

FISH AND WHIPS: USE OF GORGONIANS AS A HABITAT BY THE LARGE WHIPCORAL GOBY, *BRYANINOPS AMPLUS* (LARSON)

Justin Sih and Jeff Chou

Tropical Marine Science Institute, National University of Singapore,
18 Kent Ridge Road, Singapore 119227, Republic of Singapore
Email: jus_bluey_husky@yahoo.com (JS); jeff@illuminate-photos.net (JC)

ABSTRACT. – This study investigated the use of different species of host-gorgonians by the whipcoral goby, *Bryaninops amplus* in Singapore. Belt-transects were used to determine if *B. amplus* displayed any host preferences and if differences in goby occupation patterns exist between local host species. Collections of occupied and unoccupied colonies from two common species, *Junceella juncea* and *Dichotella gemmacea*, were used to determine the influence of host size and structure on *B. amplus*. Comparisons of occupied and unoccupied colonies found that the former were generally taller than the latter. Occupancy was dependent on colony height, which may increase the effectiveness of the host as a habitat and a refuge from predation. Although *B. amplus* did not display any preferences for any of the host species examined, *D. gemmacea* tended to have more gobies than did *J. juncea*. This may be due to the structural difference between the unbranched, *J. juncea* and the multiple-branching, *D. gemmacea*, thus hinting at the influence of habitat structure on the goby population. The results also indicate that goby size was limited by colony width on *J. juncea*, which may be from the way *B. amplus* hides behind it so as to avoid detection by predators.

KEY WORDS. – *Bryaninops*, *Junceella*, *Dichotella*, gorgonian, habitat-specialist, habitat size and structure.

INTRODUCTION

Whipcoral gobies in the genus *Bryaninops* are habitat-specialists that live in male-female pairs or small groups (Larson, 1985; Munday et al., 2002; Larson & Lim 2005), clinging to the branches of gorgonian or antipatharian corals, where they find shelter (Larson, 1985; Larson & Lim, 2005). *Bryaninops amplus* (Larson, 1985) has been commonly reported in Singapore (Goh & Chou, 1994; Goh et al., 1999; Larson & Lim, 2005) and is strongly associated with unbranched gorgonian whipcorals, especially on *Junceella juncea* (Pallas, 1766) (Larson, 1985) and *Junceella fragilis* (Ridley, 1884) (Larson, 1985; Larson & Lim, 2005). In addition, they are also found on branching gorgonians of the genus *Ellisella* and even artificial structures such as buoy lines (Larson, 1985). Goh et al. (1999) suggested that their association with gorgonians maybe linked to their dependence on these corals as a refuge from predation. While the structure (Wainwright & Koehl, 1976) and orientation (Wainwright & Dillon, 1969) of gorgonians that is adapted for capturing plankton, may also provide gobies a take-off platform to access food in the water column. Its small size and inability for sustained swimming (Larson 1985; pers. obs.) further highlights its dependence on gorgonians as a place to cling on to, feed from and find refuge from predation.

As with other small fish, the small size and limited mobility of *Bryaninops amplus* puts them at a higher risk to predation and restricts them to specialised habitats resulting in a closer association with the reef matrix in comparison to larger fish (Munday & Jones, 1998). This close habitat association in particular for obligate habitat-specialists, will in turn lead their social organization and life history strategies to be tied to habitat patch size (Munday et al., 2002). A strong dependence on their host would likely result in their distribution and abundance to be correlated to that of their host habitat (Kuwaramura et al., 1994; Munday et al., 1997) in terms of spatial and temporal availability of suitable habitats (Munday et al., 1997). This strong habitat association makes them a good candidate for studies on the effect of habitat on fish populations. Being a habitat-specialist also warrants special attention, since habitat-specialist species have been predicted to be the first to be lost from coral reefs because their highly specialised requirements make them the vulnerable to anthropogenic and climatic disturbance (Munday, 2004).

In Singapore, *B. amplus* is found on different species of gorgonians (pers. obs.) that are structurally varied, thus making it ideal for studies on the influence of different habitat variables on fish. This is primarily a baseline investigation to ascertain the ecology of *B. amplus* in terms of habitat

influence. The major objective of this study is to determine if any host species preference occurs and to investigate the patterns of habitat resource use in terms of goby occupancy and densities, on different host-gorgonians by *B. amplus* in Singapore. In addition, it also attempts to establish the effects of habitat size and structure of host-gorgonians on the goby's pattern of habitat utilization.

MATERIAL AND METHODS

Study site. – The study was conducted at the northern tip of Kusu Island (Pulau Tembaku; 1°13.55'N, 103°51.60'E) (Site 1) and the southern end of Raffles Lighthouse (Pulau Satumu; 1°9.55'N 103°44.45'E) (Site 2) in the Singapore Strait (see Fig. 1) from April 2006 to April 2007. These sites were chosen specifically because of the abundance of gorgonians and presence of *Bryaninops amplus*.

