larvae. Although spawning can occur at temperatures between 16-34 ºC and salinities ranging from 10-42%; temperatures of 20-25 ºC and salinities of 35% are considered optimal (Gillespie *et al*. 2012). However, the range of Pacific Oysters can be expanded by manual introduction to microhabitats. Adults are sessile and the only exchange between sites is through larval transport or human intervention. Adults grow relatively quickly in the first few years after settlement and growth slows with maturity and senescence.

Longevity and age structure of populations are not documented due to difficulties in establishing aging methods and criteria. New methods for aging Pacific Oysters have been tested on Pacific Oysters in China (Harding and Mann 2006), but these methods still need to be tested for the Pacific Oysters in BC. Both the literature and local knowledge suggest that Pacific Oysters can live for decades (Quayle 1988, Pauley *et al*. 1988).

Pacific Oyster populations in BC generally occur in mid to high intertidal zones on hard substrates (Bourne 1979, Ruesink *et al.* 2005) but can vary depending on the environmental conditions of the site. Fishermen have noted that Pacific Oysters are lower in the intertidal zone on the west coast of Vancouver Island (K. Vautier, Pacific Oyster fishermen, Parksville, BC, personal communication, 2012). A preferred settlement substrate is oyster shell and large aggregations form if populations are not disturbed; under appropriate conditions they can form reefs on gravel banks at the tidal mouth of small streams (Gillespie *et al*. 2012). Harvestable populations of Pacific Oysters may be present on bedrock walls and outcrops where successful larval recruitment occurs on a regular basis.

In all but a few locations in BC, successful recruitment on a large scale is sporadic. Pacific Oyster populations can exhibit local recruitment events that will sustain populations for a number of years. However, populations can become ephemeral if larval recruitment is irregular.

HARVEST

Aquaculture

Following depletion of Olympia Oyster (*Ostrea lurida* [Carpenter, 1864]) populations (Gillespie 2009) and brief attempts to culture Eastern oysters (*Crassostrea virginica* [Gmelin, 1791])(Carlton and Mann 1996), the aquaculture industry in BC moved to almost complete reliance on Pacific Oysters in the 1920s (Quayle 1969, 1971, 1988; Bourne 1979). Early aquaculture efforts were limited to select harbours and bays in the Strait of Georgia, but Pacific Oysters were subsequently transplanted to the west coast of Vancouver Island in the 1930s, where they flourished. Early attempts to establish culture operations in northern BC in the 1960s were not successful (Quayle 1971, Bourne 1979).

Cultured oysters accounted for annual landings of 4.9 to 8.3 thousand metric tonnes (Kt) and annual landed values between $5.0 and $8.9 million (M) dollars between 1996 and 2010 (Table 1; BC MoA 1999-2011a,b).

Fisheries

The commercial harvest of wild Pacific Oysters from untenured Crown foreshore began after significant widespread recruitment events in 1942 and 1958 (Bourne 1979). Participants in this fishery are mainly aquaculturists who use the oysters collected as seed stock for their leases; there also are number of First Nations communities involved in the fishery. Historically, the fishery has primarily occurred in spring months on selected beaches on the east and west coasts of Vancouver Island (Figure 1 to Figure 4).

Recently, the fishery was regulated by the Provincial Government through issuance of annual permits; each permit identified an Individual Quota (IQ) and each harvest site (which may support multiple permits) had associated Total Allowable Catches (TACs)(IEC International 2006). The harvested oysters were utilized as supplemental seed for further grow out on aquaculture tenures or as product going directly to market. Between 1998 and 2003, these landings accounted for 1.1 to 2.7% of total commercial production of Pacific Oysters in BC and the remaining 97.3 to 98.9 comes from the aquaculture industry (Table 1; BC MoA 1999-2011a,b; IEC International 2006). In 2005 a harvest of 158 tonnes was valued between $162,000 to $248,000 for 97 quotas over 52 individuals (IEC International 2006).

Commercial harvests of wild Pacific Oysters are not explicitly documented in Provincial reports of seafood production; if tracked at all, they are included in an “Other” category (with squid, octopus and other unspecified shellfish)(BC MoA 1999-2011a,b). This category accounted for between <100 and 700 t of harvest and landed values of $0.1M to $4.8M between 1996 and 2010 (Table 1).

There are also noncommercial harvests of Pacific Oysters by First Nations and in the recreational sector. Statistics on landings and values from these fisheries are extremely limited.

BC MANAGEMENT AND ASSESSMENT FRAMEWORKS

MANAGEMENT FRAMEWORK

The commercial fishery for wild Pacific Oysters provided oysters both for re-stocking of leases for eventual sale (after an appropriate grow-out or relay period) and direct sale to processors. Information in the following section comes largely from discussions with Provincial staff; no published management plan for Pacific Oysters in BC exists.

Licensing

Fishers wishing to harvest Pacific Oysters would apply annually for Individual Quotas (IQs) at specific sites; applications (Appendix Figure 2; BC MoA 2011e) were accepted up to January 31 of the fishing year (fishing year begins January 1 and ends December 31). Harvest permits were issued for a 30-day period (BC MoA 2011d). The permit was not specific to the holder, others could harvest and land product in the name of the license holder. In recent years, permits were issued to corporate entities, not limited to individuals (which has implications regarding transferability). Fishers could apply for IQs at multiple sites but not multiple IQs at a given site; the fishery was essentially controlled by the number of licensed sites and overall Total Allowable Catches (TAC).

Fishers paid an application fee of $75 (non-refundable in policy, but many exceptions in practice occurred)(BC MoA 2001e). Fishers also paid a royalty of $25/t post-harvest, based on selfreported landings documented on daily harvest logs (timing of submission was not specified). There was little audit of the logbook program, which was used to document landings and landed value of the fishery by the Province.

Fishers were required to obtain a Fishers Registration Card from DFO (annual requirement). Movement of oysters from waters classified as contaminated to leases required dual licensing from the Provincial and Federal governments (Management of Contaminated Fisheries Regulations). Authority to harvest was also limited by DFO/CFIA (Canadian Food Inspection Agency) area closures for biotoxin issues.

Individual Quotas, Total Allowable Catches and Harvest Rates

Defined IQs were not less than one ton and not more than 10 t (tonne) per fisher per site (i.e., 1 t ≤ IQ ≤ 10 t). Overall TAC for any harvested site was managed to a target of ≤20% of estimated biomass; discussions with Provincial staff indicated that final harvest rates were generally in the range of 10-14% of the estimated biomass. Core sites received multiple applications; if the overall TAC could not support the number of applications a lottery system was used to select successful applicants.

Preferred timing of the fishery was late February to June, avoiding late-summer issues with *Vibrio parahaemoliticus* and reduced condition of oysters after spawning. In practice, multiple permits per harvester and biotoxin closures often resulted in the fishery continuing through September (and occasionally into October).

Consultation, primarily with First Nations and upland owners, was conducted annually and very time consuming; this led to complaints from prospective harvesters regarding delays in permit issuance. Sites excluded from consideration included recreational map reserves, First Nations map reserves, many areas fronting National or Provincial Parks or Ecological Reserves and most contaminated areas[3] (BC MoA 2011c). Also excluded from consideration was the entire southern Gulf Islands region.

Permit duration, notification requirements, *Vibrio* and product quality issues, biotoxin considerations and the vagaries of harvester activities complicated enforcement activities. Lack of validation of reported landings made defense against allegations of overharvest difficult (although it was unclear whether public perception of overharvest was due to regulated fishery activities or illegal harvests [poaching]).

ASSESSMENT FRAMEWORK

The Provincial assessment framework was based on annual estimates of biomass of Pacific Oysters in proposed harvest areas. The framework specified post-harvest assessment of areas with a follow-up visual assessment in the spring to ensure winter mortality or unregulated harvest had not drastically affected the post-harvest estimates.

Some of these areas were consistently requested (Figures 1-4) but the open-ended nature of the management framework (i.e., fishers could apply for whichever sites merited interest) greatly complicated assessment requirements for the fishery. In general, the framework aspired to annual assessments of harvest areas in the fall, post-harvest. However, the January deadline for applications precluded complete assessment of requested harvest sites in the fall.

[3] We have not assessed alignment of Provincial and DFO recreational closures.

BC ASSESSMENT PROTOCOL

DESCRIPTION

Provincial assessments followed standard procedures for intertidal assessments, i.e., the expansion of density estimates of the desired characteristics of the population over an estimated area representative of that population. The surveys were limited to daylight low tides (unspecified depth) and generally started in March each year. The spring assessment was largely visual, with expert surveyors confirming bed areas using GPS from small boats and providing a subjective expert-based confirmation of density. Table 2 lists the beaches and number of beds/strata surveyed by the Provincial crew between 2005 and 2010.

Provincial survey protocols were documented from discussions and a single joint survey undertaken with Provincial and DFO staff in 2011.

Bed area was determined by one member of the survey crew walking the subjectively determined perimeter of the oyster bed and taking regular positions on a hand-held GPS unit. The density of oysters (in terms of biomass) was obtained by survey crew members tossing three 1 m^2 survey quadrats in a haphazard fashion within the bed area. Oysters were counted inside the quadrat if half or more of their height was within the quadrat; on two pre-determined sides of the quadrat oysters close enough to “half-in” were included in the count and oysters on the remaining two sides were excluded. Live oysters were cleaned of attached shell and substrate, weighed in aggregate and the total weight of live oysters for the quadrat recorded.

These data were later combined in a spatial analysis (undocumented) to produce estimates of total biomass for the stratum.

EVALUATION

A table of historic estimates provided by the Province indicated that a number of sites had not been surveyed recently, whether because they had not been requested or due to diminishing budgets (Table 2). “Conservative” TACs were proposed for some sites based on previous survey estimates that were 1-2 years old and anecdotal information.

Original survey data were not available from the Province, only estimates of bed area, density and total biomass were provided to DFO; none included estimates of variability (confidence intervals). Estimates of biomass were not reproducible by mathematical combination of area and density estimates; the exact method by which the estimates were derived could not be determined.

Delineation of bed margins is less troublesome for oysters, which grow on the surface, than for infaunal bivalves. For oysters, visual determination is required, whereas digging test holes and establishing density thresholds is required for infaunal bivalves. Repeatability of bed area estimation may vary somewhat between different surveyors, but relatively consistent bed boundaries are usually discernible. Delineation of oyster bed areas usually results in a conservative estimate of biomass, as it excludes a portion of the population that occurs scattered in low density outside of distinct beds.

The haphazard sampling (*ad hoc*, potentially purposive) protocol used in visually selecting quadrat locations introduces the possibility for surveyors to bias (either upward or downward) the biomass estimate, resulting in biased estimates of mean and variance. This could reduce the reliability of biomass estimates provided by third-party or Industry surveyors. Additionally, the lack of true randomization (i.e., all potential sampling elements have equal probability of selection) violates a major assumption of probability sampling-based methods, including simple or stratified random and systematic random designs (Kronlund *et al*. 1998).

The 1 m^2 quadrat was likely appropriate to reduce edge effect (the determination of whether or not an oyster is to be included in the sample) and the protocol further assists in defining two of four quadrat edges that are inclusive of oysters “too close to call” and two that exclude these oysters.

The sampling intensity utilized was very low (three quadrats per bed/stratum) and just meets the minimum for calculation of informative estimates of variance. Whether this intensity is appropriate could not be determined without original survey data or estimates of variance from previous surveys, neither of which were available.

Expert-based visual surveys were used each spring to assess whether population levels had changed radically from formal fall survey estimates (and may have been used more widely as Provincial program support diminished). Because assessment responsibilities were transferred between agencies without significant overlap for mentoring and development of expertise in DFO, considerable time and resources may be required before reliance on subjective estimates of biomass are considered reliable.

PROPOSED DFO ASSESSMENT PROTOCOL

This protocol has been developed to assist potential harvesters in conducting surveys and data collection of wild Pacific Oysters on beaches in which discrete beds of oysters are found. Discrete beds are those where well defined beds of oysters can be visually determined on beaches. In general, Pacific Oyster populations may be found in discrete beds of single or clustered oysters loose on the surface of the beach or individual oysters cemented to hard substrate (large rocks or bedrock), at times including vertical surfaces.

This protocol provides key guidance on sampling and data collection methodology, optimal quadrat size and sampling intensity for discrete oyster beds. This study also gives the background and rationale behind the importance of determining accurate Pacific Oyster population abundance and biomass estimates. The ultimate goal in development of the protocol is to ensure that accurate and standardized stock information is collected so that it can then be utilized by DFO to develop IQs and TACs in the short term and sustainable harvest strategies for specific beaches in the long term.

STRATIFIED RANDOM SAMPLING SURVEY METHOD AND ANALYSIS

The first objective of the protocol was to establish the primary methodology for surveying Pacific Oyster beds that will be commercially harvested. A review of seven different survey protocols was completed when developing survey methods for Olympia Oysters (Norgard et. al. 2010). The results of the Olympia Oyster study selected the Two Stage sampling design for Olympia Oyster because their populations are often more patchy and this survey design spreads the surveying across the bed. Whereas the populations of Pacific Oysters to be surveyed for commercial interest will be quite dense and fairly evenly distributed; therefore we recommend using a Stratified Random Sampling (StRS) design which is already widely in use for bivalve species in BC.

