New Zealand ecoregions

a classification for use in stream conservation and management

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ABSTRACT

An ecoregion classification for New Zealand was developed based on mapped data on six macro-environmental variables: vegetative cover, bedrock geology, soils, relief, rainfall normals, and Meteorological Service Climatic Regions. Maps of these variables were merged, and a new composite ecoregion map generated. Twenty-five ecoregions are proposed, 13 in the North Island and 12 in the South Island. Systematic sampling of 100 headwater streams within 10 of the South Island ecoregions was undertaken subsequently to evaluate their distinctiveness with respect to water chemistry and their benthic invertebrate faunas. Most ecoregions could be recognised by characteristic assemblages of invertebrates. `Pristine' forested ecoregions of Westland Forest, North-west Nelson Forest, North-east Nelson Forest, and the South-east Forest had high taxonomic diversity, numerous endemic species, and faunas dominated numerically by Ephemeroptera and Plecoptera. In contrast, the highly modified pastoral ecoregions of the East Coast Plains, Central Otago, and the Southland Plains had low-gradient streams with very similar invertebrate assemblages, low taxonomic diversities and a predominance of gastropod molluscs, oligochaete worms and Diptera. Regional invertebrate assemblages appear to be strongly influenced by past biogeographical events, climatic conditions and present-day vegetative cover/land use. Water chemistry varied considerably between and among ecoregions, however, South-east Forest and North-east Nelson streams in particular, were distinctive. Our findings point to the presence of some areas of high endemism that may be worthy of conservation.

1. INTRODUCTION

To be fully effective, a nationwide river classification based on biotic communities needs to incorporate a regional perspective so that its usefulness to local planners, conservators and river managers will be maximised. An ecoregion classification based on lanscape criteria such as climate, geology, vegetation and soils can be expected to provide an objective basis for such a regional classification of running waters. Site-specific studies on water quality, and the effects of land use on aquatic environments, can then be assessed against appropriate regional criteria and representative reference sites.

The few freshwater classifications proposed for New Zealand have been used for defining the hydrological properties of streams and rivers for descriptive and predictive purposes. Toebes and Palmer (1969) divided the country into 90 hydrological regions on the basis of rainfall, bedrock geology and slope, whereas Beable and McKercher (1982) suggested nine flood frequency regions using mean flow data.

The first river classification incorporating a wide range of abiotic and biotic criteria resulted from a nationwide survey by Biggs *et al.* (1990) and included flow variability, water quality, periphyton and faunal data. Biggs *et* al. (1990) proposed dividing New Zealand into five ecoregions, with the South Island provisionally representing a single region. However, large areas of the South Island, including the West Coast, Fiordland, Banks Peninsula, eastern Southland

and Stewart Island, could not be included in their study because of a lack of hydrological data.

Recent North American river classification systems have acknowledged strong associations between terrestrial and aquatic ecosystems, and as a consequence considerable emphasis has been placed on geographical features that influence catchment conditions (Likens and Bormann 1974, Hynes 1975).

A major strategy adopted to identify aquatic ecoregions is to define them by correlating macro-environmental factors with appropriate biotic data (Lotspeich 1980). Fundamental to this approach is the assumption that ecosystems and their components show regional patterns that are reflected in combinations of different biogeographical conditions (Larsen *et al.* 1986, Omernik 1987). In North America, soil, climate, water availability, vegetation type and land use criteria have been used to identify Land Resource Regions and Major Resource Areas in the United States (USDA Soil Conservation Service 1981). The same technique was adopted by Bailey (1976) to develop an ecoregion map of the USA, and Omernik (1987) who produced ecoregion maps of the Pacific Northwest and the entire United States by integrating mapped data on soil, land-surface form, potential natural vegetation, and land use. Similarly, in New Zealand the Land Resource Inventory categorises areas on the basis of soil type, geology, vegetation and slope (NWASCO 1975-79).