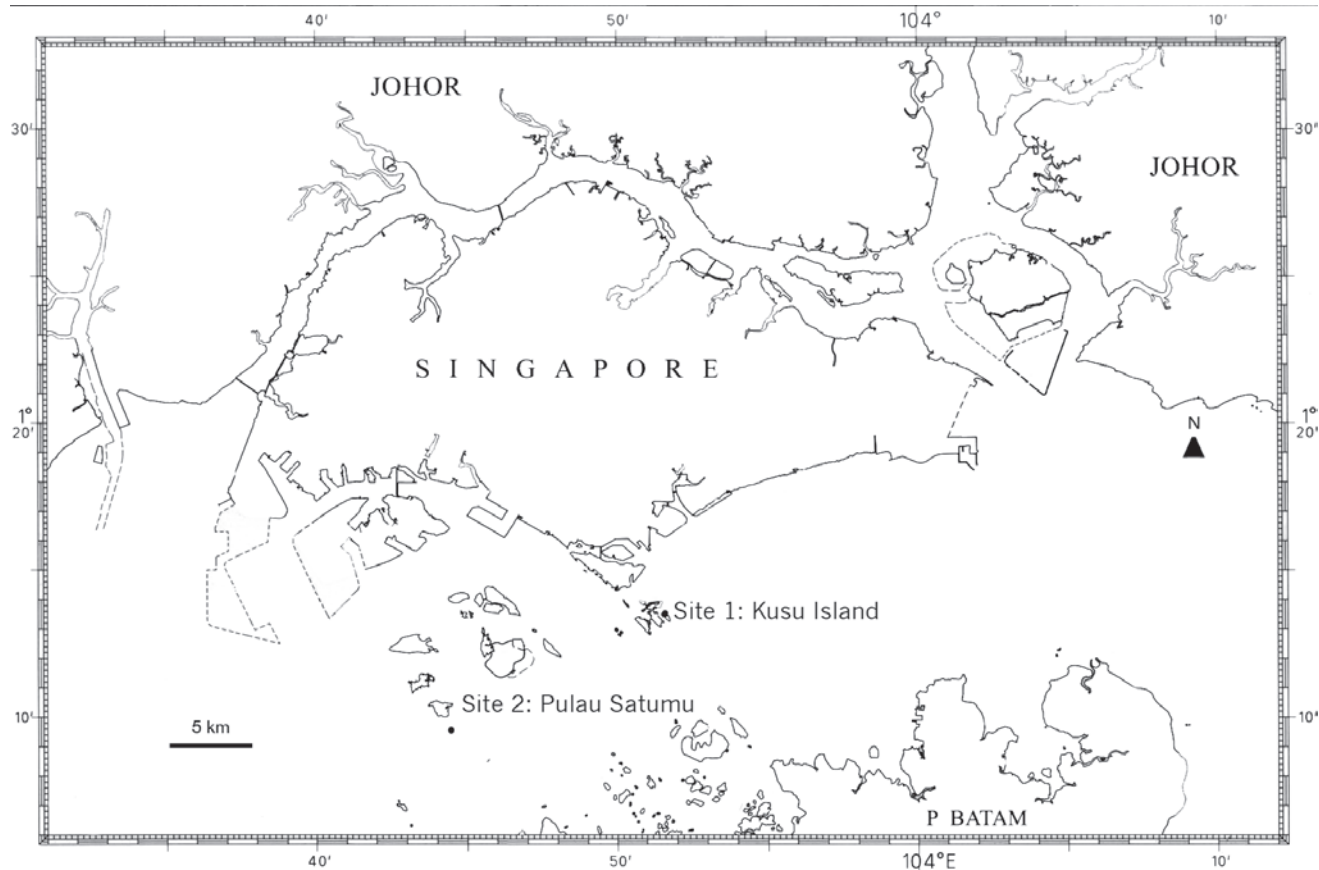


Fig. 1. Location of study sites in the Singapore Strait: Site 1, Kusu Island (Pulau Tembaku); Site 2, Raffles Lighthouse (Pulau Satumu).

Distribution of *Bryaninops amplus* on different host species. – The results from previous baseline investigations indicated that *B. amplus* inhabits four gorgonian species in Singapore waters despite the availability of many others here. These were identified as *Junceella juncea* (Pallas, 1766) (Leen P. Van Ofwegen, pers. comm.), *Dichotella gemmacea* (Milne Edwards & Haime, 1857) (Leen P. Van Ofwegen, pers. comm.), *Ctenocella pectinata* (Pallas, 1766) (Nigel K. C. Goh, pers. comm.) and *Viminella* sp. (Leen P. Van Ofwegen, pers. comm.). It is also worth noting that *J. juncea* and *D. gemmacea* in Singapore were previously reported by (Goh & Chou, 1996) in an annotated checklist as *Junceella (Junceella)* sp. A and *Junceella (Dichotella)* sp. cf. *gemmacea* respectively. Both *D. gemmacea* and *C. pectinata* have a multiple-branching growth form, while *J. juncea* and *Viminella* sp. have an unbranched and whip-like growth form (Fig. 2)

A visual SCUBA census was conducted to determine the

distribution of *B. amplus* on the above mentioned host species, taking care not to disturb the gobies. Four and five 20 m long by 2 m wide belt-transects were laid at a depth of 10 meters along the reef slope at Site 1 and 2 respectively. Counts of each host species and the number of gobies associated with each colony were scored. Colonies that were inhabited was termed as occupied and uninhabited colonies termed as unoccupied. The sum of occupied and unoccupied colonies per transect for each species was termed total colonies.

Data from all nine belt-transects was arcsine-transformed then subjected to a two-way Analysis of Variance (ANOVA), with host species and site as factors. The ANOVA compared the proportions occupied colonies to that of total colonies for each host species. That was to test if the pattern of inhabitation of different host species by *B. amplus* differed from the natural composition of host species. A significant difference would indicate a host preference by *B. amplus*.



Fig. 2. Gorgonian hosts of the goby *Bryaninops amplus*: A, *Junceella juncea* (Pallas); B, *Viminella* sp.; C, *Dichotella gemmacea* (Milne Edwards & Haime); D, *Ctenocella pectinata* (Pallas).

However, *Viminella* sp. was excluded from the ANOVA as only four individuals were encountered in both sites.

Density of *Bryaninops amplus* on different host species. –

The number of *B. amplus* associated with each colony of *J. juncea* and *D. gemmacea*, was termed occupation density. A chi-square test was conducted on the frequencies of a range of different occupation densities from the belt-transect data to determine if significant variations occurred in the

goby distribution pattern between these two host species. A significant difference would indicate a variation in habitat utilization by the goby between host species.

Effects of host colony height on occupancy by *Bryaninops amplus*. –

Eleven occupied and fifteen unoccupied colonies of *J. juncea* were collected from Site 1. A further twelve occupied and fifteen unoccupied colonies of *J. juncea* were collected from Site 2. While ten occupied and the ten

unoccupied colonies of *D. gemmacea* were collected from Site 1, and a further six occupied and eight unoccupied colonies were collected from Site 2. Gobies were counted prior to and after capture to ensure that none had escaped or moved to another nearby colony. Any colonies from which gobies managed to evade capture were abandoned from the study. However, this was seldom encountered as most colonies were spaced far enough apart to prevent fish from fleeing to another and even so the majority preferred to remain on their host.

The collected specimens of *J. juncea* and *D. gemmacea* had their height determined in the laboratory. A measuring tape was used to measure the height of *J. juncea* and *D. gemmacea* to the nearest 0.1 cm, starting from the base and ending at the tip furthest away from the base, following the natural curve of the branches. The height of occupied and unoccupied colonies of *J. juncea* and *D. gemmacea* were compared to determine if there were any significant difference between occupied and unoccupied colonies. Data was $\log_{10}(x)$ transformed and subjected to General Linear Model (GLM) to determine the effect of host species and height on occupancy by *B. amplus*.

Effects of host colony height and width on *B. amplus* density and body size. – Correlation between colony height to occupation density for both *J. juncea* and *D. gemmacea* were tested using the non-parametric Spearman rank correlation coefficient. While the correlation of colony width for the unbranched *J. juncea* and *B. amplus* size was determined by product moment correlation coefficients.

The width of *J. juncea* was measured at 10 cm from the base after Munday et al. (2002) and termed colony width. Since the cross-sections of gorgonians are more elliptical than round, the widest part of the section was taken. Goby size was scored as total length (TL), a measurement from tip of head to the tip of tail and head width (HW) as the widest distance between the edges of the opercula. Vernier calipers were used to measure the all above dimensions to the nearest 0.01 cm. Product moment correlation coefficient tests were run to determine if significant correlations exist between the TL of the largest goby on each colony and colony height, and the HW of largest goby on a colony and its host's colony width.

RESULTS

***B. amplus* distribution on different host species.** – The gorgonian *Junceella juncea* was the most common host species in the belt transects, making up $49.8\% \pm 7.2$ SE and $69.7\% \pm 2.9$ SE of total host cover at Site 1 and Site 2, respectively. This was followed by *Dichotella gemmacea*, *Ctenocella pectinata* and *Viminella* sp. in descending order of abundance (Figure 3). *Dichotella gemmacea* made up $43.9\% \pm 7.73$ SE and $27.1\% \pm 3.00$ SE of host species cover at Site 1 and Site 2 respectively, while *C. pectinata* comprised $5.7\% \pm 1.94$ SE and $1.7\% \pm 1.29$ SE at Site 1 and Site 2 respectively. *Viminella* sp. was rare and only

comprised $0.6\% \pm 0.37$ SE of total host species at Site 1 and $1.5\% \pm 0.90$ SE at Site 2. *Viminella* sp. had the highest occupancy rates, at 100%, i.e., every individual of that species encountered was always associated with gobies, though only four extremely long (≥ 2 m) colonies were encountered in the nine belt transects. The two most common host species, *J. juncea* ($n = 276$) and *D. gemmacea* ($n = 176$), registered the next two highest occupancies at 23.2% ($n = 64$) and 21.6% ($n = 38$) respectively, while the rarer *C. pectinata* ($n = 23$) was lowest at 17.4% ($n = 4$) (See Fig. 3).

