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Rainbow Trout diets and macroinvertebrates assemblages responses from watersheds dominated by native and exotic plantations

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ABSTRACT

Over the past few decades, land-use changes through conversion of global forest cover to exotic plantations is contributing to both habitat and biodiversity loss and species extinctions. To better understand human influences on ecosystem, we use diet composition from introduced Rainbow Trout *Oncorhynchus mykiss* as indicator of potential changes in the composition of stream-macroinvertebrates due to land use changes from native to exotic vegetation (eucalyptus plantations) in southern Chile. Water quality variables, aquatic macroinvertebrates and Rainbow Trout diet were studied in 12 sites from mountain streams located in two watersheds including one dominated by native riparian vegetation and the other dominated by exotic vegetation. As expected, richness and abundance of macroinvertebrates were clearly higher at sites in native forest than in those with exotic vegetation. Collector-gatherer was the most abundant functional feeding group, but there was no statistical difference in the functional composition between the two watersheds. Differences in in-stream macroinvertebrate availability was more higher correlated with changes in Rainbow Trout diets. Specifically, taxa consumed from the watershed dominated by native forests was higher than from the watershed with exotic vegetation. Additional environmental variables showed statistical differences between watersheds. The exotic vegetation sites had the highest concentrations of dissolved solids, suspended solids, nitrates, chlorides and sulphates. Our findings show that macroinvertebrate assemblage structure and trout diets can be altered by changes in riparian vegetation. The absence of specific macroinvertebrate taxa in streams with exotic vegetation was captured by the composition of trout diets. This suggest that Rainbow Trout diets can be a good biological indicator of land use practices and thus, diet can be used as a rapid and effective tool for evaluate environmental quality. Our findings provide insights about the design of aquatic monitoring programmes to improve detection of anthropogenic impacts in streams in South America and elsewhere.

1. Introduction

Freshwater ecosystems are among the most seriously threatened in the world (Saunders et al., 2002; Barletta et al., 2010). During the recent decades, the loss of freshwater biodiversity has been accentuated mainly due to changes in land use from human-related activities (e.g., forestry and livestock or arable farming) that have resulted in habitat destruction, fragmentation and eutrophication (e.g., Encalada et al., 2010; Miserendino et al., 2011; Lunde and Resh, 2012). In particular, because of the economic benefit from the cellulose industry (Valdovinos, 2006), the replacement of native forest by plantations of exotic species (i.e., monocultures of conifers and eucalyptus) has been a widespread forestry practice all over the world (Hartley, 2002).

In headwaters of forested watersheds, riparian vegetation is a major source of energy and nutrients for stream food webs through the introduction of dead leaves and large woody debris (Vannote et al., 1980). In these environments, the relatively high velocity of water and extensive shade from the canopy limit the autochthonous production (Vannote et al., 1980; Wallace et al., 1997). Therefore, modifications of riparian vegetation can modify the quality of leaf-litter inputs and alter processes in aquatic

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ecosystems such as the trophic structure and composition of aquatic communities (Abelho and Graça, 1996; Martínez et al., 2013).

Since the beginning of the 19th century, varying degrees of anthropogenic disturbance along coast of southern Chile (southern South America) have occurred (Peña-Cortés et al., 2011a). This includes an over-exploitation of the soil and the replacement of the native forest by agriculture, urbanisation, and plantations of exotic tree species (Sala et al., 2000; Peña-Cortés et al., 2006; Aguayo et al., 2009). The consequences of these activities upon aquatic food webs are still not well understood. Recently, it has been reported that among the most threatened communities by such changes in land use are the benthic aquatic macroinvertebrates (Fierro et al., 2015). A few studies conducted in headwaters (e.g., Larrañaga et al., 2009; Miserendino and Masi, 2010) have shown higher shredder richness in streams dominated by native forest compared to streams dominated by exotic plantations. More recently, Fierro et al. (2015) showed higher invertebrate densities and richness in streams dominated by native forest. Because macroinvertebrates assemblages represent intermediate trophic links between primary and tertiary consumers (Jensen et al., 2012; Bertrán et al., 2013; Cornejo-Acevedo et al., 2014; Fierro et al., 2014) as fish food sources, their availability can affect fish carrying capacity of these low-to-medium order streams populations. If prey availability is limiting, prey fish would be affected (Pequeño et al., 2010). Therefore, any change in the assemblage of macroinvertebrates, would result in changes in the functioning of aquatic ecosystems and restructuring of food chains (Richards et al., 1996; Vargas-Chacoff et al., 2013; Tiziano et al., 2014).

