J. Mar. Biol. Ass. U.K. (2004), **84**, 879–882
Printed in the United Kingdom

Highway or country road: algal recruitment with distance from an island reef

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Subtidal macroalgal assemblages differed among islands within the Recherche Archipelago, Western Australia, with respect to species biomass. To investigate whether macroalgal populations were maintained locally, settlement plates were moored in 10 to 15 m depths at a reef sampled for macroalgal diversity, and 20, 50, 100, and 500 m away from the reef. Plates were retrieved after eight months and assemblage differences were compared with distance from the sampled reef. Macroalgal richness decreased with distance from an island assemblage and molluscan richness increased. At 500 m away, the number of algal recruits was negligible and the number of bivalves was relatively high.

INTRODUCTION

In the Recherche Archipelago, Western Australia, subtidal macroalgal assemblages differed in composition and abundance among islands within the archipelago, suggesting that algal populations were maintained locally (Goldberg & Kendrick, 2004). The structure of subtidal macroalgal assemblages consisted of a canopy (>30 cm tall) that covered low-lying understory. Typical of other subtidal macroalgal assemblages along the southern coast of Australia, the canopy is not dominated by one species (Collings & Cheshire, 1998; Hotchkiss, 1999) but is a mixture of Sargassaceae and Cystoseiraceae species: *Sargassum* and *Cystophora* species, *Acrocarpia robusta* Womersley, *Scaberia agardhii* Greville, and *Scytothalia dorycarpa* (Turner) Greville. Density of canopy taxa was greatest in depths <10 m, becoming sparse with depth (Goldberg & Kendrick, 2004). In contrast, understory species contributed more to average biomass with increase in depth.

Species can maintain local dominance (biomass and abundance) in an assemblage by releasing large quantities of propagules with narrow dispersal shadows. Most propagules of Sargassaceae and Cystoseiraceae disperse <10 m from parent populations (Deysher & Norton, 1982; Schiel, 1994; Kendrick & Walker; 1995). Hotchkiss (1999) suggests that canopy taxa *Cystophora* and *Sargassum* maintain subtidal populations in south-eastern Australia via constant replacement of senescing adults by a local population of juveniles and recruits. Dilution of propagule concentrations and potential failure of successful recruitment may contribute to an observed decrease in recruitment with distance from parent populations (Gaylord et al., 2002).

No studies in southern Australia have addressed whether macroalgal propagules are present in the water column with increasing distance from an island reef. The purpose of this study was to investigate the hypothesis that macroalgal populations were maintained locally. In particular, we tested whether communities of recruits on settlement plates changed with distance from an island, and whether density of recruits of dominant canopy taxa was inversely proportional to distance from the island.

MATERIALS AND METHODS

Lion Island (32°52.8′S 122°01.7′E) is located within Esperance Bay, Western Australia, and is part of the Recherche Archipelago. Typical of other islands in the archipelago, reefs surrounding Lion Island were granitic with gently-sloping platforms, and boulders (scale of 10s m^2) with horizontal and vertical reef faces. The study site was situated along the mainland-facing side, moderately protected from south-westerly swell and subjected to microtides (±0.5 m; Pattiaratchi, 1998). North-easterly winds that blow from the mainland had a 1.5 nautical mile fetch to reach Lion Island. Currents between Lion Island and the mainland follow the contours of the coastline, flowing in a northerly or southerly direction (Pattiaratchi, 1998). Between Lion Island and the mainland's sandy beach, the seabottom consists of sea grass meadows and sandy plains (A. Bickers, personal communication), with depths ranging between 8 and 18 m.

Subtidal macroalgal assemblages from Lion Island were characterized to determine local diversity and reproductive status of canopy taxa prior to experiment deployment. Macroalgae were collected in randomly-placed 0.25 m^2 quadrats (N=9) in depths of 10 to 15 m, in September 2002. Density, wet-weight, and reproductive status (presence or absence of receptacles) of canopy taxa were recorded. Sessile molluscs were neither observed nor collected in these samples.