The ecoregions proposed by Bailey (1976) and Omernik (1987) have been tested extensively using diverse data sets, and validated within several States across the U.S.A. (Olson *et al.* 1982, Larsen *et al.* 1986, Heiskary *et al.* 1987, Hughes *et al.* 1987, Rohm *et al.* 1987, Whittier *et al.* 1988).

We have developed an ecoregion classification applicable to New Zealand stream systems based on a range of climatic and geomorphological factors considered likely to be important in influencing the distribution and abundance of stream biota. The distinctiveness of 10 of our South Island ecoregions was evaluated by surveying the water chemistry and benthic communities of 100 representative streams.

2. ECOREGIONS

2.1 Identification of ecoregions

Ecoregions were defined by comparing climatic and geomorphological parameters that on the basis of past experience were considered likely to influence stream biota (Biggs *et al.* 1990, Quinn and Hickey 1990). Lotspeich (1980) suggested that stream communities evolve in response to climatic conditions acting on the geological landscape. Biggs *et al.* (1990) proposed that climate, vegetation, geology and human activities all influence the structure and functioning of river ecosystems; and their hierarchical model with the addition of a biogeographical component was used as the basis of our classification (Fig. 1). The primary tenets of the Biggs *et al.* model are that geology, relief, climate and biogeographic conditions are the `driving' factors that influence vegetation, and land use; and that all of these factors, both directly and indirectly, influence water chemistry, stream hydrology and biota.

