Estuarine, Coastal and Shelf Science 95 (2011) 388–394

Contents lists available at SciVerse ScienceDirect

Estuarine, Coastal and Shelf Science

journal homepage: www.elsevier.com/locate/ecss

Rafting rocks reveal marine biological dispersal: A case study using clasts from beach-cast macroalgal holdfasts

Christopher J. Garden [a,b], Dave Craw [c], Jonathan M. Waters [a,*], Abigail Smith [b]

[a] Allan Wilson Centre for Molecular Ecology and Evolution, Department of Zoology, University of Otago, P.O. Box 56, Dunedin, New Zealand
[b] Department of Marine Science, University of Otago, P.O. Box 56, Dunedin, New Zealand
[c] Department of Geology, University of Otago, P.O. Box 56, Dunedin, New Zealand

ARTICLE INFO

Article history:
Received 23 June 2011
Accepted 10 October 2011
Available online 20 October 2011

Keywords:
biogeography
marine ecology
geology
rafting
floating
kelp
Durvillaea
dispersal

ABSTRACT

Tracking and quantifying biological dispersal presents a major challenge in marine systems. Most existing methods for measuring dispersal are limited by poor resolution and/or high cost. Here we use geological data to quantify the frequency of long-distance dispersal in detached bull-kelp (Phaeophyceae: *Durvillaea*) in southern New Zealand. Geological resolution in this region is enhanced by the presence of a number of distinct and readily-identifiable geological terranes. We sampled 13,815 beach-cast bull-kelp plants across 130 km of coastline. Rocks were found attached to 2639 of the rafted plants, and were assigned to specific geological terranes (source regions) to quantify dispersal frequencies and distances. Although the majority of kelp-associated rock specimens were found to be locally-derived, a substantial number (4%) showed clear geological evidence of long-distance dispersal, several having travelled over 200 km from their original source regions. The proportion of local versus foreign clasts varied considerably between regions. While short-range dispersal clearly predominates, long-distance travel of detached bull-kelp plants is shown to be a common and ongoing process that has potential to connect isolated coastal populations. Geological analyses represent a cost-effective and powerful method for assigning large numbers of drifted macroalgae to their original source regions.

1. Introduction

Tracking biological dispersal presents an important challenge in ecological and biogeographic research. In the marine environment, for example, understanding dispersal dynamics is key to assessing the ecological effects of boundary currents (e.g. Collins et al., 2010; Coleman et al., 2011). To this end, ecologists use a wide variety of ecological techniques to monitor migrations, such as tagging individuals using physical or chemical (e.g. Hettler, 1984) markers, or by individual photographic identification (Hillman et al., 2003). Additionally, biological movements can be directly monitored via radio telemetry (Kenward, 2001) or by satellite-tracking (e.g. Bonfil et al., 2005). Alternatively, analyses performed using genetic markers (e.g. DNA microsatellites: Hansen et al., 2001; mtDNA: Bowen et al., 1995) or microchemical techniques (e.g. otolith or statolith trace elements: Gillanders, 2002; Zacherl et al., 2003) can potentially identify source regions and/or migration histories for highly mobile individuals.

Assessing biotic dispersal in the marine environment can be particularly difficult and expensive given the limited opportunities for direct observations of dispersing individuals (but see Smith, 2002). Moreover, studies performed using satellite-tracking or molecular analyses are typically expensive. Here we describe a cost-effective method for assigning large numbers of detached macroalgal specimens to their original source regions based on geological data.

High latitude shores of the southern hemisphere are dominated by bull-kelp (*Durvillaea*), a large macroalgal genus that includes the widespread and buoyant *Durvillaea antarctica*, a species that has potential to drift for long distances at sea following detachment (Smith, 2002; Fraser et al., 2009). Although genetic data have recently been used to assign beach-cast *D. antarctica* individuals and their epibionts to original source populations (Collins et al., 2010; Fraser et al., 2011), such analyses are expensive, and are limited by the resolution of existing molecular markers. For instance, *D. antarctica* exhibits genetic homogeneity at mtDNA and chloroplast markers across extensive regions of New Zealand's southern South Island (Collins et al., 2010), and indeed much of the subantarctic (Fraser et al., 2009), limiting the ability of these markers to discriminate between alternative source populations in such regions.

* Corresponding author. Department of Zoology, University of Otago, 340 Great King St, Dunedin 9016, New Zealand.
E-mail address: jon.waters@otago.ac.nz (J.M. Waters).

0272-7714/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.ecss.2011.10.008

While recent genetic studies have revealed that oceanic rafting does occur in *Durvillaea* (Collins et al., 2010; Fraser et al., 2011), no study has yet quantified the relative abundance of 'local' versus 'foreign' beach-cast specimens in regions where it grows. A potential alternative method for quickly assigning large numbers of beach-cast bull-kelp specimens to source regions involves the use of geological data. As with other large macroalgal species (e.g. Woodborne et al., 1989), floating or drifted bull-kelp specimens frequently retain substantial amounts of geological material in their holdfasts following detachment from the rocky shore (e.g. Emery and Tschudy, 1941; Emery, 1963; Smith and Bayliss-Smith, 1998; Garden and Smith, 2011). In this study we use geological analysis of clasts found in the holdfasts of beach-cast specimens to infer their geographic origins. Although the potential geological importance of kelp-mediated rock transport has been understood for some time (Woodborne et al., 1989; Smith and Bayliss-Smith, 1998), to our knowledge the current study is the first to use geological clasts to characterise and quantify biological dispersal events. While a recent genetic study showed the utility of epibiont taxa in assigning kelp specimens to source regions (Fraser et al., 2011), the current study relies on geology alone. We test the hypothesis that long-distance transport of detached kelp is a common phenomenon in southern New Zealand.

