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# Gorge Waterway Subtidal Olympia Oyster Surveys
# Phase 1 – Pilot Methodologies

**Report to:**

**CRD Harbours Environmental Action Program**


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**May, 2012**

**Executive Summary**

The Olympia oyster (*Ostrea lurida*) is the only native oyster species in BC. However, despite a historical abundance that supported substantial fisheries in the early 1900s, it is now of special concern in Canada, listed in the Species At Risk Act (SARA) registry. The Gorge Waterway, an urban inlet on the southern west coast of Vancouver Island, sustains an anomalous particularly dense population of the Olympia oysters despite environmental challenges.

This report summarizes information from intertidal and subtidal investigations of this oyster population, including descriptions of this information in the CRD Harbours Atlas. Intertidal surveys in 2009 demonstrated the presence of oysters in most of the regions of the Gorge, including the predominant muddy and soft substrates. Exploratory subtidal surveys of two sites of the Gorge Waterway identified very dense and patchy oyster beds, though work continues to adequately characterize these beds as well as develop a methodology that can be applied elsewhere in the Gorge in a cost-effective manner. Particularly challenging are the cryptic nature of the oysters and their patchiness at scales of less than 0.5 $m^2$. Also notable are the comparable size frequencies from subtidal and intertidal surveys, indicating that subtidal oysters found so far may not be the reproductive reservoir we had expected, which could have explained the remarkable resilience of this population.

From a methodological point of view, we found that diver observations were apparently more effective in detecting borders of oyster beds, in comparison to observations from the surface or photographic methods, but quantitative assessments of density and identification of density bands required formal transects and quadrat sampling with removal and counting in the laboratory. Diver counts were very poorly correlated with actual oyster numbers.

Recommendations for further work include:

1) Continuation of annual intertidal reference site monitoring, moving to a new soft substrate site this year (at Craigflower Bridge to also monitor impacts of this project) and tagging some oysters and permanent quadrat sites on hard substrate (part of summer student and career focus projects at WFT);
2) Water quality monitoring, including pH to integrate with other projects that are monitoring ocean acidification (in collaboration with UVic thesis and neighbourhood initiative to foster swimming in the Gorge; coordination with CRD & VIHA & pursuing other partnerships);
3) Monitoring of oyster settlement and larval patterns (unfunded this year at WFT, but may get some information from invasive species monitoring being done in collaboration with the BC Museum and DFO);
4) Continuing investigation of subtidal oyster beds (unfunded so far);
5) Continuing investigation of docks, including in the adjacent harbours (unfunded so far).

## Table of Contents



## List of Figures



## List of Tables

## Introduction

The Gorge Waterway, an inland extension of the Victoria Harbour, is a distinctive inlet with several unique characteristics. One of these is a large population of the native Olympia oyster (*Ostrea lurida*), a species that was historically important for food and culture to local First Nations and early settlers, and is now listed as one of “special concern” with respect to possible extinction on the Pacific coast of North America. Several factors are thought to have led to the species’ decline relative to huge densities a century ago – including overfishing, effects of introduced species, and side effects of industrialization and urbanization. The population in the Gorge Waterway appears to have survived this relative extirpation that has happened on much of the rest of the coast, despite being near a city centre with a history of agricultural, urban, and industrial impacts. It is thus a particularly important remnant population for providing information for the species on determinants of resilience to negative impacts, and for studying global impacts such as climate change and ocean acidification. The information gathered on this population is also important for mandatory considerations for any local development plans.

The local municipalities have a responsibility to manage impacts on local harbours and waterways, which created incentive to the development by the Capital Regional District of the Victoria Harbours Atlas in the early 2000s. This atlas includes information on the distribution of native oysters in the Gorge and other parts of the harbour, but needs updating. Also, due to methodological restrictions, this data is not quantitative enough to allow good times-series comparisons of densities, does not provide enough information on intertidal distributions, and does not distinguish well between live oysters and dead shells.

World Fisheries Trust (WFT) has been carrying out work on the intertidal portion of the Gorge oyster populations over the last few years, in collaboration with the Departments of Environment and Fisheries and Oceans Canada. With the current project, the CRD contracted WFT to carry out a pilot study on mapping subtidal portions of the oysters in the Gorge, to complement the current information in the Harbours Atlas and investigate costs and methodologies for a broader characterization of subtidal areas in the Gorge and adjacent harbours. In this work, WFT’s prior data on intertidal oyster distributions were also added to the atlas, and biological growth on representative float structures was investigated for both methodological approaches and possible reservoirs for oysters.

## Methods

*Subtidal oyster beds:*
Two of the principal subtidal oyster beds in the Gorge Waterway were identified from the Harbours Atlas and surveyed in detail: one that extends underneath the Craigflower

Bridge, and one about 800m downstream that coincides with a DFO intertidal index site (Figs. 1-3).

