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A METHOD FOR ASSESSING THE EFFECTS OF RUNNELING ON SALT MARSH GRAPSID CRAB POPULATIONS

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ABSTRACT. Runneling, a type of habitat modification using shallow channels, is an effective method for controlling mosquitoes that breed in intertidal salt marshes. Grapsid crab populations were studied to assess the environmental effects of runneling on nontarget species. Pitfall traps provided a means of monitoring crab distribution and relative abundance at Coomera Island in southeastern Queensland. The study indicated that although runneling does not have a significant effect on the total number of crabs, it may have a significant impact on species distribution. Significantly greater numbers of *Parasesarma erythrodactyla* were found at the runneled site. In contrast, *Helograpsus haswellianus* was more abundant at the unrunneled control site. Associations were also found between species abundance, distance from the tidal inlet, and vegetation type. *Helograpsus haswellianus* was associated with mixed vegetation, whereas *Parasesarma erythrodactyla* was associated with tall, dense salt marsh couch. No correlation was found between the number of crab burrows present at the study site and the number of crabs caught in the traps. However, the runneled site had approximately twice the number of crab burrows of the unrunneled control site. These results were consistent for 3 consecutive monthly sampling periods. The method has proven suitable for further studies on the long-term environmental impact of runneling.

KEY WORDS Mosquito, *Aedes vigilax*, habitat modification, salt marsh crabs

INTRODUCTION

Aedes vigilax (Skuse), a major vector of arboviruses such as Ross River and Barmah Forest viruses, breeds in intertidal areas around Australia. Because of the risk to human health, the mosquito is controlled by using both environmental management and chemical methods. To avoid prolonged use of chemicals and to effect a long-term wetland management program for mosquito control, a system known as runneling was implemented in northern New South Wales and Queensland (Hulsman et al. 1989). Runneling, which deepens natural drainage lines, modifies the marsh hydrology by linking isolated pools in which mosquitoes breed to the tidal inlet via shallow (<0.30 m) spoon-shaped runnels or channels. The method controls mosquitoes by increasing tidal flushing and access of predators. Compared to ditching in open marsh water management (OMWM), the environmental effects are minimal. Ditching generally lowers the water table, whereas runneling causes it to rise slightly, thereby increasing the wetness of the area (Dale and Hulsman 1991, Dale et al. 1996). This reduces the density of *Sporobolus virginicus* (Kunth), the dominant grass (Dale et al. 1993). Impacts of OMWM on fauna were reviewed by Dale and Hulsman (1991) and, more recently, by Wolfe (1996). Wolfe reported impacts on some invertebrates, such as its reduction of the populations of some snails (*Melampus bidentatus*), and the increase of the populations of some crabs. Runneling is less disturbing than OMWM, and its effect on fauna may not be similar. However, little has been done with respect to faunal impact of runnels except that Morton et al. (1987a, 1987b) noted that runnels were likely to improve fisheries through enhanced access to intertidal marshes and improved nutrient exchange.

The salt marsh environment plays a pivotal role in the processes operating between the salt marsh and adjacent estuarine and marine ecosystems. These systems provide habitat for commercially important organisms such as crabs and fish. Morton et al. (1987b) found that grapsid crabs were an important item of diet for commercially valuable fish species visiting the salt marsh on the spring tides. Grapsid crabs, particularly sesarmids, are common inhabitants of the salt marsh and mangrove environment and play an important role in these ecosystems. The burrowing and feeding activities of these crabs displace and mix up the top 20–30 cm of mud, producing soil enrichment by bringing organic material up to the surface. This process has been shown to increase the productivity of salt marsh plants (Davie 1993). Since sesarmids contribute significantly to mangrove ecosystems (Robertson 1986), they might serve as a useful indicator group for studies on the environmental effect of runneling.