The StRS method to survey Pacific Oysters was tested when DFO conducted surveys during summer low tides in 2012, at Shack Island (49 13.687 N, 123 57.272 W) and Neck Point (49 14.121 N, 123 58.211 W) in Nanaimo, BC. These beaches were chosen because the Pacific Oyster populations were dense and evenly distributed across the beaches.

Within the boundaries of the discrete beds, sampling units or strata (non-overlapping groups) were defined and a simple random sample was drawn from each group (quadrats) (Figure 5). Determining the number of strata is dependent on the physical characteristics of the beaches and prior knowledge of the site. Stratification can be useful in dividing the beach into manageable survey units to account for specific population characteristics. For example, high density areas of a bed may be partitioned into a stratum separate from areas of lower density. Thus, one stratum may differ markedly from another but variability within the stratum would be small. If no prior knowledge of the beach exists it is possible to stratify by substrate type or tidal elevation. In the case of Pacific Oysters, epifaunal beds are relatively easily delineated and strata represent distinct aggregations.

A key feature of the StRS method is that a sample (quadrat) is selected from each stratum independently of other strata and quadrats can be randomly placed throughout strata using a random number generator. Randomization provides a fair and repeatable means of avoiding bias in the selection of sampling sites (Kronlund *et al*. 1998).

For the 2012 surveys in Nanaimo, the primary surveyor walked the beach using a Trimble GPS (Trimble Pro XT) logging waypoints to delineate the boundaries of discrete oyster beds. At Neck Point, three surveyors undertook the same procedure to determine boundaries of the oyster bed with the Trimble. The result was that each surveyor mapped almost identical beds to each other, confirming that the boundaries of the discrete bed were obvious and discernible (Tammy Norgard, Fisheries and Oceans, Nanaimo, BC, unpublished data). A single stratum was setup to cover as much of this discrete bed as possible. At Shack Island, two strata were established to account for two higher density areas that were separated by a low density area and because of the curvature of the beach. By setting up two separate strata we were able to reduce variability with each stratum.

At the Nanaimo sites, the strata were divided into 1 m by 1 m quadrats. At Neck Point 80 random quadrats were selected for sampling within one stratum of size 1125 m^2. At Shack Island 15 and 25 quadrats in stratum 1 (1925 m^2) and stratum 2 (2150 m^2) respectively were selected. At each quadrat location the total weight of oysters was recorded for four different nested quadrat sizes, details on this examination is found in the ‘Optimal Quadrat Size’ section (p. 10).

To obtain weights, surveyors started from the smallest sized quadrat (25 cm x 25 cm) and broke excess shell and rock from oysters using a small hammer and then weighed all the oysters together. The number of oysters was recorded and oysters were then placed in a metal basket to obtain an aggregate weight using a hand held digital fish weighing scale. The weight of the basket was subtracted to obtain the true oyster weight in kilograms. This was repeated for each quadrat size at each sampling site within the stratum. From these weights an estimate of abundance and biomass was calculated for each stratum (Table 3).

This methodology does not include sampling oysters outside the stratum (Figure 5); therefore the biomass and abundance estimates are not extrapolated to determine biomass or abundance of oysters of the entire bed. This results in a conservative estimate of biomass that can be used to set a sustainable harvest rate.

The survey data collected from both beach surveys in 2012 were used to determine optimum quadrat size and sampling intensity for Pacific Oysters.

Estimating the Population Mean

One objective of the survey is to estimate the mean density (number and weight) of oysters in the survey area. Statistical notation for the equation listed in this section is provided in Appendix Table 2 and are list below;

h stratum index,

H maximum strata number,

i — y-value index,

N — total number of sampling units (quadrats) in the population,

N_h — total number of sampling units in stratum h,

n — number of units (quadrats) in the sample, or sample size,

n_h — number of units in the sample from stratum h,

$\bar{y}_h$ — estimated population mean density in stratum h,

y_{hi} — y-value i in stratum h (number of oysters) ,

μ — population mean,

τ — population total

$\bar{y}$ — estimated population mean,

$\hat{V}(\bar{y})$ — estimated variance of the population mean,

$\hat{\tau}$ — estimated population total,

$\hat{V}(\hat{\tau})$ — estimated variance of the population total,

s_h^2 — sample variance in stratum h,

$z_{\alpha/2}$ — t-value may be replaced with this estimator for large sample sizes

a_h — variable within Satterthwaite's approximation

The mean density over the surveyed area (weighted mean of strata densities) for a given beach or harvest area is estimated as:

$$\bar{y} = \frac{1}{N}\sum_{h=1}^{H} N_h \bar{y}_h \qquad (1)$$

The variance of the mean is estimated as:

$$\hat{V}(\bar{y}) = \frac{1}{N^2}\sum_{h=1}^{H} N_h^2 \left(\frac{N_h - n_h}{N_h}\right)\frac{s_h^2}{n_h} \qquad (2)$$

where

$$s_h^2 = \frac{\sum_{i=1}^{n_h}\left(y_{hi} - \overline{y}_h\right)^2}{n_h - 1} = \frac{\sum_{i=1}^{n_h} y_{hi}^2 - \left(\sum_{i=1}^{n_h} y_{hi}\right)^2 \Big/ n_h}{n_h - 1} \qquad (3)$$

An estimate of the total number or weight (where *y* is either number or weight depending on the estimate) of oysters in the survey area can be obtained by expanding the mean estimate over the total surveyed area:

$$\hat{\tau} = N\overline{y} = \sum_{h=1}^{H} N_h \overline{y}_h \qquad (4)$$

The variance associated with this estimate can be calculated as:

$$\hat{V}\left(\overline{y}\right) = \frac{1}{N^2}\sum_{h=1}^{H} N_h^2 \left(\frac{N_h - n_h}{N_h}\right)\frac{s_h^2}{n_h} \qquad (5)$$

where

$$s_h^2 = \frac{\sum_{i=1}^{n_h}\left(y_{hi} - \overline{y}_h\right)^2}{n_h - 1} = \frac{\sum_{i=1}^{n_h} y_{hi}^2 - \left(\sum_{i=1}^{n_h} y_{hi}\right)^2 \Big/ n_h}{n_h - 1} \qquad (6)$$

Confidence Intervals

Confidence intervals for population parameters can be computed in a variety of ways for stratified random sampling. The choice of the method may depend on the sample size within each stratum, or on whether normality is assumed.

When the sample size within each stratum is greater than 30 units, then the normal approximation may be used. For the population mean:

$$\overline{y} \pm t_{\alpha/2,d}\sqrt{\hat{V}\left(\overline{y}\right)} \qquad (7)$$

For the population total:

$$\hat{\tau} \pm t_{\alpha/2,d}\sqrt{\hat{V}\left(\hat{\tau}\right)} \qquad (8)$$

where t is the upper $\alpha/2$ point of Student's t distribution with d degrees of freedom computed using Satterthwaite's approximation. If sample sizes are large, then the t-value may be replaced with $z_{\alpha/2}$.

When sample sizes are small (as a rule of thumb, less than 30) an adjustment to the degrees of freedom for the t-statistic is appropriate. The adjustment is called Satterthwaite's approximation (Satterthwaite 1946):

$$d = \frac{\left(\sum_{h=1}^{H} a_h s_h^2\right)^2}{\left[\frac{\sum_{h=1}^{H}\left(a_h s_h^2\right)^2}{n_h - 1}\right]} \tag{9}$$

where

$$a_h = \frac{N_h\left(N_h - n_h\right)}{n_h}. \tag{10}$$

If all stratum sizes are equal and all sample sizes are equal, then the degrees of freedom are n-H, where $n = \sum_{h=1}^{H} n_h$.

An alternative to assuming the normal distribution is to use resampling (bootstrap) techniques to compute a non-parametric estimate of the confidence interval. This method is described by Rao and Wu (1988), Sitter (1992), and Kronlund *et al*. (1998).

OPTIMAL QUADRAT SIZE

A second objective of the study was to determine optimal quadrat size for sampling Pacific Oyster. Population estimates are a function of the characteristic of quadrats in relation to the distribution of the species on the beach (Kronlund *et al*. 1998). In this study, the criterion for "optimal" quadrat size was based on the quadrat size that had the least edge effect, lowest variance, best tradeoff for cost (time) and practicality.

The experiment used nested quadrats at Shack Island and Neck Point in Nanaimo, BC, to determine the optimal quadrat size (Krebs 1998, Wiegert 1962, Kronlund *et al*. 1998). Four sizes of square quadrat were used: 25 cm x 25 cm ($0.0625m^2$), 50 cm x 50 cm ($0.25m^2$), 75 cm x 75 cm ($0.5625m^2$) and 100 cm x 100 cm ($1m^2$) (Figure 6).

Edge effect can occur when a sampler decides whether to count an oyster that lay on the quadrat edge as inside or outside the quadrat. Upwardly biased estimates may result from keen samplers counting oysters that lay on quadrat edges as being inside the quadrat. Training of samplers can reduce the edge effect. However, it is better to choose a larger quadrat sizes (75 cm x 75 cm or 100 cm x 100 cm) because they have smaller edge-to-area ratios and reduced edge effects (Wiegert 1962).

If no edge effect was present, it would increase the likelihood that all mean and biomass estimates from the four quadrat sizes (standardized to 1 m^2) would be the same. Results from surveys at Neck Point and Shack Island show that edge effect was present in these surveys since the estimates were not the same for each of the quadrat sizes.. For example, in Table 3, the highest mean biomass (7.18 kg/m^2 and 20.64 kg/m^2) and highest mean abundance (58.00/m^2 and 68.48/m^2) respectively were seen in the smallest quadrat at almost all sites (25 cm x 25 cm).

Wiegert's (1962) method was used to analyze the data collected in nested quadrat experiments for Shack Island and Neck Point to determine optimal quadrat size. This method proposes that the two factors of primary importance in determining sample size are the relative variability in the oyster population and relative cost (time or effort) required to assess abundance or biomass of each quadrat size. The time required to count the number of Pacific Oysters in each of the four quadrat sizes in both strata 1 and 2 at Shack Island was calculated and utilized in Wiegert's analysis. No time data were collected for the Neck Point survey so the time data from the Shack Island survey was used for the analysis of this survey.

This analysis was completed using timed results from the stratum 1 and stratum 2 at Shack Island (Table 4). The optimal cost x variance is calculated using the Weigert analysis. This analysis multiplies a standardized relative variance by a standardized cost (Time).

$$\text{Standardized relative variance} = \frac{(\text{Standard deviation})^2}{(\text{Minimum standard deviation})^2} \times \frac{\text{Standardized}}{\text{Cost}}$$

The lowest standardized cost x standardized variance is the optimal quadrat size. The smallest quadrat (25 cm x 25 cm) was the optimal quadrat in almost all cases using this analysis. However, the smallest quadrat showed relatively high variance in biomass and abundance estimates and the largest edge effect.

When only considering the amount of time to complete surveying of each quadrat relative to the quadrat area (Cost/Quadrat Area column from Table 4) the 75 cm x 75 cm quadrat was the optimal quadrat size (Table 4).

OPTIMAL SAMPLING INTENSITY

The third objective of the study was to determine optimal sampling intensity for any given potential Pacific Oyster harvest site. Two methods were used to determine optimal sample size for Pacific Oyster surveys. In Method 1, precision estimates were calculated using the index of dispersion (Elliot 1977; Method 1). The second method calculates estimates of sample size utilizing a formula from Quinn and Keough (2002; Method 2).

Method 1

Kingzett and Bourne (1998) completed the analysis described below to obtain estimates of precision based on historic butter clam survey data from Seal Island, BC.

The number of sampling units required to achieve a given precision in a study may be predicted with knowledge of the variation within a population (typically from an initial sample or previous surveys) for randomly distributed populations. For populations where the negative binomial distribution is a suitable model (populations with aggregated distributions), the index of dispersion statistic common (k) may be used. To calculate the required number of samples for a given precision, the standard error of arithmetic mean to ratio index of precision (d) was used. The value of d represents the standard error as a percentage of the mean μ . Percentage confidence limits of d about the mean were calculated by incorporating the Student's t-distribution statistic in the equations (t=1.96 for 95% confidence interval). For a negative binomial distribution the number of required samples (n) was solved for various levels of desired accuracy (d) using the following formula (Elliot 1977):

$$N = \frac{t^2}{d\left(\frac{1}{\mu} + \frac{1}{k}\right)} \tag{11}$$

The index of dispersion (k) was approximated using the following formula

$$k = \frac{\mu^2}{\sigma^2 - \mu} \tag{12}$$

Results are presented in Table 5, Figure 7 to Figure 10.