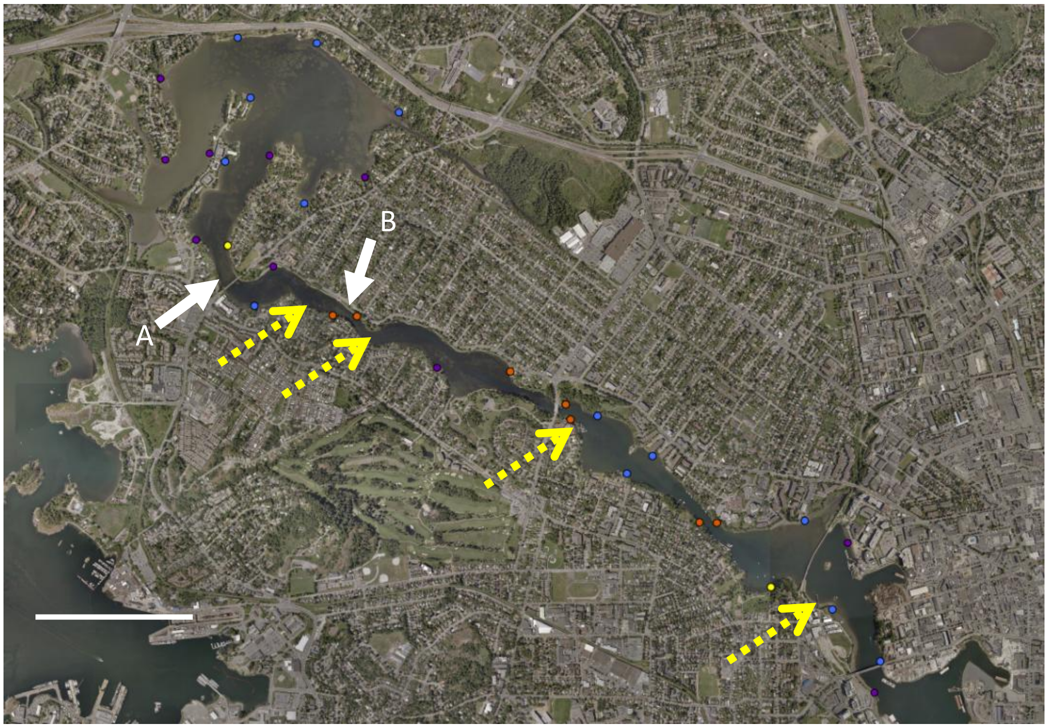


**Figure 1. Gorge Waterway intertidal oyster distribution (2009), sites of subtidal surveys of this report (A = Craigflower Bridge, B = Site 9), and areas of docks investigated (dashed yellow arrows). Intertidal abundance scale: red = abundant, yellow = common, blue = present, purple = absent. Scale bar = 1 km.**

**Figure 2. Subtidal native oyster bed at the Craigflower Bridge (green area), showing distribution density contour, transect line (blue line), and sites of sampling quadrats (red dots). Green outline is boundary of oyster shells, with inner polygon outlining area of significant live oysters.**

**Figure 3. Subtidal native oyster bed at Index Site 9, showing diver transects (blue lines) and quadrat sampling sites (red spots). Green outline is boundary of oyster shells, with inner polygon outlining area of significant live oysters.**

Several survey approaches were tested:

1) Free-swimming divers and snorkelers explored the putative oyster bed to identify the boundaries of significant oyster concentrations and shell deposits;
2) Observations of bed boundaries were also carried out from a boat with the use of a surface viewer;
3) Divers surveyed oyster densities and distribution of associated flora and fauna along a marked transect line. In this protocol, developed through several iterations in the study, one diver swam the transect line to identify boundaries of "biophysical zones" – characterized generally by a complex of substrate type, depth, and characteristic communities of animals and plants, including native oysters. This diver focused on characterizing oyster densities in these zones. The second diver, swimming from the opposite end of the transect, made more detailed observations on the fauna and flora in the different zones, also noting the edges of these zones independently. Densities were recorded as % cover and/or on a 4-point abundance scale of Absent – Abundant, depending on the characteristic. In addition, biological resources were characterized on the 4-point scale of abundance/patchiness used by the Harbours Atlas: few, patchy, uniform, continuous, and dense (Archipelago Marine Research Ltd., 2000).
4) Quantitative samples of oyster density were carried out by collecting all shells and organisms in separate Ziploc bags from within 4 equal sub-sections of a 0.25 $m^2$ quadrat. Quadrats were placed "randomly" from the boat by tossing it into

the zones pre-identified by the diver survey, close to the transect line. Prior to sampling, in the early transects, the diver made visual counts of oysters in each of the quadrat sub-sections, and in some cases, took photographs.

5) All areas had either a mud or mixed shell/mud substrate, with oysters present up to 1 or 2 centimeters within the substrate. Thus, the divers collected all shell or small hard substrate to a depth of about 5 cm within each sub-quadrat. These samples were taken to the laboratory for counting and biometrics, before being returned live to the oyster bed. Both live and dead oyster shells were measured in each quadrat to provide information on current size frequencies and size frequencies integrated over a longer time period.
6) Hand-held underwater video was taken along the transect lines and on several exploratory dives to assess the utility of this tool in outlining oyster densities. Video footage was also taken of growth on floats to see to what extent these can be used to characterize oysters and other organisms.
7) Positioning of all oyster bed boundaries, transect and quadrat locations was carried out from a boat both with a Garmin eTrex Legend HCx GPS and dead reckoning with a compass and range finder.

Positional data and oyster distribution data from the surveys were used to map the extent of the oyster beds using ArcGIS software at the CRD (Figures 1 and 2) as an ArcGIS project ready for integration into the Harbours Atlas. GPS positional data were corrected by dead reckoning information from compass and rangefinder measurements where needed, generally close to bridge structures (Fig. 4). Oyster patchiness data from transects, quadrat-based density measures, and free-swimming observations were used to estimate oyster densities in the areas investigated (expressed on the Atlas' scale of "patchiness"). However, as extrapolation of density polygons within the oyster bed appeared questionable, so far these were entered into the atlas as associated tables. Actual location of transects and quadrats were also mapped, and more detailed information on actual oyster densities and associated flora and fauna were included as associated tables as well.

