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Impact of Artificial Reef Associates on Macrobenthic Community Structure in Florida Bay

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Impact of Artificial Reef Associates on Macrobenthic Community Structure in Florida Bay

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In Partial Fulfillment

of the Requirements for the Degree of

Master of Arts

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by

Heinz M. Proft

1995

APPROVAL SHEET

This thesis is submitted in partial fulfillment of
the requirements for the degree of

Master of Arts

Heinz M. Proff

Approved: March 1995

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DEDICATION

To Hermann H. Proft - my grandfather
For without his courage, vision, and luck, none
of this would have ever been possible.

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ACKNOWLEDGEMENTS

I would like to thank my major professor, Dr. Romuald Lipcius, who gave me the opportunity to work in Florida Bay and supported my research. I thank the remaining members of my committee, Jacques van Montfrans, Dr. Rebecca Dickhut, Dr. Robert Diaz, and Dr. David Eggleston for their guidance, patience, and understanding during the completion of my work.

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This work was funded by sources including the Caribbean Marine Research Center and the Commonwealth of Virginia.

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ABSTRACT

Macrobenthic community structure in the southeastern United States is regulated by a number of physical and biological factors including predation and habitat complexity. Artificial shelters (i.e.casitas) were placed in Florida Bay during the summer of 1990 and housed up to 264 juvenile and adult spiny lobster per habitat within one year. Casitas were arranged in densities of 8 and 16 casitas in 1 hectare sites at two replicate locations, and there were two control sites. Between 26 July and 12 August 1991, sites were censused using a suction pump device to determine the impact of casita associates upon macrobenthic community structure. In order to quantify abundance patterns of macrobenthic organisms, benthic samples were obtained from within each casita site as well as 50 m and 100 m away. To determine habitat complexity, core samples (3 cm diameter) and visual quadrats ($1 m^2$) were also taken within each control and casita site, as well as 50 m and 100 m away. Suction samples contained molluscs, crustaceans, echinoderms, polychaetes, and fish. Macrobenthic abundance was significantly reduced within sites containing 16 casitas. Abundance of spiny lobster and significantly lower densities of bivalves and gastropods indirectly implicate the spiny lobster as the casita associate with the greatest predatory impact. It appears as if predation was an important factor in structuring the macrobenthic community in the experimental sites. Habitat complexity varied between locations, and therefore, the overall impact of casita associates due to predation was most likely modified by a function of habitat complexity.

IMPACT OF ARTIFICIAL REEF ASSOCIATES ON MACROBENTHIC COMMUNITY STRUCTURE IN FLORIDA BAY

INTRODUCTION

Community structure of invertebrates associated with seagrass in the southeastern United States is regulated by a number of physical and biological factors. Physical factors include, in part, latitude, salinity, temperature, and sediment properties. Biological factors, which can have a significant influence on the macrobenthic community structure include predation, competition, habitat complexity, and reproduction/recruitment (Virnstein 1987, Main 1987). Although physical factors define habitat characteristics and limits of a community, biological factors largely determine specific structure (Livingston 1984). For example, habitat complexity is widely considered an important factor in regulating the structure of macrobenthic communities in seagrass systems, and predation is cited as the major factor regulating community structure (Virnstein 1987).

Predation regulates and structures marine communities by directly controlling faunal abundances. This direct effect of predation is typically measured as a function of prey mortality or prey abundance (Paine 1966, Sih et al. 1985, Posey & Hines 1991). Indirect effects of predation have also been studied and have resulted in outcomes termed "Keystone predator effect" (Paine 1966), "three-trophic-level effect" (Hurlbert et al. 1972), and "cascading trophic interactions" (Carpenter et al. 1985). Paine (1966) showed that prey diversity was determined by the extent to which predators prevented the monopolization of resources by one species. Typically, trophic interactions are inherent in communities where predators affect multiple species at lower trophic levels, or where the impact of a predator is mediated by other species.

Biota associated with seagrass beds can be separated into four broad categories: (1) epiphytic organisms (any organism growing on a plant), (2) epibenthic organisms (organisms that live on the surface sediment), (3) infaunal organisms (organisms which live in the sediments), and (4) nektonic organisms (highly mobile organisms that live in or above the plant canopy). Epibenthic organisms such as gastropods are the most prominent trophic group feeding on epiphytic algae in seagrass beds (Zieman 1982). Amphipods, isopods, crabs, and other crustaceans ingest a mixture of epiphytic and benthic algae, detritus, or often prey on other resident consumers (Odum & Heald 1972). A major predator on gastropods and bivalves in seagrass beds is the Caribbean spiny lobster, *Panulirus argus*. They primarily forage after sunset and seek protection and cover in dens during the day (Zieman 1982). Studies describe spiny lobster, *Panulirus spp.*, preying primarily on mollusks and crustaceans (Davis 1977, Joll & Phillips 1984, Marx & Herrnkind 1985, Barkai & McQuaid 1988, Davis & Dodrill 1989, Edgar 1990). In a tropical seagrass ecosystem, predation and predominant energy flow follows the general progression of epiphytes being preferentially grazed upon by small invertebrates, which in turn are preyed upon by decapod crustaceans (i.e., shrimp, crabs, and lobsters) and small fish. These crustaceans and small fish then become prey items for larger predators (Virnstein 1987).

