Ecotoxicological sediment evaluations in marine aquaculture areas of Chile

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Abstract Given its geographic characteristics, the southern Chilean fjord area is subjected to growing environmental pressure from the development of diverse forms of aquaculture (i.e., fish, algae, shellfish). The sediments accumulate substances as a natural sink, and ecotoxicology assays offer a reliable and robust proxy for sediment quality analyses. This study’s objective was to establish a mid-range toxicity base line for the sediments in the region by applying a battery of non-specific ecotoxicological assays. Sediment samples (28) were collected in the channels and fjords studied during the CIMAR-Fiordos 11 cruise (July 2005). The sediments were evaluated using different species endemic to the eastern Pacific as targets: Ampelisca arauana, Tisbe longicornis, Arbacia spatuligera, and Dunaliella tertiolecta. The conditions for each assay were reported previously. Of the four species used as ecotoxicological tools, only D. tertiolecta differed significantly from the control group (negative) in terms of its growth. This difference could be attributed to nutrient enrichment. In general, we concluded that, although local changes occurred in the sediments, the mesoscale magnitude of the ecotoxicological alterations was small. Nonetheless, a surveillance program should be implemented that would allow us to follow-up and analyze the changes that are taking place in the systems on broader scales of time and space.

Keywords Multiple ecotoxicology assays · Sediment quality · Estuarine zone · Marine areas of Chile

Introduction

The sediments act as a sink for a complex mixture of particulate and dissolved substances that are input into the marine ecosystem. These substances react by forming deposits or being adsorbed onto particles or colloids and falling to the sea bottom, where they constitute a complex environmental matrix (Elderfield 1978; Izquierdo et al. 1997). In a natural state, the chemical composition of this sink depends on the mineralogical make-up of the mother rocks, primary production, and the site’s advective and sedimentary processes (Libes 1992). Contaminants are another component of this matrix; these are input as residues from the ever-increasing and diverse activities developed along the basin borders (Grande et al. 2007).

Procedures are required that allow an integrated analysis of the alterations generated by
anthropogenic activities. Recently, toxicological quality has been evaluated with specific or non-specific bioassays (Casado-Martínez et al. 2006; Moreno-Garrido et al. 2007). These tests establish the potential negative effects of pollution on certain target species used as test organisms. Bioassays can be used to assess either water or sediment. These advanced tools (e.g., chemical, ecotoxicological, ecological assays) are able to rapidly identify critical areas requiring further studies (Chapman 1995; Moreno-Garrido et al. 2006; Grande et al. 2007).

The number and type of tests needed to provide a weight-of-evidence for assessing possible biological effects depends on the questions being addressed. In general, two to four bioassays using several test organisms of different taxa and exposure pathways are recommended (OSPARCOM 1998).

Salmon farming has grown exponentially since beginning in Chile in the 1980s. Production in 2000 was 200,000 tons year$^{-1}$ (Buschmann et al. 2001); four years later it had increased to 550,000 tons year$^{-1}$ (Buschmann et al. 2006). Residues from fish (salmon) farming centers are known to have a significant impact on the sediments. Fish farms generate residues derived from antibiotic treatments (growth stage), biocide applications (farming), and organic matter from fish food (fattening stage). These residues affect the ecosystems in a variety of ways, i.e., affecting the natural bacteria, increasing organic matter content in the sediments, decreasing the dissolved oxygen content, and increasing vitamins and nutrients in the water column (Brown et al. 1987; López et al. 1988; Hargrave et al. 1993).

Although aquaculture production is considered to be consolidated in Chile, there is a lot of pressure for the industry to expand in the far south, where the coastal areas are still pristine (Buschmann et al. 2006) and scant scientific information is available on the sediment quality. According to the international agreements signed by Chile, said pressure for industrial growth and lack of scientific information are not compatible (Arévalo et al. 2001).

The study area of this work covers the Interior Sea of Chiloé, which stretches from $41.5^\circ$ S to $43.5^\circ$S. Its population is estimated at 0.8 inhabitants per km$^2$. This region is made up of channels, islands, protected basins, and coastlines; is interrupted by fluvial and glacial valleys; and receives important contributions from continental waters. The waters of the Interior Sea of Chiloé are characterized by high planktonic productivity, which is reflected in high chlorophyll-a (chl-a; 1–12 mg chl-a m$^{-3}$) values and elevated phytoplanktonic proliferation (1–26 mg C m$^{-3}$ h$^{-1}$; Iriarte et al. 2007) and zooplanktonic abundance (Palma and Silva 2004). The area’s elevated productivity is favored by its oceanographic characteristics (Cáceres et al. 2002; Valle-Levinson et al. 2007). Two microbasins have been identified in the area. These are separated by the Desertores Islands and the northern microbasin has higher particular organic carbon (POC) contents in the sediments (Silva and Calvete 2002). Analyses of material caught in sediment traps indicate that, in this area, the fecal pellets from zooplankton are the most important vehicle for carrying POC to the sediments (González et al. 2004).

The objective of this study was to analyze and compare sediment quality through non-specific experimental tests (i.e., survival assays with Ampelisca australis and Tisbe longicornis juveniles; fertilization assays with Arbacia spatuligera gametes; growth assays with the microalga Dunaliella tertiolecta) considering the possible mid-range alterations generated by the increased growth of anthropogenic activity along the coast of the Interior Sea of Chiloé.

Work is being done in Chile to standardize toxicity assays in order to unify criteria as to testing conditions and the acclimatization of native species. The species selected in this study are the most used and the ones for which the most information is available. The sea urchin fertilization assays were standardized for A. punctulata by the U.S. EPA 600/4-91/003 (1988) and adapted for Arbacia spatuligera by Zuñiga (1999). The assay has been used successfully by Larraín et al. (1999), Arévalo et al. (2001), and Rudolph et al. (2007). Advances in the understanding of sea urchin biology, feeding regimen, and acclimatization to laboratory conditions have been achieved by Silva et al. (2004). Larraín et al. (1998a) and Soto et al. (2000) proposed assays, respectively, with the native species Tisbe longicornis and A.