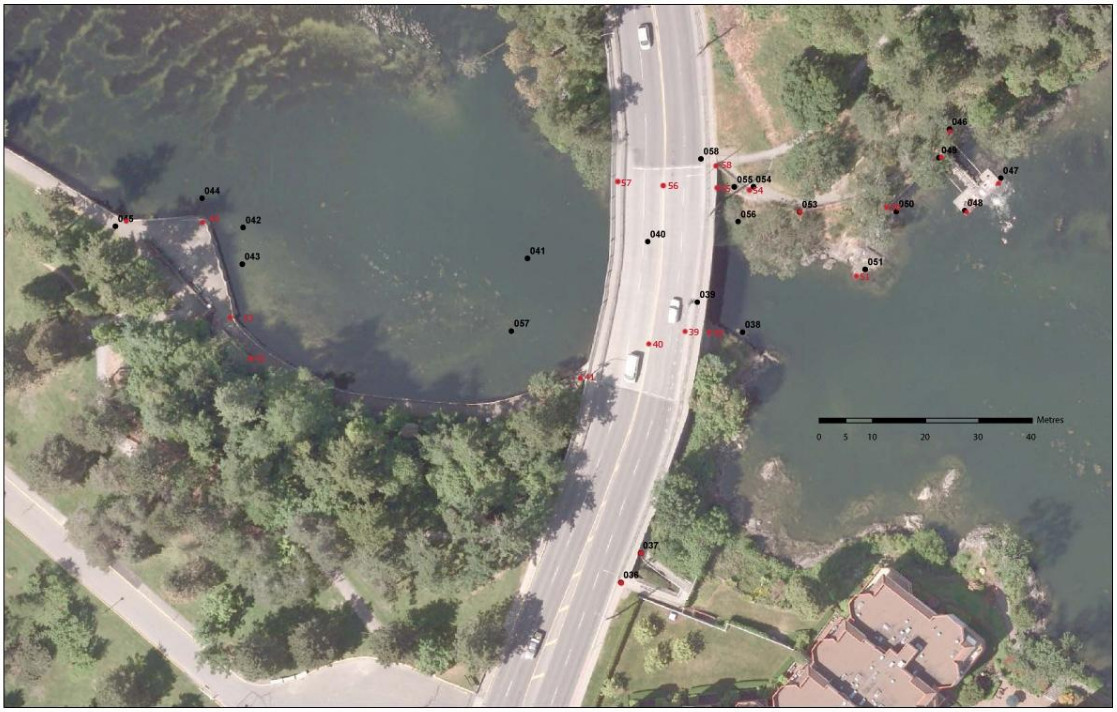


**Figure 4. Effects of Gorge structures on GPS readings: red figures are actual locations, black numbers are GPS positions.**

*Intertidal surveys:*

Intertidal distribution of native oysters in the Gorge Waterway was studied by WFT in 2009, with a protocol adapted from Norgard et al. (2010). Transects were laid perpendicular to the shore, spaced regularly at 500m around the Gorge Waterway and Portage Inlet. These transects extended from a baseline set close to highest high water to the water line at the time of the survey, or to the estimated low water limit (if accessible). Quadrats ($0.0625m^2$) were flipped along both sides of the transect line, counting all visible live oysters (including probing the surface of the mud with fingers), providing an estimate of oyster densities along the whole transect.

The lower intertidal portion of this survey was converted to an abundance scale and mapped as colour-coded point data to the Harbour Atlas ArcGIS mapping interface (Figure 3).

*Float communities and oysters:*

Snorkel dives and filming were carried out on 5 representative floats in the region of the oyster beds that were surveyed. An *ad hoc* species list was constructed for each float and the underlying substrate, with abundance estimates and observations on apparent community structure. Particular attention was given to the presence of native oysters. Photographs and video were also recorded in some cases.

## Results & Discussion

### Oyster densities in the Gorge:

Subtidal oyster densities in the pilot areas investigated in the Gorge are amongst the highest recorded for Olympia oysters on the BC coast. "High" densities elsewhere on the West Coast of Vancouver Island are in the order of 255 oysters/$m^2$, whereas under the Craigflower bridge, densities of up to 450 oysters/$m^2$ were found (Table 1). The oysters at this site, however, are quite small (the majority less than 4 cm in length). In the case of the oysters under the bridge, comparison with the size of dead shells in the same quadrat (which integrate sizes over potentially many years; Figure 5) suggests that this is a size distribution that is commonly found here. At Index site 9, however, a similar comparison (Figure 6) suggests that the sample had more young oysters than are present over the long-term average. This may suggest high annual or inter-annual mortalities that vary between years and between the different oyster beds (Figure 7) or that mortalities at this site tend to occur later in the year than in March, the time when sampling occurred.

**Table 1. Subtidal oyster densities at two sites on the Gorge Waterway in 2011/12**

| Site | Quadrat sample | # Olympia oysters/$m^2$ |
|---|---|---|
| Craigflower bridge (January) | 1 | 244 |
| | 2 | 492 |
| | 3 | 220 |
| | 4 | 136 |
| | 5 | 100 |
| | **Site average** | **238.4 ± 153.6** |
| Index site 9 (March) | 1 | 112 |
| | 2 | 28 |
| | 3 | 64 |
| | 4 | 132 |
| | **Site average** | **84 ± 47.0** |