Currently, crab distribution and abundance is assessed by visual counts of numbers of crabs and their burrows. Visual counts are difficult to implement in salt marsh because of dense marine couch (*Sp. virginicus*) and the succulent vegetation *Sarcocornia quinqueflora* (Bunge ex Ung. Stern) A. J. Scott. Furthermore, some grapsid crabs are nocturnal, making visual counts impossible (Davies, personal communication). There may also be variation in foraging between species, or between sexes within a species, with the result that some crabs may be more easily observed than others. It is possible to count crab burrows in some areas of the salt

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marsh; however, there is little evidence that the total number of crab burrows is a reliable indicator of population size. For example, the number of crabs occupying a single burrow may vary between species; also, some burrows may have more than one entrance. It has also been demonstrated that marine intertidal organisms display a circatidal pattern of activity, thus making the timing of observation important (Kitching et al. 1987). Crab populations are classified according to the zones they occupy and their degree of terrestrialization. The zones extend from mean low water spring (LWS) to mean high water spring (HWS) and are described by the most conspicuous species present (Snelling 1959). Crabs from the family Grapsidae, whose members have short eye stalks and a more or less square carapace, are the most conspicuous in the salt marsh habitat of southeastern Queensland. The aim of this study was to design an expedient and cost-effective system for monitoring relative crab numbers to facilitate assessment of the impact of runnels.

MATERIALS AND METHODS

Study area: Coomera Island (27°51′S, 153°33′E), southeastern Queensland, Australia, is a major site of ongoing research into runneling. It comprises 8 ha of salt marsh, with full tidal inundation occurring only when spring tides exceed 2.4 m. The vegetation types at this site have been described by Dale et al. (1986a, 1986b). Classification was based on the size and density of the flora, with the 2 dominant species being *Sp. virginicus* and *S. quinqueflora.* In November 1985, approximately 0.5 ha of salt marsh on the southern side of the small tidal inlet was runneled, and long-term monitoring of mosquito and plant populations has been conducted (Hulsman et al. 1989, Dale et al. 1993). As in previous studies, the northeastern side of the inlet was selected as an unrunneled control site for comparison of crab populations.

Pitfall traps: The pitfall traps used in this study are a modification of those designed by Smith et al. (1991), and were constructed from 15-cm-diameter by 20-cm-deep PVC pipe. The traps were placed into the sediment with the upper edges flush with the surface. Sediment was placed nearby so it could be replaced after trap removal. Each trap was fitted with a removable disk-shaped insert of perforated perspex with a central handle that operates as a plunger. During sampling, the perspex disk was at the bottom of the trap. For counting and identification, the insert was raised to approximately 6 cm from the top, and collected crabs were removed by hand. Between sampling periods, the trap was left *in situ* with the insert reversed, so that the perspex disk was at the top of the trap and flush with the ground surface, forming a cap (Fig. 1).

Sampling methods: Three transects were established at each of the runneled and unrunneled areas of the marsh (Fig. 2) from the edge of the inlet, extending 50 m across the salt marsh. Pitfall traps were placed at 10-m intervals along each transect in both the runneled and unrunneled control areas. Traps were opened at each spring tide inundation of the salt marsh and then checked daily for 4 days. Collected crabs were identified, counted, and then released. After the 4-day sampling period, the traps were closed, and the numbers caught each day were totaled for each trap. Sampling commenced in May 1995 and was carried out monthly until July 1995. At the beginning of May, the percentage cover for each vegetation type and the number of crab burrows present was recorded from 1-m^2 quadrats adjacent to each trap.

Vegetation type was classified according to Dale et al. (1986a) as follows: 1) tall dense *Sp. virginicus,* 2) medium-tall dense *Sp. virginicus* with *S. quinqueflora,* 3) dense *S. quinqueflora* with short *Sp. virginicus,* and 4) dense *S. quinqueflora.* An additional category 5) described the edge of the tidal inlet. This was composed predominantly of bare mud with pneumatophores of the mangrove *Avicennia marina* (Forsk.). The distance from tidal inlet was also considered as a possible influence (other than runneling) on the distribution and abundance of crab species.

The data were analyzed using a series of 1 and 2-way ANOVAs. The 2 independent factors for the 2-way ANOVAs were runnels and distance from tidal inlet, and these were included in each analysis of total number of all crabs, total number of *H. haswellianus,* total number of *P. erythrodactyla,* and total number of crab burrows. Additional single-factor ANOVAs were carried out using the vegetation category as the independent variable and each of the crab groups, as already stated, as the response variable. A Spearman's rank correlation was used to assess possible correlation between the number of crab burrows and number of crabs within the 1-m^2 quadrat adjacent to each pitfall trap.