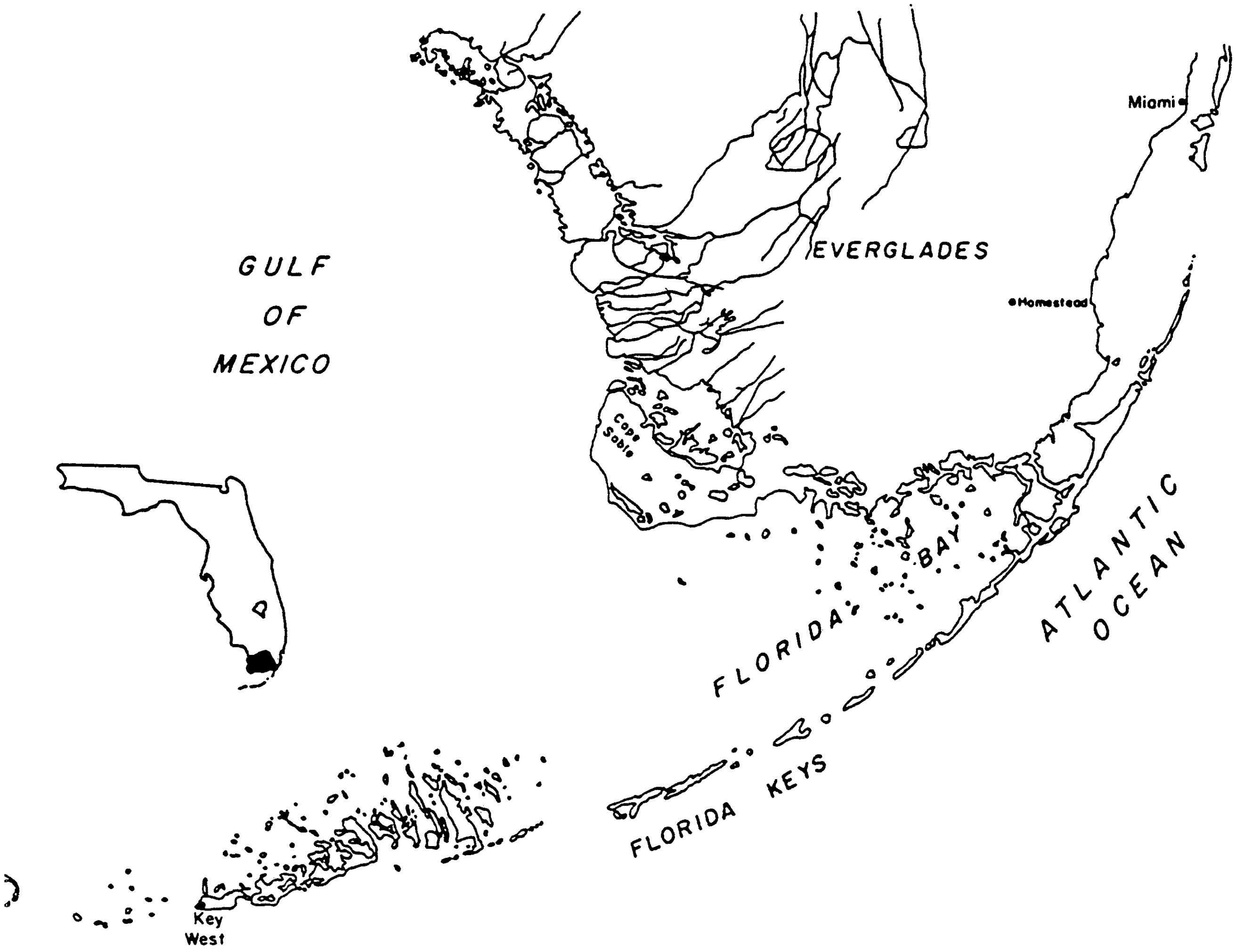
Previous studies have shown that artificial reefs affect adjacent soft bottom communities by altering species abundance and distribution patterns, sediment grain size distributions and organic content, density of food resources, and local abundance of piscine predators (Davis et al. 1982, Alevizon & Gorham 1989, Ambrose & Anderson 1990, Polovina 1991). Although the impact of artificial reefs on surrounding infaunal and benthic communities has been examined, these studies have been conducted entirely within a sand-plain environment (Davis et al. 1982, Alevizon & Gorham 1989, Ambrose & Anderson 1990, Polovina 1991). To date there has been no research on the ecological impact of artificial reefs on macrobenthic organism density in tropical seagrass and macroalgal habitats, such as those in Florida Bay. Thus, the objective of this study was to quantify the impact of artificial reef associates on macrobenthic organism abundance in Florida Bay. My hypothesis was that the artificial shelters, with their associated predators, would have a significant impact on prey abundance and that the impact would diminish with distance from the shelters.