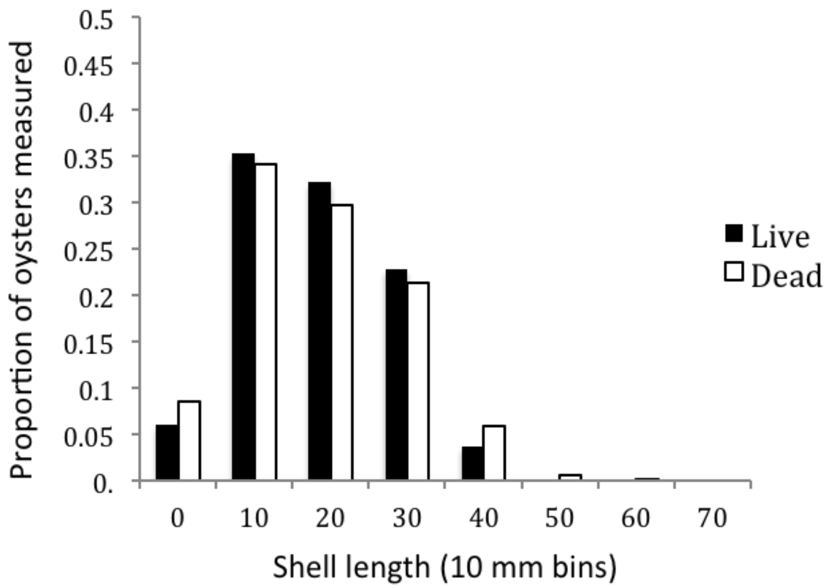


**Figure 5. Size frequency of live and dead subtidal oyster shells at Craigflower Bridge**

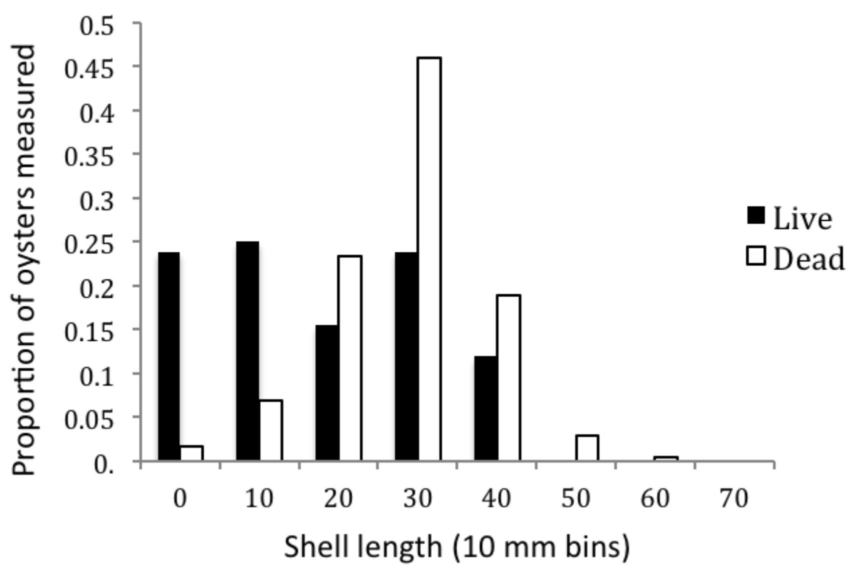


**Figure 6. Size distribution of subtidal Olympia oysters at Index Site 9**

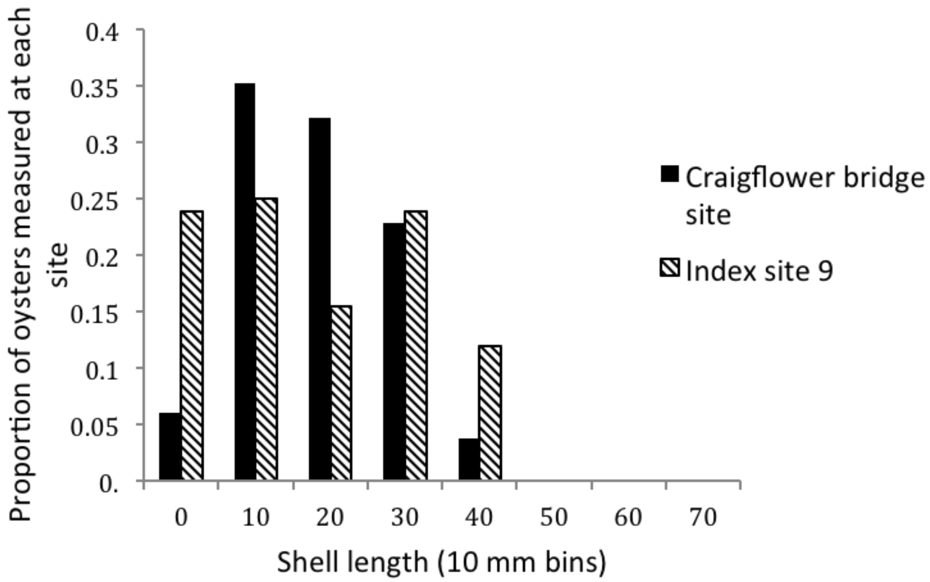


**Figure 7. Comparison of shell size of live subtidal Olympia oysters from two sites on the Gorge Waterway**

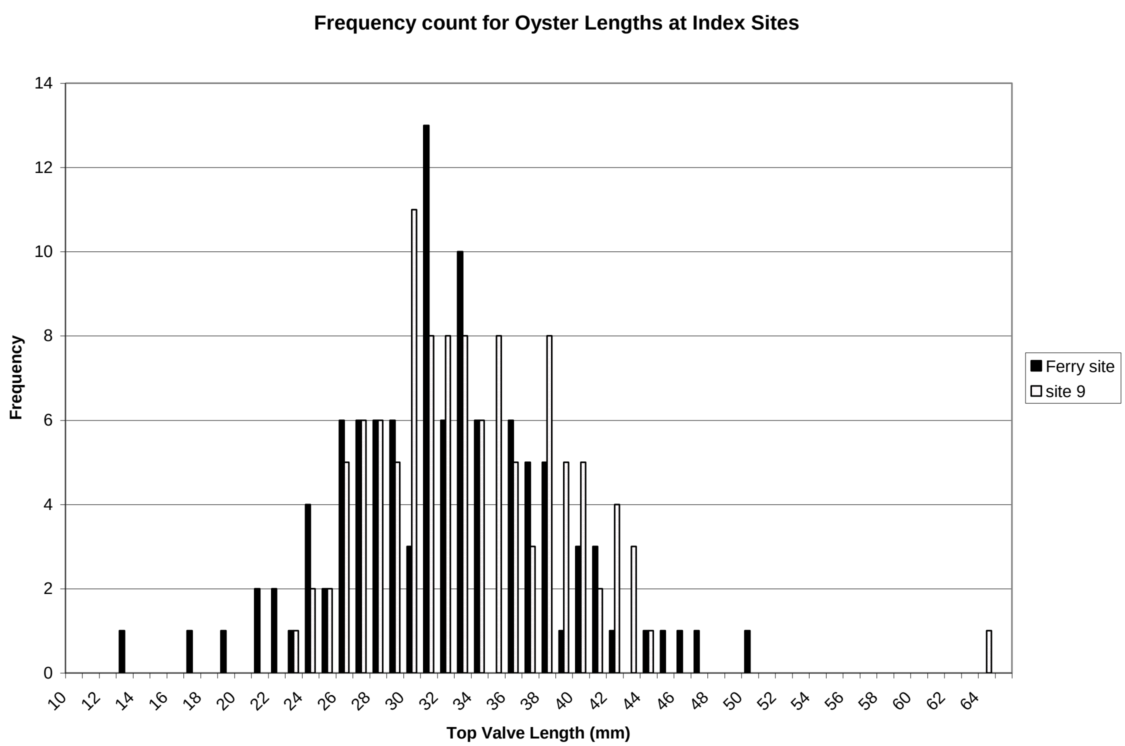


**Figure 8. Intertidal Olympia oyster size frequencies**

We had expected to find larger oysters subtidally than are present intertidally. However, this did not seem to be the case (compare to fig. 8), suggesting that we have not yet found the reproductive reservoir we had expected that provides the Gorge oyster the observed resilience over time. This may be found in other subtidal oyster beds that have not yet been surveyed. However, Olympia oysters are not much larger at other BC sites (Norgard et. al., 2010).