RESULTS

Crabs in the Coomera salt marsh were represented mainly by the family Grapsidae. Over the three-month period, 485 adult crabs representing 5 species were caught in the pitfall traps. The collected species included *H. haswellianus* (n = 340), *P. erythrodactyla* (n = 103), *Helice leachi* (Hess) (n = 23), *Australoplax tridentata* (n = 3), and *Paragrapsus laevis* (Dana) (n = 16). *Helice leachi* and *P. laevis* were not present in high enough numbers in any month to enable statistical analysis. *Australoplax tridentata,* a small ubiquitous crab in southeastern Queensland, was also abundant but was confined to the wetter areas of the runnels and was rarely caught in the pitfall traps. *Holoecious cordiformis* (Family Ocypodidae) was observed close to the tidal inlet but was not caught in any of the pitfall traps. The total number of crabs caught, in-

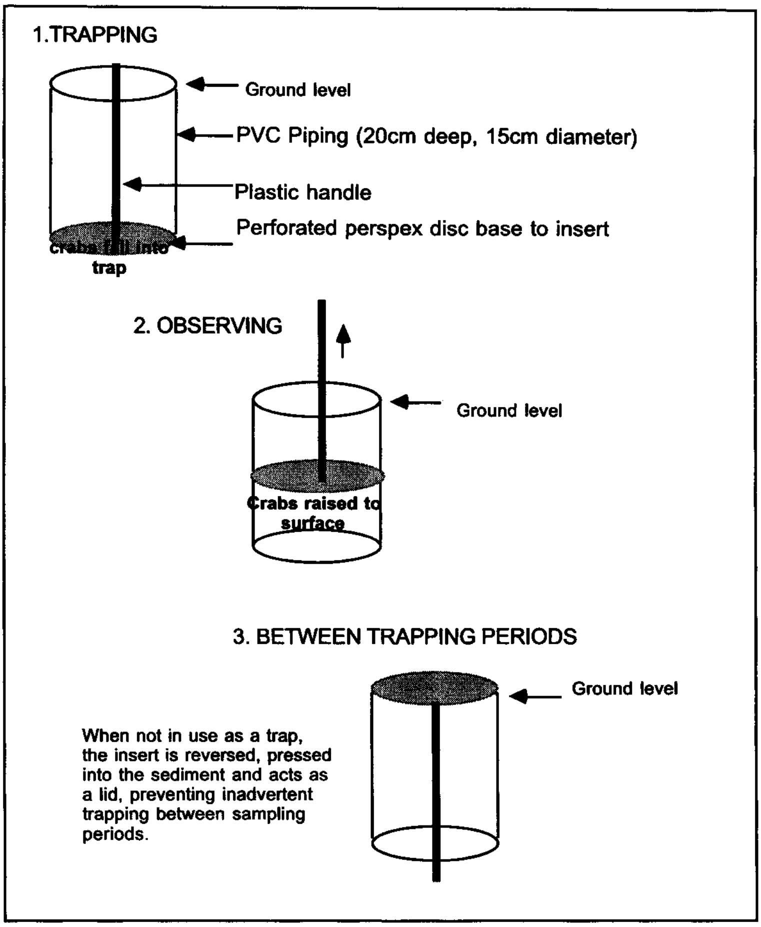

Fig. 1. Pitfall trap design.

cluding juveniles, decreased from 348 in May to 237 in June and 128 in July. This coincided with decreasing mean air temperatures for May (14.5–23.3°C), June (10.6–20.6°C), and July 1995 (7.4–21.0°C) (Bureau of Meteorology 1995).

Although the total number of crabs caught in the unrunneled control area was greater than that in the runneled area, the effect was not significant at any time (Table 1). There was a significant association between the total number of crabs caught and 1) distance from the tidal inlet for each of the 3 monthly sampling periods (Table 1 and Fig. 3A) and 2) vegetation type in both May (F = 5.33; df 5,24; P = 0.029) and July (F = 4.755; df 4,31; P = 0.004) (Table 2). The results for June approached significance (F = 2.288; df 4,31; P = 0.082) (Fig. 3B). There were no significant interactions between distance from the tidal inlet and whether or not a site had been runneled. *Helograpsus haswellianus* predominated in the unrunneled area (Fig. 4A), while *P. erythrodactyla* predominated in the runneled area (Fig. 4B). This difference was not detected when the data for both species were combined.

