Continental Shelf Research 31 (2011) 172–186

Contents lists available at ScienceDirect

Continental Shelf Research

journal homepage: www.elsevier.com/locate/csr

Temporal and spatial distribution of floating objects in coastal waters of central–southern Chile and Patagonian fjords

Iván A. Hinojosa [a], Marcelo M. Rivadeneira [a,b,c], Martin Thiel [a,b,*]

[a] Universidad Católica del Norte, Larrondo 1281, Coquimbo, Chile
[b] Centro de Estudios Avanzados en Zonas Áridas (CEAZA), Coquimbo, Chile
[c] Center for Advanced Studies in Ecology and Biodiversity (CASEB), Departamento de Ecología, Pontificia Universidad Católica de Chile, Alameda 340, Santiago, Chile

ARTICLE INFO

Article history:
Received 23 December 2009
Received in revised form
16 April 2010
Accepted 26 April 2010
Available online 9 June 2010

Keywords:
Rafting
Floating kelp
Driftwood
Anthropogenic debris
Fjords
Dispersal

ABSTRACT

Floating objects are suggested to be the principal vector for the transport and dispersal of marine invertebrates with direct development as well as catalysts for carbon and nutrient recycling in accumulation areas. The first step in identifying the ecological relevance of floating objects in a specific area is to identify their spatio-temporal distribution. We evaluated the composition, abundance, distribution, and temporal variability of floating objects along the continental coast of central–southern Chile (33–42°S) and the Patagonian fjords (42–50°S) using ship surveys conducted in austral winter (July/August) and spring (November) of the years 2002–2005 and 2008. Potential sources of floating items were identified with the aid of publicly available databases and scientific reports. We found three main types of floating objects, namely floating marine debris (mainly plastic objects and Styrofoam), wood (trunks and branches), and floating kelps (*Macrocystis pyrifera* and *Durvillaea antarctica*). Floating marine debris were abundant along most of the examined transects, with markedly lower abundances toward the southern fjord areas. Floating marine debris abundances generally corresponded to the distribution of human activities, and were highest in the Interior Sea of Chiloé, where aquaculture activities are intense. Floating wood appeared sporadically in the study area, often close to the main rivers. In accordance with seasonal river run-off, wood was more abundant along the continental coast in winter (rainy season) and in the Patagonian fjords during the spring surveys (snow melt). Densities of the two floating kelp species were similar along the continental coast, without a clear seasonal pattern. *M. pyrifera* densities increased towards the south, peaking in the Patagonian fjords, where it was dominant over *D. antarctica*. Densities of *M. pyrifera* in the Patagonian fjords were highest in spring. Correlation analyses between the abundances of floating objects and the distance to the nearest sources were generally non-significant, suggesting that post-supply processes affect the distribution of the floating objects in the study region. The identification of several major retention zones supports this idea. Accumulation areas of floating objects appear to be more common in the fjord zones. In general, the results underscore the abundance of floating objects throughout the study region and the fact that floating marine debris sources are mostly local, whereas floating algae may be dispersed over greater distances. Future studies should focus on the ecological role of floating objects in biota dispersal and nutrient cycling.

1. Introduction

Rafting dispersal via floating objects is considered to be the most likely mechanism explaining the ample geographic range, disjunct population distribution, and molecular pattern of organisms that have direct development (Johannesson, 1988; Castilla and Guiñez, 2000; Thiel and Haye, 2006). Whereas the importance of floating objects as dispersal vehicles has been repeatedly emphasized in recent years (e.g., Waters and Roy, 2004; Donald et al., 2005; Thiel and Gutow, 2005a, 2005b; Fraser et al., 2009), the role of these items in carbon and nutrient cycling and transfer has been mostly ignored. However, epibionts on floating algae (and other floating objects) can substantially contribute to the community respiration in the open ocean (Smith et al., 1973). Furthermore, floating objects accumulated in frontal systems are thought to play an important role in nutrient recycling (e.g., Thiel and Gutow, 2005b, and references therein). In order to evaluate the role of floating objects in species dispersal and biogeochemical cycles, it is important to first understand the

* Corresponding author at: Universidad Católica del Norte, Larrondo 1281, Coquimbo, Chile. Tel.: +56 51 209939; fax: +56 51 209812.
E-mail address: thiel@ucn.cl (M. Thiel).

0278-4343/$ - see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.csr.2010.04.013

factors that drive their abundance and distribution, which may vary substantially throughout the world's oceans.

The most common floating objects of natural origin are macroalgae, wood, seeds, land plants, and volcanic pumice (Jokiel, 1990; Maser and Sedell, 1994; Worcester, 1994; Hobday, 2000; Nelson, 2000). Floating anthropogenic objects are mainly plastics; these are usually denominated floating marine debris (FMD; Coe and Rogers, 1997; Williams et al., 2005). Some natural items have a high nutritional value for rafting organisms, whose feeding activity reduces the floating potential and persistence of floating objects at the sea surface (Vandendriessche et al., 2007; Rothäusler et al., 2009). On the other hand, some anthropogenic items of abiotic origin (e.g., plastics and buoys) have no food value for travelers. Since these items are not consumed, they persist for long periods at the sea surface, potentially transporting travelers over extensive distances (Barnes, 2002; Barnes and Fraser, 2003; Astudillo et al., 2009).