Inter-annual variation of oyster populations should be discernible as changes in densities or size frequencies and/or in changes in the boundaries of the intertidal and subtidal oyster beds. Both could be difficult measures for identifying changes.

The density distribution of oysters, even within the oyster beds, is quite variable – even at the spatial scale of sub-quadrats (Table 2). This potentially interferes with monitoring of changes in oyster densities, as the large error bars make comparisons between sampling dates difficult. We are still in the process of evaluating our data, and that of other oyster distributions, to see how to deal with this element of "patchiness." Norgard et al. (2010) have made some estimates of sample sizes that would be applicable to the intertidal regions of the Gorge, which we will be testing, though costs of such sampling, particularly subtidally, could be prohibitive. The qualitative scale used by the harbor atlas to describe patchiness and abundance together was difficult to apply objectively to our measures with any confidence, due to some ambiguity in its definition. We will try this again, but the measure appears unlikely to be good for describing inter-annual variance with confidence.

**Table 2. Patchiness of live and dead subtidal oysters per 0.5 $m^2$ quadrats described as Coefficient of Variances of four subquadrats**

| | **Live oysters** | | | **Dead oyster shells** | | |
|---|---|---|---|---|---|---|
| **Quadrat** | **Mean** | **SD** | **CV (%)** | **Mean (dead sectional)** | **SD** | **CV (%)** |
| CB 1 | 15.25 | 10.07 | 66 | 103.75 | 45.77 | 44 |
| CB 2 | 30.75 | 10.96 | 36 | 170.25 | 30.69 | 18 |
| CB 3 | 13.75 | - | - | 101 | - | - |
| CB 4 | 8.5 | 5.00 | 59 | 201.5 | 108.86 | 54 |
| CB 5 | 6.25 | 7.93 | 127 | 68.25 | 53.85 | 79 |
| Ind9-1 | 7 | 5.47 | 78 | 49.25 | 14.57 | 30 |
| Ind9-2 | 1.75 | 1.70 | 98 | 8.5 | 5.45 | 64 |
| Ind9-3 | 4 | 4.32 | 108 | 39.25 | 9.22 | 23 |
| Ind9-4 | 8.25 | 3.77 | 46 | 46.75 | 3.40 | 73 |
| Overall Mean | 10.61 | | | 87.61 | | |
| Mean Craigfl. | 14.9 | | | 128.95 | | |
| Mean Site 9 | 5.25 | | | 35.93 | | |

The boundaries of the oyster beds may also not be very precise due to their cryptic nature. Intertidally, oysters are present throughout much of the Gorge, on most substrates except man-made beaches and particularly muddy regions (Fig. 1 & 9 and Table 3). Only Portage Inlet stands out as an area with dead oyster shells but without live oysters. Delimitation of edges of oyster beds along the shore was difficult.

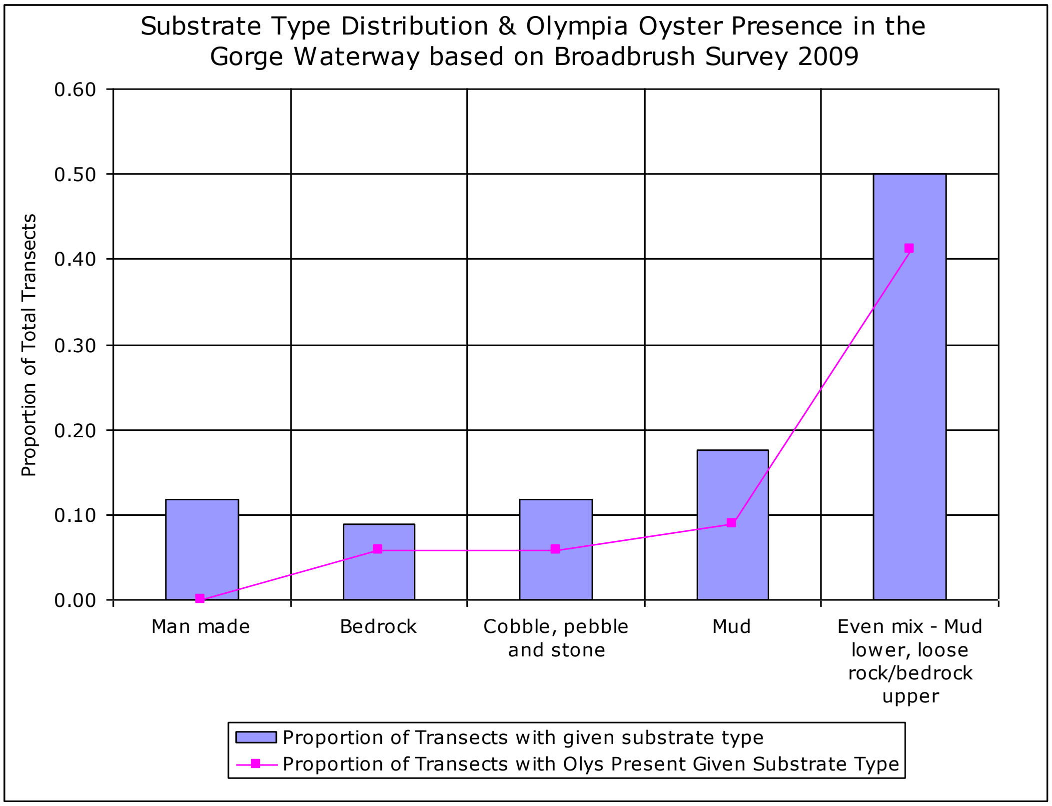


**Figure 9. Presence of intertidal Olympia oysters on different substrates in the Gorge Waterway**

Subtidal detection of live oysters is also problematic. Tests comparing diver observations and actual counts of quadrats samples are substantially different, and apparently not adequately uniform to indicate that a correction factor would be very precise (Fig. 10).