For *H. haswellianus,* there was a significant association between runnels and number of crabs caught for May (F = 3.896; df 4,31; P = 0.011) but not for June and July, although the overall pattern was similar. There was also a significant association between the number of *H. haswellianus* caught and 1) the distance from the tidal inlet (Table 1 and Fig. 5A) and 2) vegetation type (Table 2 and Fig. 5B) for each of the 3 monthly samples. Numbers increased with distance with *Helograpsus haswellianus* associated with mixed *Sp. virginicus/ S. quinqueflora* (vegetation categories 2–4).

A significant association between runneling and numbers of *P. erythrodactyla* was recorded for each of the 3 months of the study (Table 1 and Fig. 3B). There was a significant association with vegetation for June (F = 3.371; df 4,13; P = 0.021) and July (F = 2.672; df 4,31; P = 0.050), but no association with distance from the tidal source. Greatest numbers were collected in tall dense *Sp. virginicus*

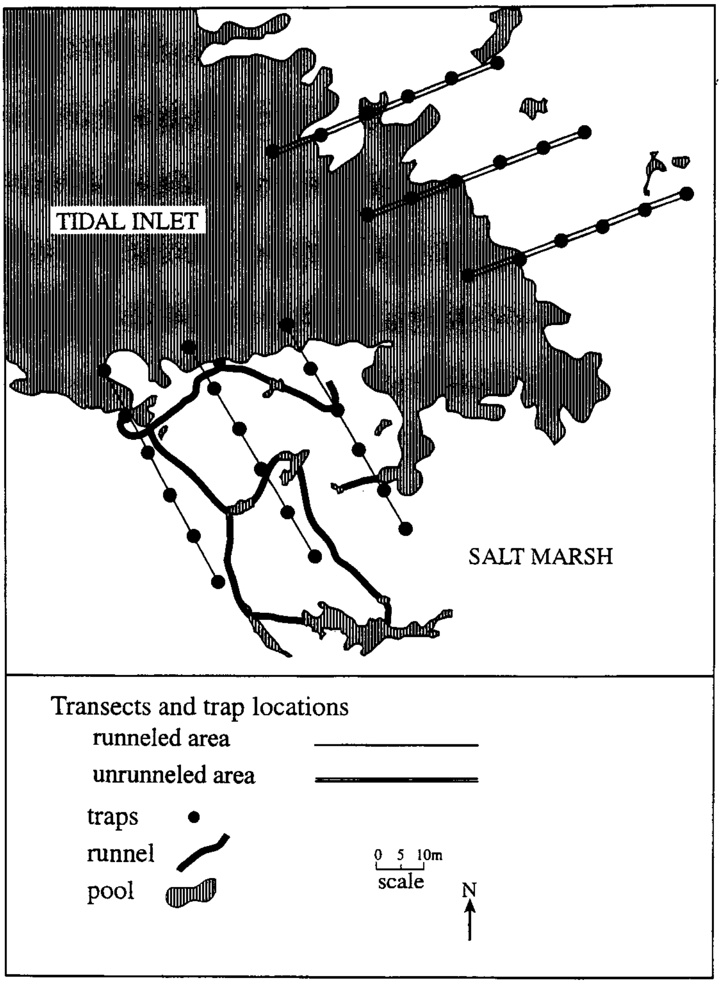

Fig. 2. Study site at Coomera Island showing transect layout.

Table 1. Two-factor ANOVA results for association between (A) presence of runnels and (B) distance from tidal inlet and crab groups.

Source of variation	May df	May F	May P	June df	June F	June P	July df	July F	July P
Total number of crabs									
Runnels vs. no runnels (A)	1,24	3.373	0.0787	1,24	1.543	0.2262	1,24	1.161	0.2919
Distance from tidal inlet (B)	5,24	4.295	0.0062*	5,24	4.102	0.0078*	5,24	5.142	0.0024*
AB interaction	5,24	1.29	0.30508	5,24	0.229	0.9462	5,24	0.91	0.4912
Helograpsus haswellianus									
Runnels vs. no runnels (A)	1,24	5.33	0.0299*	1,24	0.787	0.3837	1,24	3.646	0.0682
Distance from tidal inlet (B)	5,24	2.812	0.0389*	5,24	6.104	0.0009*	5,24	2.628	0.0495*
AB interaction	5,24	1.181	0.3474	5,24	0.532	0.7489	5,24	0.689	0.6366
Parasesarma erythrodactyla									
Runnels vs. no runnels (A)	1,24	4.96	0.0356*	1,24	10.256	0.0034*	1,24	8.258	0.0084*
Distance from tidal inlet (B)	5,24	0.617	0.6877	5,24	0.674	0.6474	5,24	0.284	0.9173
AB interaction	5,24	0.122	0.9861	5,24	0.674	0.6474	5,24	0.361	0.8698

* Significant F ratio at $P < 0.05$.

