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Distribution, inventory and turnover of benthic organic biomass in the Strait of Georgia, Canada, in relation to natural and anthropogenic inputs

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ABSTRACT

Recently compiled databases facilitated estimation of basin-wide benthic organic biomass and turnover in the Strait of Georgia, an inland sea off western Canada. Basin-wide organic biomass was estimated at 43.1×10^6 kg C and production was 54.6×10^6 kg C yr^{-1}, resulting in organic biomass turnover (P/B) of $1.27 \times yr^{-1}$. Organic biomass and production for sub-regions were predictable from modified organic flux ($r^2 > 0.9$). P/B declined significantly with increasing modified organic flux, suggesting greater biomass storage in high flux sediments. Biomass and production were highest, and P/B lowest near the Fraser River. Annual basin-wide benthic production was 60% of previously estimated oxidized organic flux to substrates, which agrees with proportional measurements from a recent, localized study.

Deviations from expected patterns related to organic enrichment and other stressors are discussed, as are potential impacts to benthic biomass and production, of declining bottom oxygen, increasing bottom temperature and potential changes in riverine input.

1. Introduction

There is growing concern about how benthic marine ecosystems will respond to increasingly rapid changes in climate conditions, particularly in areas of existing stress from anthropogenic sources. The first-order driver in climate change is rising temperature, which can increase sensitivity of benthic organisms to hypoxia (Vaquer-Sunyer and Duarte, 2011). Furthermore, warmed communities tend to show dramatic shifts in the ratio of production to biomass (P/B) that imply changes in metabolism (biomass turnover) and behavior (e.g., bioturbation) in sediments. Declining pH due to ocean acidification by CO_2 promotes the loss of carbonate structures, thus potentially affecting molluscs most acutely (Hale et al., 2011; Fabry et al., 2008). These sorts of stresses then lead to a variety of responses that may include disruption of trophic structure (Petchey et al., 1999), loss of biodiversity (McCann, 2000; Hillebrand et al., 2010), and pole-ward movement of communities (Schiel et al., 2004). A potentially large effect could be the extirpation of species over large areas (Lewis, 2006) as implied by increased species turnover and declining compositional stability along temperature gradients produced by thermal discharges (Hillebrand et al., 2010 and see Schiel et al., 2004).

At present, it is not clear how the aforementioned effects of climate change may interact with existing effects from extraordinary organic input and/or contaminants. To assess quantitatively the regional impacts of changing conditions in marine ecosystems, whether they be related to global climate change or local human activities, current baselines are required for patterns in biomass and energy flow on broad geographic and habitat scales (c.f. Dolbeth et al., 2012). The focus of this paper is to use extensive physical, geochemical and biological data sources to extrapolate existing benthic biomass and turnover patterns in the Strait of Georgia, which is the inland sea (part of the Salish Sea) spanning the southern half of the Canadian west coast.

Burd et al. (2012a) previously described empirical relationships between sediment invertebrate organic biomass and production versus habitat characteristics throughout the Strait of Georgia. Benthic trophic structure and macrofaunal size distributions have also been delineated at the basin scale for the Strait (Macdonald et al., 2012a, b). Our historical understanding of sediment substrate distributions and basin characteristics in the Strait based on hydrographic charts and shoreline mapping (Levings et al., 1983; Thomson and Foreman, 1998; Burd et al., 2008a), has recently been significantly improved through multibeam sonar surveys, numerous grabs and extensive towed video footage, collected throughout the Strait (Quester-Tangent, 2009). In addition to this fundamental mapping of sediment composition, detailed geochemical studies of organic and inorganic sedimentation patterns and carbon cycling

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throughout the Strait have been done using a more limited set of grab samples and ^{210}Pb-dated sediment cores (Burd et al., 2008b, 2009, 2012a; Johannessen et al., 2005a, 2008; Macdonald et al., 2008).

In this paper we apply the extensive sediment substrate mapping and sedimentation data together with the detailed work on benthic organic biomass (B) and organic carbon cycling (secondary production P) described above, to extrapolate basin-wide estimates of organic carbon inventories (standing stock benthic organic biomass) and turnover rates (P/B). Although the focus of previous benthic studies in the Strait has been on soft sediments (sands – muds), estimates of biomass inventory and turnover for rocky substrates are also addressed here by reference to global empirical patterns described in Cusson and Bourget (2005). The estimates of benthic inventories and production presented here are intended to provide a baseline against which future change in benthic function can be compared relative to changes in temperature, pH, inflow hydrology and dissolved oxygen (e.g., Johannessen and Macdonald, 2009; Johannessen et al., 2014; Riche et al., 2014). The baseline provided here may also be used to assess the regional relevance of local changes in benthic faunal processes due to point-source anthropogenic inputs.