At the time of the macroalgal collection, settlement plates were deployed at the sampled reef and up to 500 m away from the reef, and left undisturbed for eight months. One settlement plate (20×20 cm, sand-blasted polyvinyl chloride) was attached to each settlement-plate frame (galvanized wire mesh) by plastic zip ties and was oriented parallel to the sea-floor. Plates were used as a settlement surface to control for variability in substratum texture, with a surface comparable with *in situ* reef that had been

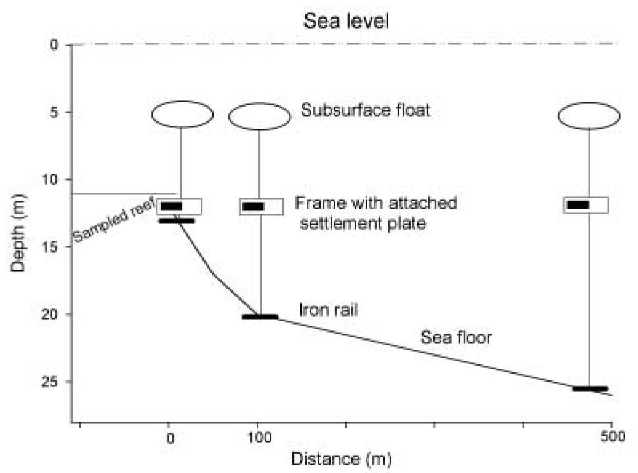

Figure 1. Stylized figure of settlement plates attached to moorings. Settlement plates were suspended in the water column in depths of 10 to 15 m, and moorings were placed 0, 20 (not shown), 50 (not shown), 100, and 500 m away from the sampled reef.

cleared of organisms. Other assumptions included that propagules in the water column successfully recruited to the settlement plates, and that densities of Sargassaceae, Cystoseiraceae, and molluscs on the plates were approximate estimates of algal propagules and invertebrate larvae in the water column (Hruby & Norton, 1979). One settlement-plate/frame unit was attached to each mooring. Four moorings were deployed at each of the following distances: 0, 20, 50, 100, and 500 m away from the reef where macroalgae were collected (Figure 1). The sea-floor was a rocky reef at the 0 and 20 m sites, a mix of reef and sand at the 50 m sites, and sand at the 100 and 500 m sites. In the same depths as were sampled for macroalgae (depths 10 to 15 m), settlement-plate/frame units were suspended by moorings that were anchored with iron rail and buoyed in the water column by a subsurface polystyrene float. Densities of algal propagules and larvae were assumed to be similar between the sea-floor and in depths of 10 to 15 m. Upon retrieval of settlement plates in April 2003, organisms were identified to the lowest taxonomic level possible and density (individuals taller than 5 mm) of Cystoseiraceae, Sargassaceae, and bivalves were counted by hand from the upward-facing surface of each plate.

Community diversity and densities of canopy and bivalve taxa were tested for differences among the five distances (N=4 plates per distance) from Lion Island. Differences in community diversity (presence/absence data) with the main factor distance were evaluated with a one-way analysis of similarity (ANOSIM; PRIMER, version 5) based on the Bray–Curtis similarity coefficient. The Clarke's R test statistic (a value between 0 and 1) quantifies whether assemblages were separated by distance: the closer to 1.0, the more separated were the assemblages. Non-parametric Spearman rank correlation tested for differences in richness (for macrophytes and molluscs) and density of organisms (for the Sargassaceae, Cystoseiraceae, and bivalves) with distance, because variances were heterogeneous and sample size unequal due to the loss of one mooring at the 20 m site (N=3).

RESULTS

Canopy taxa at Lion Island in depths of 10 to 15 m consisted predominantly of *Sargassum* (5 species) and *Cystophora* (5 species), in addition to *Ecklonia radiata* (C. Agardh) J. Agardh, *Acrocarpia robusta*, *Scaberia agardhii*, and *Scytothalia dorycarpa* (Table 1). Average canopy density was 25 individuals per 0.25 m^2. All canopy species were reproductive except for *Sargassum verruculosum* C. Agardh and *E. radiata* (Table 1). *Acrocarpia robusta* was reproductive but individuals could not be distinguished. The reproductive status of *Scaberia agardhii* was not recorded due to difficulty in discerning reproductive structures. Forty-nine species of macroalgae were recorded of which 16 were canopy species.