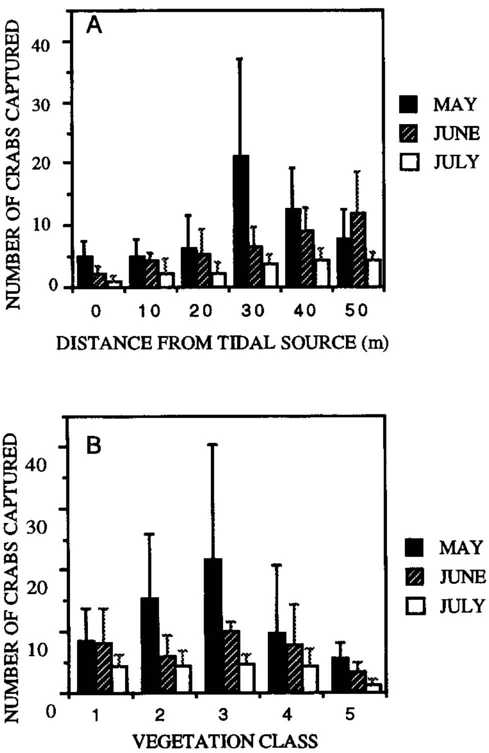

Fig. 3. Relationship between crab numbers and (A) distance from the tidal inlet and (B) association with vegetation types for total number of crabs. Mean (±SD) number of crabs caught per trap.

(vegetation category 1), followed by mangrove edge of the tidal inlet (vegetation category 5) (Fig. 6B).

There was no significant correlation ($r = -0.249$, $P = 0.158$) between the number of crab burrows and total crab numbers, but there was a highly significant relationship between runneling and the number of crab burrows (F = 14.49; df 1,34; $P = 0.0006$). The number of burrows in the runneled area was twice that in the unrunneled area. There was also a significant association between vegetation and the number of crab burrows (F = 15.06; df 4,31; $P = 0.006$) and distance from the tidal inlet (F = 2.927; df 2,33; $P = 0.067$).

DISCUSSION

This method of collecting information on grapsid crabs was successful for the salt marsh environment, with useful baseline data being collected. Although the numbers of crabs caught may not be an accurate estimate of the numbers of crabs present, the object of the study was to assess relative change, so exact numbers should not be necessary. Traps placed among mangrove trees in a pilot study tended to fill with leaves, allowing escape of crabs, which could lead to an underestimation of numbers in the mangroves. This problem was not encountered on the salt marsh. In the absence of entrapped vegetation, the crabs are unable to escape the traps once they are inside, even underwater. Grapsid crabs lack the paddle-like rear legs of portunid crabs and are therefore unable to swim out. The traps themselves are constructed of durable material and, during the 3 months of use, remained firmly in place without accidental capture of crabs in the periods between sampling. Also, because they are set flush with the surface, they are not highly visible to passersby, and this may reduce the likelihood of vandalism. The methods developed in this study could also have application for monitoring crab populations in OMWM projects or for monitoring changes in wetlands during rehabilitation. A further advantage of the method is that there is minimal disturbance to the environment, which occurs only when the traps are first installed. Soil removed during trap installation can be replaced once the traps are removed.

The analysis of trapping results, using total crab numbers, indicated that there was no significant impact due to runneling and that any observed differences were a result of an association with vegetation type. As runneling appears to result in reduced size and density of *Sp. virginicus* (Dale et al. 1993), it would appear likely to disadvantage *P. erythrodactyla,* which is associated with this vegetation type. However, because we recorded more of the *Sp. virginicus* dominant vegetation types in the runneled area than in the unrunneled control area, this could account for the larger numbers of *P. erythrodactyla* occurring there. If the long-term effect of runneling is to diminish this vegetation type, then an eventual reduction in the numbers of *P. erythrodactyla* may result.