Results from the two-way ANOVA did not reveal any significant difference ($F_{3,12} = 0.952$; $P > 0.05$) between the proportions of occupied colonies and that of total colonies. Neither was there any difference ($F_{3,12} = 0.968$; $P > 0.05$) for combined effects of host species and sites. However, a significant difference was detected between ($F_{3,12} = 0.416$; $P < 0.05$) sites, which revealed site variation in the proportions of *J. juncea* and *D. gemmacea*. Post-hoc Tukeys test revealed that the proportions of *J. juncea* were greater at Site 2 than at Site 1, while the opposite was true for *D. gemmacea*.

***B. amplus* density on different host species.** – The mean occupation density of *B. amplus* on *J. juncea* and *D. gemmacea* colonies from the belt-transects were 1.20 gobies/colony ± 0.06 SE and 1.76 gobies/colony ± 0.15 SE, respectively. With Site 2 having a relatively greater mean density than Site 1 (Fig. 4). The highest number of gobies observed on a single gorgonian colony in the belt-transect was three in *J. juncea* and four in *D. gemmacea*. Chi-square goodness-of-fit test conducted on the frequencies of observed occupation densities on *J. juncea* and *D. gemmacea* revealed a significant difference ($\chi^2_{3df} = 30.256$, $P < 0.001$) between the two host species. Figure 5 shows *J. juncea* is usually occupied by a single goby, while *D. gemmacea* had a higher likelihood to be occupied by two or more gobies than compared to *J. juncea*.

Effects of host colony height on occupancy by *B. amplus*. – The mean heights of collected colonies of occupied and unoccupied *J. juncea* were 86.8 cm ± 5.47 SE and 50.2 cm ± 3.23 SE (Figure 6) and similarly for occupied and unoccupied *D. gemmacea* were 61.5 cm ± 4.05 SE and 37.4 cm ± 3.03 SE (Figure 6) respectively. The GLM two-way ANOVA of $\log_{10}(x)$ transformed colony heights showed a significant difference between occupied and unoccupied colonies ($F_{3,83} = 54.48$; $P < 0.001$) as well as between gorgonians of the species *J. juncea* and *D. gemmacea* ($F_{3,83} = 17.75$; $P < 0.001$).

No significant difference was found for the combined effect of occupancy and host species on colony height ($F_{3,83} = 0.04$; $P > 0.05$). A posthoc Tukeys test showed that occupied colonies were significantly taller than unoccupied colonies for both *J. juncea* and *D. gemmacea*, while occupied colonies of *J. juncea* were significantly taller than both occupied and unoccupied colonies of *D. gemmacea*. However, unoccupied colonies of *J. juncea* were not significantly different from those of occupied colonies of *D. gemmacea*.

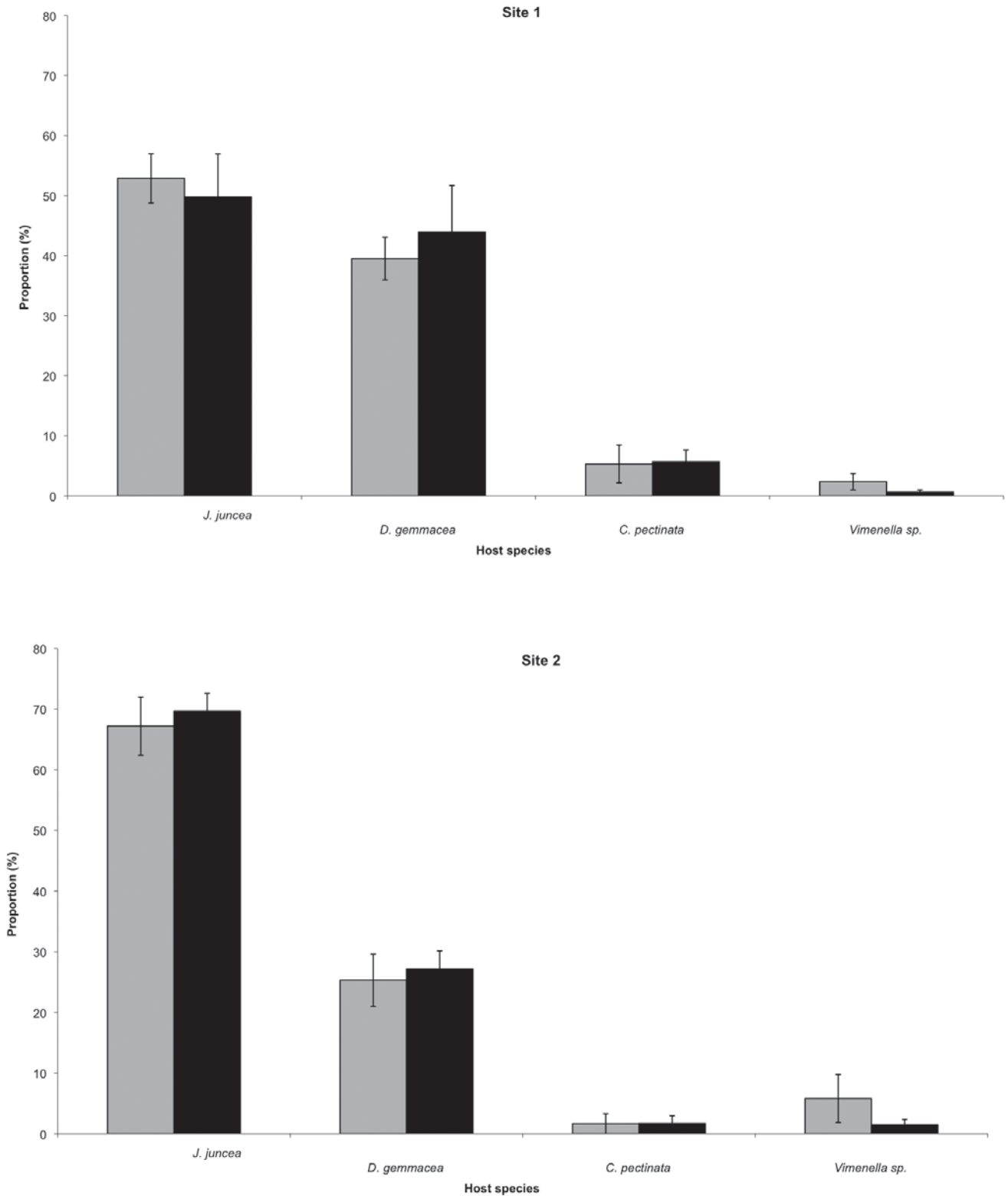


Fig. 3. Proportion of gorgonian colonies occupied by *Bryaninops amplus* (grey bars) to the total number of gorgonian colonies (black bars) from: Site 1, Kusu Island; Site 2, Pulau Satumu.