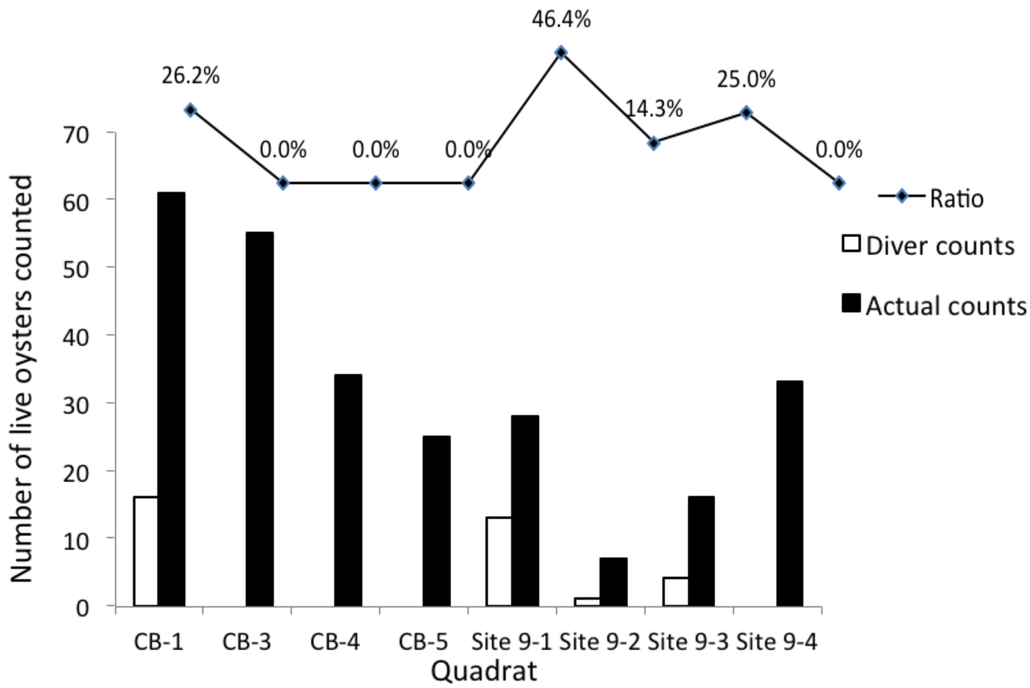


**Figure 10. Comparison of oyster counts in subtidal quadrats as observed by divers and counted in the laboratory**

## Oyster survey methodologies:

The intertidal surveys reported here have been reviewed by Norgard et al. (2010), and are likely to lead to a reliable methodology comparable with other areas of the coast. However, relatively large numbers of quadrats are required for estimates with good precision, and the sampling appears to be quite destructive of oyster beds in muddy areas, which includes much of the Gorge. With a team of 3-4 people, two sampling areas are feasible (45 quadrats) per tidal cycle, but analysis of the oysters takes two people another day or two in the laboratory. Annual repetition of reference sites in muddy regions is thus probably prohibitive both due to high costs and biological damage. Hard substrate sites with lower oyster densities may be preferable, though possibly creating biased monitoring. We plan to pursue this next, including tagging some oysters and setting up permanent quadrats to get a more refined estimate of growth and recruitment.

Subtidal surveys are likewise expensive. We found that soft substrate or shell debris – the substrates most common to subtidal oyster beds – harbor many cryptic oysters that are not detected reliably for quantitative estimates by diver observations or photographic means. Qualitative measures may be better at this, but we have not yet managed to map these out in the oyster beds on a reliable basis. We are not yet sure how well we can extrapolate polygons of abundance or patchiness/abundance within an oyster bed from the relatively few transects that were conducted. Spot dives have not yet been useful for this purpose, but could be used to test estimated maps.

Experience with the subtidal Gorge environment appears to be important in the survey methodology. A team of 4 people appears indicated (2 divers, 1 boat tender, 1 positioning technician), though 3 may be able to do the job with practice. A marked-off lead-line transect through the oyster beds is the most reliable for assessment, though this creates some practical limitation on the length of the transect. Four transects are feasible per day, bracketing a tidal cycle with particularly high tides.

Estimating the edges of the oyster beds as indicated by oyster shells appears more straightforward, either from the surface or with divers. Subsequent estimation of where live oysters start requires diver observations. However, so far we have not managed to link subtidal and intertidal data – the subtidal maps appear to indicate that the live oysters stop below the intertidal beds. This may be a methodological artifact or because of a low density band at the low tide line. We are planning to investigate this more closely this year.

**Associated flora and fauna & mortalities:**

Our surveys also documented flora and fauna that were associated with the oyster beds (Table 3). This was meant to provide some information on the presence of potential predators, synergistic or competing entities, indicators of environmental conditions, and the prevalence of invasive species. This aspect took some time to get to a level of reliable documentation by divers, firstly trimming an extensive list of potential presences to those of very likely occurrence, and secondly building consensus on underwater identification. This information is not yet fully analyzed, but some interesting aspects are the absence of potential predators, the low frequency of Pacific oysters, and the prevalence of invasive colonial tunicates (likely misidentified in previous surveys for the Harbours Atlas).