Method 2

We compared the methods of Elliot (1977) and Quinn and Keough (2002) and produced identical results. Quinn and Keough (2002) used the equation:

$$n \geq \frac{z_\alpha{}^2 \sigma^2}{d^2} \tag{13}$$

where *n* is sample size, z_α is the *z* value from a standard normal distribution for the chosen α (we used 1.96 which is 0.05 for the 95% confidence interval), σ^2 is the variance of the population, and *d* is the maximum allowable absolute difference between the true population mean the estimated population mean (tested for a range of 10% to 100% in Table 5).

The calculated optimal number of quadrats to obtain a specified precision about the mean are shown in Table 5. All estimates give the approximate number of samples that would be needed to obtain precision of the mean with 95% confidence. Estimated sample numbers for each survey give a general indication of the precision that should be obtainable in future surveys when the mean and standard deviations are unknown (Table 5, Figure 7 to Figure 10).

The optimal sample size was determined on the result of utilizing Methods 1 and 2 and setting the target for precision of 30% (or better). The precision of 30% has been found to be reasonable measurement of precision for bivalve surveys. Based on these criteria, future surveys of discrete beds require sampling of 6 to 14 quadrats using a 75 cm x 75 cm quadrat size and 4 to 11 quadrats using a 100 cm x 100 cm quadrat size.

Biological Sampling

Pacific Oysters have been studied in detail in relation to aquaculture for the past 100 years but studies of wild oyster populations in BC are very limited (Gillespie *et al*. 2012). There is limited understanding of life history parameters such as growth and recruitment in BC. Pacific Oyster growth is relatively rapid in the first two years and is influenced by wave action, temperature and location on the beach and all these affect the in shell shape (Quayle 1969). Aging studies of Pacific Oysters using the cross section of valves has been successful for oysters collected in China and could help determine growth and maximum age for wild Pacific Oysters in BC, but the method has yet to be validated (Harding and Mann 2006).

Provincial government assessment work has largely focused on weight estimates which did not provide data on populations and stock types (IEC International 2006). A 2006 survey of harvesters showed that while oysters may have been present on the beach, they may not have been the required types or sizes for market needs. Collection of survey information to include size classes and cluster sample (weight clusters) has been suggested as being potentially useful for the industry. This data could be used to partition estimates of biomass or abundance into specific size classes as is done with size limit thresholds in other commercial bivalve surveys.

Oyster height is the largest measurement and is the distance between the umbo and the ventral valve margin (Galtsoff 1964). Height frequency distributions can be used to provide information on the recent recruitment (<30 mm) events but height data for the larger oysters becomes less useful as their shape depends on the habitat in which they grow. If height frequency data was to be collected for oysters, typical requirements for random sample selection and consistent measurement of shell size (*fide* Gillespie and Kronlund [1999] for intertidal clams) are vital.

Biological samples should be randomly selected at the quadrat level, and the final quadrat completed once the sample size threshold is achieved. Further work is required to determine meaningful measurements (shell length, height, thickness, total weight, recovered weight, or some combination of these metrics) of oysters required depending on the purpose.

The sample size for biological measurement should be appropriate to achieve a reasonable level of precision in measurement and should accurately represent the oyster population of a specific beach. One study has suggested that a minimum sample size of 10 times the number of height classes in the sample would be a reasonable compromise between effort and precision (Gerritsen and McGrath 2007). Using this guideline for Pacific Oysters (approximate maximum height of 300 mm in BC), 10 classes of 30-mm bins would give a sample size of 100 oysters. But, if time and funding permits, more samples should be measured.

Biological Sampling by Industry

Industry will be utilizing this protocol to conduct surveys; therefore the expectation for the level of biological sampling must be practical in terms of time and cost. If possible we recommend obtaining a sample of 100 random oyster heights recorded from various quadrats within a stratum to obtain potential recruitment data

The IEC International (2006) report suggested that size class sample and cluster sampling may be of interest to industry and should also be considered. Formal consultation with industry will be required to finalize potential biological sampling requirements for the assessment, depending on the needs of industry and for fishery management.

MORTALITY ESTIMATES AND HARVEST RATES

Introduction of a discussion on mortality estimates and harvest rates is important in providing additional context to this assessment protocol. No formal harvest rates models were used by the Provincial Government in the management of the Pacific Oyster fishery. Further, the lack of fishery data does not facilitate the use of complex fishery models to set harvest rates. As more data become available, models should be reviewed to set new harvest rates.

MORTALITY ESTIMATES

The simplest methods to set harvest rates require mortality estimates which have not been calculated for Pacific Oysters in BC. Hoenig's (1983) model to estimate mortality rates in data-poor situations has been used in studies for Manila clams (Gillespie *et al.*1998b) and scallops (Surry *et. al*. 2011) but requires knowledge of the maximum age. Although maximum age of Pacific Oysters has not been directly estimated in BC, two documented anecdotal estimates of maximum age were 20 years (Quayle 1969) and ≥40 years (Pauley *et al*. 1988).

Hoenig (1983) described relationships between mortality and the maximum observed age for fish, cetaceans, and molluscs and provided coefficients specifically for molluscs based on a data set that included clams, cockles, gastropods, oysters, and scallops. The relationship was:

$$\ln(M) = a + b\ln(t_{\max}) \tag{14}$$

where M is the instantaneous natural mortality, and $t_{\max}$ is the maximum observed age. The values for a and b for molluscs were 1.23 and -0.832, respectively (Hoenig 1983).

Estimated mortality rates ranged from 16% to 36% using maximum age estimates of 40 to 15 years, respectively (Table 6).

Recent studies of winter mortality in Pacific Oysters from Denmark, Sweden and Norway showed the lowest annual rates of 25% (75% annual survival) at the lowest latitude in Denmark with an increase to 87% and 55% respectively (Strand et al. 2012). If we assume that our winters are not as harsh as those experienced in Denmark, then we can assume that the BC annual mortality rates are somewhere below 25%. A 25% annual mortality corresponds to a constant, instantaneous mortality rate of approximately 0.28 ($year^{-1}$).

HARVEST RATES

Mortality estimates calculated above were used in Gulland's (1971) harvest rate model:

$$MSY = XMB_0 \tag{15}$$

where MSY is the maximum sustainable yield, X is a constant, M is the natural mortality, and B_0 is the unexploited or virgin biomass. Lauzier *et al*. (2005), Boutillier *et al*. (1998) and others have used values of X=0.2. In other unpublished studies of butter clams a value of X=0.5 has been used (Gillespie, unpublished data).

Gulland's (1971) model is often used to provide preliminary estimates of MSY in new and developing fisheries, but may not be the best choice of model and should not be used for fisheries in which there is already significant exploitation (Garcia *et al*. 1989). Gulland's equation has been criticized by Francis (1974), Deriso (1982) and Beddington and Cooke (1983), among others, and it is now generally recognized that fishing mortality is often lower than M in equation 15 and that using a value of X=0.5 overestimates MSY. Therefore values of $X \leq 0.5$ might be preferred.

One approach to estimating MSY in data limited situations has been proposed by Garcia *et al.* (1989). Their (gross) approximation of MSY is based on the Fox (1970) or Schaefer (1954) surplus production models and requires only one year of estimates of catch and biomass. The assumptions of this method include:

- Biological processes are deterministic;
- Catchability is not density-dependent;
- The fishery acts on a single stock with stable age/size distributions (equilibrium), and that fishery characteristics are changing slowly;
- Natural mortality rate (M) is known;
- The relationship between M and fishing mortality rate (F_{msy}) is of the form $F_{msy}=XM$ where X is a constant that depends on stock parameters; and
- Observations of current biomass (B_c) and current yield (Y_c) are available for one year only.

Note that F_{msy} and M correspond to annual rates rather than instantaneous rates following the notation of Garcia *et al.* (1989):

$$F_{msy} = XM \quad (16)$$

where X is a constant that depends on stock parameters (Gillespie *et al*. 1998a).

For the Schaefer model, given one year of biomass estimates (B_C) and catch (Y_C), MSY is given by the following:

$$MSY = \frac{(F_{MSY} B_C)^2}{2F_{MSY} B_C - Y_C} \quad (17)$$

Similarly, for the Fox model, MSY is given by the following:

$$MSY = F_{msy} B_C e^{\left(\frac{Y_C}{2F_{msy} B_C} - 1\right)} \quad (18)$$

The biomass estimate B_C is the biomass estimate for one year, and both the catch and biomass referred to should have the same age or size structure (Garcia *et al*. 1989).

The Schaefer model becomes unstable as F approaches $2F_{msy}$ and Y_C and B_C approach zero. Thus, the Schaefer model should not be used when there is a high level of effort or the stock has been badly overfished. Similarly, the Fox model becomes unstable as B_C approaches zero, but this occurs at extremely high values of F (Gillespie *et al*. 1998).

Table 7 contains an evaluation of MSY for the Gulland, Schaefer and Fox models for three values of F: 0.38, 0.28, 0.20 and 0.16, based on maximum ages 15, 20, 30 and 40 years, respectively. A range of values for X (0.2-0.5) in the relationship $F_{msy}=XM$ (Garcia *et al*. 1983) were tested in the models at three potential maximum ages. The data from the 2010 Pacific Oyster fishery harvest and biomass estimates were used in this analysis (Table 7).

Harvest rates ranged between 3 and 7% for the three models when the constant of X=0.2 was selected. Whereas the rates ranged between 5 and 18% when a constant of X=0.5 was used. Therefore, from this preliminary review, harvest rates between 3% and 18% may be appropriate to apply to the wild Pacific Oyster fishery, but a more thorough review of this is required before any recommendations can be made.

DISCUSSION

The wild Pacific Oyster fishery is small in terms of tonnage harvested, and financial value to Industry when compared to Pacific Oyster aquaculture harvest. However, harvest biomass of wild Pacific Oyster doubled between 1996 and 2005 and growth of this fishery could continue if Industry is able to increase demand for its product and create new markets. Data derived from future assessment of wild Pacific Oysters and fishery information will be important in informing DFO whether the trend in growth of the industry is continuing. Responsibility for data collection, management and analysis will need to be defined in order to ensure the utility and reliability of data for use in setting harvest rates.

We have recommended implementation of the Stratified Random Sampling (StRS) design as the best survey method to attain accurate and conservative biomass estimates during assessment of discrete beds with uniform density. This survey design requires that strata be defined to cover individual beds on a beach, that quadrats are randomly placed within the stratum and that oysters within those quadrats are weighed. This design recommends surveying each bed/stratum separately then combining all the results for each stratum into beach biomass estimate. DFO recommendation for implementation of this protocol for harvest of wild Pacific

Oysters can be rationalized in that it is a standardized scientifically defensible methodology that eliminates surveyor bias, the precedent and requirement for a similar protocol is used by depuration clam fishery, and because the haphazard approach (which relies heavily on visual assessment) is subjective and has inherent bias thereby reducing reliability of data used setting future harvest rates.

Implementation of this sampling design has important implications for Industry given that this design is more systematic, requires more time (and likely increased cost) to sample than the haphazard approach and also recommend some form of biological sampling. DFO's review of Provincial Government surveys from 2005 to 2010 indicate a very large number of strata were completed each year and on some beaches up to 34 strata were assessed (Table 2). The StRS survey is more time consuming which will result in a reduction in the number of strata assessed on each beach. In order to utilize StRS, expertise within Industry may have to be gained or assessments be contracted by Industry to qualified surveyors. However, the advantage of the StRS method to Industry is that no GPS mapping of the beds need to be conducted during set up the survey. In either case a sampling manual detailing assessment methodology and elements of this protocol should be developed to ensure consistency of data. DFO will be responsible in ensuring Industry conforms with the assessment protocol role, which can be achieved through monitoring, enforcement and through discussions with Industry.

Monitoring not only provides DFO important with information about oyster assessments but also a monitoring protocol can be developed to provide information on ecosystem impacts. This monitoring can provide information about recruitment and can be designed to evaluate factors influencing conservation and sustainability of the fishery. Photo documentation of site condition prior to and post-harvest could be utilized as a tool in monitoring.

The 75 cm x 75 cm quadrat is the optimal recommended quadrat size for sampling Pacific Oysters on beaches in BC because it showed a low level of variance, took the least time for the amount of area surveyed and was less affected by edge effect. The 100 cm x 100 cm quadrat has similar results to the 75 cm x 75 cm quadrat and may be used for the ease of selecting the random quadrats in the survey set up. The additional time it takes to complete the beach survey using the larger quadrat, in addition to the reduced practicality of this size of quadrat should be considered when setting up the survey protocol. DFO is aware that Industry may currently utilize round (1 m diameter) equipment for assessment and this will have to be switched to square quadrats to be consistent with this protocol and reduce potential variations in data.