STUDY SYSTEM

One of the largest tropical seagrass ecosystems in the world is Florida Bay, a triangular region lying west of the upper Florida Keys and south of the Everglades (25°N 81°W; Fig. 1). Florida Bay is a 226,000 ha shallow basin (2-3 m) harboring a luxuriant growth of seagrass and algae (Zieman 1982). Although seagrasses are common in shallow coastal waters around the world, there are few locations where seagrass areal coverage is as extensive as in Florida Bay (Iverson & Bittaker 1986). A large portion of Florida Bay is located within Everglades National Park (1800 km^2), and most of this area is covered by seagrass (Zieman et al. 1989). Florida Bay is highly productive, faunally rich, and an ecologically important habitat. Seagrasses play an important role in the coastal ecosystem by providing food, shelter from predators, and overall greater habitat complexity than areas lacking seagrasses (Decho et al. 1985). A variety of epibenthic and infaunal organisms are associated with seagrasses including annelids, mollusks, crustaceans, and echinoderms (Hudson et al. 1970, Zieman 1982, Virnstein et al. 1983, Decho et al. 1985, Holmquist et al. 1989, Zieman et al. 1989).

The most abundant and robust seagrass in south Florida is turtle grass, *Thalassia testudinum*. The density of *Thalassia* can vary widely; under optimum conditions it forms vast meadows (Schomer & Drew 1982, Zieman et al. 1989).

Figure 1. Map of South Florida including Florida Bay (25°N 81°W).


GULF OF MEXICO
EVERGLADES
Miami
Homestead
Cape Sable
FLORIDA BAY
ATLANTIC OCEAN
FLORIDA KEYS
Key West

Although *Thalassia* is dominant, shoal grass, (*Halodule wrightii*) and manatee grass (*Syringodium filiforme*) are also common (Holmquist et al. 1989).

Drift algae (unattached benthic macroalgae) is also common in many tropical seagrass systems, providing significant habitat for invertebrates (Dawes et al. 1975, Cowper 1978, Gore et al. 1981, Virnstein & Carbonara 1985). In Florida Bay, dense stands of red algae (e.g.*Laurencia spp.*) are an important habitat for small invertebrates and the primary settlement habitat for postlarval spiny lobster (Marx & Herrnkind 1985, Butler & Herrnkind 1986). Several types of green algae are also abundant in Florida Bay including (*Caulerpa spp.*, *Halimeda spp.*, *Penicillus spp.*, and *Udotea spp.*), and contribute to the overall floral diversity of this expansive seagrass system (Virnstein 1987).

The ability of juvenile spiny lobster (< 60 mm carapace length) to utilize the food rich seagrass habitat is short lived since residence time in the seagrass is about 10-12 months (Eldred et al. 1972). Juvenile lobsters which live in coral heads, sponges, limestone solution holes, and undercut banks of seagrass beds (Herrnkind et al. 1975, Andre 1981, Marx & Herrnkind 1985, Herrnkind & Lipcius 1989) grow into sub-adults or adults and depart to reef areas for breeding. Field experiments in the Florida Keys indicate shelter is a limiting resource in seagrass beds for juvenile *Panulirus argus*. Experiments with artificial shelters indicated that the abundance of spiny lobsters increased significantly in sites augmented with artificial habitats, but not in control sites (Lipcius & Eggleston in press).

Manipulation of marine environments with artificial shelters is not new; use of artificial reefs for marine fish and invertebrates has occurred worldwide, especially in the Mediterranean, Pacific Islands, Japan, Australia, Southeastern Asia, North America, and throughout the Caribbean (Seaman et al. 1989). The primary goal of deploying artificial reefs (i.e.artificial habitats or shelters) has been to increase the catch of commercially valuable species (McGurrin et al. 1989, Polovina & Sakai 1989). Caribbean spiny lobster, *Panulirus argus*, have been harvested in Mexico with artificial shelters (casitas) since 1968 (Miller 1982,1989). Original casitas were sunken flat-top structures made of wood, metal, asbestos, and ferrocement, supported 10-15 centimeters off the bottom by palm trunks (Miller 1982, Lozano-Alvarez et al. 1991). Recently, researchers have used casitas to standardize many of the complex physical attributes of natural dens, and thereby manipulate shelter availability in different habitats (Fig. 2; Eggleston et al. 1990, 1992, Eggleston & Lipcius 1992, Lipcius & Eggleston in press). Presently, there are over 300,000 casitas in use in Cuba (Cruz & Brito 1986), over 50,000 casitas located in a single, large bay (740 km^2) on the Yucatan Peninsula of Mexico (Miller 1989, Lozano-Alvarez et al. 1991), and over 200,000 casitas in the northern Bahamas (Eggleston et al. 1992, Lipcius & Eggleston in press).

