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Moderate effect of damming the Romaine River (Quebec, Canada) on coastal plankton dynamics

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A B S T R A C T

Rivers' damming disrupts the seasonal cycle of freshwater and nutrient inputs into the marine system, which can lead to changes in coastal plankton dynamics. Here we use a 3-D 5-km resolution coupled biophysical model and downscale it to a 400-m resolution to simulate the effect of damming the Romaine River in Québec, Canada, which discharges on average 327 $m^3 s^{-1}$ of freshwater into the northern Gulf of St. Lawrence. Model results are compared with environmental data obtained from 2 buoys and *in situ* sampling near the Romaine River mouth during the 2013 spring–summer period. Noteworthy improvements are made to the light attenuation parametrization and the trophic links of the biogeochemical model. The modelled variables reproduced most of the observed levels of variability. Comparisons between natural and regulated discharge simulation show differences in primary production and in the dominance of plankton groups in the Romaine River plume. The maximum increase in primary production when averaged over the inner part of Mingan Archipelago is 41%, but 7.1% when the primary production anomaly is averaged from March to September.

1. Introduction

Although coastal regions are amongst the most productive ecosystems on the planet (Gazeau et al., 2004), the lower Estuary of St. Lawrence presents relatively low annual planktonic primary production (Cloern et al., 2014), with values of 100 g C m^{-2} yr^{-1}. High seasonality characterizes the Estuary and Gulf of St. Lawrence (EGSL), in addition to a cyclonic estuarine circulation, strong and deep (>100 m) wind-induced mixing during the cold and darker winter, continuous tidal mixing, and frequent upwelling events forced by dominant westerly winds along the northern coast (Bourque and Kelley, 1995). Stratification resulting from surface warming and vernal irradiance favour sustained primary productivity during summer and fall (Le Fouest et al., 2005, 2006).

On the northern coast of the Gulf of St. Lawrence, several rivers enter the Gulf. Among them, the Romaine River, a 300 km long river that originates near the Québec–Labrador border (Fig. 1). It discharges into the Mingan Archipelago on the northern shore of the Gulf of St. Lawrence. The Romaine River drains a 14 500 km^2 basin, and has a mean annual runoff of 327 $m^3 s^{-1}$ (μSv). Plankton production in the northern Gulf of St. Lawrence (GSL) and in the area around Jacques Cartier Strait, including the Mingan Archipelago, is supported by the supply of nutrient-rich water of oceanic origin, with nitrate concentrations ranging from 0.0 to 12.5 μM, and an overall mean of 6.5 μM (Plourde and Therriault, 2004). Nitrate concentrations of the Romaine River are low all year long (0.07 ± 0.06 μM; Hydro-Québec, 2007). However, other estimates indicate that nitrate content can reach up to 3.5 μM during spring freshet with an annual average of 1.5 ± 0.9 μM (S. Bélanger, unpublished results). No measure of primary production in this

