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Effects of local land-use on riparian vegetation, water quality, and the functional organization of macroinvertebrate assemblages

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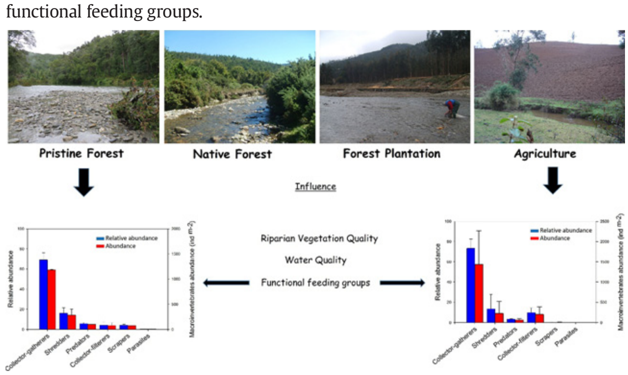
HIGHLIGHTS

- Land-use changes diversely affected river biodiversity.
- Land-use altered riparian vegetation, water quality & macroinvertebrate assemblages.
- No land-use differences found for functional feeding groups.
- Agricultural streams had worst water quality and macroinvertebrate diversity.

GRAPHICAL ABSTRACT

Land-use changes effectively impacted riparian vegetation, water quality, and macroinvertebrate assemblages, but not functional feeding groups.



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ABSTRACT

Land-use change is a principal factor affecting riparian vegetation and river biodiversity. In Chile, land-use change has drastically intensified over the last decade, with native forests converted to exotic forest plantations and agricultural land. However, the effects thereof on aquatic ecosystems are not well understood. Closing this knowledge gap first requires understanding how human perturbations affect riparian and stream biota. Identified biological indicators could then be applied to determine the health of fluvial ecosystems. Therefore, this study investigated the effects of land-use change on the health of riparian and aquatic ecosystems by assessing riparian vegetation, water quality, benthic macroinvertebrate assemblages, and functional feeding groups. Twenty-one sites in catchment areas with different land-uses (i.e. pristine forests, native forests, exotic forest plantations, and agricultural land) were selected and sampled during the 2010 to 2012 dry seasons. Riparian vegetation quality was highest in pristine forests. Per the modified Macroinvertebrate Family Biotic Index for Chilean species, the best conditions existed in native forests and the worst in agricultural catchments. Water quality and macroinvertebrate assemblages significantly varied across land-use areas, with forest plantations and agricultural land having high nutrient concentrations, conductivity, suspended solids, and apparent color. Macroinvertebrate assemblage diversity was lowest for agricultural and exotic forest plantation catchments, with notable non-insect representation. Collector-gatherers were the most abundant functional feeding group, suggesting importance independent of land-use. Land-use areas showed no significant differences in functional feeding groups. In conclusion, anthropogenic land-use changes were detectable through riparian quality, water quality, and

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macroinvertebrate assemblages, but not through functional feeding groups. These data, particularly the riparian vegetation and macroinvertebrate assemblage parameters, could be applied towards the conservation and management of riparian ecosystems through land-use change studies.

1. Introduction

Land-use changes have ecological consequences for the health of terrestrial and aquatic ecosystems (Bruno et al., 2014; Lammert and Allan, 1999). Although the effects of land-use changes are well documented for aquatic ecosystems, few studies have specifically assessed riparian vegetation in this context in South America (Hepp and Santos, 2009; Moraes et al., 2014). Changes in riparian vegetation can affect water quality and aquatic communities. Indeed, agriculture, pasture, and urban land-use changes often result in decreased diversity and shifts in relative abundance among the functional feeding groups (FFGs) of aquatic macroinvertebrate assemblages. In contrast, sites of good riparian quality present higher densities of scrapers, predators, and collector-gatherers (Mesa, 2014; Miserendino et al., 2011).

Global deforestation, forest degradation, and the replacement of native forests with exotic forest plantations or agricultural lands are ongoing, growing trends (Manuschevich and Beier, 2016). For example, south-central Chile is globally recognized as a biodiversity hotspot with a high degree of endemism (Myers et al., 2000). Nevertheless, increasing rates of land-use change over recent decades threaten this region, particularly resulting from native forest conversion for agriculture, forest exotic tree plantations, and urbanization (Fierro et al., 2017; Hernández et al., 2016). Riparian environments, which are ecotones between terrestrial and aquatic ecosystems (Valdovinos, 2001), are heavily degraded due to the aforementioned human activities. This degradation limits the normal role of riparian environments as biological buffers against contaminant, sediment, and nutrient influxes from adjacent land-use areas. Riparian habitat destruction can also increase the quantity of particulate matter in water, which can affect light penetration, increasing water temperature, and contribute to excessive eutrophication (Baillie et al., 2005). Therefore, any deterioration of riparian vegetation can directly and indirectly affect water quality and associated aquatic communities (Fernández et al., 2009; Foley et al., 2005).

