An ecological study of the sea hare, *Dolabella auricularia*, on the south-eastern coast of Viti Levu, Fiji

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Introduction

Gleaning for the sea hare, *Dolabella auricularia*, is an important activity for women throughout the Pacific because this species is an important food source (Singh and Vuki 2009). Women glean sea hares on mudflats during low tides in the afternoons when they are most abundant. Egg masses and the animals are also eaten and sold at municipal markets in urban areas across the Pacific.

Egg masses of *Dolabella auricularia* are eaten in many parts of the world such as the Visaya Islands in the Philippines, Samoa, Tonga and Fiji. In Fiji, the egg masses and the animal are collected mostly by women and are sold in urban markets and eaten raw or cooked. Anti-cancer agents have been isolated from *Dolabella auricularia* (Pettit et al. 1976).

The diet of *D. auricularia* is principally seaweeds and seagrass, and its choice of seaweed and seagrass is generally broad, its eating habits immense, and its growth rate is fast. The majority of its behaviour involves eating, copulating and laying eggs.

All sea hares are herbivorous and are usually associated with seagrass beds. They are most frequently found in shallow waters, where they feed on algae and seagrasses. Members of the genus *Aplysia* feed on large algae, while the genus *Bursatella* consumes large amounts of sand, and *D. auricularia* consumes various seagrasses. Few studies on sea hares have been conducted in the Pacific.

This ecological study of the sea hare, *Dolabella auricularia*, (Lightfoot, 1786) on the southeastern coast of Viti Levu, Fiji, was undertaken at two sites: Kaba Point mudflats and the Veivatuloa mudflats. There is limited information on the biology and population characteristics of the sea hare. Information on its abundance, size, population structure, distribution patterns and association with seagrass beds is needed in order to manage the sea hare fishery in the future.

Therefore, the specific objectives of this research work were to study populations of *Dolabella auricularia* in two aforementioned sites in Fiji. Population size structure was the focus of the study so that ecological patterns and the factors that influence them could be determined. The second objective of this study was to determine the distribution patterns, estimate abundance, habitats and densities by transect analysis within and between the sites where women collect sea hare in Fiji.

Description of study areas and sampling dates

The sampling sites are located on the southeastern coast of Viti Levu, which is Fiji's main island (Fig. 1). The sites were the Veivatuloa mudflats (site 1) and the Kaba Point mudflats (site 2); both sites are located close to Veivatuloa Village and Dromuna Village, respectively (Figs. 2 and 3).

Both study sites were covered with coarse mud and sand, and seagrass beds, low coral forms, burrowing invertebrate, colonial zoanthids and echinoderms dominated the sites. Tidal pools were also common to both sites.

Sea hare population densities were measured during transect studies for two days on in August 2008 at the Veivatuloa study site. The Kaba Point study site was also surveyed for two days in August 2008.

Methodology

The population density of *D. auricularia* was counted in quadrats measuring 1 m x 1 m, which were set at 10-m intervals along two 250-m transect lines. The transect lines and quadrats were laid at 0-m depth during low tide. The transect lines were laid perpendicular to the shoreline, and the quadrats were placed starting from the shore end of the seagrass bed on the mudflat. Within each quadrat frame, all *D. auricularia* were identified, counted and measured using a ruler. Seagrass was identified to the species level whenever possible.

A brief description of habitats in each quadrat was also made. The percentage of seagrass cover at every 10-m interval was also calculated. The maximum

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Figure 1. Satellite image of the southeastern coast of Viti Levu showing the locations of Kaba Point near Cautata (1) and Veivatuloa near Mau (2) (Source: Google Earth).

Figure 2. Satellite image of Dromuna Village and its mudflats on Kaba Point (Source: Google Earth).

Figure 3. Satellite image of Veivatuloa Village and its mudflats (Source: Google Earth).

animal size of sea hare in each quadrat was plotted against the quadrat number to see if larger animals tended to live in certain zones along the mudflats.

After sea hares were collected and their lengths measured, they were returned (live) to the sea. Young juveniles were also searched for from under rocks, in tidal pools, and among seagrass beds on each sampling trip.

