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In-stream water quality, invertebrate and fish community health across a gradient of dairy farming prevalence in a New Zealand river catchment

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ABSTRACT

Dairying is an intensive form of agriculture influencing stream ecosystems worldwide via increased levels of nutrients, deposited fine sediment and other contaminants. However, it is not fully understood how dairy farming affects food supply for stream fish. We investigated relationships between dairy farming prevalence in the catchments of nine tributaries of a New Zealand river (0% to 79% of the catchment area) and fish and invertebrate communities. Streams were sampled four times at monthly intervals for brown trout density, fitness/growth-related trout response variables, native fish density, invertebrate community metrics as well as physical and chemical water quality variables. Densities of both brown trout and native fish declined as dairying increased, with no trout found in streams where dairy farms covered more than 50% of the catchment area. Increasing dairy farming prevalence was also associated with higher in-stream levels of dissolved nutrients and deposited fine sediment. These findings suggest that increasing the extent of dairy farming in New Zealand based on practices at the time of sampling results in less abundant and diverse fish communities.

1. Introduction

Agricultural activities and land-use intensification are important causes of elevated fine sediment and nutrient inputs to surface waters (Allan, 2004; Larsen et al., 1999; Matthaei et al., 2006; Wagenhoff et al., 2011). Excessive deposited fine sediment can smother stream substrata and degrade habitat quality for aquatic animals (Kemp et al., 2011; Wood and Armitage, 1997), and elevated nutrient concentrations reduce water quality (Biggs, 2000; Hamill and McBride, 2003).

The combination of high in-stream deposited fine sediment and elevated nutrients change benthic invertebrate community composition in agricultural streams (Townsend et al., 2008; Wagenhoff et al., 2011, 2012). Such contaminants reduce the prevalence of pollution-sensitive taxa (Neumann and Dudgeon, 2002) and/or increase the prevalence of tolerant taxa (Egler et al., 2012; Weijters et al., 2009). Because aquatic invertebrates represent an important food resource for fish (Sagar and Eldon, 1983), agriculture-induced changes in invertebrate abundance and composition often negatively affect stream fish communities (Jowett and Richardson, 1996; Kemp et al., 2011).

Dairy farming has increased in many countries including New Zealand, due to a growing demand for dairy products (Dong, 2006; Foote et al., 2015). In New Zealand, conversion of sheep/beef farms to more intensive (in terms of stock densities, fertilizer and pesticide use) dairy farming often negatively affects physical and chemical measures of water quality (Wilcock et al., 1995, 1998). Nevertheless, relatively few studies worldwide have focused specifically on dairy farming effects on stream invertebrates (e.g. Matthaei et al., 2006; Townsend et al., 2008) and, to our knowledge, no studies exist that investigated dairying effects on fish communities, diets and fitness and the size structure of invertebrate communities.

To address these knowledge gaps, we examined the ecology and the physical and chemical water quality in relation to dairy farming prevalence in nine tributary subcatchments of a New Zealand river. We studied density, condition, diet and growth of juvenile brown trout (*Salmo trutta*), native fish density and macroinvertebrate community metrics, plus patterns of in-stream levels of dissolved nutrients and deposited fine sediment (inorganic particles less than 2 mm in diameter; Zweig and Rabeni, 2001). Based