The recommended sampling intensity of this protocol is higher in order to achieve a reasonable level of precision. The requirement for increased sampling intensity and precision can be justified when comparing survey of other bivalves such as Manila clams. For example, the survey precision of 30% for Manila clams has been produced fairly reliable estimates of biomass (Norgard, unpublished data). We found for Pacific Oysters survey to obtain approximately 30% survey precision of discrete beds a sampling range of between 6 and 14 quadrats would be required when using a 75 cm x 75 cm quadrat size and a range between 4 and 11 quadrats would be required when using a 100 cm x 100 cm quadrats. When comparing to the sampling intensity under Provincial management of 3 quadrats/strata, this new protocol requires an increase to a minimum of 5 quadrats/strata and optimally 10 quadrats/hectare. So we have recommended a sampling intensity of 10 quadrats per hectare with a minimum sample size of 5 quadrats per stratum. DFO will evaluate data collected from assessment of surveys using the methodology recommended within this protocol and will consult with Industry to determine whether the recommended sampling intensity requires adjustment or survey design requires modifications. At this time, DFO may also consider whether to expand and broaden the assessment protocol to include other beach types (other than oysters distributed in discrete beds).

The development of this protocol has resulted in consideration of a recommended harvest rate. It is DFOs policy to apply the precautionary approach and adaptive management approach to management of fisheries which are important considerations in setting future sustainable harvest rates. It should be noted that the harvest rates recommended within this protocol were developed in the absence of key information about Pacific Oyster in BC waters. Gaps in understanding currently exist in the following areas:

- The size of the Pacific Oyster stock in BC;
- The potential effects of climate change (sea level rise and variability in ocean temperature) on the population and fishery;
- Lack of age data from which to reliably estimate mortality;
- The variables affecting recruitment on beaches in BC; and
- The ecological impacts of this wild fishery.

Since mortality estimates are currently unavailable for wild Pacific Oyster, the only method we used to set harvest rates was based on the Hoenig's (1983) model. This model has been used in studies to estimate mortality rates in Manila clams (Gillespie *et al.*1998b) and scallops (Surry *et. al*. 2011) but requires knowledge of the maximum age of the species. Longevity estimates of Pacific Oysters range from 20 years (Quayle 1969) to 40 years and the model yielded mortality rates ranging from 16% to 36%.

One approach to estimating *MSY* in data limited situations has been proposed by Garcia *et al.* (1989). Their (gross) approximation to MSY is based on the Fox (1970) or Schaefer (1954) surplus production models and requires only one year of estimates for catch and biomass. We applied these models to the catch (202 tonnes) and biomass (5090 tonnes) data from 2010 Pacific Oyster fishery provided to DFO by the Province and found that harvest rates between 3% and 18% would be appropriate to apply to the wild Pacific Oyster fishery. DFOs harvest range recommends a larger range than the Provincial government harvest rate of 10 to 14% harvest rates but which fall with the suggested range of the recommended harvest rates in this study. As more fishery, assessment and mortality rate data become available further analysis and possible modification of DFOs recommended harvest rates should be undertaken.

DFO will also have to consider if or when to undertake further study to improve understanding information gaps given the relatively small size of this commercial fishery, the DFO resources available and importance relative to other Departmental priorities.

In summary, we have conducted an evaluation of the assessment and management frameworks utilized by the BC MoA for wild oyster harvest and have proposed a Pacific Oyster assessment protocol for assessing biomass on beaches. Also, we have recommended a range of harvest rates to be applied by managers to surveyed beaches. All of this information was derived from extremely limited data. Collection of higher volumes of more diverse data could support more sophisticated assessment advice in the future.

FUTURE WORK

- To facilitate transfer of standards and acceptable protocols to Industry or third-party surveyors, a formal survey manual for Pacific Oyster surveys should be developed (following ratification of the methods and standards presented herein).
- The current advice is for relatively high density populations in discrete beds (the preferred harvest sites). Future work can be done to develop survey protocols for other population types (e.g., oysters attached to bedrock or rock walls).

- The use of oyster shells or ligaments to determine age of oysters would provide a better understanding of age composition, recruitment and mortality rates (and thus a more sophisticated approach to determining acceptable harvest rates). Over the longer term, this work could allow development of age-based assessments of oyster populations.
- Biological sampling protocols should be developed in consultation with Industry. Provision of minimal assessment advice (i.e., biomass estimates and preliminary harvest rates for fishery management) does not require biological samples. However, any advance in the assessment framework, and the quality of advice provided to managers and Industry, will require increased sampling of biological characteristics of harvested populations.

RECOMMENDATIONS

1. Stratified Random Sampling survey methods should be used on relatively high-density discrete beds. Formal adherence to randomization for locating quadrats prevents bias, allows established probability statistics to be used and improves defensibility of third-party or Industry assessments.
2. We recommend a quadrat size of no less than 75 cm x 75 cm. Smaller quadrat sizes exhibited higher variance, more edge effect and appeared to be more affected by small-scale patchiness. Larger quadrat sizes did not exhibit these problems to the same degree, and the 75 cm x 75 cm quadrat size outperformed the 100 cm x 100 cm quadrat in cost effectiveness (and to some extent in practicality).
3. We recommend a sampling intensity of 10 quadrats per hectare with a minimum sample size of 5 quadrats per stratum. This sampling intensity will be reviewed as more survey results become available.

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TABLES

Table 1. Landings (Kt) and landed values (x106 $Cdn) of cultured and commercially harvested shellfish in British Columbia, 1996-2010.

a) Landings

Category[1]	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Cultured Shellfish	**6.6**	**5.7**	**6.1**	**6.5**	**6.5**	**8.9**	**9.1**	**10.2**	**9.9**	**10.1**	**10.2**	**9.9**	**7.5**	**7.7**	**10**
Clams	1	0.8	0.7	0.9	1.1	1.4	1.5	1.7	1.6	1.9	1.7	1.7	1.3	1.3	1.5
Oysters	5.5	4.9	5.4	5.6	5.3	7.4	7.5	8.3	8.1	8	8.2	7.5	5.6	5.7	7.4
Scallops/Other[2]	0.1	<0.1	<0.1	<0.1	<0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.7	0.6	0.7	1.1
Wild Shellfish[3]	**24.4**	**25.2**	**19.3**	**17**	**17.7**	**20.1**	**18.6**	**20.6**	**21.7**	**18.1**	**15.1**	**16.9**	**16.1**	**15.9**	**14**
Clams	1.4	1.6	1.6	1.6	1.6	1.8	1.9	1.6	1.4	1.4	1.1	0.9	0.8	0.8	0.7
Other[4]	0.7	0.6	0.7	0.4	0.7	0.6	0.6	0.4	0.2	0.4	0.1	0.2	0.2	0.1	0.3
Wild Oysters	0.06	0.06	0.07	0.11	0.14	0.15	0.12	0.22	0.21	0.16	-5	-	-	-	-

b) Landed value

Category	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Cultured Shellfish	**11**	**8.7**	**9**	**10.5**	**12.1**	**17.2**	**15.2**	**17.9**	**15.9**	**17.9**	**19**	**21.3**	**16.2**	**17.3**	**21.7**
Clams	4.4	3.4	3.7	4.7	6.1	8.2	7.2	8.2	7.4	8.5	8.9	9.3	7.2	7.2	8.1
Oysters	5.7	5.1	5	5.7	5.7	8.5	7.5	8.9	7.7	8.4	8.6	8.6	6.5	7.1	8.8
Scallops/Other	0.9	0.2	0.3	0.1	0.3	0.5	0.5	0.8	0.8	1	1.5	3.4	2.5	3	4.8
Wild Shellfish	**114.2**	**112.2**	**94.3**	**95.1**	**118.2**	**129.5**	**108.4**	**123.9**	**129.4**	**125.7**	**110.8**	**110.2**	**99.5**	**106.9**	**108.9**
Clams	3.7	4.3	5.3	5.3	4.9	6.1	6.4	5.4	4.3	3.9	3.3	2.6	2.1	2	1.8
Other	1.2	1.3	1.1	0.6	0.8	0.7	1	0.7	0.4	0.6	0.3	0.4	0.3	0.4	0.5

Notes:
[1] Data from BC MoA (1999-2011a,b) except Wild Oyster landings from IEC International (2006).
[2] Cultured “Other” includes mussels and scallops, depending on the year.
[3] “Wild Shellfish” includes commercial landings of crab, shrimp, prawn, scallops, sea cucumbers, geoducks & sea urchins.
[4] Wild “Other” includes octopus, squid and other unspecified shellfish.
[5] Not available.

Table 2. Area and number of strata surveyed at each location by the BC MoA during the surveys from 2005 to 2010.

Location	Total Area (m^2) 2005	# of Strata 2005	Total Area (m^2) 2006	# of Strata 2006	Total Area (m^2) 2007	# of Strata 2007	Total Area (m^2) 2008	# of Strata 2008	Total Area (m^2) 2009	# of Strata 2009	Total Area (m^2) 2010	# of Strata 2010
Atrevida Reef	-	-	-	-	-	-	-	-	-	-	3,843	2
Bird Cove	-	-	-	-	161	1	21,359	11	-	-	-	-
Blind Bay	-	-	-	-	-	-	-	-	6,541	24	8,968	34
Booth Bay	-	-	-	-	-	-	273	1	-	-	7,603	9
Carrington Bay	-	-	-	-	-	-	1,662	5	-	-	-	-
Comox Harbour	-	-	-	-	6,958	4	-	-	-	-	-	-
Davie Bay	-	-	-	-	683	3	-	-	-	-	5,178	12
Dog Bay	-	-	6,623	18	-	-	-	-	-	-	-	-
East Hernando	-	-	-	-	-	-	-	-	4,307	6	13,857	8
False Bay	-	-	-	-	-	-	-	-	-	-	9,261	15
Galiano Bay	4,235	21	-	-	-	-	-	-	-	-	-	-
Goliath Bay	-	-	-	-	5,390	15	-	-	-	-	-	-
Harwood Island	-	-	-	-			-	-	-	-	12,822	5
Hernando Reef	-	-	-	-	19	1	-	-	-	-	69,557	30
Hisnit Inlet	-	-	-	-	-	-	23,533	52	-	-	-	-
Jane Bay	-	-	7,800	3	-	-	-	-	-	-	-	-
Killam Bay	-	-	-	-	-	-	-	-	-	-	4,183	8
Kuper Island	-	-	-	-	-	-	1,839	6	-	-	684	2
Lloyd Point	-	-	-	-	-	-	9,730	20	-	-	-	-
Marvinas Bay	-	-	-	-	6,642	20	-	-	-	-	-	-
Mooyah/Crescent	-	-	-	-	-	-	-	-	7,735	25	-	-
Mouat Bay	-	-	-	-	7,610	11	944	4	-	-	18,197	26
Myrtle Rocks	-	-	-	-	-	-	-	-	-	-	37,060	24
Narrows Inlet	-	-	-	-	4,277	10	-	-	-	-	-	-
Perketts Creek	-	-	-	-	2,593	13	-	-	-	-	-	-
Scottie Bay	-	-	-	-	-	-	5,181	9	-	-	-	-
Seaford	-	-	-	-	-	-	411	3	-	-	16,736	10
Seal Islets	10,041	4	-	-	-	-	-	-	-	-	-	-
Sechelt Inlet	-	-	-	-	5,072	19	-	-	-	-	-	-
Shark Spit	-	-	-	-	-	-	-	-	-	-	20,833	11
Shingle Spit	-	-	2,483	5	-	-	-	-	-	-	-	-
Smelt Bay	-	-	-	-	-	-	1,153	2	-	-	20,025	26
St Vincent Bay	-	-	-	-	519	2	-	-	-	-	8,476	23
Stag Bay	-	-	-	-	-	-	-	-	-	-	36,595	33
Storm Bay	-	-	-	-	4,683	11	-	-	-	-	-	-
Tahsis Channel	-	-	-	-	-	-	16,273	48	-	-	-	-
Teakerne Arm	-	-	-	-	-	-	-	-	10,488	34	-	-
Theodosia	-	-	-	-	10,264	10	-	-	-	-	1,932	3
Toquart Bay	-	-	-	-	-	-	55,758	83	-	-	-	-
Toquart River	-	-	-	-	75,681	22	-	-	-	-	-	-
Union Bay	-	-	-	-	-	-	-	-	21,572	12	-	-
Vanguard Bay	-	-	-	-	3,598	8	-	-	-	-	-	-
West Hernando	-	-	-	-	-	-	-	-	-	-	18,167	9
Westview	-	-	-	-	-	-	-	-	-	-	34,643	11
Total	14,276	25	16,906	26	134,150	150	138,114	244	50,643	101	348,621	301

Table 3. Estimated abundance (oysters/quadrat), biomass (kg/quadrat) and precision for Pacific Oyster surveys using four quadrat sizes. Data from each quadrat size were standardized to 1 m^2.