In addition to influencing the physicochemical conditions of waterways, riparian vegetation also creates habitats and provides nutrients to terrestrial and aquatic organisms, especially in headwater systems, where allochthonous inputs form a principal energy source. A decrease in riparian vegetation will alter trophic food webs, thereby affecting the composition of primary and secondary producers in rivers, in addition to having knock-on impacts for higher tropic levels (Cummins and Klug, 1979). In effect, changes in land-use and, consequently, riparian vegetation can alter the normal distribution of aquatic fauna, which naturally varies within rivers (Vannote et al., 1980).

To evaluate human impacts on aquatic ecosystems, many studies use biological indicators that can provide integrated information about the cumulative or synergistic temporal effects caused by environmental alterations (Alba-Tercedor, 1996). Aquatic organisms are often used to evaluate river health, particularly as these organisms can serve as a record for various perturbations and multiple pollutants (Karr, 1981; Hughes et al., 1998; Allan, 2004; Macedo et al., 2016). Macroinvertebrate assemblages are excellent indicators of water quality due to varied sensitivities to organic pollution (Fierro et al., 2012). Therefore, these assemblages can be used to evaluate aquatic ecosystem responses to adjacent land-use changes.

Basic metrics such as abundance, taxa richness, and diversity are commonly used. However, a variety of other metrics are affected by distinct disturbance gradients (Hughes et al., 1998; Pont et al., 2009). High macroinvertebrate diversity and taxa richness exist in rivers surrounded by natural pristine forests, whereas rivers impacted by human perturbations show altered communities with dominating taxa groups (e.g. dipteran or oligochaetes families) (Brand and Miserendino, 2015). Bioindices developed over the last three decades integrate other measures that basic metrics alone cannot establish. For example, the Hilsenhoff Biotic Index (HBI; Hilsenhoff, 1988) is widely adapted in many countries and is based on quantities of pollution-tolerant macroinvertebrates at different locations. Since water quality is closely related to land-use, related indicators not only indicate river health, but also the health of adjacent riparian areas (Sweeney et al., 2004). Indeed, riparian vegetation quality in itself can serve to describe the biological or habitat conditions of rivers. This parameter can be determined by several methods, including basic methods such as the presence or biomass of native species. One simple field method for evaluating the status of riparian areas is the Riparian Quality Index (QBR, "*Qualitat del Bosc de Ribera*"; Munné et al., 2003). This index assesses differences in the grade and quality of vegetative coverage, the structure thereof, and the habitat naturalness for the river channel.

In addition to these ecological indices, many biomonitoring programs assess macroinvertebrate FFGs (Callisto et al., 2001; Gebrehiwot et al., 2017). The concept of FFGs is based on associations of (i) feeding adaptations by and food-resource categories for aquatic invertebrates with (ii) longitudinal changes in allochthonous and autochthonous organic matter sources from the headwaters of large rivers (Vannote et al., 1980). Consequently, any human perturbations that impact organic matter sources can modify FFG compositions. For example, shredder abundances decline as native forests and riparian vegetation decline, while collector-filterers and scrapers increase in abundance in rivers with diminished or degraded riparian vegetation quality (Brand and Miserendino, 2015; Moraes et al., 2014).

The aims of this study were to investigate the effects of land-use changes in catchment areas, i.e. drainage basins, on aquatic and riparian health in south-central Chile using a variety of indicators, namely water quality (via physicochemical parameters), riparian vegetation (via QBR), and aquatic macroinvertebrate assemblages (via modified HBI and FFGs). The assessed sites were within a region recognized as a biodiversity hotspot with high levels of endemism. However, this region has been greatly impacted by deforestation, exotic forest plantations (namely pine and eucalyptus), and intensive agricultural land conversion. We hypothesized that land-use changes in catchment areas would negatively affect riparian vegetation and water qualities. We further hypothesized that land-use changes would alter aquatic invertebrate communities, which are often used as bioindicators of water quality, as well as impact invertebrate diversity and FFG compositions. The generated information represents a valuable tool that could aid in policy-making and the establishment of biomonitoring and management programs, namely by identifying anthropogenic factors and biological indicators that can alter the health of aquatic ecosystems in southern South America.

2. Materials and methods

2.1. Geographical traits and land-use categorizations of assessed catchment areas

2.1.1. General geography of the study area

All assessed catchment areas and respective study sites were located in the Araucanía and Los Ríos Regions of Chile (38°54′0″S, 72°40′0″W). This area, situated in the south-central part of the country, was selected due to its noted natural biodiversity and growing incidence of land-use