There was an increasing tendency for taller colonies to be associated with at least one goby, and nearly all colonies in the taller size-classes were occupied. Furthermore, shorter colonies were not inhabited by gobies for both *J. juncea* (Figure 7a) and *D. gemmacea* (Figure 7b). For *J. juncea*, gobies were absent from all colonies less than 25 cm in

height, while those more than 1 m in height were always occupied (Figure 7a). Similarly, *B. amplus* was entirely absent from colonies below 40 cm for *D. gemmacea* whereas the taller size classes were either partially or fully occupied. However, one tall, unoccupied colony was present out of a total of eight individuals in the tallest size class (Figure 7b).

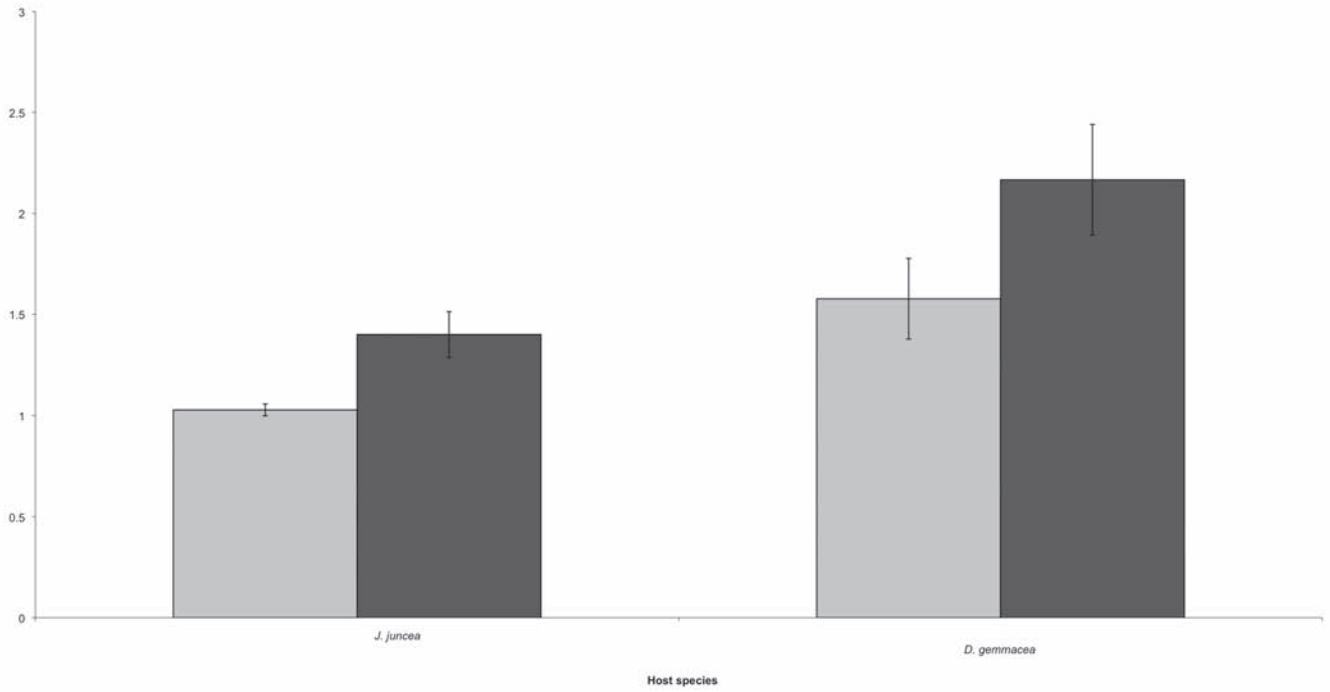


Fig. 4. Mean occupation density of *Bryaninops amplus* on *Junceella juncea* and *Dichotella gemmacea* at Site 1 (Kusu Island; light grey) and Site 2 (Pulau Satumu; dark grey).

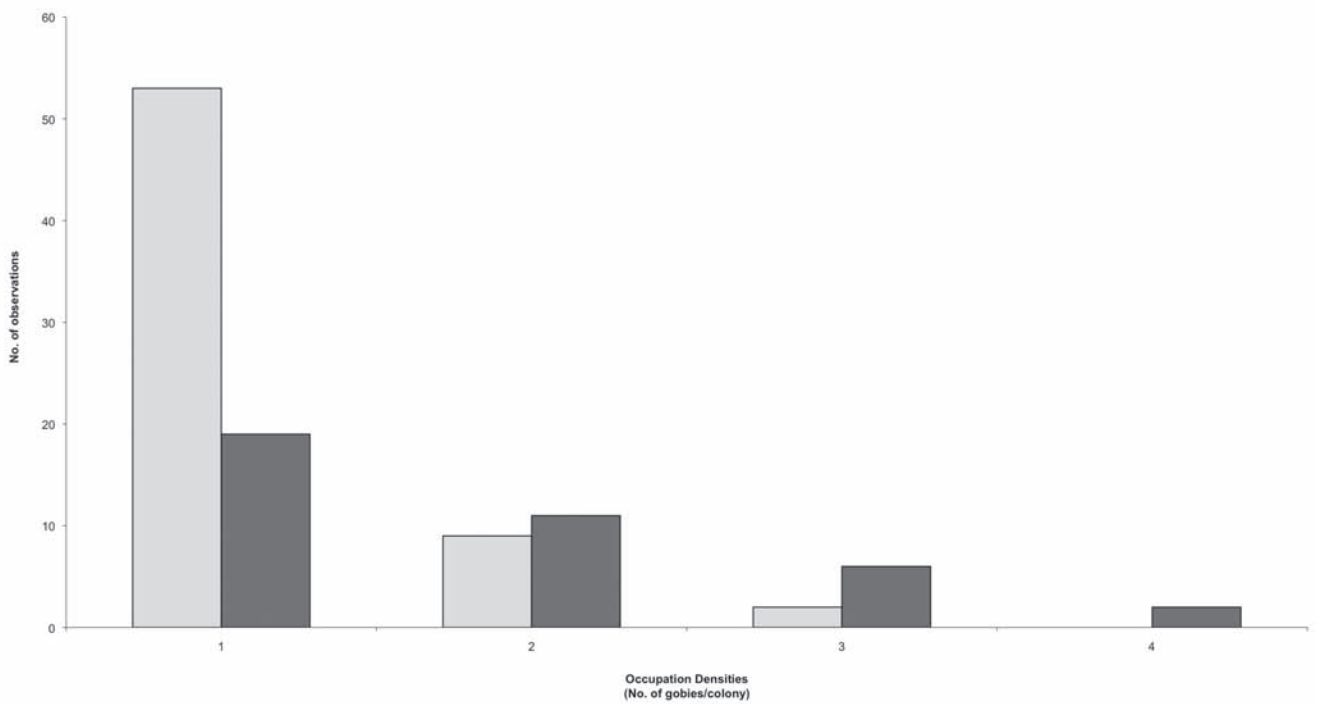


Fig. 5. Occupation densities of *Bryaninops amplus* on *Junceella juncea* (light grey) and *Dichotella gemmacea* (dark grey).