Further, non-native fish introductions represent one of the greatest threats to freshwater ecosystems in southern Chile (Arismendi et al., 2014). In this region, salmonids have been introduced into freshwaters, mainly for recreational fisheries and aquaculture purposes (Arismendi et al., 2014). Rainbow Trout (*Oncorhynchus mykiss*, Walbaum) is one of the most successful introduced species, and currently it is widely distributed in southern South America, reaching higher abundances than native fishes (Arenas, 1978; Soto et al., 2006; Arismendi et al., 2012, 2014). Like other salmonids in the region, Rainbow Trout is known as generalist and largely opportunistic feeder (e.g., Arenas, 1978; Campos et al., 1984; Ruiz, 1993; Berrios et al., 2002; Palma et al., 2012; Arismendi et al., 2012; Vargas-Chacoff et al., 2013). Most of these studies have related the diet of Rainbow Trout with the availability of macroinvertebrates in the environment in summer, but few of them have investigated this across seasons (Buria et al., 2009; Di Prinzio et al., 2013).

The first goal of this study is to characterise macroinvertebrate assemblages and functional feeding groups from two land use types (native forest and exotic plantations). The second goal is to examine whether diets of Rainbow Trout can be used as predictors of macroinvertebrate assemblage composition from these two land use types. Collectively, our study provides an assessment of the influences of eucalypt plantations on macroinvertebrate functional feeding groups and fish diets. This could help to clarify how land use change may impact aquatic food webs, contribute to the development of management practices on freshwater ecosystems, and serve as a baseline for future investigations of ecological processes in streams under human-related disturbances.

2. Materials and methods

2.1. Study area

Field sampling was conducted seasonally during 2010, in summer (10–13 January), autumn (10–13 May), winter (10–13 August) and spring (10–13 November) at the coastal zone of the Araucanía Region (Fig. 1). We sampled water quality, macroinvertebrates and stomach contents from streams between 2nd and 4th order ($n = 12$; Table 1, Fig. 1). The climate in this area is maritime with a Mediterranean influence; the average annual precipitation is between 1200 mm and 1600 mm (Di Castri and Hajek, 1976). The landscape geomorphology varies from mountain systems to marine abrasion platforms, with elevations ranging between 870 masl and −2 masl (Peña-Cortés et al., 2009, 2011b). Our sites encompassed two watersheds with varying land uses: the Moncul River located in the northern part of the region is dominated by forest practices on exotic species – mainly *Eucalyptus globulus* (Labill); the Queule River, located in the southern part of the region is dominated by forest practices on native forest, the dominant species being *Nothofagus dombeyi* (Oersted), *Nothofagus obliqua* (Oersted) and *Drimys winteri* (Forster & Forster). The study sites within each watershed were selected according to the proportion covered by riparian vegetation type, including up to 60% of exotic vegetation in the Moncul watershed, dominated by *Eucalpytus* spp., and up to 60% of native forest in the Queule watershed, dominated by *Nothofaguss* spp. (Vargas-Chacoff et al., 2013). The eucalyptus plantations have mostly been planted during the last 20–25 years, while the native forest sections have been present for over 50 years.

2.2. Sampling

2.2.1. Environmental characteristics

The water samples were collected in duplicate in the morning (8–11 AM) from the centre of the active channel, deposited in bottles and taken to the Analytical Chemistry Laboratory of the Institute of Chemistry and Natural Resources, Universidad de Talca, for the following parameters to be determined: bio-chemical oxygen demand, suspended solids, dissolved oxygen, chlorides, sulphates, dissolved solids, apparent colour, nitrates and phosphates. All the analyses were carried out following standard methods for water and wastewater (APHA, 2005). The temperature, pH and conductivity were measured in situ with a pH meter (WTW pH model 330i/SET), and a conductivity meter (WTW cond. Model 330i/SET).

2.2.2. Availability of prey

Together with the water samples in each sampling station, three separates samples were taken in a zone of riffles (the most common habitat type) using a Surber net with 500 μm mesh (0.09 m^2 area). The samples were fixed in situ with 90% ethanol and then taken to the Benthos Laboratory of the Institute of Marine and Limnological Sciences, Universidad Austral de Chile, where they were separated, identified and counted under stereo microscope (Olympus, model SZ 51, 40×) and optical microscope (Olympus, model CX 31, 100×) at lowest possible taxonomic resolution following Domínguez and Fernández (2009). The taxa identified were assigned to seven functional feeding groups (FFG): shredders, collector-gatherers, collector-filterers, grazers, predators, detritivores and parasites, following the criteria of Merrit and Cummins (1996) and Fierro et al. (2015).

2.2.3. Fish sampling

Individuals of Rainbow Trout were captured using an electrofishing equipment (EFKO, model FEG 1000, 1 kW, 150–600 V) at the same sampling sites where the invertebrates were collected. The electrofishing method was carried out on a 100 m stretch of stream for 15 min. The fish captured were fixed and preserved in ethanol 90% and then transported to the Benthos Laboratory of the Institute of Marine and Limnological Sciences, Universidad Austral de Chile, where the individuals were measured (standard length, 0.1 mm) and weighed (0.001 g accuracy).