A) Abundance					Abundance			Strata Abundance Estimates			Survey Abundance Estimates		
Location	Quadrat Size (cm)	Stratum	Stratum Area (m^2)	quadrat #	Mean (#/m^2)	SD	SE	Strata Stock Estimate	95% Confidence Interval of the Strata Stock Estimate	Strata Precision (stock est/95%)	Total Stock Estimate	95% Confidence Interval of the Total Stock Estimate	Precision
Neck Point	25x25	1	1125	80	58.00	40.91	4.57	65,250	10,291	15.8%	-	-	-
Neck Point	50x50	1	1125	80	52.15	28.20	3.15	58,669	7,095	12.1%	-	-	-
Neck Point	75x75	1	1125	80	45.51	21.96	2.46	51,200	5,524	10.8%	-	-	-
Neck Point	100x100	1	1125	80	48.93	21.26	2.38	55,041	5,347	9.7%	-	-	-
Shack	25x25	1	1925	15	37.33	37.60	9.71	71,867	37,372	52.0%	219,099	54,273	24.8%
Shack	25x25	2	2150	25	68.48	43.93	8.79	147,232	37,778	25.7%	-	-	-
Shack	50x50	1	1925	15	36.53	26.89	6.94	70,327	26,726	38.0%	187,631	36,910	19.7%
Shack	50x50	2	2150	25	54.56	28.03	5.61	117,304	24,104	20.5%	-	-	-
Shack	75x75	1	1925	15	33.07	21.41	5.53	63,653	21,284	33.4%	174,039	30,389	17.5%
Shack	75x75	2	2150	25	51.34	24.11	4.82	110,386	20,738	18.8%	-	-	-
Shack	100x100	1	1925	15	39.13	22.19	5.73	75,332	22,055	29.3%	202,526	31,289	15.5%
Shack	100x100	2	2150	25	59.16	24.63	4.93	127,194	21,181	16.7%	-	-	-

B) Biomass					Biomass			Strata Biomass Estimates			Survey Biomass Estimates		
Location	Quadrat Size (cm)	Stratum	Stratum Area (m^2)	quadrat #	mean (kg/m^2)	SD	SE	Strata Stock Estimate	95% Confidence Interval of the Strata Stock Estimate	Strata Precision (stock est/95%)	Total Stock Estimate	95% Confidence Interval of the Total Stock Estimate	Precision
Neck Point	25x25	1	1125	80	7.18	5.65	0.63	8,082	1,423	17.6%	-	-	-
Neck Point	50x50	1	1125	80	6.88	3.71	0.41	7,742	932	12.0%	-	-	-
Neck Point	75x75	1	1125	80	5.99	2.92	0.33	6,734	736	10.9%	-	-	-
Neck Point	100x100	1	1125	80	6.48	2.73	0.31	7,294	687	9.4%	-	-	-
Shack	25x25	1	1925	15	8.67	9.19	2.37	16,685	9,140	54.8%	61,061	13,878	22.7%
Shack	25x25	2	2150	25	20.64	11.75	2.35	44,376	10,108	22.8%	-	-	-
Shack	50x50	1	1925	15	9.34	6.71	1.73	17,972	6,671	37.1%	52,860	9,058	17.1%
Shack	50x50	2	2150	25	16.23	6.71	1.34	34,888	5,767	16.5%	-	-	-
Shack	75x75	1	1925	15	8.60	4.91	1.27	16,559	4,877	29.5%	49,429	7,083	14.3%
Shack	75x75	2	2150	25	15.29	5.73	1.15	32,870	4,930	15.0%	-	-	-
Shack	100x100	1	1925	15	10.24	5.09	1.31	19,706	5,063	25.7%	56,562	7,119	12.6%
Shack	100x100	2	2150	25	17.14	5.54	1.11	36,856	4,766	12.9%	-	-	-

Table 4. Results of Wiegert's cost-benefit analysis using four quadrat sizes. Quadrats were not timed at Neck Point; the table below uses the mean time from Shack Island survey. Mean times for each quadrat type differ in each stratum at Shack Island; this table shows times for each quadrat size and calculates a standardized cost. The upper part of the table uses the mean time to complete each quadrat size at Shack Island in stratum 1 and the lower part of the table uses the mean time for stratum 2. The lowest 'standardized cost x standardized variance' (highlighted) is the optimal quadrat size for each scenario and is calculate by multiplying the standardized cost by the standardized relative variance. Cost/Quadrat Area (sec/m2) is the mean time to survey a quadrat divided by the quadrat area.

		Standard Deviation					Standardized cost x Standardized Variance			
Quadrat size (cm)	Quadrat area (m^2)	Shack Island Stratum 1	Shack Island Stratum 2	Neck Point	**Cost Mean Time** (Mean Time from Quadrats in Stratum 1 at Shack Island) (sec)	**Standardized Cost** Calculated from Cost Mean Time	Shack Island Stratum 1	Shack Island Stratum 2	Neck Point	Cost/Quadrat Area
25x25	0.0625	9,196	11,758	5,668	27.2	1	3	4	4	435
50x50	0.25	6,717	6,715	3,739	83.3	3	6	4	5	333
75x75	0.5625	4,923	5,758	2,989	161.7	6	6	6	7	287
100x100	1	5,113	5,574	2,833	290.8	11	12	11	11	291

		Standard Deviation					Standardized cost x Standardized Variance			
Quadrat size (cm)	Quadrat area (m^2)	Shack Island Stratum 1	Shack Island Stratum 2	Neck Point	**Cost Mean Time** (Mean Time from Quadrats in Stratum 2 at Shack Island) (sec)	**Standardized Cost** Calculated from Cost Mean Time	Shack Island Stratum 1	Shack Island Stratum 2	Neck Point	Cost/Quadrat Area
25x25	0.0625	9,196	11,758	5,668	36.3	1	3	4.4	4	580
50x50	0.25	6,717	6,715	3,739	96.9	3	5	3.9	5	388
75x75	0.5625	4,923	5,758	2,989	182.3	5	5	5.4	6	324
100x100	1	5,113	5,574	2,833	328.8	9	10	9.1	9	329

Table 5. Results of estimated precision analysis. Mean and standard deviation are calculated from aggregate weight of Pacific Oysters by quadrat. The estimated precisions are the number of quadrats required to obtain each precision level.

								# of Quadrats Required to Reach the Precision Level Below										
Location	Stratum	Quadrat Size (cm)	Mean (kg/m^2)	Standard Deviation	Stratum Area (m^2)	Actual Sample #	Actual Survey Precision %	10%	15%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Neck Point	1	25x25	7.2	5.65	1125	80	16	238	106	59	26	15	10	7	5	4	3	2
Neck Point	1	50x50	6.9	3.71	1125	80	12	112	50	28	12	7	4	3	2	2	1	1
Neck Point	1	75x75	6.0	2.92	1125	80	11	91	41	23	10	6	4	3	2	1	1	1
Neck Point	1	100x100	6.5	2.73	1125	80	10	68	30	17	8	4	3	2	1	1	1	1
Shack Island	1	25x25	8.7	9.19	1925	15	52	432	192	108	48	27	17	12	9	7	5	4
Shack Island	1	50x50	9.3	6.71	1925	15	38	198	88	50	22	12	8	6	4	3	2	2
Shack Island	1	75x75	8.6	4.91	1925	15	33	125	56	31	14	8	5	3	3	2	2	1
Shack Island	1	100x100	10.2	5.09	1925	15	29	95	42	24	11	6	4	3	2	1	1	1
Shack Island	2	25x25	20.6	11.75	2150	25	26	124	55	31	14	8	5	3	3	2	2	1
Shack Island	2	50x50	16.2	6.71	2150	25	21	66	29	16	7	4	3	2	1	1	1	1
Shack Island	2	75x75	15.3	5.73	2150	25	19	54	24	13	6	3	2	1	1	1	1	1
Shack Island	2	100x100	17.1	5.54	2150	25	17	40	18	10	4	3	2	1	1	1	0	0

Table 6. Estimated mortality by maximum age using Hoenig's (1983) method.

Maximum Age (yr)	Mortality estimate (Hoenig 1983)
15	36%
20	28%
25	24%
30	20%
40	16%

Table 7. Summary of results for the Gulland (1971), Schaefer(1954) and Fox (1970) harvest rate models for Pacific Oysters using maximum ages of 20, 30 and 40 years. HR = Harvest Rate, and MSY= Maximum Sustainable Yield.

Harvest and biomass are from the 2010 fishery data provided by the Province.

Hoenig (1983) Mortality Rate Estimate	2010 Harvest (tonnes)	2010 Biomass Estimate (tonnes)	Model Constant X	Fishing Mortatily Rate (Fmsy)	Gulland Model (1971)		Schaefer model (1954)		Fox model (1970)	
					MSY	HR	MSY	HR	MSY	HR
				Maximum Age = 15 Years						
0.36	202	5090	0.2	0.07	366	7%	253	5%	234	5%
0.36	202	5090	0.3	0.11	550	11%	337	7%	292	6%
0.36	202	5090	0.4	0.14	733	14%	425	8%	355	7%
0.36	202	5090	0.5	0.18	916	18%	515	10%	420	8%
				Maximum Age = 20 Years						
0.28	202	5090	0.2	0.06	285	6%	221	4%	213	4%
0.28	202	5090	0.3	0.08	428	8%	280	5%	252	5%
0.28	202	5090	0.4	0.11	570	11%	346	7%	299	6%
0.28	202	5090	0.5	0.14	713	14%	415	8%	348	7%
				Maximum Age = 30 Years						
0.20	202	5090	0.2	0.04	204	4%	202	4%	202	4%
0.20	202	5090	0.3	0.06	305	6%	228	4%	218	4%
0.20	202	5090	0.4	0.08	407	8%	271	5%	246	5%
0.20	202	5090	0.5	0.10	509	10%	318	6%	278	5%
				Maximum Age = 40 Years						
0.16	202	5090	0.2	0.03	163	3%	214	4%	207	4%
0.16	202	5090	0.3	0.05	244	5%	208	4%	205	4%
0.16	202	5090	0.4	0.06	326	6%	236	5%	223	4%
0.16	202	5090	0.5	0.08	407	8%	271	5%	246	5%

FIGURES

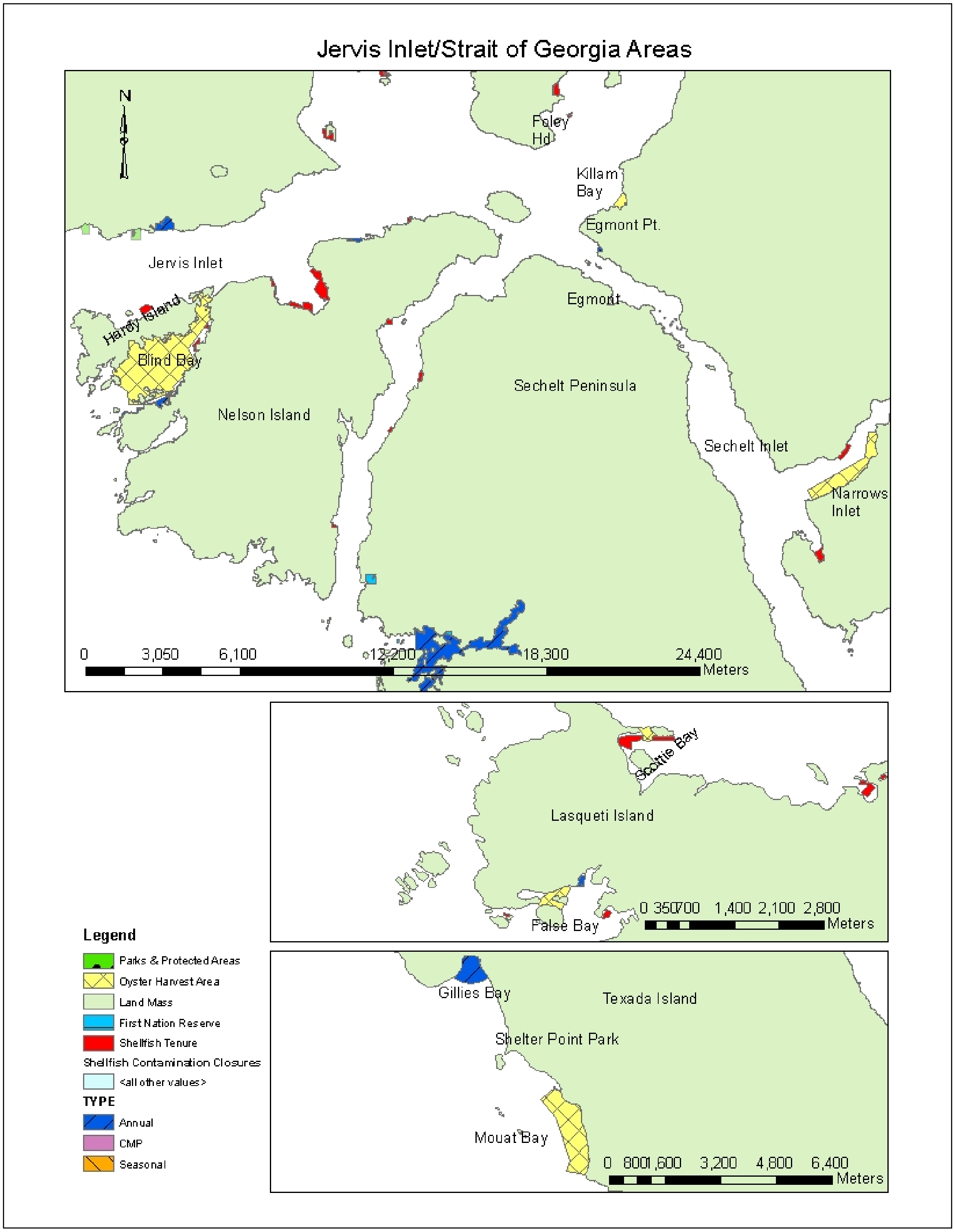

Figure 1. Areas supporting commercial harvest of Pacific Oysters (Crassostrea gigas) in Jervis and Sechelt Inlets, Lasqueti Island and Texada Island, Strait of Georgia, British Columbia. Source: BC MoA (2011f).