Figure 2. Casita, artificial spiny lobster shelter, (177 cm x 118 cm x 12 cm) constructed of a reinforced concrete roof bolted to a supporting PVC-pipe frame.

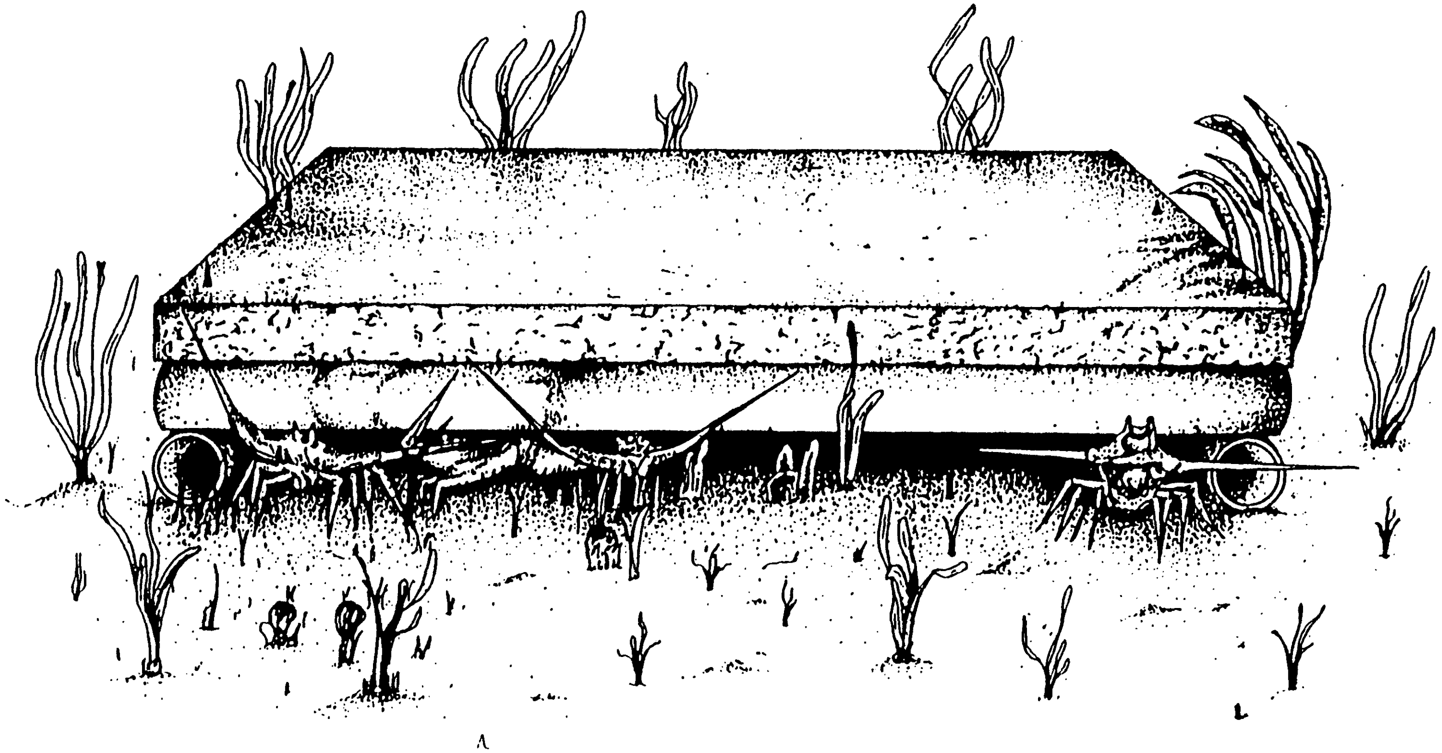
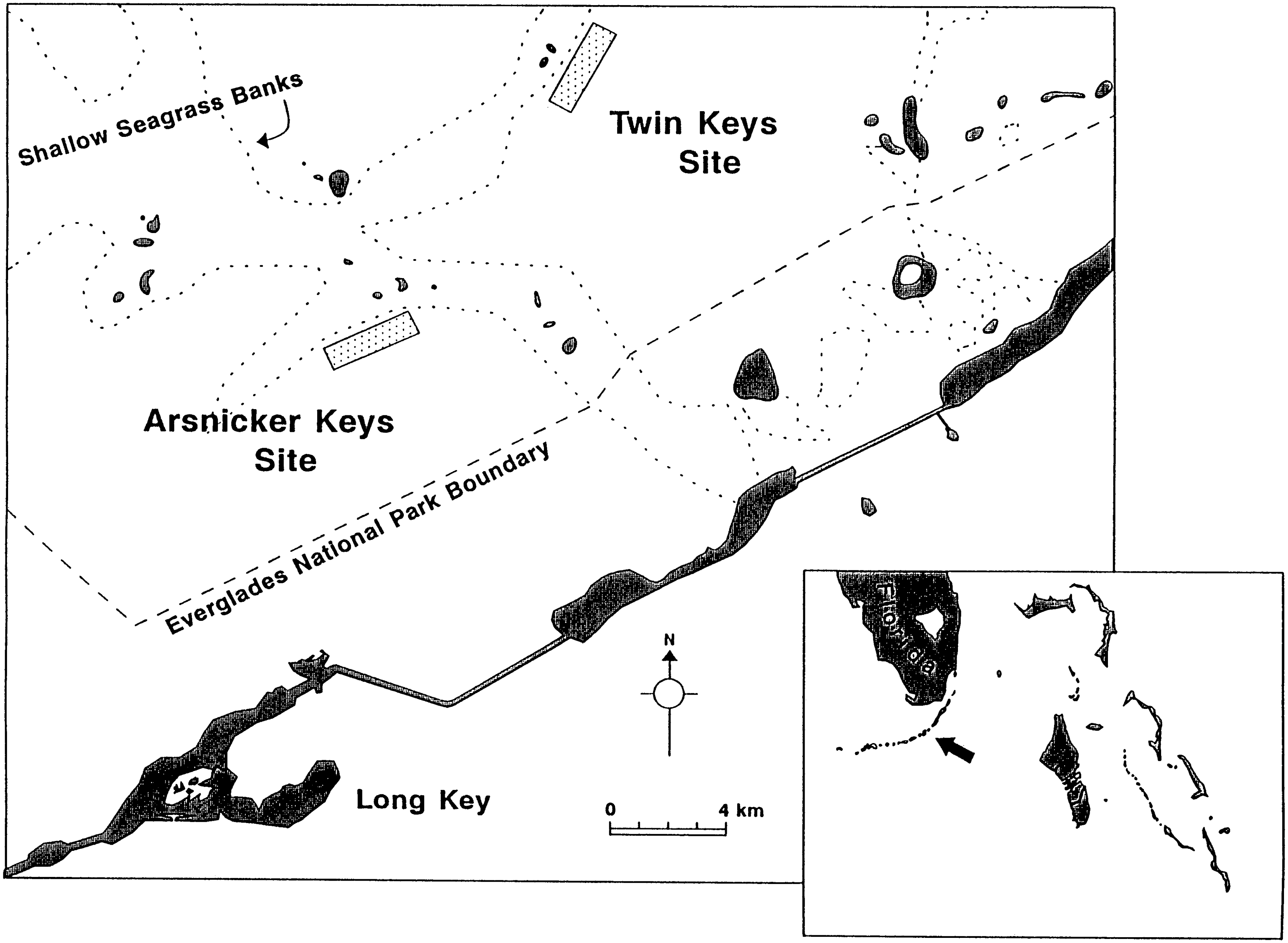