Communities on the settlement plates differed with increasing distance from the reef sampled in September 2002. Composition of taxa on the settlement plates was significantly different with distance (Clarke's R=0.59, $P<0.001$). Although macroalgal richness was greater at sites <500 m away from the sampled reefs, richness was not correlated with distance (Spearman R=0.36, $P>0.05$). In contrast bivalve richness was correlated with distance (Spearman R=0.72, $P<0.05$), with greatest richness at the 500 m sites (Table 2).

Table 1. *Density (±SE) and reproductive status of canopy species present at Lion Island, in depths of 10 to 15 m. N=9.*

Species	Density per 0.25 m^2	Reproductive status
Sargassum fallax Sonder	3.8 ±1.35	*
S. linearifolium (Turner) C. Agardh	3.1 ±1.39	*
S. spinuligerum Sonder	3.4 ±1.70	*
S. varians Sonder	2.2 ±0.64	*
S. verruculosum (Mertens) C. Agardh	1.8 ±0.72	
Cystophora brownii (Turner) J. Agardh	2.3 ±1.96	*
C. expansa (Areschoug) Womersley	1.2 ±1.66	*
C. monilifera J. Agardh	1.8 ±0.94	*
C. pectinata (Greville & C. Agardh) J. Agardh	2.3 ±1.36	*
C. racemosa (Harvey *ex* Kuetzing) J. Agardh	2.4 ±0.62	*
Ecklonia radiata (C. Agardh) J. Agardh	0.1 ±0.10	
Scytothalia dorycarpa (Turner) Greville	0.4 ±0.24	*

* species was reproductive.

Table 2. *Taxon richness (±SE) of macroalgae and bivalves per 0.04 m² with increasing distance from the sampled reef at Lion Island, in depths of 10 to 15 m. N=4 at all distance-sites, except at the 20 m sites which had N=3.*

Distance (m) from sampled reef	Macroalgae	Bivalves
0	14.2 ±1.4	1.2 ±1.2
20	8.7 ±6.3	0.7 ±0.7
50	15.2 ±5.0	0.5 ±0.5
100	13.7 ±1.4	3.7 ±1.2
500	6.0 ±2.8	6.2 ±0.2

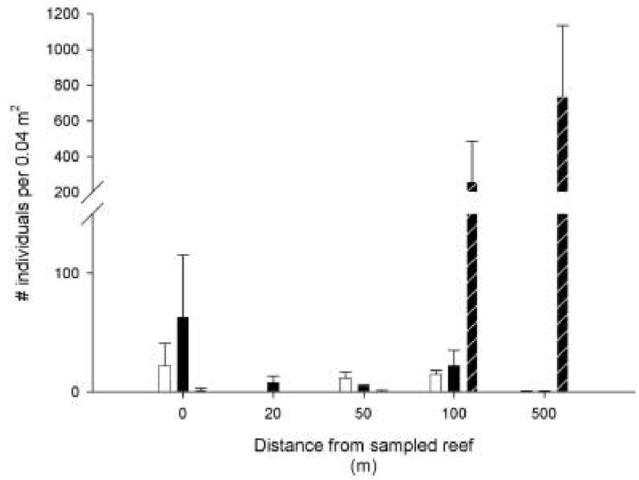

Figure 2. Number of individuals (+SE) of canopy algae (Sargassaceae and Cystoseiraceae) and bivalves per settlement plate with distance from the sampled reef at Lion Island, in depths of 10 to 15 m. N=4 at all distance-sites, except at the 20 m sites which had N=3. White bars, Sargassaceae; black bars, Cystoseiraceae; striped bars, bivalves.

Densities of canopy taxa Cystoseiraceae and Sargassaceae were more abundant on plates <500 m away and bivalves were more abundant on plates 100 and 500 m away from the sampled reef (Figure 2). Cystoseiraceae density decreased with distance from the sampled reef, though the trend was marginal (Spearman R=0.46, $P<0.05$). Sargassaceae density showed no significant difference with distance. In contrast, bivalve density increased with distance (Spearman R=0.82, $P<0.05$). Mussel density comprised 35 ±20% of the bivalves on plates 100 m away, and 91 ±2.7% of the bivalves on plates 500 m away from the sampled reef. Algal and invertebrate taxa were present on the entire plate surface.