Spatial and temporal supply dynamics influence the raft abundance in particular areas. Sources of floating objects are often highly localized (e.g., rivers, human population centers, natural kelp forests). The temporal supply of floating objects also varies, and they might appear in high densities during some periods and be practically absent during others. For example, seasonal variations in river run-off influence the supply of floating objects (e.g., wood, Johansen, 1999; plastics, Moore et al., 2002). Floating marine debris (FMD) of human origin (shipping, sea-based aquaculture operations, urban activities) often does not vary significantly over time because the supply is almost continuous (Vlietstra and Parga, 2002; Edyvane et al., 2004; Hinojosa and Thiel, 2009). The temporal supply of floating macroalgae can be highly variable, often related to algal growth seasons. For example, in coastal waters along the West Pacific, floating *Sargassum* is very abundant in spring and summer (due to fragmentation during the growth season) but almost absent in winter (Deysher and Norton, 1982; Kingsford, 1992; Hirata et al., 2001). On the other hand, no seasonal variation was observed for large rafts of the giant kelp *Macrocystis pyrifera* in the coastal waters of California, which might be due to the high supply of floating algae after storms (Kingsford, 1992; Hobday, 2000). In general, macroalgae and wood appear to enter the coastal waters on a seasonal basis, whereas anthropogenic floating items are continuously supplied.

Once at sea, floating objects are at the mercy of currents, winds, and particular oceanic features such as fronts, tides, and waves. Ocean currents influence long-term movements, whereas wind and coastal fronts drive short-term or local dispersal and

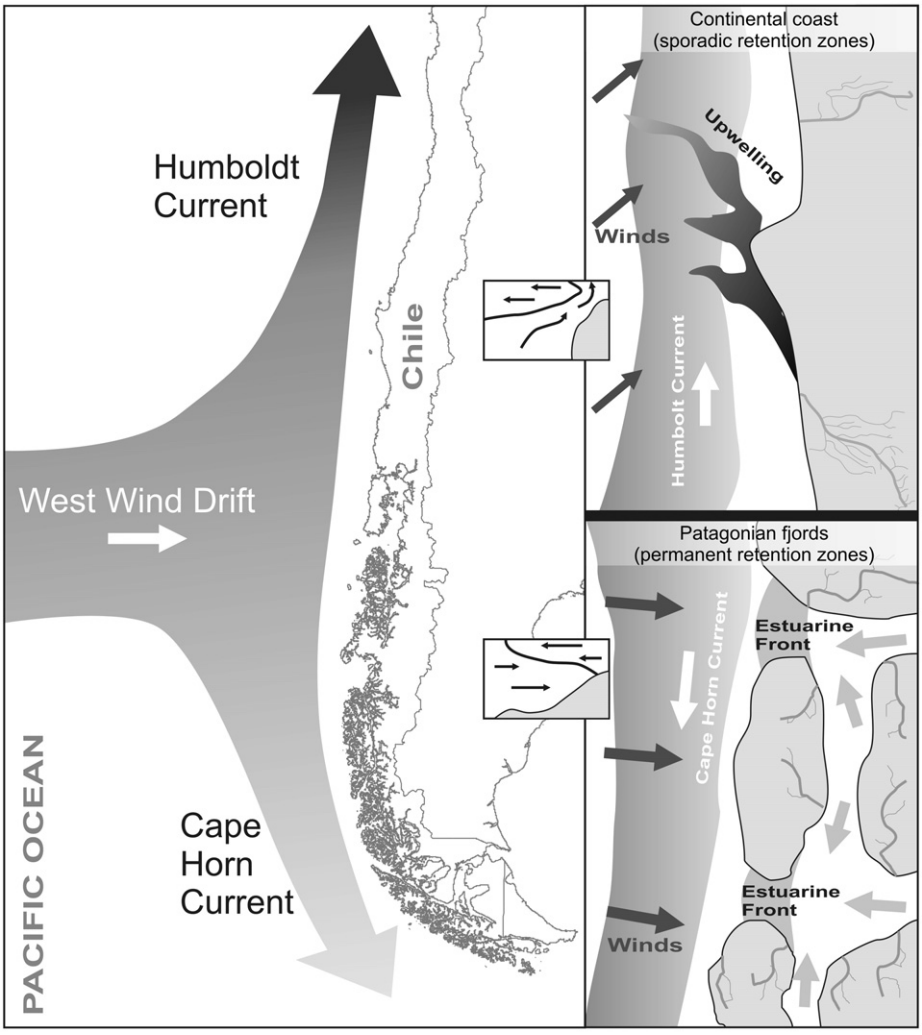

Fig. 1. Main oceanographic currents along the coast of southern Chile and conceptual model of the main oceanographic features along the continental coast of central–southern Chile and in the Patagonian fjords. Small inserts exemplify the interaction between the two main water masses in each area. General oceanographic features of the SE Pacific based on Acha et al. (2004) and for the Patagonian fjords after Sievers and Silva (2008); for additional details, please, see those references.