This is consistent with the hypothesis posed by Wolfe (1996) that progression from high-marsh to low-marsh habitat would disadvantage high-marsh organisms (in this case snails) and would explain the reduced numbers of *Melampus bidentatus* observed on OMWM treated sites on the east coast

Table 2. One-factor ANOVA results for association between the category of vegetation and crab groups.

	May			June			July		
Source of variation	df	F	P	df	F	P	df	F	P
Total number of crabs	4,31	3.183	0.0266*	4,31	2.288	0.0823	4,31	4.755	0.0041*
Helograpsus haswellianus	4,31	60.349	0.0112*	4,31	2.948	0.0356*	4,31	5.639	0.0016*
Parasesarma erythrodactyla	4,31	1.244	0.3128	4,31	3.371	0.0211*	4,31	2.672	0.0504*

* Significant F ratio at $P < 0.05$.

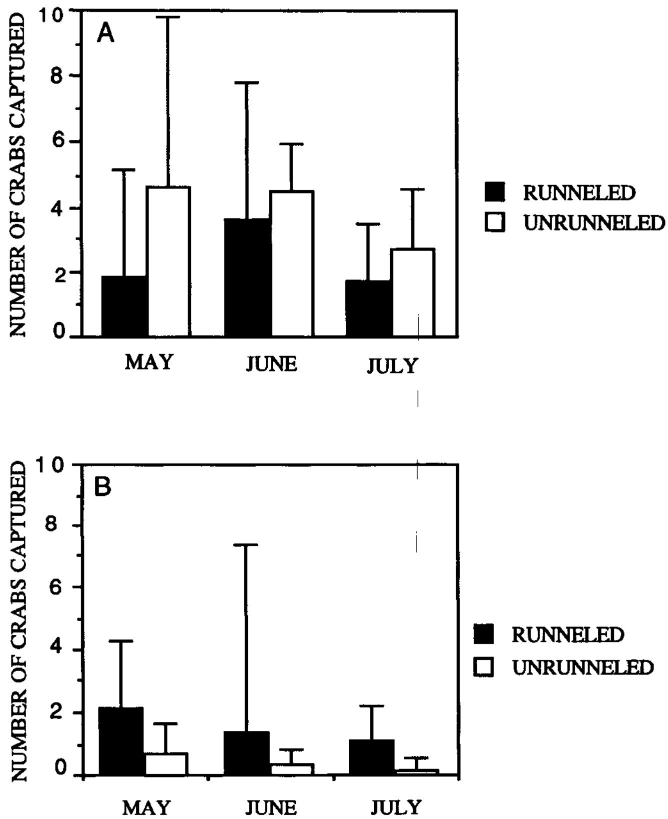

Fig. 4. Number of crabs caught in runneled and unrunneled areas of the salt marsh for (A) *Helograpsus haswellianus* and (B) *Parasesarma erythrodactyla.*

of the USA. At the Coomera Island study site, *Sp. virginicus* is usually associated with higher marsh areas, and the reduced density of *P. erythrodactyla* could be related to increasing wetness and reduced plant density similar to that of a lower marsh. However, *Sp. virginicus* reduction may also be exacerbated by the activities of crabs that prefer the wetter areas, such as *A. tridentata* and *H. cordiformis,* which were observed but not caught in this study. The complete saturation of the sediment is a significant factor in determining where the ocypodid sand fiddler crab *Uca pugilator* (Bosc) forages (Reinsal and Rittschof 1995).

The zones occupied by crabs are by no means constant, and the main factor limiting vertical distribution is not period of exposure but the soil moisture content (Snelling 1959). This is why *Euplax* (=*Australoplax*) *tridentata* is often found above HWS but is restricted to areas of wet mud. In our study, we found large numbers of *A. tridentata* in the zone generally above HWS but restricted to the runnels, which are slightly lower and wetter than the surrounding salt marsh. This indicates that the range of this crab species may be extended linearly by runneling. Similarly, *H. cordiformis* was observed in the runneled area of the upper marsh, whereas it is usually found in the zone around mean sea level (MSL).