Effects of host colony height and width on *B. amplus* density and body size. – A significant positive correlation ($r_s=0.42$, $n = 23$; $P < 0.05$) between occupation density and colony height was observed for *J. juncea* (Figure 8a). In contrast, there was no significant correlation ($r_s = 0.41$, $n = 16$; $P > 0.05$) found between occupation density and colony height on *D. gemmacea* (Figure 8b).

In addition, no significant correlation was detected between the TL of the largest goby on each colony and colony height on *J. juncea* ($r = 0.37$, $n = 23$; $P > 0.05$) (Figure 9a). However, a significant positive correlation between HW of the largest goby on each colony and colony width ($r = 0.62$, $n = 23$; $P < 0.05$) was detected on *J. juncea* (Figure 9b).

DISCUSSION

Distribution on different host species. – The results revealed that *Bryaninops amplus* occurred on different species of host-gorgonians in the same proportions as how these gorgonians occur in the natural environment. This strongly suggests that *B. amplus* has little or no preference for any host-gorgonian species, with the exception of *Viminella* sp., which was not analyzed due to the low numbers encountered. However, *Viminella* sp. was always associated with fish whenever it was encountered. Since all of the *Viminella* sp. colonies encountered were relatively taller than that of the similarly unbranched *J. juncea*, it was believed that the relatively taller height of *Viminella* sp. (~2 m) was the reason for their strong association with *B. amplus*. If so, occupancy (whether a seawhip is occupied or not) is a function of host colony height, which is in turn related to host species, rather than that of species alone (see below). In summary, the preference study indicated that with the exception of *Viminella* sp., there was no apparent preference by *B. amplus* for the different types of host-gorgonian species in Singapore waters. *B. amplus* was reported on many gorgonian species, such as *J. juncea*, *J. fragilis*, *Junceella* sp., *Ellisella maculata*, and *Ellisella* sp. (Larson, 1985) and even on artificial structures such as bamboo fish traps, buoy lines, current meter moorings (Larson, 1985), mooring lines (pers. obs., 2007) as well as artificial-reef moorings designed to collect settling juvenile fishes (Leis et al., 2002). Since *B. amplus* are not exclusive to artificial structures that resemble the elongated cylindrical shape of whipcorals, it is likely that their common association with specific host gorgonian species is linked to the suitability of the physical structure and the size of these host species, rather than from a direct preference for certain host species itself, unlike some anemone fish which select their host based on an innate host-species preference (Elliot et al., 1995). Nonetheless, controlled studies based on preference and survival experiments are required to test this hypothesis using artificial hosts of various sizes and structures.

Goby density on different host species. – The greater occupation densities on *D. gemmacea* compared to *J. juncea* are probably due to high habitat complexity provided by this branching host-gorgonian species compared to unbranched

J. juncea. This morphological complexity would presumably increase available surfaces and thus allow occupation by a greater number of fish.

Fish also prefer to settle on structurally complex habitats (Tolimieri, 1995; Öhman et al., 1998) and fish settlement studies on artificial substrates by Leis et al. (2002) found that *B. amplus* preferred to settle on a structurally complex habitat. Thus this settlement preference for structurally complex habitats by *B. amplus* may be the cause for a greater number of small fish seen on *D. gemmacea* than *J. juncea* in our studies. In addition, the multiple-branching form of *D. gemmacea* colonies and their orientation of these branches into the current leads to an increased exposure to drifting plankton, which may in turn increase the chances of fish larvae encountering and eventually settling onto *D. gemmacea* compared to *J. juncea*.

Complex habitats offering refuge from predators have been reported by numerous authors (e.g., Heck & Thoman, 1981; Stoner, 1982; Orth et al., 1984; Ryer, 1988; Werner & Hall, 1988; Jordan et al., 1996). Ryer (1988) explained that increased habitat complexity act to reduce predation by placing more visual obstructions in the path of predators thus increasing the ability of mobile prey to hide, evade and escape. Therefore, gobies on *D. gemmacea* could take advantage of its complex multiple-branching structure to confuse predators and avoid detection by switching from one branch to another (pers. obs.). This may result in an increased refuge capacity in multiple-branching hosts and thus greater goby densities compared to unbranched forms. However, survivability experiments conducted with artificial substrata or branching colonies of various complexities but standardized heights are required to determine the effects of host habitat complexity on predator deterrence for *B. amplus*.

Effects of host colony height on occupancy by *B. amplus*. – In general, occupied gorgonians tend to be taller than unoccupied gorgonians for both *J. juncea* and *D. gemmacea* (Fig. 6), indicating that *B. amplus* generally prefers to inhabit taller host-gorgonians. Statistical comparisons between heights of occupied and unoccupied *J. juncea* with that of occupied and unoccupied *D. gemmacea* revealed that occupied *J. juncea* were taller than both occupied and unoccupied *D. gemmacea*. On the other hand, unoccupied *J. juncea* were only taller than unoccupied *D. gemmacea* and not occupied *D. gemmacea*. The result suggests that *B. amplus* tend to associate with *D. gemmacea* individuals at a shorter height than compared to *J. juncea* individuals. It may also explain the lack of preference for *J. juncea* over *D. gemmacea* by *B. amplus*, despite *J. juncea* being generally taller than that of *D. gemmacea*. In doing so, it hints at the possibility of a positive influence of the more complex physical structure of multiple-branching hosts on goby occupancy.

The size class-frequency graph of proportions of occupied and unoccupied colonies (Fig. 7) also showed increasing occupancy as hosts became taller, indicating the suitability

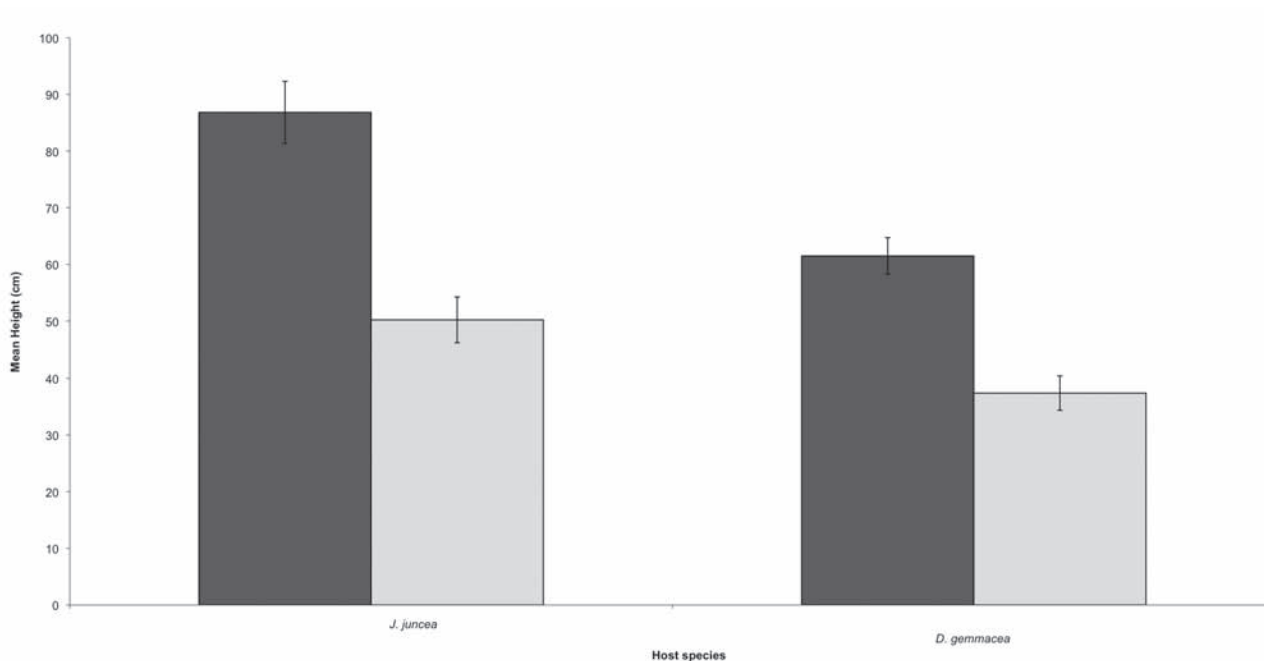


Fig. 6. Mean heights of occupied and unoccupied colonies of *Junceella juncea* and *Dichotella gemmacea*.