2. Methods

2.1. Study area

The Strait of Georgia (Fig. 1) is a semi-enclosed inland sea with an extensive and hydrographically complex coastline (Thomson, 1981; Davenne and Masson, 2001). Including its contiguous fjords, there are 3721 km of shoreline (Levings et al., 1983), with water

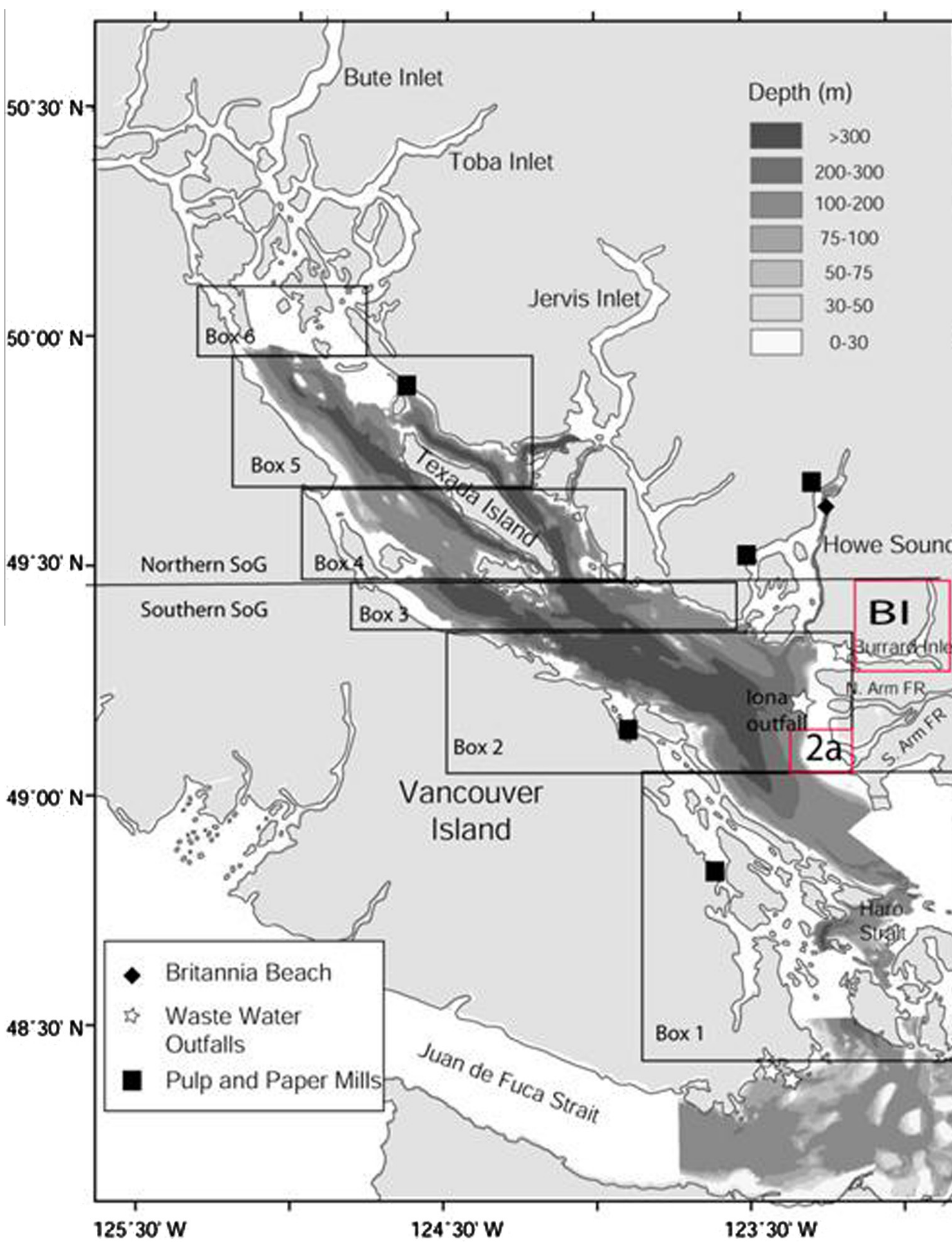

Fig. 1. Strait of Georgia with 6 regional (1–6) and 2 sub-regional (BI, 2A) boxes used for summation of biophysical statistics for the organic biomass and production extrapolation. Multibeam depth stratification (from CHS and Natural Resources Canada) is superimposed. Major anthropogenic input sources (wastewater outfalls in the southern Strait and pulp mills) are also shown. FR = Fraser River.