Complex interactions between plants and crab populations may result from the physical modification of a salt marsh, and this can influence the data collected from pitfall traps. For example, different species or different genders within a species may have different foraging behaviors, and therefore some may be more likely to be caught in traps than others. Failure to catch them in the traps does not mean they are not there. Crabs that prefer wetter areas may be advantaged by runneling in terms of increasing their range, whereas others may suffer habitat loss as a direct effect of the modification due to the creation of small corridors of "lower" marsh into the upper marsh or by the impact on vegetation caused by increasing the range and disturbance by other crab species.

There is also the issue of bias in design and trapping. The difficulty in selecting appropriate controls relates to marsh heterogeneity and the fine scale of variation (Dale and Hulsman 1988). Selecting very large numbers of samples over the maximum variation will minimize the problem but may not be feasible. Other approaches include assessing rela-

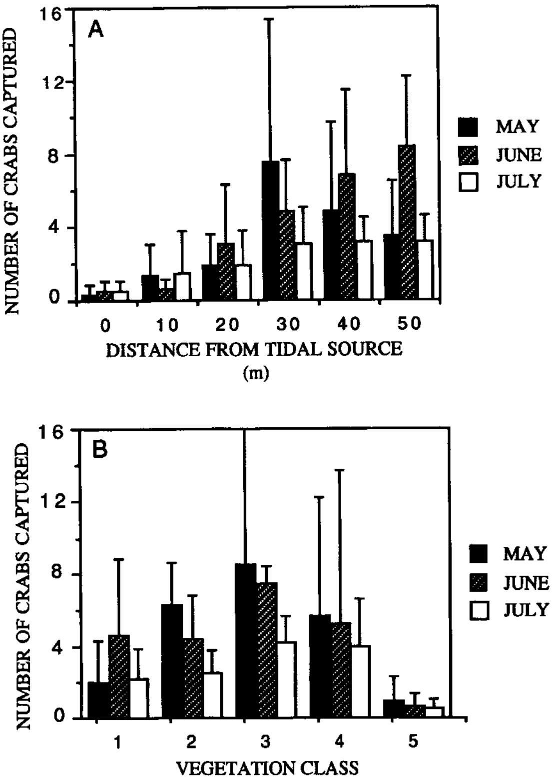

Fig. 5. Relationships between crab numbers and (A) distance from the tidal inlet and (B) association with vegetation types for *Helograpsus haswellianus*. Mean (±SD) number of crabs caught per trap.

tive changes over time, as was done in Dale and Hulsman (1988).

In conclusion, this study has shown that for this study site, runnels are related to a change in distribution but not in overall abundance of grapsid crabs. This is potentially related to the increase in wetness of the runneled area. The long-term consequences of such a change are not yet well understood. Broad-scale adoption of mosquito control interventions must be shown to be environmentally acceptable before implementation, and this is the reason for carrying out this type of study. The pitfall traps have proven to be a suitable tool for long-term monitoring of changes that may occur in a salt marsh due to habitat modification for mosquito control.

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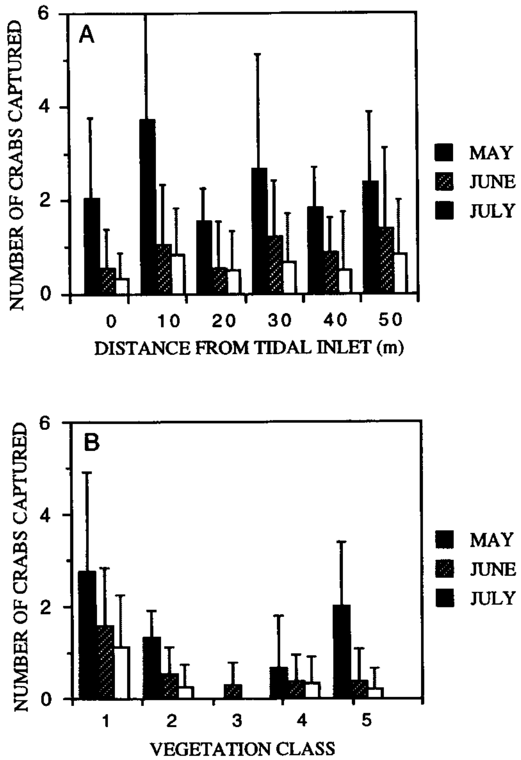

Fig. 6. Relationships between crab numbers and (A) distance from the tidal inlet and (B) association with vegetation types for *Parasesarma erythrodactyla*. Mean (±SD) number of crabs caught per trap.

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