Figure 3. Locations of study sites within Everglades National Park, Florida Bay.


Shallow Seagrass Banks
Twin Keys Site
Arsnicker Keys Site
Everglades National Park Boundary
Long Key
N
0
4 km
Florida

In June 1990, casitas were deployed in two locations (Arsnicker Keys and Twin Keys) within Everglades National Park in Florida Bay (Fig. 3). Everglades National Park is a federally protected nursery ground for spiny lobster and other marine species. The two locations were approximately 10 km apart and separated by a continuous island-bar system. Arsnicker and Twin Keys are expansive, and shallow (1-4 m) nursery areas for finfish and invertebrate assemblages. Floral and faunal composition of these areas are dominated by turtle grass (*Thalassia testudinum*), red algae (*Laurencia spp.*), calcareous green algae and an assortment of sponges and gorgonian corals resident in a thin sediment layer overlying a limestone foundation (Marx & Herrnkind 1985). Both locations harbor suitable settlement habitat for spiny lobster postlarvae and an abundance of spiny lobster prey (e.g.gastropods and bivalves; Zieman 1982, Virnstein 1987, Zieman et al. 1989).

Within each location, three previously established experimental sites of 1 ha in area and 1 km apart were selected. One of three shelter treatments (e.g.0 casitas, 8 casitas, 16 casitas) was randomly assigned to each 1 ha site at both locations (Fig. 4), to test potential shelter limitation in spiny lobster (Lipcius & Eggleston in press). The abundance and size frequency of fish and spiny lobster occupying casitas and resident in the experimental and control sites were monitored weekly with visual