of a host for habitation by *B. amplus* is dependent on its height. No individuals of *J. juncea* below 25 cm in height were associated with *B. amplus*, while all colonies more than 100 cm were totally occupied. Similarly, observations in *D. gemmacea*, where colonies under a critical height of 40 cm were never associated with *B. amplus*, but those greater than 60 cm in height were almost always associated with at least one fish. This suggests that hosts must reach a critical height, before it becomes a suitable habitat for *B. amplus*. A similar relationship between the size of the host-coral, *Stylophora pistillata* and the occupancy of its fish associate, *Paragobiodon echinocephalus* was also observed by Kuwamura et al. (1994), where small corals under 15cm were seldom inhabited but occupancy increased with coral size to the point that large corals over 15 cm were almost always inhabited. Similarly, *Bryaninops yongei* (a congener of *B. amplus*) was only associated with taller wire-corals, *Cirripathes anguina* (Munday et al., 2002) and were absent on smaller wire-corals under a critical size. In the former study, Kuwamura et al. (1994), suggested that this was because *P. echinocephalus* does not settle onto host-corals under a critical size as the host will not grow large enough to provide a suitable nesting site by time the goby attains reproductive size. Similarly, Munday et al. (2002) suggested that taller wire-corals may provide a greater surface area for egg laying, and hence increasing wire-coral size heightens the suitability of the host as a nest-site since *B. yongei* are demersal spawners that lay their eggs near the tip of their host (Munday et al., 2002). Because *B. amplus* exhibits a similar egg laying behaviour and is very similar to *B. yongei* (Larson, 1985) in morphology and in their association with structurally similar whip-like hosts, the effect of a larger nest space on larger hosts may also be the determining factor leading to higher occupancy on larger host-gorgonians by *B. amplus* in our current study.

However, another reason why colony height is such an important determinant of occupancy is because taller colonies reach higher into the water column thus allowing the rheophilic *B. amplus* better access to zooplankton prey. Larson (1985) reported that fish of the genus *Bryaninops* “pick plankton drifting past, by rapidly darting out a short distance into the water column to take a food item before darting back to cling on its associate” concurs with our observations of *B. amplus* feeding from *J. juncea*, where individuals darted off the higher parts of their host-gorgonians that extend into the water column to feed. Munday et al. (2002) also provided a similar explanation for the high occupancy on larger wire-corals, stating that “large seawhips [wire-corals] also extend further into the water column and could expose the fish to a greater volume of water containing the plankton on which the fish feed”. The gorgonian structure has been suggested by Goh et al. (1999) to be advantageous to rheophilic gorgonian associates that feed from the water column. This is because they orientate towards prevailing water to maximize water flow around their branches (Wainwright & Koehl, 1976) and their arborescent morphology is such that branches are held above the still boundary layer near the substrata and into faster flowing water above it (Wainwright & Dillon, 1969). So it seems plausible that the taller gorgonian colonies have a greater proportion of its surface held in the fast-flowing plankton-rich zone, thus increasing the accessibility of their plankton-feeding associates such as *B. amplus* to pelagic food sources. In addition, the increased penetration into the water column by taller host-gorgonians may also increase the dispersal of newly hatched fish, since the eggs of *B. amplus* are laid near the tips of host-corals. Increasing host size may thus increase their suitability as a nest site as suggested by Munday et al. (2002). However, other effects of host size on habitability such as its effect as a shelter from