Results

A nested ANOVA (analysis of variance) test was used to test the means of distribution, which was found to be not significantly different at both sites ($P < 0.05$) (Table 1). The non-difference may be attributed to the small sample size (n = 54).

Despite, the non-difference in the mean sample size, transect data from within each site was pooled in an attempt to investigate certain attributes of the population. Unimodal length–frequency distribution characterised the population at each site (Fig. 4).

Quadrats without similar animals were not included in the analyses. It must be noted that in order to carry out a nested ANOVA test, two assumptions have to be met:

1. the data needs to be normally distributed; and
2. the data should have equal variances.

In this study, the above requirements were not met, therefore, the data had to be transformed (square root transformed).

The Veivatuloa sea hare population had a slightly wider size range (i.e. 134.2–133.0 mm) than the Kaba Point population (125.4–127.9 mm). A small number of very large animals were found on the Veivatuloa mudflats. No *D. auricularia* less than 95 mm in length was observed during the study period at either site.

The nested ANOVA was also used to compare the mean body sizes of the two populations based on pooled data. The mean measures of size of *D. auricularia* from the Veivatuloa and Kaba Point mudflats are presented in Table 2. From Table 1, the ratio F (between sites) was 3.580/0.661, or 5.416; and, therefore, the null hypothesis (the two populations have the same body means) was P<0.05. There is

Table 1. Data from nested ANOVA test for the mean sizes of the two populations.

Sources of variation	Sum of squares (SS)	Degrees of freedom (df)	Mean square (MS)	Ratio F	Significance
Sites	680.4	1	6,801.4	3.580	0.197
Transects	3,784.3	2	1,892.2	0.661	0.521
Residuals	140,283.9	49	2,862.9		
Total	**1.5×10^5**	**52**	**1.2×10^4**		

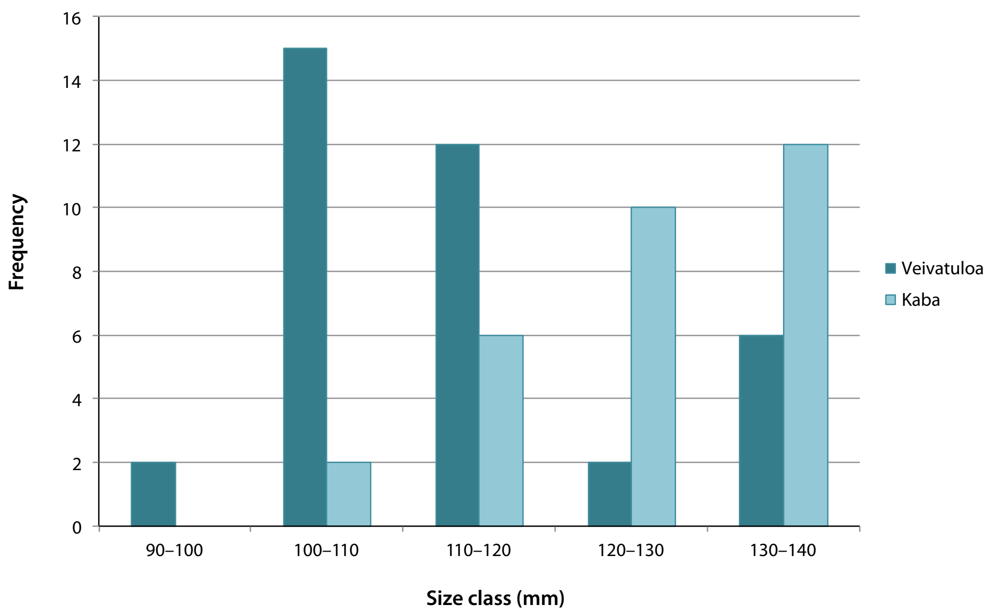

Figure 4. Length-frequency for Kaba Point and Veivatuloa sites.

no significant difference between the body means at both sites.