surveys using SCUBA; then quarterly through 1994. In September 1991, the casitas were sampled quantitatively for spiny lobster by encircling each casita with a large seine and herding all the lobsters into the cod-end of the seine. In conjunction with the casita surveys, nighttime transects were visually surveyed across the spiny lobster foraging grounds in the control and casita sites. The transects were performed twice per night as described earlier (Lipcius & Eggleston in press).

In Florida Bay, artificial habitats significantly increased the abundance of the Caribbean spiny lobster, *Panulirus argus*, over 15 months in the replicate experimental casita sites (Fig. 5; Lipcius & Eggleston in press). Night transects of foraging activity further demonstrated that spiny lobster not only reside in the artificial habitats, but they also foraged in the associated seagrass and algal beds (Fig. 6; Lipcius & Eggleston in press). Given the density and observed foraging activity patterns of lobsters in the casita sites (Figs. 5 and 6), my hypothesis was that the casitas, with their associated predators, would have a significant impact on prey abundance and that the impact would diminish with distance from the casitas. My objective, therefore, was to quantify the impact of spiny lobster and other casita associates on macrobenthic organism abundance in these experimental and control sites in Florida Bay.

Figure 4. Schematic of artificial shelter treatments and casita placement within the sites.

Artificial Shelter Treatments

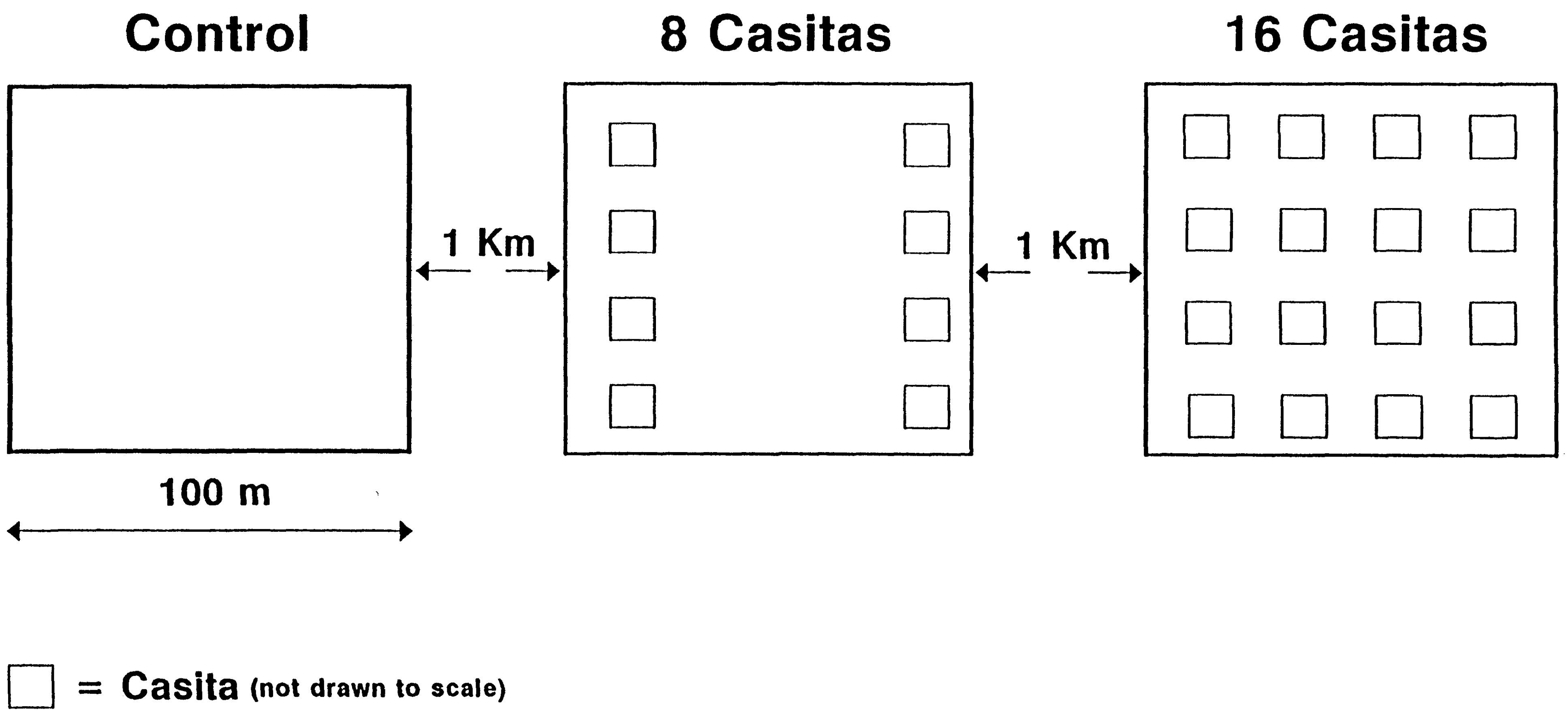
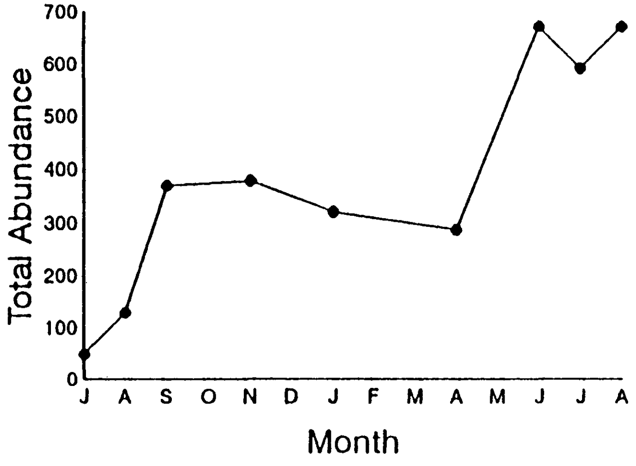
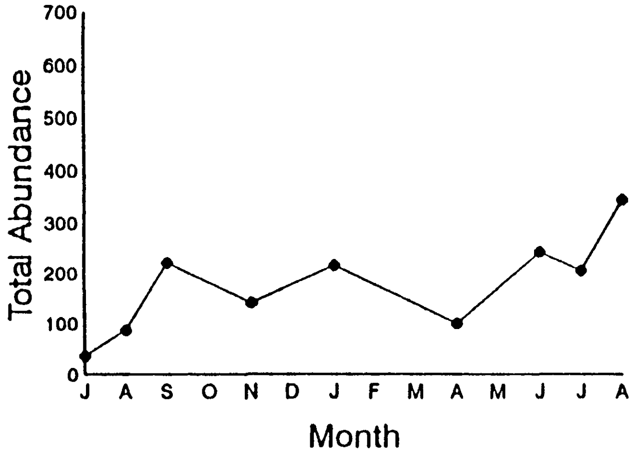