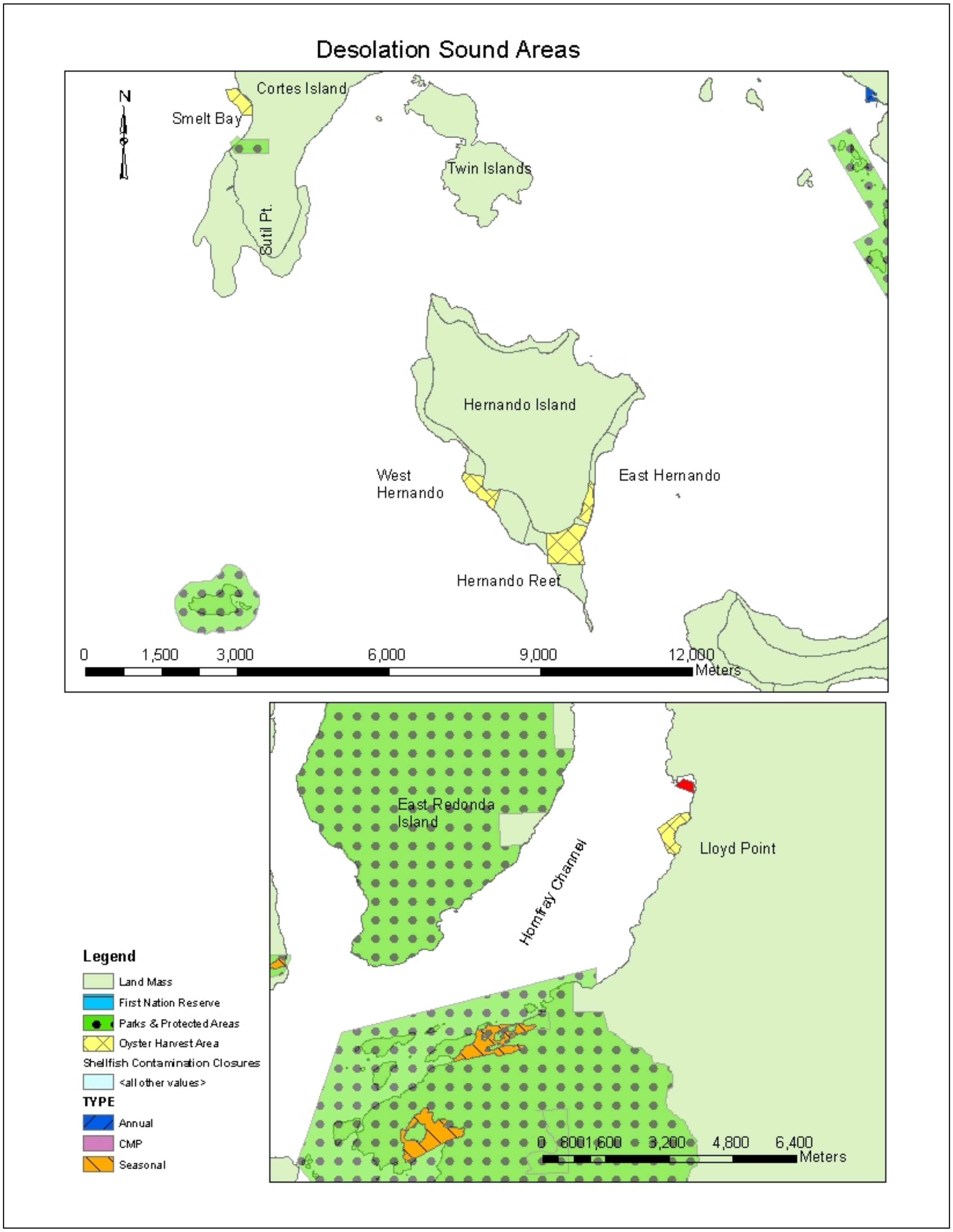

Figure 2. Areas supporting commercial harvest of Pacific Oysters (Crassostrea gigas) in Desolation Sound, British Columbia. Source: BC MoA (2011g).

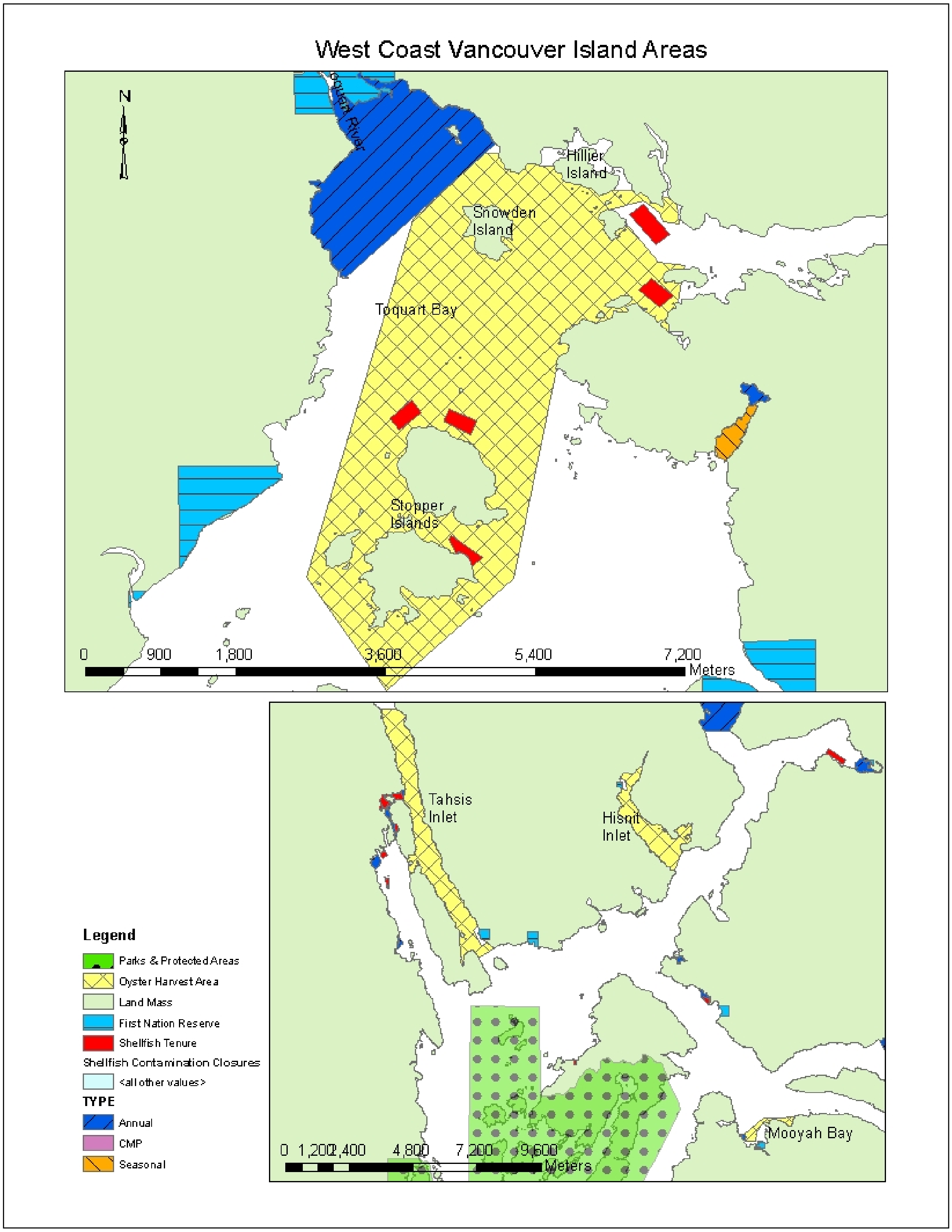

Figure 3. Areas supporting commercial harvest of Pacific Oysters (Crassostrea gigas) in Barkley and Nootka Sounds, West Coast of Vancouver Island, British Columbia. Source: BC MoA (2011h).

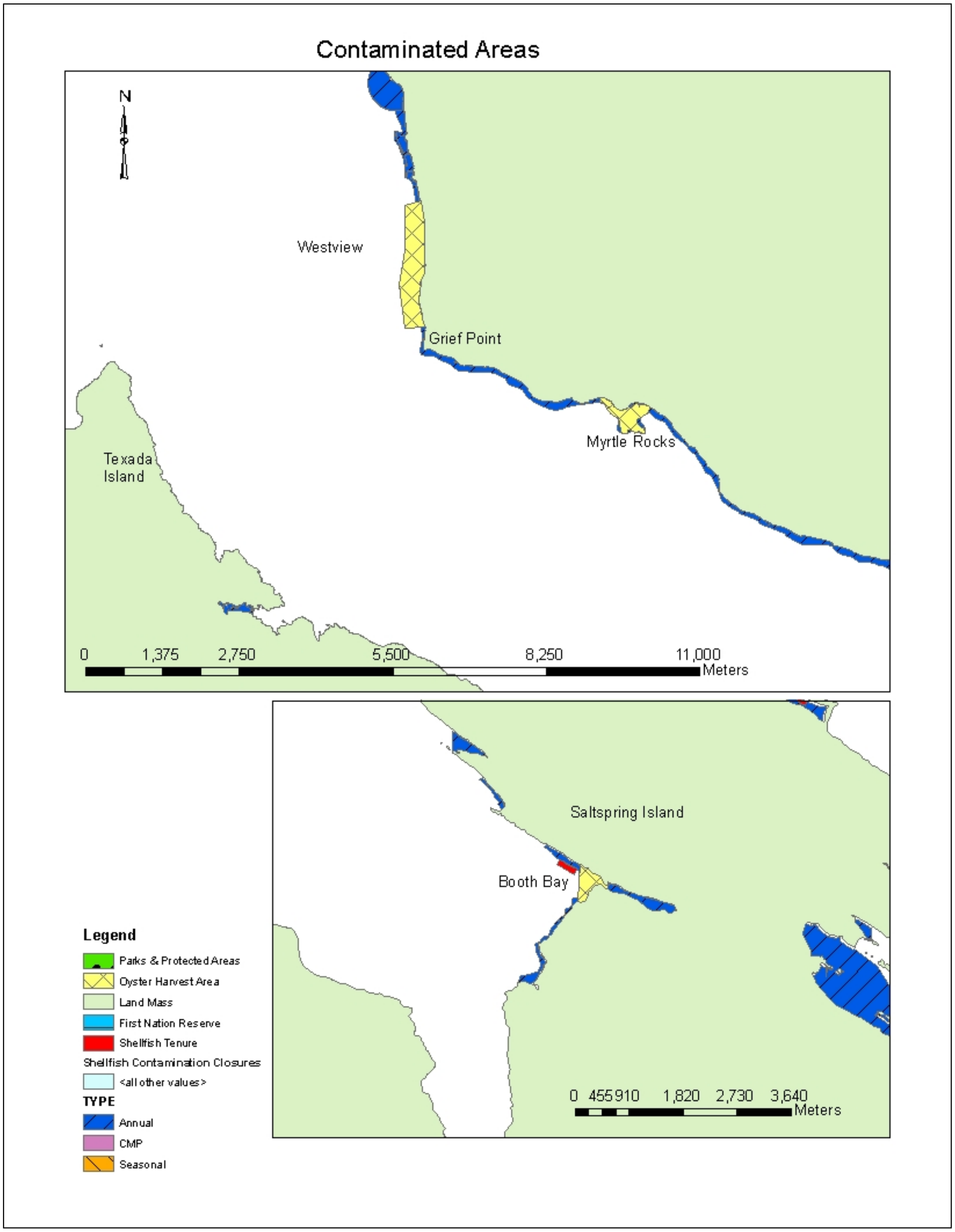

Figure 4. Areas supporting commercial harvest of Pacific Oysters (Crassostrea gigas) in Stuart Channel and Malaspina Inlet, Strait of Georgia, British Columbia. Source: BC MoA (2011i).