It is evident that the mean body sizes at both sites are quite similar although Veivatuloa animals have a larger maximum body size, and have a mean length of 101.1 mm (SD = 52.4, n = 28). Kaba Point animals had a mean length of 101.0 mm (SD = 53.9, n = 25). The size distribution and the mean size length of *D. auricularia* are very similar between the two study sites.

Density and abundance

Distinct zonation patterns were apparent along transects across the Kaba Point and Veivatuloa mudflats. The first 130 m from the shoreline consisted of only bare sand with little or no seagrass beds. From 130 m to approximately 310 m, seagrass (*Syringodium* spp., *Halophila* spp., *and Halodule* spp.) was present, with increasing amounts of *Sargassum* spp. The third zone consisted of 310 m$^+$, which lacked seagrass beds. These zones along the transect lines did not have sharp discontinuities but a transitional area existed between zones.

In total, 65 *D. auricularia* individuals were collected from 128 quadrats along the transect lines at both sites, giving a mean density of 0.51 individuals per quadrat. Many quadrats were empty while others contained only a small number of animals.

The number of *D. auricularia* fluctuated between 0 and 4 animals per quadrat. The highest densities were found in seagrass beds and tidal pools. Low or no density areas were associated with sandy areas with no seagrass beds. These areas were found mainly at the beginning and towards the end of the transect lines.

The density of sea hare was 0.48 per m^2 at Veivatuloa and 0.56 per m^2 at Kaba Point (Table 3).

Distribution patterns and habitat descriptions

Data from the transect lines were also tested to see whether the distribution patterns of *D. auricularia* were clumped or random. The variance of the sample was found to be greater than the arithmetic mean, suggesting that the population was clumped (Table 4). From the Table 4, the ratio F (between

Table 2. Vital length statistics for *D. auricularia* from the mudflats at Veivatuloa and Kaba Point.

Sites	Sample variance	Sample mean	Standard deviation (SD)	Standard error (SE)	Sum
Veivatuloa					
Transect 1	2,104.5	106.2	45.9	12.3	14
Transect 2	3,026.2	95.8	55.0	15.3	13
Kaba Point					
Transect 1	2,789.6	83.5	52.8	13.6	15
Transect 2	3,177.9	70.6	56.4	16.6	11

Table 3. Vital count statistics for *D. auricularia* from Veivatuloa and Kaba Point sites.

Sites	Sample variance	Sample mean	Standard deviation (SD)	Standard error (SE)	Sum
Veivatuloa					
Transect 1	0.80	1.21	0.92	0.24	17
Transect 2	1.08	0.58	0.75	0.21	14
Kaba Point					
Transect 1	1.69	1.73	1.31	0.36	13
Transect 2	1.27	1.42	1.19	0.36	14

Table 4. Data from nested ANOVA test on mean distributions of the two populations.

Sources of variation	Sum of squares (SS)	Degrees of freedom (df)	Mean square (MS)	Ratio F	Significance
Sites	3.980×10^{-2}	1	3.978	0.955	0.426
Transects	8.090×10^{-2}	2	4.050×10^{-2}	0.105	0.900
Residuals	18.477	48	0.385	-	-
Total	18.56	51	4.4	-	-

sites) was equal to 0.995/0.105, or 9.090, which therefore results in rejecting the premise that the distribution pattern of both populations is clumped ($P<0.05$). It can, therefore, be concluded that there is no significant difference between the body mean sizes at either study site.

As far as the relationship between the presence of *D. auricularia* and seagrass beds, the correlation coefficient of the relationship was compared to the critical value of r of 0.134 ($P < 0.05$, n = 65). From the results obtained using the Pearson correlation test, it can be concluded that there is a weak correlation between the number of *D. auricularia* and the higher percentage cover of seagrass beds.

From Table 5, the ratio F (between sites) equals 11.75/2.05, or 5.73, which results in rejecting the premises that *D. auricularia* 1) populations are associated with seagrass beds, and 2) does not increase in numbers as the percentage cover of seagrass increases. It can, therefore be concluded that *D. auricularia* are associated with seagrass beds but the numbers of *D. auricularia* do not increase with an increase in seagrass beds.