**Table 3. Invertebrate and algal species associated with subtidal oyster beds in the Gorge Waterway**

| **Species** | **Category** |
|---|---|
| Amphipod | Amphipod |
| *Botrylliodes violaceus* | Invasive tunicate |
| *Botryllus schlosseri* | Invasive tunicate |
| *Callophyllis* | Red alga |
| Caprellid | Crustacean |
| *Codium* | Green alga |
| *Chthalamus sp* | Barnacle |
| Boring sponge (*Cliona*; evidence only) | Sponge |
| Filamentous diatoms | Diatom (algae) |

| | |
|---|---|
| Filamentous red algae | Red alga |
| *Mytilus galloprovincialis* | Bivalve |
| Flatworm | Turbellid |
| *Halichondria* (yellow sponge) | Sponge |
| Hermit crab (in a mudflat snail shell) | Crab |
| Hydroid | Hydrozoan |
| Littleneck clam | Bivalve |
| *Littorina* | Snail |
| *Macoma* bent nose clam | Bivalve |
| *Macoma* clam | Bivalve |
| *Metridium* | Anemone |
| *Mopalia* | Chiton |
| Mudflat snail – *Battinaria sp.* | Snail |
| *Mya arenaria* | Bivalve |
| *Mytilus sp* | Bivalve |
| Polychaete | Annelid |
| Pacific oyster | Bivalve |
| Red Algae | Red alga |
| *Sargassum* | Brown alga |
| Scale worm | Annelid |
| *Schizoporella* | Bryozoan |
| *Smithora naidum* (eelgrass epiphyte) | Red alga |
| Striped anemone | Anemone |
| Terebellid | Annelid |
| Tube worms | Annelid |
| *Zostera marina* (eelgrass) | Flowering plant |

The sampling in March also revealed a recent mortality of a variety of shellfish at both sites, including oysters and clams. It is unclear if this was associated with unusual cold exposure or recent fuel spills in the region. The oysters at the Craigflower Bridge were sampled for parasites and diseases by DFO in mid-April, as part of their coast-wide survey, indicating a higher incidence of disseminated neoplasia (26%) than is common in other populations, though this was not considered a serious risk.

**Float communities:**

Divers evaluated six floating docks in the upper Gorge Waterway, to assess community assemblages and oyster presence. A further three in the lower Gorge and upper harbour have been monitored from the surface.

For these surveys, diving or snorkeling analysis is clearly the most informative method. Photographic evaluation with underwater cameras was not adequate to investigate community assemblages on its own, though it could identify likely composition based on prior classifications by snorkeling.

These preliminary data indicate some trends that could be investigated further. In the upper Gorge, we found what looked like a relatively recent colonization community (possibly 0.5 – 1 year) on plastic, Styrofoam, and wood substrate. This consisted of quite diverse patches of invasive colonial tunicates (mostly *Botryloides violaceus*), hydroids (mostly *Obelia*), mussels (*M. galloprovincialis*), barnacles (sp. unknown), a variable number of Olympia oysters and some *Molgula* (solitary tunicate).

An older dock adjacent to the aforementioned dock, that appeared identical in construction, was entirely covered by the *Molgula* tunicate. This organism is distinctive in its propensity to accumulate detritus and mud on its tunic, which could choke out other organisms. Live oysters and some mussels were still present under this mat, with barnacles, mussels, and hydroids around the edges.

One recent dock on plastic barrels in the Gorge Narrows (Table 4), below Index site 9, was particularly densely covered by Olympia oysters, but was removed before the March sampling period.

**Table 4. Example of data input to Harbours Atlas from dock surveys**

| Dock ID | Dock description | Depth (m) | Zone | Species | Abundance | Comments |
|---|---|---|---|---|---|---|
| G03D001 | Dock upstream of narrows. Blue barrel flotation, solid wood dock | 1.40 | 1 | Native oyster | Abundant | |
| | | | 1 | Botrylloides violaceus | Present | Invasive tunicate |
| | | | 1 | Yellow sponge | Present | Most likely Halichondria |
| | | | 1 | Chthalamus | Common | |
| | | | 1 | Metridium | Common | |
| | | | 1 | Hydroid | Common | Most likely Obelia sp. |
| | | | 3 | Zostera | Abundant | Eelgrass |
| | | | 3 | Native oyster | Present | On rocks |
| | | | 3 | Mya clam shell | Present | |
| | | | 3 | Littleneck clam | Present | |
| | | | 3 | Sargassum | Present | |
| Depth adjusted for Chart datum according to Victoria Harbour tides + 2 hours | | | | | | |
| Zone description: 1 = dock, 2 = pilings, 3 = benthos | | | | | | |

Some docks in the upper harbor were distinctive in their populations of the alga *Codium fragile*, usually most abundant on the outer exposed coast. These appeared to be over-wintering, also unusual for this species. A dock just below the Gorge Narrows appears to have a mixed character (including oysters).

The distinctive character of the different docks could provide substantial information on biological dynamics of the waterways. We are still working on developing a better photographic tool that may help in this evaluation, though snorkeling and diving will likely still be necessary components of this work.

**Harbours Atlas Data**

The data was entered into ArcGIS mapping interface in order to be compatible with the CRD Harbours Atlas. When entering the data into this program, WFT followed coding based on previous CRD projects (Table 5).

**Table 5. Explanation of identification units assigned to the CRD Harbours Atlas map attributes. For each ID unit there is an explanatory sub-table**

| | |
|---|---|
| **ID Unit** | [LOCATION_NUMB][SAMPLE TYPE][ATTRIBUTE][UNIQUE_NUMB] |
| **Example ID Unit** | [G01][B][L][001] |
| **Example description** | *G01BL001 corresponds to live oyster boundary point 1 for the Craigflower Bridge Olympia oyster bed.* |

Table 5.1. LOCATION_NUMB

| | |
|---|---|
| G01 | Craigflower Bridge- Gorge Waterway |
| G02 | DFO intertidal sampling site 'Calvin's'; boat ramp- GW |
| G03 | 937 Mesher Place, dock below on GW |

Table 5.2. SAMPLE_TYPE

| | |
|---|---|
| D | Dock Survey |
| B | Boundary |
| S | Sample or Quadrat Point |
| T | Transect |
| N | Navigation |
| P | Polygon |

Table 5.3 ATTRIBUTE – for reference, not unique labeling

| | |
|---|---|
| F | Few |
| P | Patchy |
| U | Uniform |
| C | Continuous |
| D | Dense |
| S | Shell |
| L | Live |
| A | Abundant (16+ in 0.5m x 0.5m) |
| C | Common (6-15 in 0.5m x 0.5m) |
| P | Present (1-5 in 0.5m x 0.5m) |

Additional coding was used in some cases. For instance, intertidal zones, adapted from a report by Wesltand Resource Group (2000) for the CRD, were applied to the study sites from WFT's broad brush survey in 2009 (Table 6), assuming relatively uniform shoreline slopes. This should be refined once actual tidal heights are available.