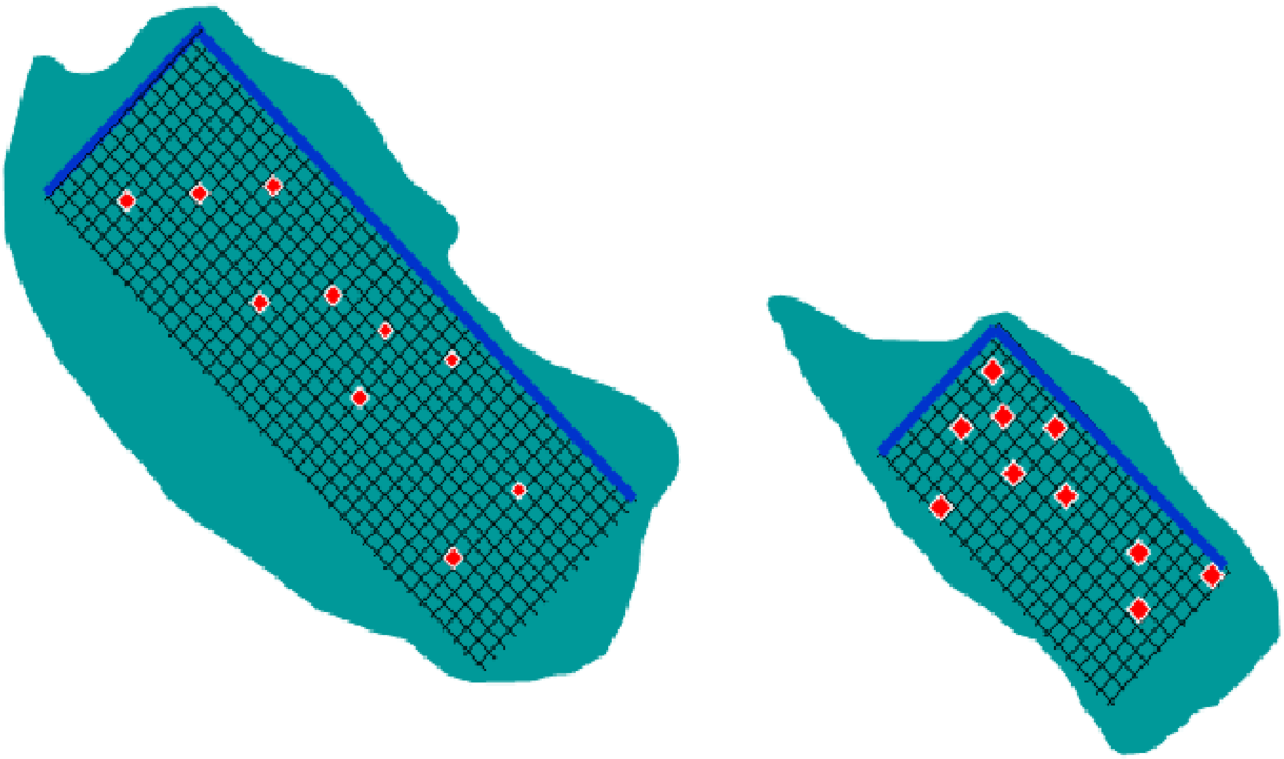

Figure 5. Survey design using Stratified Random Sampling. The baseline is established along one side of the bed (large green amorphous shape), setting up an x and y axis grid (stratum), then random quadrats (red squares) are selected throughout the stratum. The grid show all the possible sampling locations and the two areas show that this design can be setup on multiple strata on the same beach.

Figure 6. Nested quadrats - smallest is the 25 cm x 25 cm, 50 cm x 50 cm, 75 cm x 75 cm, up to 100 cm x 100 cm.

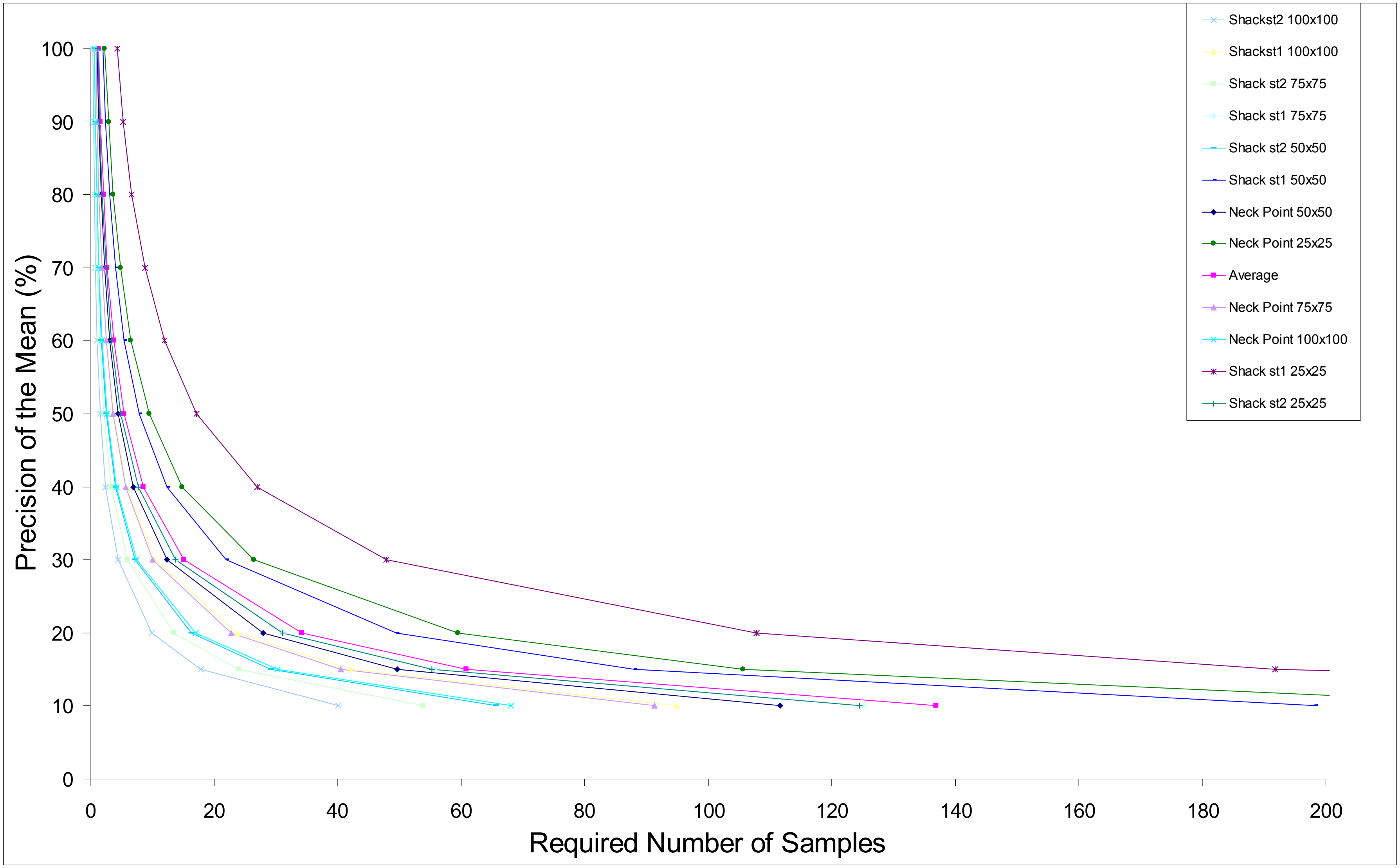

Figure 7. Results of the precision analysis for each beach surveyed.

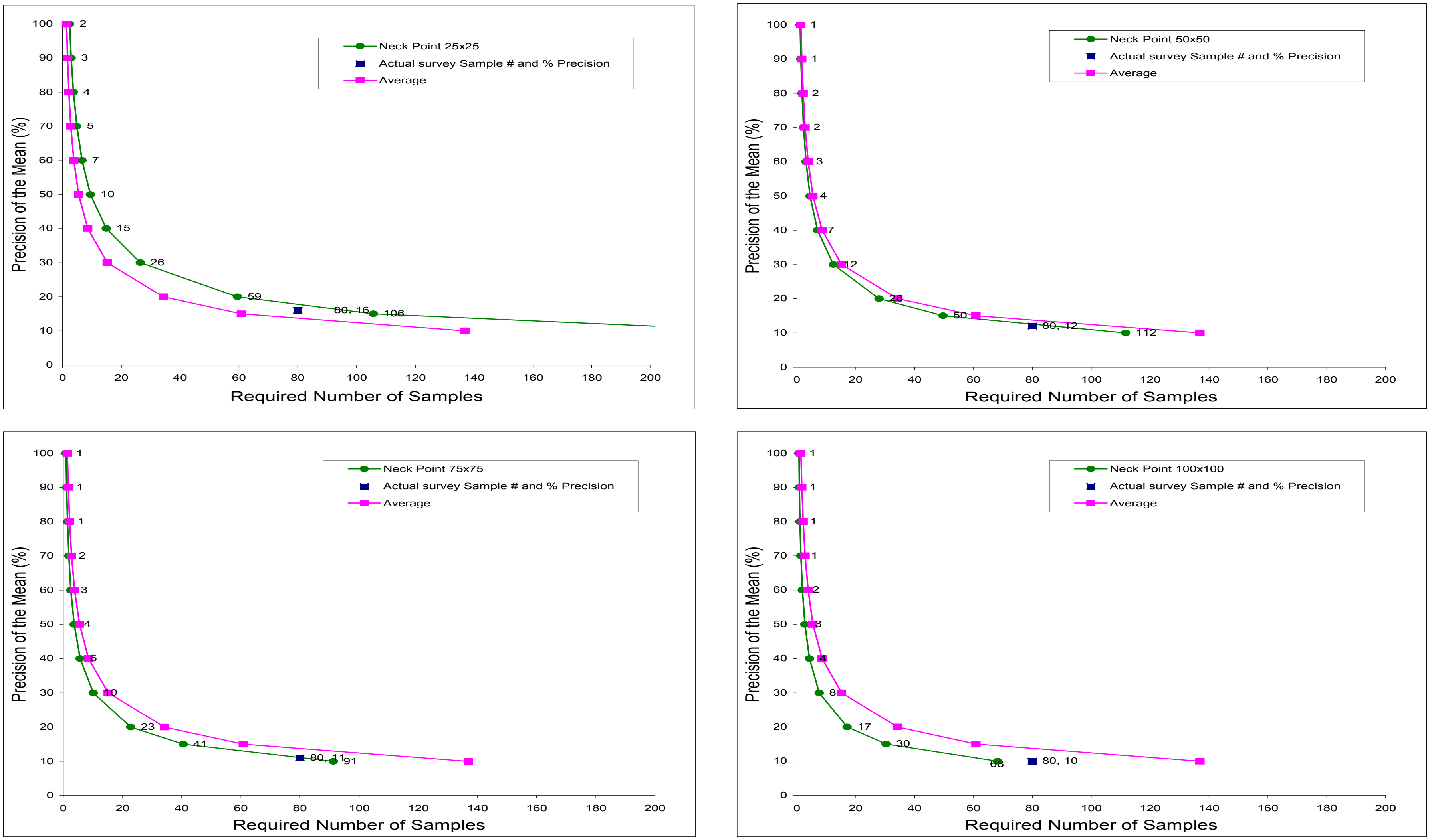

Figure 8. Results of the precision analysis for Neck Point at all 4 quadrat sizes. Point labels along the line refer to the number of samples needed at each level of precision. The lone point on the graph is the actual precision from that survey.

