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Community composition of the intertidal in relation to the shellfish aquaculture industry in coastal British Columbia, Canada

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ABSTRACT

The intertidal region of the Pacific Northwest is under ever increasing pressure to be used exclusively for the industrial sized operations of shellfish aquaculture. In British Columbia (BC), aquaculture practices include seeding the intertidal with the non-indigenous *Venerupis philippinarum* followed by the application of anti-predator netting. Ecological consequences of such practices applied at large scales are unknown. To assess for possible impacts 28 farm and reference sites from 3 geographically distinct regions of BC were surveyed in each of two years and their epibenthic, endobenthic and macroflora communities compared. The three regions differed in their intensity of industry from low (Barkley), medium (Desolation) to high (Baynes). Marked regional differences in intertidal community composition were observed. Of the three regions Baynes Sound, which has 101 tenures, was the most altered with the greatest numbers of the invasive species, *Batillaria* sp. and *Hemigrapsus oregonensis*. Barkley Sound, the region with the lowest industrial intensity, was characterized by *Mytilus trossulus* and the absence of *H. oregonensis*. The mid-intensity region, Desolation Sound, was characterized by *Littorina scutulata* and *Tectura persona*. Within Baynes Sound, seeding appears to be acting as an attractant for crab predators with farm sites having on average 3-fold greater numbers as compared to reference sites. Farming practices were also found to encourage growth and biofouling of the intertidal with *Ulva* sp. Consequences of changes in community composition in this case, an increase in the abundance of a major intertidal predator, *H. oregonensis*, on ecosystem functioning within these sensitive coastal areas are not known.

1. Introduction

A major industrial development to coastal ecosystems as a consequence of the ever increasing demand for a secure source of protein is finfish and shellfish aquaculture (Naylor et al., 2000). On the west coast of British Columbia (BC), Canada, industry and the federal and provincial governments are aggressively expanding shellfish aquaculture with *Venerupis* (*Ruditapes*) *philippinarum* (A. Adams and Reeve, 1850) one of the main products farmed. *V. philippinarum* is an invasive species which “hitch-hiked” on oyster seed brought over from Japan in the mid 1930s (Gillespie et al., 2012; Quayle and Bourne, 1972).

Currently there are 284 tenures for *V. philippinarum* culture in BC with the greatest intensity occurring within Baynes Sound (Gillespie et al., 2012). Dumbauld et al. (2009) have suggested that shellfish aquaculture can be viewed as a disturbance to the coastal environment in three ways; 1) changes in materials processing (e.g., nutrient flux), 2) addition of physical structures (e.g., anti-predator netting) and 3) pulse disturbances such as harvesting. Although not noted in their review, near-bottom marine aquaculture of *V. philippinarum* that includes seeding with juvenile clams at densities of 200 to 700/m^2 could also be considered as a “pulse disturbance”.

All of the above listed disturbances have the potential to alter the existing intertidal environment and hence community. Sorokin et al. (1999), Bartoli et al. (2001), Beadman et al. (2004) and Bendell-Young et al. 2010 have all shown that netted farm sites accumulate more organic matter and silt as compared to sites not farmed. Intensive shellfish farming has also been reported to decrease benthic diversity and change the intertidal species composition to one dominated by bivalves and deposit feeding worms (Bendell-Young, 2006; Spencer et al., 1997). By contrast, McKindsey et al. (2007) note that application of anti-predator nets to the intertidal increases its structural complexity and in some cases may increase the abundance of intertidal organisms taking advantage of the new three dimensional habitat. For example, Powers et al. (2007) report that macroalgae growing on anti-predator netting enhanced nursery habitat for mobile invertebrates and juvenile fishes as compared to an unstructured sand flat.

Possibly contributing to the conflicting reports is that studies to date have been limited in geographical scope and have not taken into consideration the intensity of shellfish farming that can occur. Hence, the objective of this study was through a comparison of farm versus reference intertidal sites from three regions of coastal BC which

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experience different intensities of industrial shellfish farming activity, to assess the potential effects of applying anti-predator netting in combination with seeding on the intertidal macroflora, epibenthic (surface) and endobenthic (sub-surface) communities. Such information will add to a better understanding as to how the intertidal community responds to the practices of shellfish farming structure such that we can better manage these sensitive ecosystems. This study also represents the most comprehensive intertidal survey of the low to high tide regions of coastal BC.