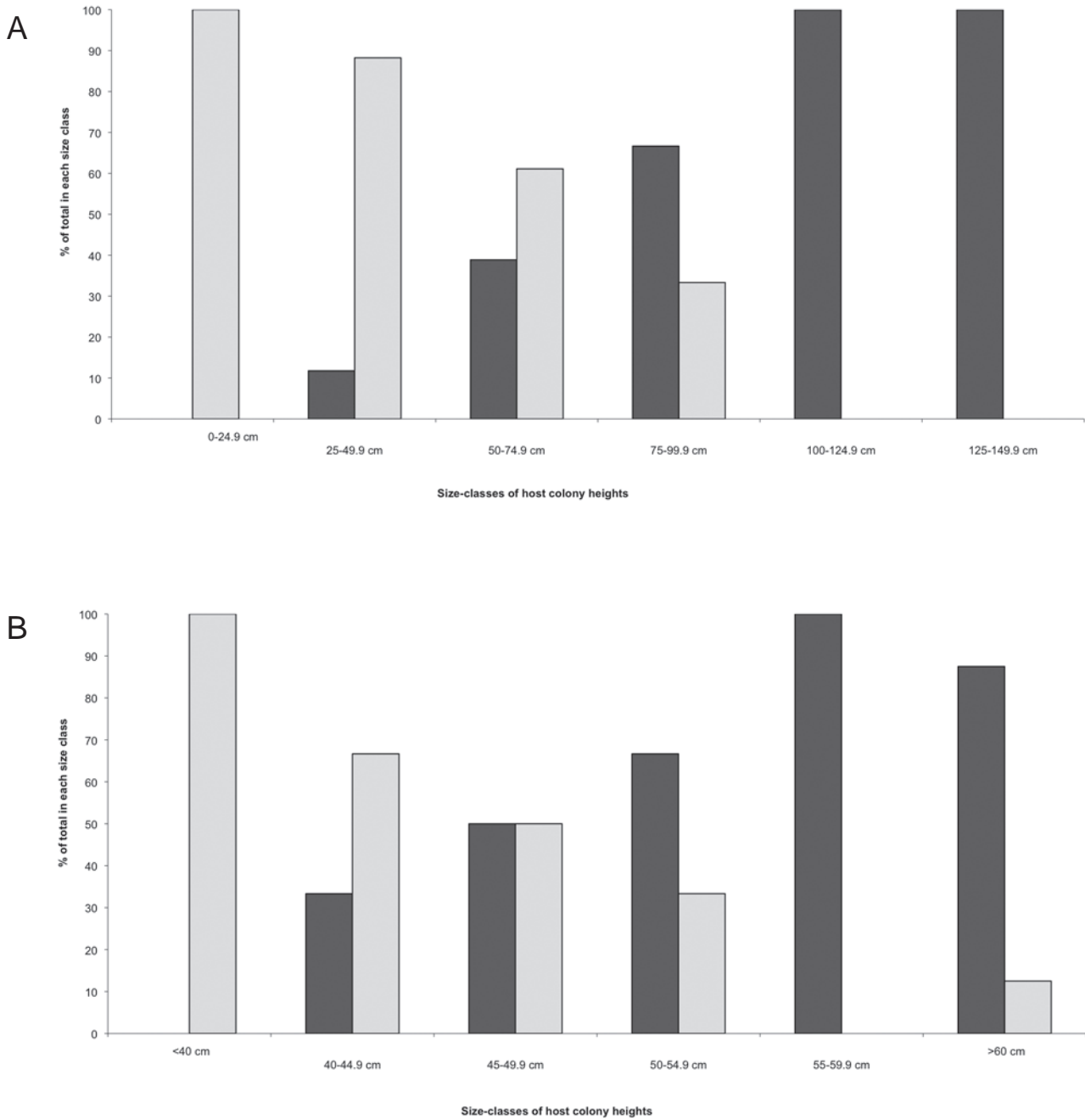


Fig. 7. Goby occupancy on different size-classes of host colony heights in: A, *Junceella juncea*; B, *Dichotella gemmacea*; light grey, unoccupied; dark grey, occupied.

predation may also contribute substantially. The small body size of *B. yongei* made them more vulnerable to predation, and larger wire-corals may help gobies avoid reef-based predators (Munday et al., 2002).

Effects of host colony height and width on *B. amplus* density and body size. – As seen in this study, the increase in the occupation density associated with *J. juncea* colonies as the host increased in height (Fig. 8a) parallels observations of host size on fish densities by Kuwamura et al. (1994) and Wong et al. (2005). Investigations on the effects of coral colony size on the social organization of the pygmy coral croucher, *Caracanthus unipinna* by Wong et al. (2005) also demonstrated a positive correlation between the host-coral

colony size and the number of fish it harbored, indicating that spatial constraints might limit the number of fish residing on a host (Wong et al., 2005). Such spatial constraints may also occur on *J. juncea* colonies, where gobies are often seen lined up in single file when two or more individuals share the same whip coral. Thus a whipcoral of a certain size can only accommodate a limited number of gobies, either because of the limitations of the host as a refuge, nest site or food resource or by density-regulating behaviour of the goby.

On the other hand, the lack of correlation between fish densities and colony height for the multiple-branching *D. gemmacea* may be because its structural complexity, since

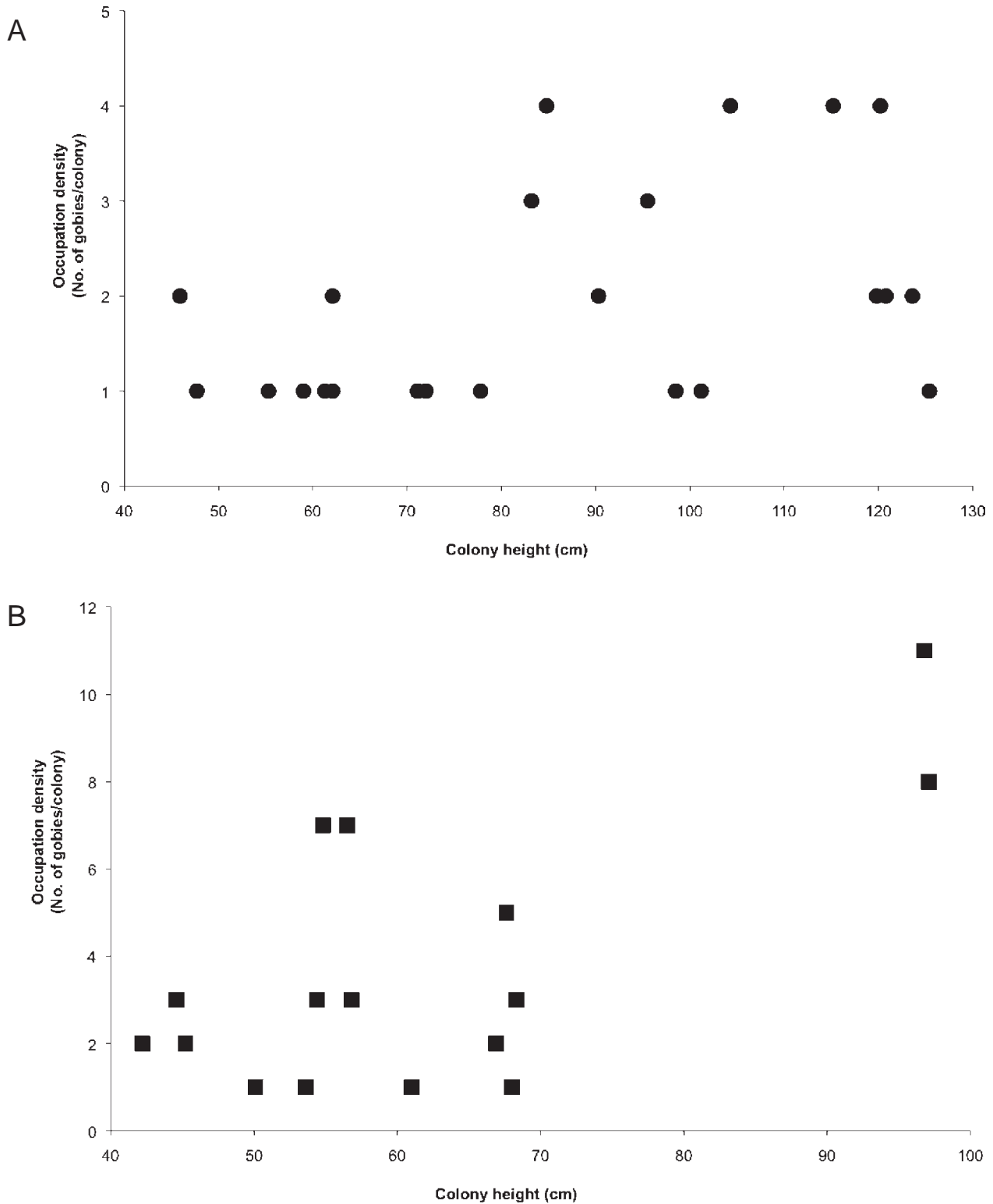


Fig. 8. Correlation between *Bryaninops amplus* occupation density and colony height on: A, *Junceela juncea* ($r_s = 0.42$, $n = 23$; $P < 0.05$); B, *Dichotella gemmacea* ($r_s = 0.41$, $n = 16$; $P > 0.05$).

it tends to harbor more fish despite being generally shorter than the unbranched *J. juncea*. Field observations of how the gobies are able spread out on separate branches on *D. gemmacea*, compared with being restricted to a single file on *J. juncea* (pers. obs.) attest to the differences in the way that they utilize the different structures of their various hosts. And as mentioned before the increased habitat complexity

in *D. gemmacea* may result in increased refuge capacities, thus blurring the effects of host height on goby densities.