The numbers of *D. auricularia* also varied along the various zones of the transect lines. Although the number of individuals did not increase with an increase in seagrass beds, *D. auricularia* populations were found to be concentrated in seagrass beds, and therefore, the numbers of *D. auricularia* were found to be weakly correlated with the percentage of seagrass cover in the mid-zones along the transects.

Discussion

Similarities were found in the size structure of the two populations at these two study sites. There were significant mean body size similarities between quadrats and between transect lines at each of the sites, and a smaller sample size may be the reason why. More transects should be surveyed to obtain better estimate of abundance on the Veivatuloa and Kaba Point mudflats.

The sea hare populations studied had a unimodal size structure. Information on population size structure derived from transects at Kaba Point and Veivatuloa is likely to be less representative due to the number of samples collected. Possible sample bias may also contribute to the lack of representations.

The Veivatuloa population was significantly similar in mean body size when compared to the Kaba Point population. The maximum size obtained from the Veivatuloa site was notably greater than that collected from Kaba Point site. Generalisations about the population size structure are difficult to make at this point due to the lack of sample representations.

There were no juveniles (very small size) *D. auricularia* observed in this study, which may be due to the seasonal reproduction of *D. auricularia*. The lack of small individuals may also be due to poor recruitment during the months of August to October. In order to be able to make statements on recruitment, reproductive studies need to be undertaken. Only one egg mass was located (at the Kaba Point mudflat). *D. auricularia* lay eggs in jelly-like mass, often arranged in a long, tangled string. Eggs of *D. auricularia* either hatch as free-swimming larvae or as small crawling juveniles (William B. Rudman, Senior Fellow, Australian Museum, pers. comm.).

D. auricularia were found to be less common molluscs on the mudflats in terms of their density and frequency. Their presence in these two areas is strongly correlated with seagrass beds. Generalisations about the population structure of *D. auricularia* were based on pooled data because it was more representative. It was difficult to compare density data between the two sites and to state whether the density estimates of Kaba Point were comparatively higher than those from Veivatuloa. In order to gain a better perspective, several more transect lines across the two mudflats should be conducted.

The factors that affect sea hare densities and distribution patterns on the Veivatuloa and Kaba Point mudflats were varied and may be related more strongly to habitat types and less strongly to the substratum types. Our findings showed high abundances of sea hare in seagrass bed areas, and this was supported by a study undertaken by Calumpong (1979) who found that the highest numbers

Table 5. Data from nested ANOVA test on two populations' association with seagrass beds.

Sources of variation	Sum of squares (SS)	Degrees of freedom (df)	Mean square (MS)	Ratio F	Significance
Sites	4,508.7	1	4,508.7	11.75	0.75
Transects	769.6	2	384.8	2.05	0.14
Residuals	9,198.2	49	187.7	-	-
Total	1.45×10^{-4}	52	5.08×10^{3}	-	-

of *D. auricularia* were found in seagrass beds. Table 6 shows variations in densities in *D. auricularia* between Fiji and the Philippines.

It was evident from the statistical tests that the distribution of *D. auricularia* in the Veivatuloa and Kaba Point mudflats was clumped. Similar observations were made by Zager et al. (1979) in northern Bais Bay, Philippines. *D. auricularia* normally copulate in pairs and with this clumped distribution, individuals may encounter one another more frequently than they would in a random distribution having the same mean densities (MacArthur and Jones 1966).

The main limiting factor for sea hare distribution is food availability. This is supported by Miller (1969), who found that in temperate parts of the world, food is the dominating influence. Sea hares have special diets and are naturally most common where their food is plentiful.

The usual habitat of *D. auricularia* is the shallow seagrass community. As observed by Calumpong in 1979, *D. auricularia* is also associated with tidal pools. In this preliminary survey of this economically important invertebrate in the Veivatuloa and Kaba Point mudflats, *D. auricularia* were more abundant on a substrate of sand with sparse growth of seagrass than on mud or silt with seagrass.