2. Methods

2.1. Study area

Three distinct regions of coastal BC were chosen for the study; Barkley Sound, Baynes Sound and Desolation Sound (Fig. 1). The number of BC shellfish tenures licensed for the culture of *V. philippinarum* reported in 2012 for Baynes, Desolation and Barkley Sounds were 101, 32 and 21 respectively (Gillespie et al., 2012). Baynes Sound has been a site of industrial scale shellfish aquaculture since the 1940s and of the three regions has been the most intensively exploited for this purpose with over 50% of shellfish produced in BC farmed within the region (Jamieson et al., 2001). Desolation Sound has been farmed since the late 1960s (Zydelis et al., 2009). By contrast, Barkley Sound is the most remote having experienced the least amount of farming as compared to the other two regions. At the time of sampling, farms had only been established for one year. Farmed sites were selected based on permission for access from lease holders and the availability of suitable reference sites. Nine farm-reference paired sites were surveyed in the first year with a subset of seven pairs, including one new pair, surveyed in the second year. Two "pre-farm" sites sampled in the first year, A5 and D3 had been selected for future clam aquaculture, although no aquaculture activity had started at the time of sampling. These sites are included as additional reference sites in the multivariate analysis and served as important reference sites i.e., an intertidal region selected for clam culture but yet subject to seeding or predator netting. The farm-reference A3 pair (A3R and A3F, Fig. 1) was omitted from the paired analysis as the reference beach was seeded after sampling began. A3F Fig. 1 was included in the multivariate analysis which does not take pairing into account. Discrete regions of the intertidal surveyed between 1 and 2 m above chart datum and above 2 m to the top of netted areas were labeled as "low" and "mid" respectively. Average age in years of farms for each region was 9, 4 and 1 for Desolation, Baynes and Barkley Sounds respectively (Table 1). Paired reference sites were selected to match a paired farm site according to area, tidal range, slope, wave exposure and sediment type (after Wentworth, 1922). Such selection would then allow the most important "experimental" difference between farm and reference sites being the application of seed and netting to farm sites (e.g., see Bendell, 2013; Whiteley and Bendell-Young, 2007).

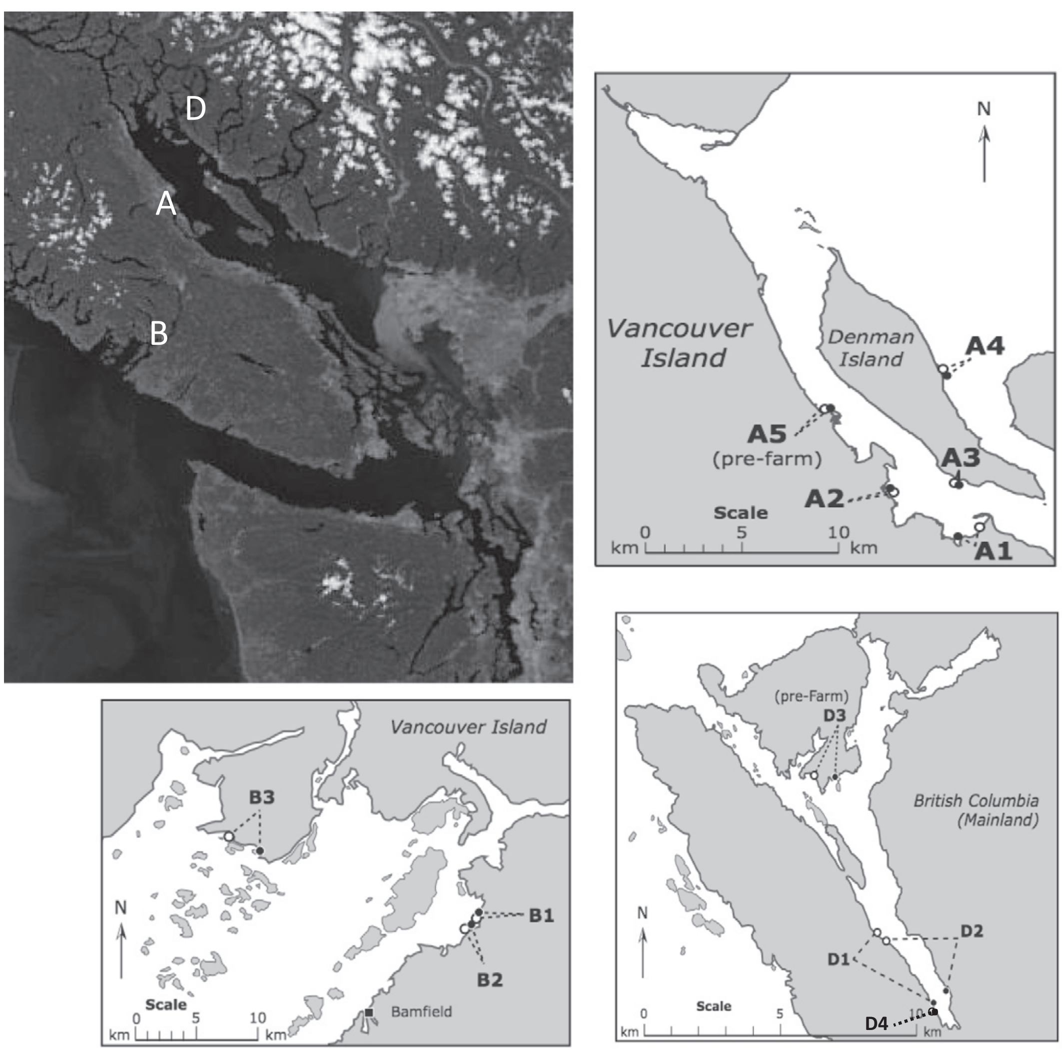

Fig. 1. Location of the three study regions; A; Baynes Sound, B; Barkley Sound and D; Desolation Sound. Insets show approximate locations of intertidal sites, both farm (closed circles) and paired reference (open circles) sites.