2. Study area

Southern New Zealand is topographically complex, reflecting the tectonic uplift of an active collisional plate boundary superimposed onto several different geological terranes (Fig. 1; Turnbull and Allibone, 2003). The geological basement continues beyond the present shoreline beneath a broad shallow continental shelf, with water depths of <100 m extending up to 40 km from shore. The present shoreline, formed during post-glacial marine transgression across that shallow shelf, consists of numerous rocky promontories and cliffed areas, interspersed with sand and gravel beaches. The cliffed portions of the coast are controlled by hard competent rocks, whereas the intervening bays have been eroded into less competent rocks.

The coastline has a general east-to-northeast trend, which cuts across a wide range of rock types exposed by the complex underlying geological structure (Fig. 1; Table 1). In the west, two terranes with coarse-grained crystalline rocks (Fiordland and Brook Street Terranes) are separated at the coast by a belt of overlying Cenozoic sedimentary rocks in the Waiau Basin (Table 1; Turnbull and Allibone, 2003). These sedimentary rocks were derived from the underlying crystalline basement. Farther east, the coast is dominated by greywacke and argillite of the Murihiku Terrane (Table 1), and these rocks are interbedded on the 1–100 m scale to form numerous headlands (greywacke) and bays (argillites). Another sedimentary basin is exposed at the coastline immediately to the northeast of the Murihiku Terrane, and these sediments were derived from the underlying Otago Schist belt that is exposed on the coast farther northeast (Fig. 1; Table 1). The Otago Schist is fine-grained (50–100 μm), generally highly micaceous, with abundant quartz veins. Cenozoic sediments, including prominent cliffs of calcareous sandstone, overlie the Otago Schist near Dunedin, and these sediments are in turn overlain by the Dunedin Volcano (Fig. 1; Table 1). The competent rocks of the Dunedin Volcano form the prominent Otago Peninsula.

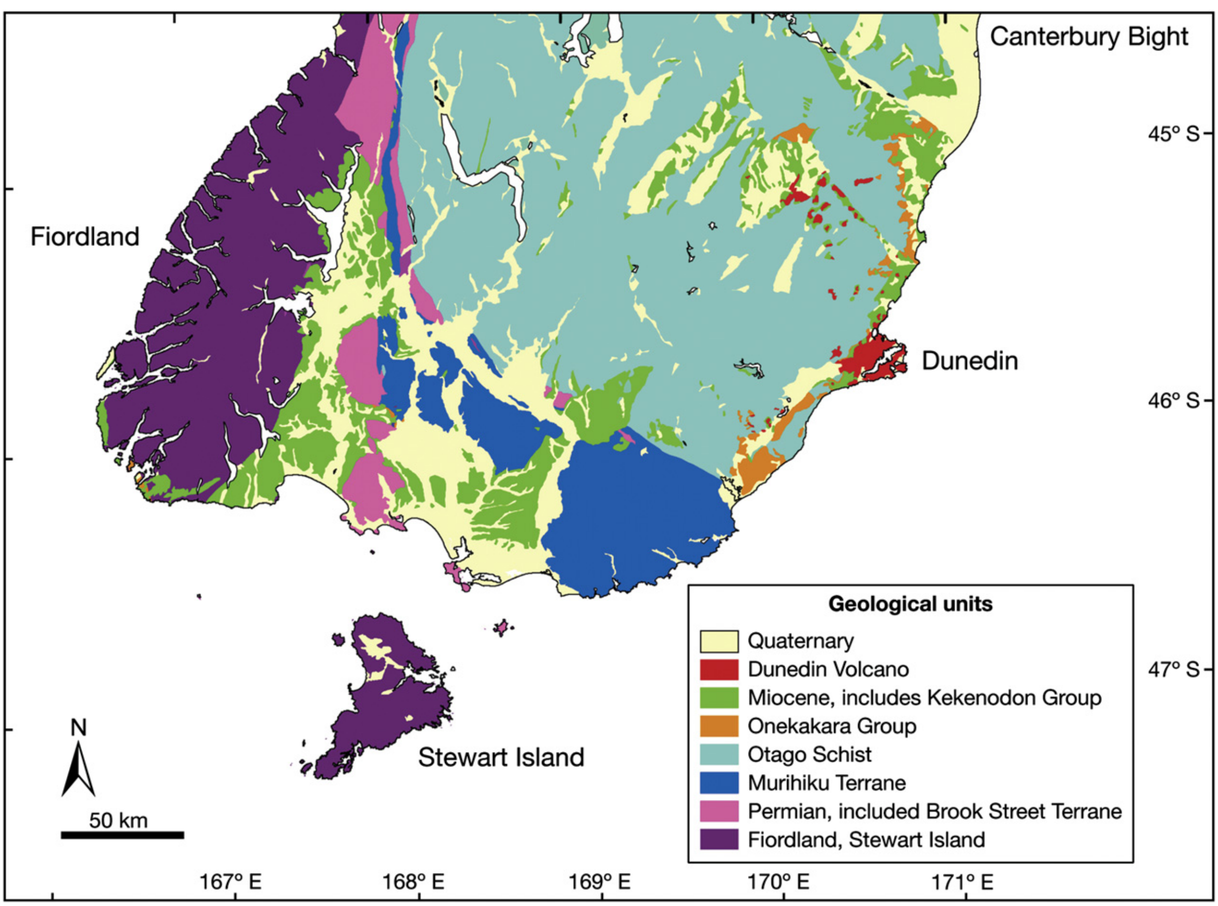

Fig. 1. Geological map of the lower South Island of New Zealand showing distribution of geological units.