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Allochthonous subsidies of organic matter across a lake–river–fjord landscape in the Chilean Patagonia: Implications for marine zooplankton in inner fjord areas

Cristian A. Vargas [a,d,*], Rodrigo A. Martinez [a,1], Valeska San Martin [a], Mauricio Aguayo [b], Nelson Silva [c], Rodrigo Torres [d]

[a] Aquatic System Unit, Environmental Research Center EULA Chile, Universidad de Concepción, PO Box 160-C, Concepción, Chile
[b] Territorial Planning Unit, Environmental Research Center EULA Chile, Universidad de Concepción, PO Box 160-C, Concepción, Chile
[c] Escuela de Ciencias del Mar, Pontificia Universidad Católica de Valparaíso, PO Box 1020, Valparaíso, Chile
[d] Centro de Investigación en Ecosistemas de la Patagonia (CIEP), Bilbao 449, Coyhaique, Chile

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ABSTRACT

Ecosystems can act as both sources and sinks of allochthonous nutrients and organic matter. In this sense, fjord ecosystems are a typical interface and buffer zone between freshwater systems, glaciated continents, and the coastal ocean. In order to evaluate the potential sources and composition of organic matter across fjord ecosystems, we characterized particulate organic matter along a lake–river–fjord corridor in the Chilean Patagonia using stable isotope ($\delta^{13}C$) and lipid (fatty acid composition) biomarker analyses. Furthermore, estimates of zooplankton carbon ingestion rates and measurements of $\delta^{13}C$ and $\delta^{15}N$ in zooplankton (copepods) were used to evaluate the implications of allochthonous subsidies for copepods inhabiting inner fjord areas. Our results showed that riverine freshwater flows contributed an important amount of dissolved silicon but, scarce nitrate and phosphate to the brackish surface layer of the fjord ecosystem. Isotopic signatures of particulate organic matter from lakes and rivers were distinct from their counterparts in oceanic influenced stations. Terrestrial allochthonous sources could support around 68–86% of the particulate organic carbon in the river plume and glacier melting areas, whereas fatty acid concentrations were maximal in the surface waters of the Pascua and Baker river plumes. Estimates of carbon ingestion rates and $\delta^{13}C$ in copepods from the river plume areas indicated that terrestrial carbon could account for a significant percentage of the copepod body carbon (20–50%) during periods of food limitation. Particulate organic matter from the Pascua River showed a greater allochthonous contribution of terrigenous/vascular plant sources. Rivers may provide fjord ecosystems with allochthonous contributions from different sources because of the distinct vegetation coverage and land use along each river's watershed. These observations have significant implications for the management of local riverine areas in the context of any human project that may modify terrestrial habitats as well as the productivity, food webs, and community structure of rivers, lakes, fjords, and the coastal ocean in the Chilean Patagonia.

1. Introduction

For decades, ecologists working in food web analysis have focused their studies on interactions among elements of well-defined ecosystems, putting little emphasis on the interactions and transitions among the ecosystems themselves. Recently, it has become increasingly apparent that fluxes of energy and biogeochemical elements across operationally defined systems represent an important and usually neglected component of ecosystem dynamics (e.g., Polis et al., 1997; Carpenter et al., 2005). The fact that ecosystems might act as both sources and sinks of allochthonous nutrients and detritus is essential for understanding primary productivity and food web dynamics at a landscape level (Jefferies, 2000).

Fjords constitute a typical case requiring a landscape-wide approach to ensure a thorough understanding of ecosystem functioning and vulnerability under natural or anthropogenic stressors. These areas represent an interface and a buffer between freshwater systems (i.e., lakes and rivers), glaciated continents,

* Corresponding author at. Aquatic System Unit, Environmental Research Center EULA Chile, Universidad de Concepción, PO Box 160-C, Concepción, Chile, Tel.: 56 41 2204032; fax: 56 41 2207076.
E-mail address: crvargas@udec.cl (C.A. Vargas).
[1] Present address: Dept. Biologia Marina i Oceanografia, Institut de Ciències del Mar (CSIC), Passeig Marítim de la Barceloneta, 37-49, 08003 Barcelona, Spain.

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