At the Kaba Point and Veivatuloa mudflats, *D. auricularia* populations were found only on seagrass beds, and none were observed in adjacent muddy areas near mangroves. Two adults and one freshly laid egg mass were found along transect 1 on the Kaba Point mudflat. These were in the area of sparse seagrass (*Thalassia* spp.). According to Calumpong (1979), *Thalassia* spp. and *Halophila ovalis* constitute the bulk of the sea hare's diet. However, sea hares will exploit whatever available algae there are in the environment, and could easily survive in a laboratory on strictly algal diets.

From the nested ANOVA test it can be concluded that *D. auricularia* were closely associated with the presence of seagrass beds. However, the presence of seagrass beds alone does indicate the presence of *D. auricularia*. Furthermore, this does not necessarily mean that there is a linear correlation between the numbers of *D. auricularia* and the percentage of seagrass cover in a particular area.

Conclusions

The data obtained indicate that *D. auricularia* is found among seagrass beds of *Thalassia* spp. and *Halophila ovalis*. Although the types of food this sea hare eats may limit its distribution within seagrass communities, factors other than seagrass beds may have limited its distribution on the mudflats at both study sites. *D. auricularia* is less abundant on both the Veivatuloa and Kaba Point mudflats than on other sites in Fiji.

Our findings indicate that the population from both study sites had a unimodal size structure (mostly clumped) distribution, with a noticeable absence of juveniles (< 90 mm) in both populations. This clumped distribution may be related to the breeding habits of *D. auricularia*. Populations of *D. auricularia* at the two study sites were significantly similar when comparing mean body sizes, and this similarity is probably due to the small sample size.

Recruitment rates were low for *D. auricularia* at both the Veivatuloa and Kaba Point mudflats. The size distribution of *D. auricularia* was significantly similar to that of Veivatuloa populations, and this again may be due to the small sample size.

The distribution patterns of *D. auricularia* across the Veivatuloa and Kaba Point mudflats were not random and this may be related to habitat types and/or seagrass community types at the study sites. The average sizes of similar animals distributed across both mudflats were fairly even, but generally, larger animals were found on Veivatuloa mudflats. The densities of *D. auricularia* encountered in this study were low and were variable between ecological zones.

Acknowledgements

Table 6. Densities of *D. auricularia* based on this study and one from the Philippines.

Density	Area	Reference
0.48 per m^2	Veivatuloa, Fiji	This study
0.56 per m^2	Kaba Point, Fiji	This Study
0.18 per m^2	North Bais Bay, Philippines	Calumpong (1979)
0.41 per m^2	Siyt Bay, Philippines	Calumpong (1979)

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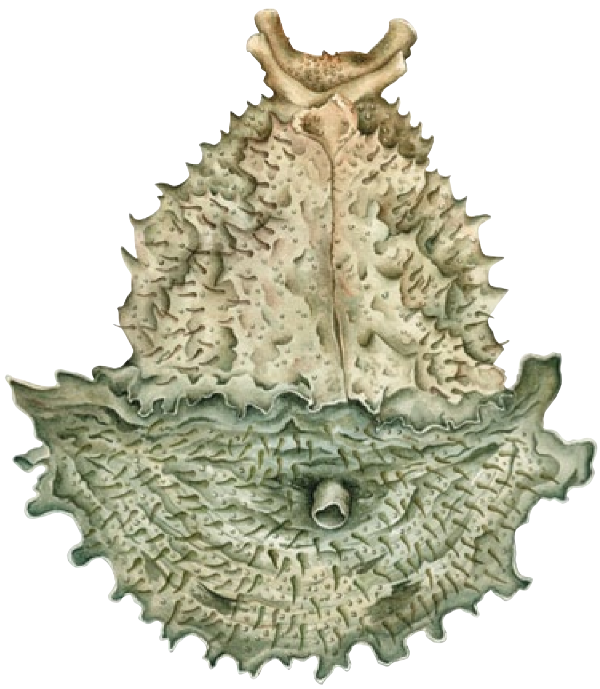

The sea hare, *Dolabella auricularia*
(illustration: Rachel O'Shea, © SPC)