**Table 6. Intertidal zones, adapted from Westland Group (2000)**

| Zone | Transect length | Description |
|---|---|---|
| B upper | 0 – 4.9m | Mid-upper intertidal zone, borders the upper intertidal splash zone |
| B mid | 5 – 9.9m | Mid-lower intertidal zone |
| B mid | 10 – 14.9m | Mid-lower intertidal zone |
| B lower | 15 – 19.9m | Lower intertidal zone, borders subtidal zone |
| C upper | 20$^+$m | Beginning of subtidal zone |

*Note: Index Ferry site has a significantly steeper slope than other sites; may transition into deeper zones more quickly.

Dock/float community surveys were classified in three dock 'zones', modelled on the intertidal zone classification (Table 7).

**Table 7. Zones applied to dock environments, modeled after intertidal zones.**

| Zone | Description |
|---|---|
| 1 | Dock – floating structure |
| 2 | Pilings/dock support |
| 3 | Benthic – beneath dock |

*Data for floating docks with no pilings currently say zone 1,2 in the dataset, which needs to be corrected.

The interactive data file includes associated tables for many features, such as quadrats, transects, sample sites, and polygons. These tables often included species names for the organisms associated with the feature. WFT decided to input the names that are most likely identifiable by the user, which may or may not be the scientific name. In order to prevent confusion, we created a supplementary table (Table 8) to be added to the CRD Harbours Atlas as an index table. This table lists both the common and scientific name of all organisms included in our data, and should be incorporated into the Atlas and updated regularly.

**Table 8. Scientific names to closest known taxonomic level for associated species listed in the Harbours Atlas data. Where the scientific names were used as the name entered in the Atlas, no alternate is given.**

| Organism name as entered in the Harbours Atlas | Scientific name |
|---|---|
| Amphipod | *Gammaridae* |
| *Botrylliodes violaceus* | - |
| *Botryllus schlosseri* | - |
| *Callophyllis* | - |
| Caprellid | *Caprellidae* |
| *Codium* | *Codium fragile* |
| *Chthalamus sp* | - |
| Purple boring sponge | *Cliona* |
| Filamentous diatoms | *Bacillariophyceae* |
| Filamentous red algae | *Rhodophyta* |
| *Mytilus galloprovincialis* | - |
| Flatworm | *Turbellaria* |
| *Halichondria* | - |
| Hermit crab | *Pagurus* |
| Hydroid | Likely *Obelia* |
| Littleneck clam | *Protothaca staminea* |
| *Littorina* | - |
| *Macoma* bent nose clam | *Macoma nasuta* |
| *Macoma* clam | *Macoma sp.* |
| *Metridium* | *Metridium senile* |
| *Mopalia* | *Mopalia muscosa* |
| Mudflat snail | *Batillaria sp.* |
| *Mya* clam | *Mya sp.* |
| *Mytilus sp* | - |
| Polychaete | |
| Pacific oyster | *Crassostrea gigas* |
| Red Algae | *Rhodophyta* |
| *Sargassum* | *Sargassum muticum* |
| Scale worm | |
| *Schizoporella* | - |
| *Smithora naiadum* | - |
| Striped anemone | *Diadumene lineata* |
| Terebellid | |
| Tube worms | *Eudistylia* |
| *Zostera marina* | - |

**Recommendations & Conclusions**

The Gorge Waterway houses a unique population of Olympic oysters that is particularly interesting for a number of reasons, including:

1) Persistence through time, despite impacts of historical harvesting, sedimentation from agriculture, and pollution from urbanization;
2) Both strong intertidal and subtidal components, despite exposure to cold winter temperatures and freshwater run-off;
3) Abundance in soft substrate, including mud
4) Very high densities, though patchy

Monitoring of interannual variation is still methodologically challenging, as is an understanding of key elements that allow the survival of this populations. Some doubts include:

1) Linkage between subtidal and intertidal portions of the population
2) More complete characterisation of the subtidal beds, in particular to identify reproductive reservoir groups;
3) Sources of mortality – winter low tides are the expected time of greatest mortality, but current observations suggest mortalities may be in March;
4) Role of docks in oyster population dynamics
5) Recruitment and growth patterns – particularly in Portage Inlet, where there is an anomalous absence of live oysters

Some activities that we recommend:

1) Continuation of annual intertidal reference site monitoring, moving to a new soft substrate site this year (at Craigflower Bridge to also monitor impacts of this project) and tagging some oysters and permanent quadrat sites on hard substrate (part of summer student and career focus projects at WFT);
2) Water quality monitoring, including pH to integrate with other projects that are monitoring ocean acidification (in collaboration with UVic thesis and neighbourhood initiative to foster swimming in the Gorge; coordination with CRD & VIHA & pursuing other partnerships);
3) Monitoring of oyster settlement and larval patterns (unfunded this year at WFT, but may get some information from invasive species monitoring being done in collaboration with the BC Museum and DFO);
4) Continuing investigation of subtidal oyster beds (unfunded so far);
5) Continuing investigation of docks, including in the adjacent harbours (unfunded so far).

**Acknowledgements**

We acknowledge the Habitat Stewardship Program, which helped fund some of our surveys for the Olympia oyster in the Gorge Waterway. We thank the Department of Fisheries and Oceans Canada, specifically Tammy Norgard, for her guidance and support throughout our research on the Gorge Waterway. We also thank Mary Vasey, Alicia Donaldson, Paige Erickson-McGee, Kitty Lloyd, who were involved in various stages of data collection and analysis, and the many volunteers who gather intertidal and subtidal data. A special thank you to Shane Ruljancich of the CRD, who expertly guided us through the workings of ArcGIS, and made adding this data to the CRD Harbours Atlas possible.

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