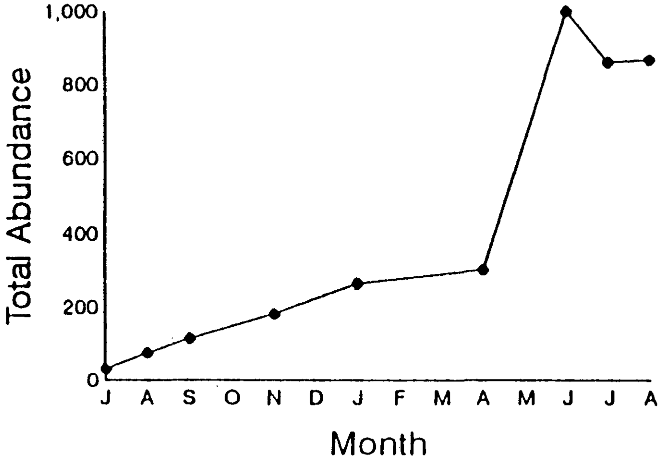
Figure 5. Spiny lobster abundance in casita sites from July 1990 through August 1991. (a) Arsnicker Keys, 16 casita site; (b) Twin Keys, 16 casita site; (c) Arsnicker Keys, 8 casita site; (d) Twin Keys, 8 casita site. Results for the two control sites are not shown because there were rarely more than 10 lobsters observed per control site.