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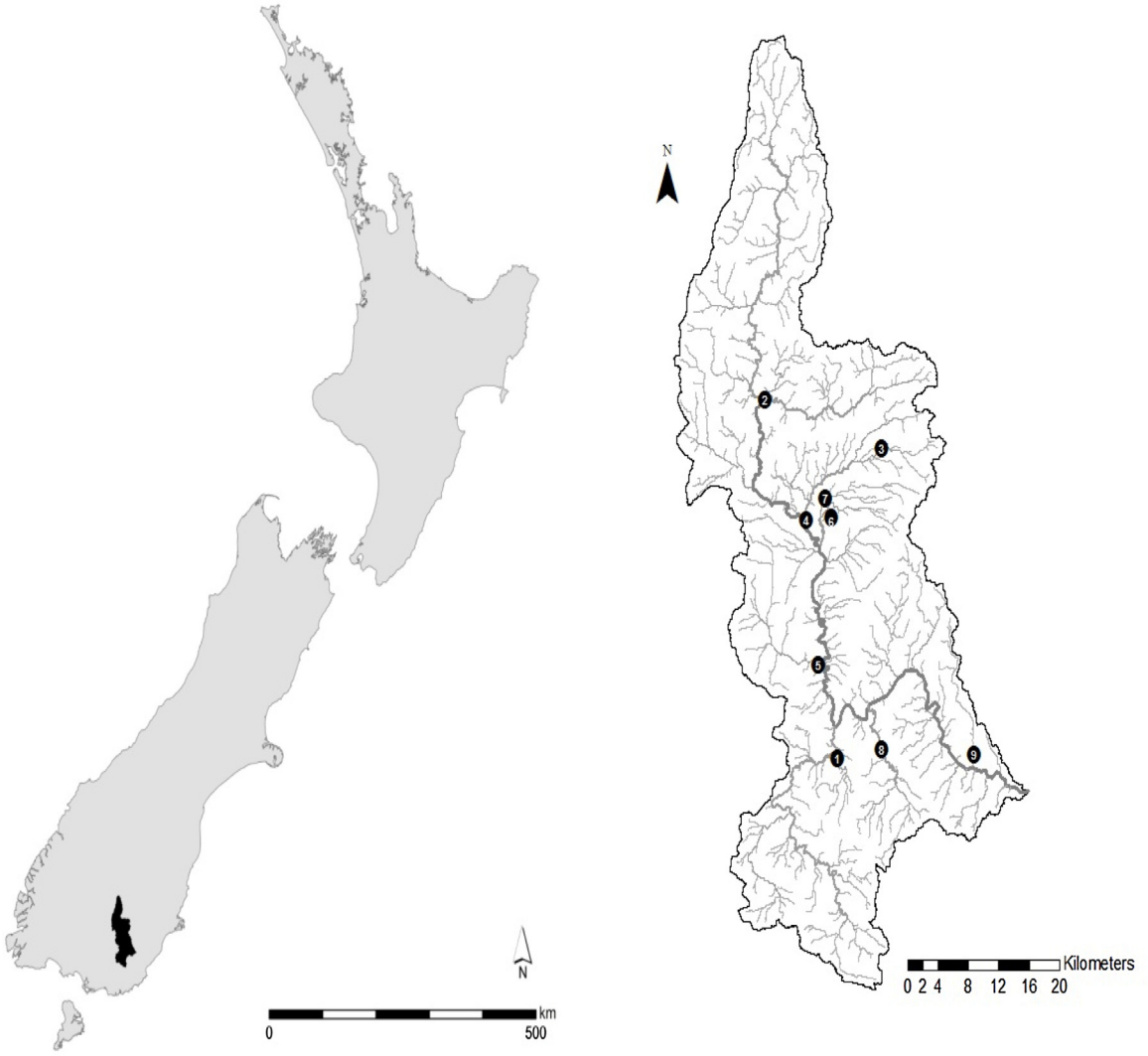

Fig. 1. Map of Pomahaka River catchment showing the locations of the sampling sites.

on the findings of related previous research, we hypothesized that, as catchment dairying prevalence increases:

1. invertebrate community health metrics and prevalence of pollution-sensitive taxa (Ephemeroptera, Plecoptera and Trichoptera; EPT) will decrease (see Matthaei et al., 2006);
2. trout density and condition and native fish density will decline due to less available preferred invertebrate prey because EPT taxa comprise a number of taxa known to be important prey items for brown trout in New Zealand (Huryn, 1996);
3. concentrations of dissolved nutrients and standing stocks of deposited fine sediment will increase (Matthaei et al., 2006), and
4. invertebrate body size will become smaller due to low bed porosity in streams with high levels of deposited fine sediment (Townsend and Thompson, 2007).

2. Material and methods

2.1. Study area

The study was conducted in the Pomahaka River catchment in the South Island of New Zealand (Fig. 1). The catchment incorporates a range of agricultural land use intensities (Harding et al., 1999; Otago Regional Council [ORC], 2011) and supports a regionally important trout fishery (Fish and Game New Zealand, 2003; Young and Hayes, 1999). In recent years, the prevalence of dairy farming in the catchment has increased considerably. Between 1999 and 2008, the number of dairy farms increased from 38 to 105 and average dairy farm size from 179 to 197 ha (ORC, 2011). Anecdotal evidence (personal conversations with farmers in the area) suggests that farming intensity (e.g. stocking densities per hectare) in existing dairy farms has increased as well (ORC, 2011). Native forest or native tussock grasslands comprise about 9% of the catchment area and are located primarily in steeper, higher altitude areas.

Nine tributaries (3rd–5th order) were sampled on four occasions (14 December, 2010, 20 January, 3 March and 4 April, 2011) during Austral summer and autumn. Land use in the subcatchments spanned a gradient from 0% to 79% area in dairy farming (Table 1), plus varying percentages used for sheep/beef farming or covered by plantation forests/native vegetation. These proxies of subcatchment land-use intensity were included as predictors in the statistical analysis (see below). All data in Table 1 were determined using AgriBaseTM (http://www.asurequality.com), a central database of farm type, ownership, location and management in New Zealand. This information was complemented by personal conversations of Otago Regional Council (ORC) staff with farmers in the area (ORC, 2011). Because dairying has been shown to have