The correlation of HW of the largest goby per colony to colony width, but the lack of it between TL of the largest goby per colony to colony height, suggests that maximum goby size maybe limited by the width of the associated

host colony rather its height. A limitation of fish size by the size of their host was also shown by Kawamura et al. (1994), where they found a positive correlation between the size of the largest individual on each coral, for the obligate coral-dwelling goby, *P. echinocephalus* and the size of their coral host, *S. pistillata*. However, they did not elaborate on the possible reasons why such a correlation occurred. Hobbs & Munday (2004) proposed that competition for large corals resulting in the displacement of smaller fish by larger individuals, as the reason for the positive relationship between the size of *Gobiodon histrio* and the size of

their host-coral, *Acropora nasuta*. The presence of small immature fish on smaller wire-coral, high occupancy of larger wire-corals and the restriction of larger wire-corals to adult pairs observed by Munday et al. (2002), led them to also suggest that competitive exclusion of smaller fish by larger individuals was the explanation for their observation of a positive correlation in fish and coral sizes.

However, *G. histrio* and *B. yongei* tend to form monogamous pairs and rarely exceed two fish per coral colony, which contrasts for *B. amplus* where several gobies from a

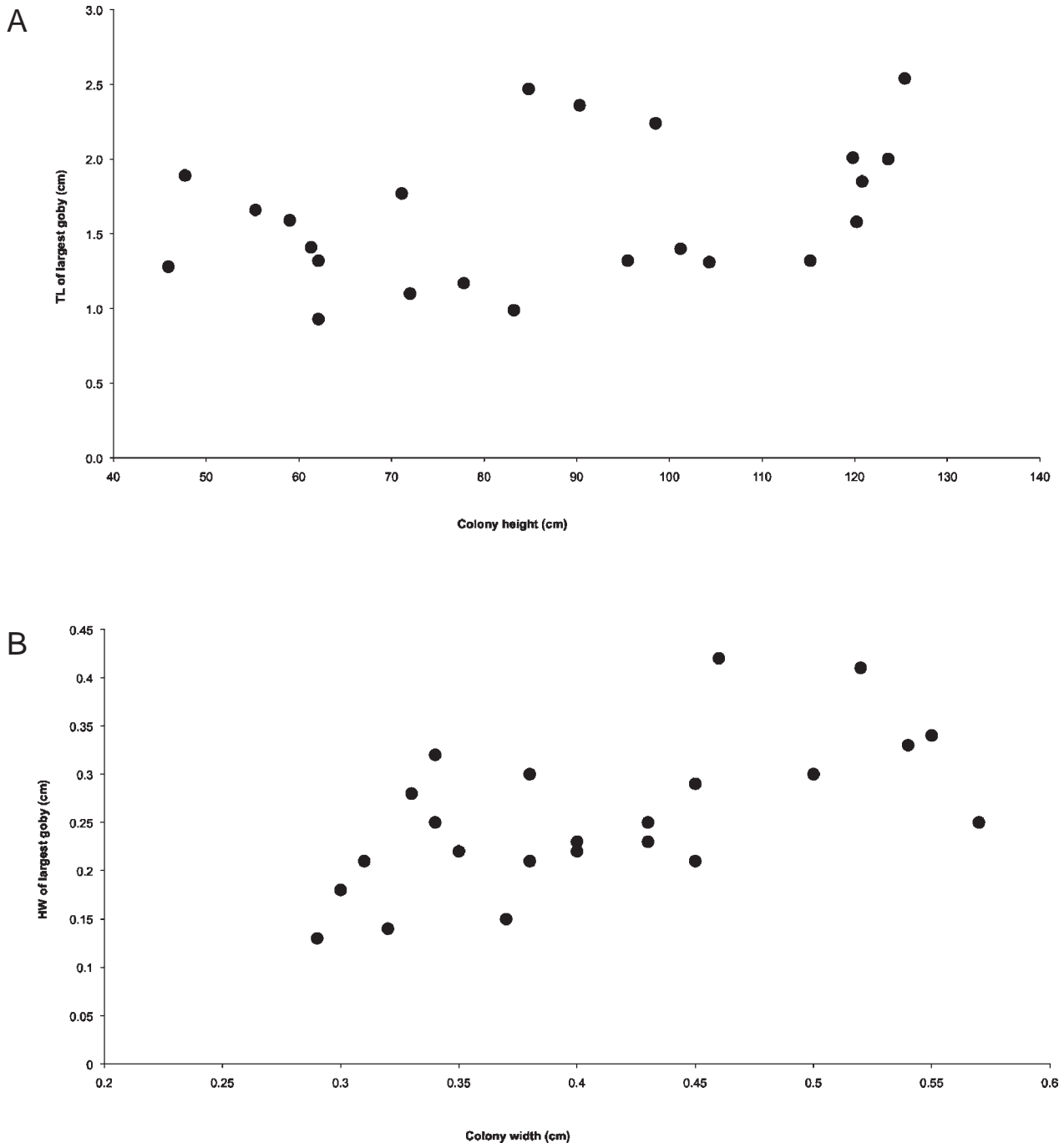


Fig. 9. Correlation between: A, length (as total length, TL) of the largest *Bryaninops amplus* on each gorgonian (*Junceella juncea*) colony and colony height ($r = 0.37$, $n = 23$; $P > 0.05$); B, width (as head width, HW) of the largest goby on *J. juncea* colony and branch width ($r_s = 0.62$, $n = 23$; $P < 0.05$).

large range of sizes can occur on a single host-gorgonian. Therefore this scenario for *G. histrio* and *B. yongei* may not be applicable to *B. amplus*, which forms harems (Larson, 1985). On the other hand, we believe that the correlation between *B. amplus* size and the colony width of *J. juncea* may be due to the way it uses the structure of this unbranched species of host-gorgonian as a refuge from predation.

Field observations show that *B. amplus* react to detection from potential predators by using the host *J. juncea* colony to conceal itself. It can freeze when it detects a potential threat, so that its silhouette blends in with the outline of the gorgonian colony. Alternatively, it can move to the opposite side of the gorgonian from which the potential predator is coming from, in order to hide from the threat. It was observed to usually hide near the basal half of the whip coral where the colony width is usually at its thickest, since the tip of the whip coral is tapered and thinner making that area a relatively less suitable hiding place. When further disturbed, smaller juvenile gobies tend to remain still taking advantage of their transparent body. Larger pigmented adults will maintain a position by having the gorgonian colony between themselves and the threat, and, may sometimes also dart up or down, along the colony away from the source of the disturbance. Therefore gobies substantially wider than their host are less capable of using it to avoid detection by predators.

CONCLUSIONS

This study has demonstrated that habitat preference by whipcoral gobies is dependent on the physical properties of the habitat, rather than the species of the host, with taller host colonies being favored over smaller ones. While, colony width may limit goby size on unbranched *J. juncea* due to the way it uses its host as a refuge from predation. On the other hand, the multiple-branching structure of *G. gemmacea* may have a positive influence on goby densities, compensating to some extent for the limitations imposed on goby densities by colony height. Therefore the structural differences between various host species may influence the same fish associate differently leading to a variety of trends on different hosts. Lastly, more in-depth studies are necessary to determine the numerous factors that influence the social structure and behaviour of gobies dwelling on these gorgonians and the mechanism behind them. For example, experiments utilizing artificial substrates can be used to ascertain the effects of different habitat structures, size or complexity on goby density, size and survivability. While manipulative experiments that involve the addition and/or removal of gobies from host colonies can provide a deeper insight into their behaviour and social structure.

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