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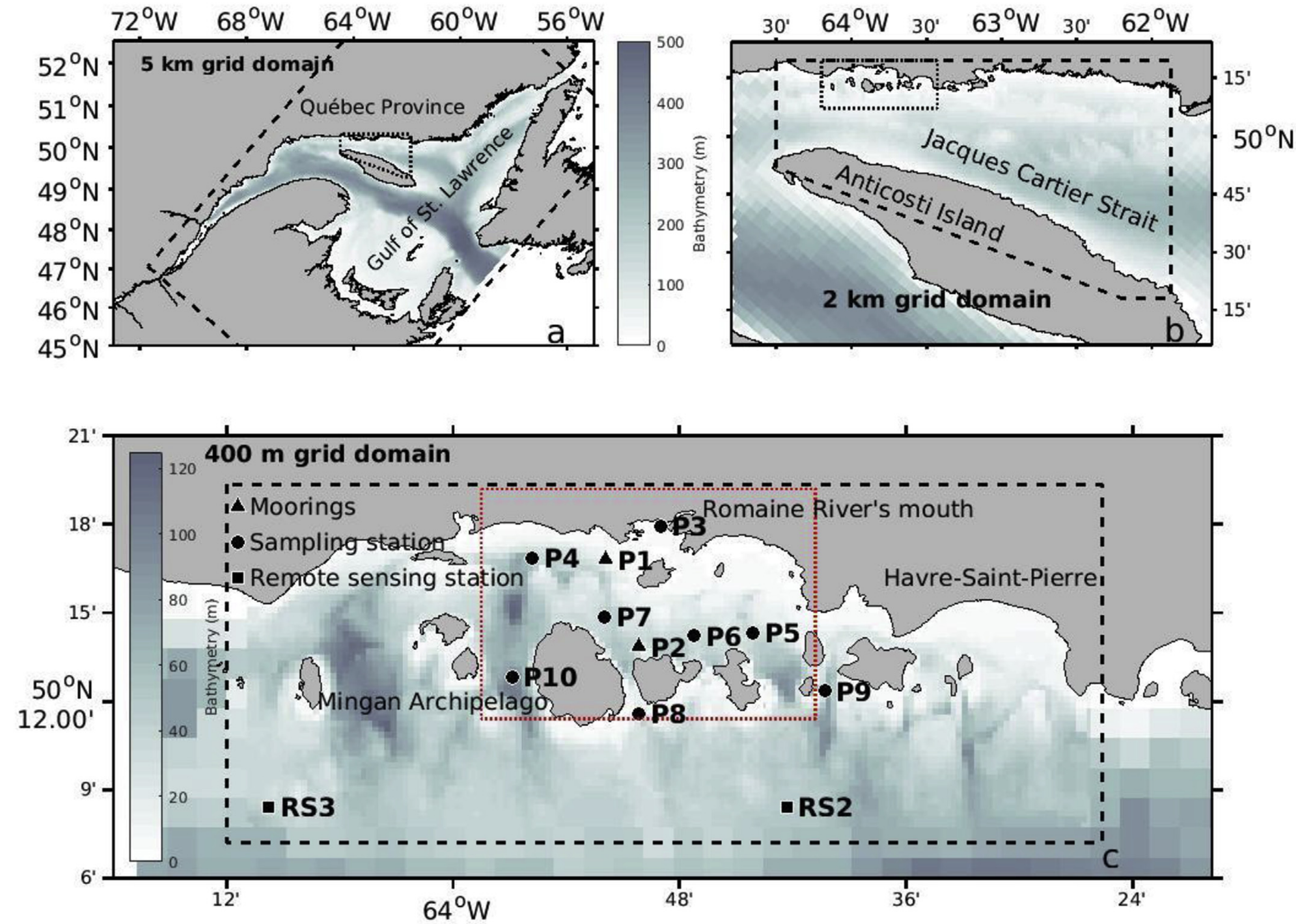

Fig. 1. Bathymetric maps (m) showing station positions and the different model domains. a) The 5 km grid domain (dotted line); b) the 2 km grid domain between Anticosti Island and the North Shore; c) the 400 m grid section in the Mingan Archipelago. Panel c shows the 10 sampling stations (P1 to P10), including the two mooring stations (P1, P2) and the two remote sensing stations (RS2, RS3). The red square corresponds to the domain where most of the analyses were done. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

relatively small area exists, although modelling studies estimated production rates as high as 150 g C m^{-2} yr^{-1} for the Jacques Cartier area (Le Fouest et al., 2005).

In 2009, Hydro-Quebec began the construction of a 1550 MW hydroelectric complex on the Romaine River. The complex of four generating stations fed by reservoirs is slated for completion in 2020, and the first generating station was commissioned in December 2014. Creating and managing the four Romaine complex reservoirs will modify the hydrologic and hydraulic regimes of the river. The mean annual discharge would remain the same, but seasonality would change markedly. In general, the normally low summer and winter discharges will be higher compared to natural conditions, while spring and fall freshets will be considerably dampened (Jaegler, 2014; Hydro-Québec, 2007). Nevertheless, discharge peaks may still occur during the spring flood period, potentially affecting phytoplankton dynamics in coastal areas near river mouths (Domingues and Galvao, 2007).

In situ sampling, satellite remote sensing, ecosystem modelling, or a combination of these different methodological approaches can be used to study the impact of river waters on plankton in coastal waters. 3-D hydrodynamic models are the only tools that provide the necessary temporal and spatial resolutions to capture an integrated view of the physical processes on which plankton strongly depends. We will use these tools to test our main hypothesis that the damming of the Romain River should not have a significant effect on the primary production in the Mingan Archipelago. In addition, we will show that, light and biogeochemical parameterizations traditionally used in conjunction with 3-D circulation models need to be inspected and adapted to shallow coastal and river-influenced environments; they require modifications with regards to the presence of dissolved and particulate matter that greatly affect the light field in the water column and, hence, primary production. In this study, i) we present and discuss *in situ* data from spring −summer 2013 collected around the Romaine River mouth and Mingan Archipelago in natural conditions, ii) we compare these results with the outputs of a coastal domain model downscaled from an existing biophysical model (Saucier et al., 2003), coupled with a NPZD model (Le Fouest et al., 2005, 2006) for the Gulf of St. Lawrence, in which we explicitly consider the effect of coloured dissolved and particulate organic matter on light attenuation in coastal waters, and iii) we simulate the impact of damming the Romaine River on plankton production, providing overall a method for similar studies in other river-influenced systems. The ultimate objective of our work is to study the effect of river damming on coastal plankton biomass and production in the northern GSL.