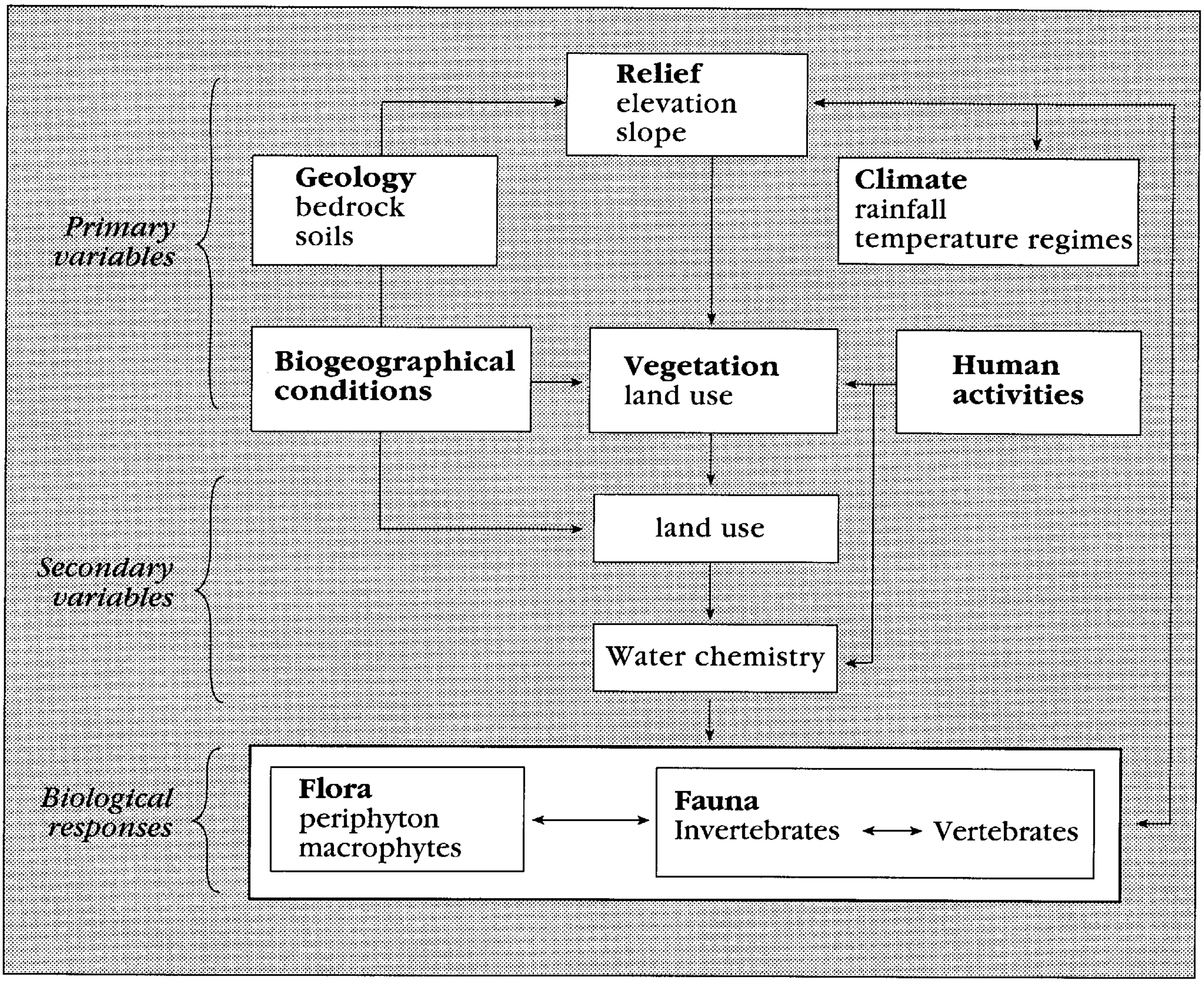

FIGURE 1. A HIERARCHICAL MODEL OF THE MAJOR VARIABLES INFLUENCING THE WATER CHEMISTRY, FLORA AND FAUNA OF STREAMS, AND THE LINKAGES BETWEEN THEM (MODIFIED AFTER BIGGS ET AL. 1990).

We used six variables to identify ecoregions and establish their boundaries. They were: New Zealand Meteorological Climatic Regions, rainfall, relief, vegetation, soils, and geology. New Zealand Climatic Regions were developed by the NZ Meteorological Service (1983), and were used to provide an indication of comparable hydrological, temperature, and climatic conditions across the country. Rainfall normals (1951-80) representing the mean annual rainfall averaged over a 30 year period were included to indicate potential differences in stream flows between streams in each ecoregion (NZ Meteorological Service 1985). Vegetative cover (Newsome 1987) was used as an indicator of current land use patterns, and soil type was included to give a perspective of past regional climate, topography (relief and slope), vegetation and bedrock material, as well as to indicate potential groundwater chemistry. Bedrock geology and soils (NZ Geological Survey 1972a,b; 1973a,b) were measured because of their effects on water chemistry, and on catchment and channel morphology. Lastly, relief (NZ Lands & Survey 1989) was considered as a surrogate of temperature (particularly seasonal extremes).

The South Island ecoregion map was constructed using the Geographic Information System (GIS) package TERRASOFT (Digital Resources 1987). TERRASOFT was used to overlay digitised linework from 1:1,000,000 and 1:2,000,000 maps of the six variables. As databases containing map linework of these variables did not exist, the linework was digitised into the computer by hand. Firstly, six GIS `layers' were created corresponding to the climatic and geomorphological variables. Each of these variables was divided into broad classes: e.g., vegetative cover was divided into forest, scrub, tussock and improved grasses. These layers were then merged and integrated, and areas of less than 1000 hectares were removed. The same procedure was used for the North Island, however, instead of using GIS, the six maps were merged by hand. The North Island is not as geologically complex as the South Island, and areas of native forest, exotic forest and grassland are more clearly defined in the North. There was probably only a minor loss of accuracy in integrating and generalising linework by hand rather than using GIS.

Changes in vegetation and altitude are often associated with changes in rainfall isohyets. Because these two variables accounted for half of the component map data, they provided the most frequent indicators of ecoregion boundaries.

Ecoregions were identified by means of a name/descriptor and a two letter code. Descriptors and codes are indicative of the general geographical area of the ecoregion; e.g., Southland Plains (SL).