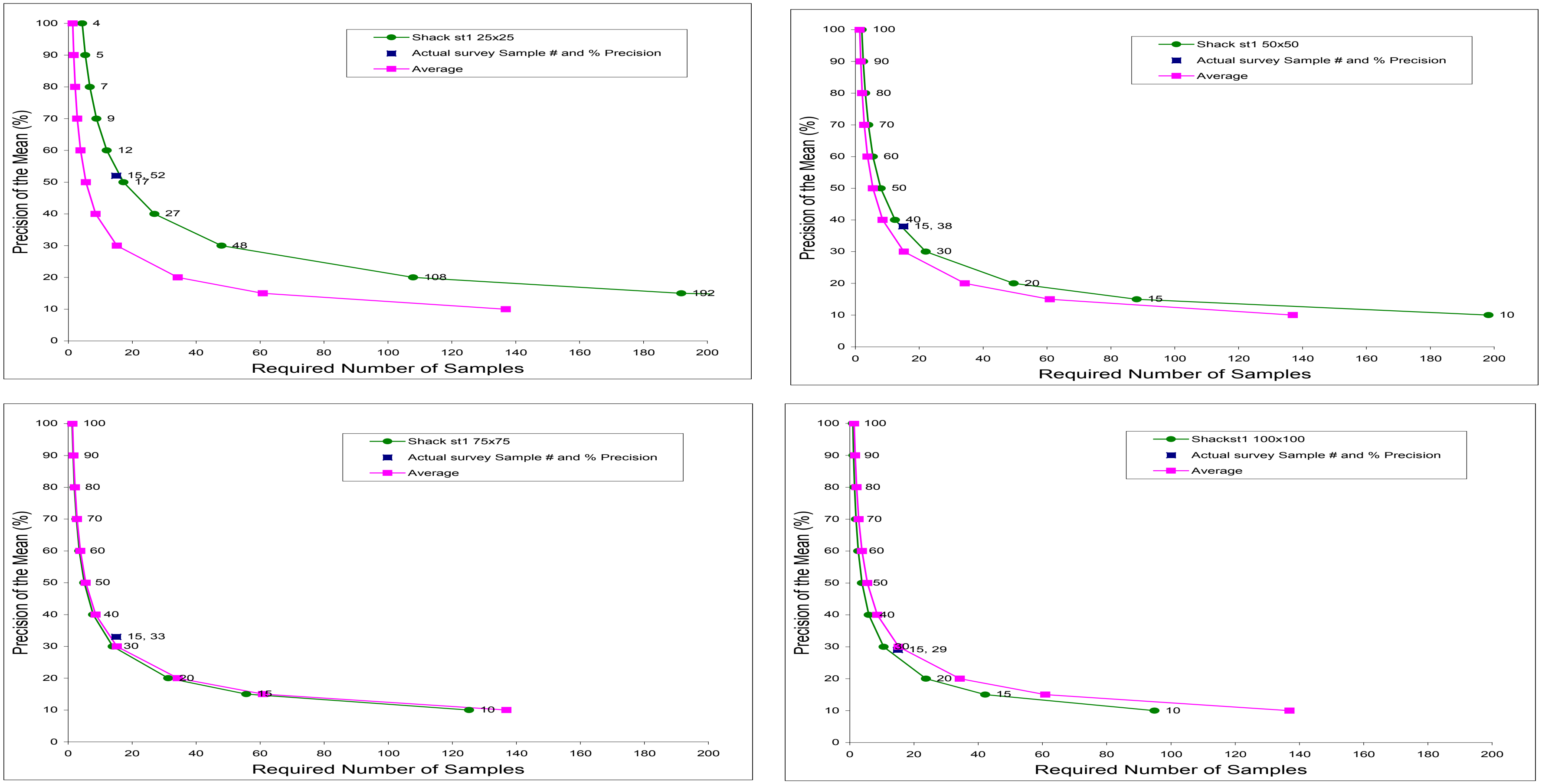

Figure 9. Results from Shack Island stratum 1. Point labels along the line refer to the number of samples needed at each level of precision. The lone point on the graph is the actual precision from that survey

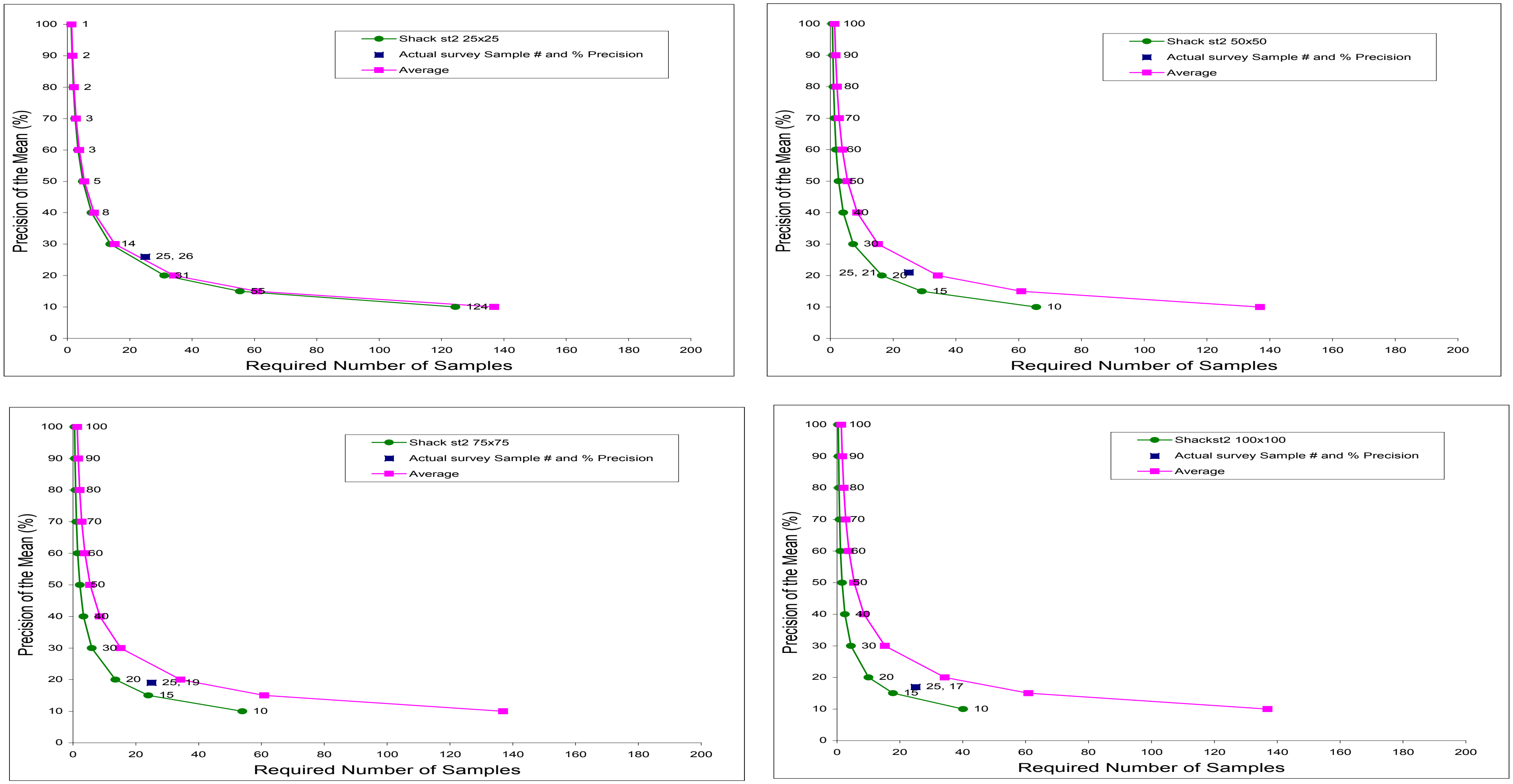

Figure 10. Results from Shack Island stratum 2. Point labels along the line refer to the number of samples needed at each level of precision. The lone point on the graph is the actual precision from that survey.

APPENDIX 1

Appendix Table 1. Statistical notation for reviewed survey analyses.

Symbol	Description
	Stratified Random Sampling
h	stratum index
H	maximum strata number
i	y-value index
N	total number of sampling units (quadrats) in the population
N_h	total number of sampling units in stratum h
n	number of units (quadrats) in the sample, or sample size
n_h	number of units in the sample from stratum h
y_{hi}	y-value i in stratum h (number of oysters)
μ	population mean
τ	population total
$\bar{y}$	estimated population mean
$\hat{V}(\bar{y})$	estimated variance of the population mean
τ	estimated population total
$\hat{V}(\hat{\tau})$	estimated variance of the population total
s_h^2	sample variance in stratum h
$z_{\alpha/2}$	t-value may be replaced with this estimator for large sample sizes
a_h	variable within Satterthwaite's approximation

APPENDIX 2

AGREEMENT between the Government of the Dominion of Canada represented by the Minister of Marine and Fisheries and the Government of the Province of British Columbia represented by the Commissioner of Fisheries thereof made in pursuance of the " Fisheries Act " and of Chapter 23 of the Statutes of Canada, 1912, entitled " An Act to amend the Fisheries Act " and under the authority of an Order in Council dated the 19th day of September, A.D., 1912.

1. The Government of the said Province of British Columbia may and is hereby authorized to grant leases from time to time of such areas of the sea coast, bays, inlets, harbours, creeks, rivers and estuaries of said Province as the Government of the said Province may consider suitable for the cultivation and production of oysters and the lessees of said Province, shall, subject, however, to the Fishery Regulations of Canada, have the exclusive right to the oysters produced or found on the beds within the limits of their respective leases. Provided, however, that in respect of Public Harbours, this agreement shall not prejudice the right or title of the Dominion of Canada to enjoy and use the same for any purpose other than the cultivation and production of oysters.

2. All the rents and profits arising from such leases shall be collected by and shall be the property of the Government of said Province.

Appendix Figure 1. Agreement between the Province of British Columbia and the Dominion of Canada (1912).

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IN WITNESS WHEREOF the said Minister of Marine and Fisheries has herewith set his hand and the seal of his office this twenty-sixth day of September, A. D., 1912, and the said Commissioner of Fisheries of the said Province of British Columbia has hereunto set his hand and the seal of his office this Seventh day of October A.D., 1912.

Signed, sealed and delivered by the said Minister of Marine and Fisheries in the presence of

. . . .

Signed, sealed and delivered by the said Commissioner of Fisheries of the Province of British Columbia in the presence of

. . . .

. . . .

. . . .
Commissioner of Fisheries for the Province of British Columbia.

Appendix Figure 1. (continued).

APPENDIX 3

BRITISH COLUMBIA
The Best Place on Earth

Ministry of Agriculture

GA Service Code: 1509
2500 Cliffe Avenue
Courtenay BC V9N 5M6
Phone: 250-897-7523 Fax: 250-334-1410

APPLICATION FOR A PERMIT TO HARVEST OYSTERS FROM VACANT CROWN FORESHORE

NAME OF APPLICANT ______________________ EMAIL ______________________

MAILING ADDRESS ______________________

CITY OR TOWN ______________ PROVINCE ______________ POSTAL CODE ______________

PHONE # ______________ CELL / PAGER # ______________ FAX # ______________

If your mailing address is a box number you must **identify a physical address** on the line below (permits will not be issued unless this information is provided).

____

Description of location where oysters are to be picked **(limit of one area per application)**. If the location is other than those designated by the Ministry of Agriculture, a detailed sketch of the requested harvest area must be attached to this application.

DFO Statistical Area

______________________ ______________

Shell stock desired: ☐ seed oysters ☐ market sized oysters ☐ both

Name of licensed Shellfish Tenure Holder to whom the shellstock will be disposed:

FRC #

____

STATEMENT OF AGREEMENT

Only the following persons are entitled to apply for and obtain a Permit to Harvest Oysters from Vacant Crown Foreshore:

a) a Canadian citizen;
b) a person who is serving or has served in the Canadian Armed Forces;
c) a person who has been lawfully admitted to Canada under the *Immigration Act* (Canada) for permanent residence;
d) official name of First Nation as defined within the *Indian Act*; or,
e) a registered BC company.

The Regulations concerning the Harvest of Oysters from Vacant Crown Foreshore, which are printed on the reverse of this form, have been studied and I agree to abide by them if a permit is issued.

The statutory authority may impose additional terms and conditions.

I certify that the information provided on this application form is true, correct and complete.

______________ ______________ ______________
SIGNATURE OF APPLICANT PRINTED NAME OF APPLICANT DATE

Please use the following check list to ensure all required information is included with your application:

☐ Application has been completed in full and **signed**. ☐ Fee(s) ☐ Map

☐ Copy of your completed Fisheries and Oceans Canada (DFO) application for a "Licence to Harvest Shellfish in a Contaminated Area" if applying for a permit within a Schedule 1 Closure (fecal contaminated area). **Failure to provide this information will result in your Ministry of Agriculture Wild Oyster Harvest application being denied.**

Please be reminded of the following:

1. **All unsigned applications will be returned**.
2. This application must be complete and submitted with a non-refundable $75.00 application fee by January 31, 2011. **Applications and fees received by the Ministry of Agriculture after January 31st will be rejected** and returned to the applicant.
3. **The deadline date should be kept in mind when mailing your application(s) as it may take up to a week for postal delivery.**
4. **Cheques post-dated to January 31st** will be accepted. You may submit one cheque to cover multiple applications. Cheques/money orders should be made **payable to the Minister of Finance. A service charge of $30.00** will be levied for all dishonored cheques.
5. It is the applicant's responsibility to ensure that the Ministry of Agriculture Licensing Section is advised of any changes to your contact information.
6. Wild Oyster harvesters must hold a current Fisher Registration Card issued annually by DFO.
7. **Harvest logs and royalty fees must be submitted to the Ministry of Agriculture within 10 days after the permit expiration.** The form must be submitted even if no harvesting takes place. Failure to do so constitutes a violation of Section 9(3) and (4) of the *Fisheries Act Regulations (RSBC)* and those permit holders will be turned over to enforcement staff. **If harvest logs and/or royalties are not received within the timeframe specified, the permit holder will be ineligible for permits.**

The information on this form is collected under the authority of the *Fisheries Act* (R.S.B.C.). The information provided will be used to process your licence application under the *Fish Inspection Regulations* (Section 23.1). If you have any questions about the collection and use of this information, please contact the Ministry of Agriculture at the above address.

(REV Nov 5/10)

Appendix Figure 2. Oyster harvest permit application. Source: BC MoA (2011e).