DISCUSSION

Data from this study support the hypothesis that richness of canopy assemblages in the Recherche Archipelago was maintained locally. The relative decrease in canopy recruits with distance from the sampled reef and the observation that density of canopy taxa decreased with reef depth in the Recherche Archipelago (Goldberg & Kendrick, 2004) would suggest that the majority of canopy propagules do not disperse and successfully recruit much farther than 100 m away from parent populations. In New Zealand subtidal assemblages, high-density stands (2200 individuals per m²) of *Sargassum sinclairii* Hook & Harvey had a greater number of reproductive individuals and recruits than in low-density stands (up to 40 individuals per m²), suggesting that high-density stands might be important in maintaining local *Sargassum* populations (reviewed in Schiel, 1994). Alternatively, drifting reproductive plants may have reached Lion Island and contributed to local recruitment. Rafts of drifting plants have rarely been observed along Lion Island (Goldberg & Kendrick, 2004) and given the lack of bays along the island, propagules may not remain close to the island for extended periods of time.

If recruits on the settlement plates did come from the island reef, the presence of canopy recruits on the farthest plates indicated that propagules could disperse and settle away from known parent populations, though in reduced densities. Deysher & Norton (1982) observed *Sargassum muticum* (Yendo) Fensholt to successfully recruit up to 30 m away from parent plants. Though drifting germlings were observed 1.3 km away, their ability to attach decreases with time in culture (Deysher & Norton, 1982). A combination of dilution effects with distance from parent populations (Gaylord et al., 2002), recruit mortality (Kendrick & Walker, 1995), and time-limited attachment capability (Deysher & Norton, 1982) may explain the low density of canopy recruits at 100 and 500 m from the sampled reef. Should these recruits survive to maturity, the likelihood of a successful second-generation stand would be diminished if recruit survivorship was inhibited in low-density canopy stands (reviewed in Schiel, 1994).

The high turnover of species in the Recherche Archipelago may be a function of understory or epiphytic macroalgae that have wider dispersal ranges than canopy taxa. Many of the genera recorded on 100 and 500 m settlement plates were epiphytic on canopy and understory macroalgae and on sea grass in subtidal assemblages across the Recherche Archipelago (N. Goldberg, personal observation), including epiphytes *Polysiphonia*, *Ceramium*, *Laurencia*, *Dilophus*, *Dasya*, *Spyridia*, *Colpomenia*, *Lobospira*, and *Hypnea*. Parent populations of these epiphytes may have originated from Lion Island or from nearby sea grass meadows with dispersed propagules having arrived via currents that flow alongside Lion Island (Pattiaratchi, 1998).

Bivalve richness and density, in particular mussel density, increased with distance from Lion Island, suggesting that larvae were not released from Lion Island. In addition, mussel populations were not observed at the island reefs. Lion Island is approximately three nautical miles away from the closest harbour (possible larval source). Mussel larvae are planktonic, can survive in the water column for days (30 days for *Mytilus edulis*; Chipperfield, 1953), and can be dispersed by wind-driven surface currents (McQuaid & Phillips, 2000). Wind speeds >20 km/h are not uncommon in Esperance Bay (N. Goldberg, personal observation). The relatively low numbers of molluscs on the settlement plates at 0, 20, and 50 m from Lion Island would suggest that if wind-driven currents transported larvae, these currents did not flow within 50 m of the island or that larvae did not have time to successfully recruit in algal-dominated assemblages.

The findings of this experiment suggest that different dispersal strategies may help explain the observation that macroalgal assemblages differed among islands within island groups in the Recherche Archipelago (Goldberg & Kendrick, 2004), despite a lack in temporal and island (spatial) replication. Canopy taxa appear to have resident populations, but epiphytic and understory members of subtidal assemblages may have parent populations from further afield. Our results suggest that waters between island assemblages may be a quiet country road for algal propagules, and a traffic-laden highway for molluscan larvae.

We dedicate this paper to the late Drew Gashler for his contribution to the marine sciences—he will be missed. This work was supported by the Strategic Research Fund for the Marine Environment and we thank the Department of Conservation and Land Management, the Mackenzies for use of their boat, skipper B. Habberly, field assistants D. Gull, E. Harvey, S.L. Grove, shop technician R. Scott, and S. Gaby of MSTEEL for donation of iron rail. This work was improved with the constructive discussions with D.I. Walker and the comments of two anonymous referees.

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Submitted 30 January 2004. Accepted 21 June 2004.