2.2 The ecoregions

The North Island was divided into 13 ecoregions (Fig. 2) and the South Island into twelve (Fig. 3). The ecoregions range in size from about 900 to 12 000 km^2, and in the case of High Country (HC), Southern Alps (SA) and Westland Forest (WD) includes small non-contiguous components. Stewart Island forms part of the Westland Forest and South-east Forest ecoregions. Each ecoregion is characterised by a suite of `representative' conditions associated with the six climatic and geomorphological variables (Tables 1 and 2). In general, vegetation was the best delineator of regions as it was often associated with changes in altitude, rainfall, and to a lesser extent soil type. Some ecoregions may be subdivisible on the basis of differences in vegetation, climate and soils. For example, much of the High Country ecoregion is dominated by short tussock (*Festuca* and *Poa* spp.) and snow tussock (*Chionochloa* spp.), although extensive beech forests (*Nothofagus* spp.) occur along the Puketeraki, Poulter, and Dampier Ranges in the headwaters of the Waimakariri and Ashley Rivers. These forested areas also have higher rainfall and higher mean temperatures than the more southern parts of the High Country ecoregion (e.g., the Hokonui and Taringatura Hills), and it can be argued that they represent a subecoregion. Several regions are clearly distinguishable by their uniformity of characteristics, e.g., East Coast Plains of the South Island (EC), and Mt Taranaki (TK), whereas others are less distinctive and included complex combinations of vegetation, geology and soils, e.g., Northern Hill country of the North Island (ND), and North-east Nelson Forest (NE).

3. STREAM ENVIRONMENTS AND STREAM FAUNAS OF SOUTH ISLAND ECOREGIONS

To be useful entities for ecologists, biogeographers, conservation biologists and resource managers, ecoregions need to incorporate distinctive, identifiable environments, and in the present context, characteristic stream communities. The greatest likelihood of finding distinctive running water communities reflecting features of local geography is in low-order streams (headwater tributaries) where the strongest functional relationships between aquatic and adjacent terrestrial ecosystems can be expected to occur. In fact, in such situations the boundaries between the two nominal ecosystem types can be distinctly blurred.

As a first step towards evaluating the validity of the ecoregions defined above we carried out biological and chemical surveys on 10 small (<1.5 m wide) streams in each of 10 South Island ecoregions. No field validation has been undertaken in the Marlborough Plains (MP) and Nelson Plains (NP) ecoregions, or in the North Island. The streams used were identified on topographical and other maps, and had to conform with the principal vegetational, geological, and other catchment criteria most typical of the ecoregion.

This did not mean they were all located in pristine unmodified environments, although this was the case (or closely approximated the situation) in the five predominantly forested, or upland regions. Where the characteristic environment of an ecoregion is now pasture, streams were located there.

3.1 Methods

Physico-chemical and biological surveys were carried out in the 100 headwater streams in the summers of 1993 and 1994. In each stream, sampling was confined to a reach about 10 m long, selected on the basis of visual criteria as being representative of the stream. Physical measurements made in each reach were stream width, water depth and water velocity. The substrate index of Jowett and Richardson (1990) was calculated to provide a comparative measure of average particle size of bed materials. A water sample was taken from each stream for chemical analysis and five benthic invertebrate samples were taken with a Surber sampler (0.11 m^2, 0.25 mm mesh). Full details of sampling, analytical and statistical procedures used are given in Harding (1994).

3.2 The ecoregions

Locations of the 10 sampling sites in each of the 10 South Island ecoregions surveyed in the field are shown in Fig. 4. Summary data for physical characteristics of the streams in each ecoregion are given in Appendix 1 and Appendix 2 shows the total number of macroinvertebrate taxa, and the numbers of taxa belonging to major taxonomic groups in each ecoregion. A list of those taxa collected in at least six streams within an ecoregion is given in Appendix 3, and Appendix 4 lists the five most abundant taxa recorded in each ecoregion. Appendix 5 provides a comparative summary of stream water chemistry.

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