Arsnicker Keys


(a) 16 - Site


(c) 8 - Site

Twin Keys


(b) 16 - Site

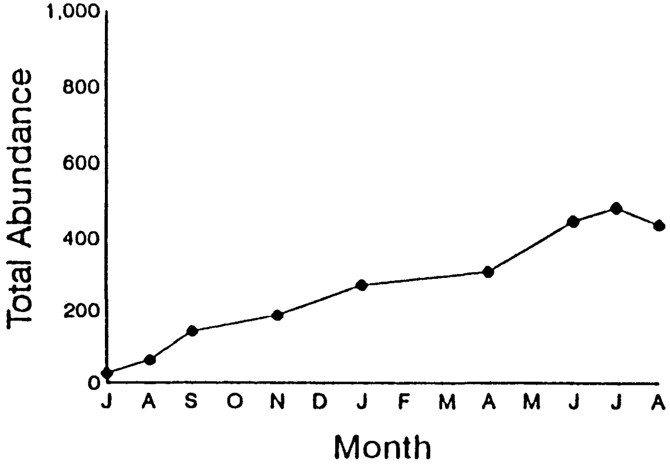
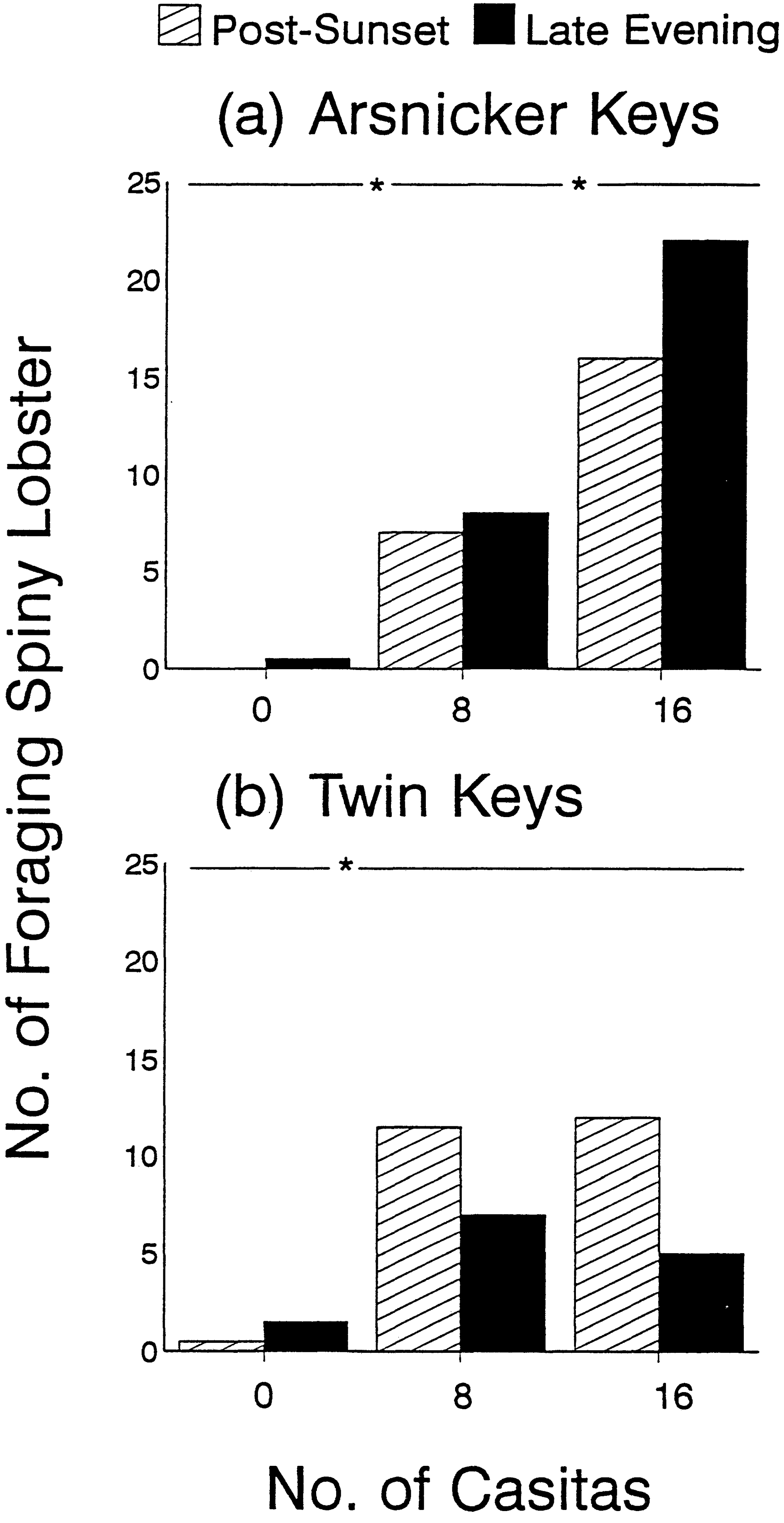

(d) 8 - Site

Figure 6. Spiny lobster foraging activity as a function of casitas per site; control sites = 0 casitas. (a) Arsnicker Keys; (b) Twin Keys. Horizontal lines above each histogram represent results of a Ryan's Q multiple comparison procedure. Levels separated by an asterisk differ significantly at the 0.05 level.



▨ Post-Sunset ■ Late Evening
(a) Arsnicker Keys
25
20
15
10
5
0
*
*
0
8
16
(b) Twin Keys
25
20
15
10
5
0
*
0
8
16
No. of Foraging Spiny Lobster
No. of Casitas

MATERIALS and METHODS

Benthic samples were collected at four random points along 100 m transects located 50 and 100 m to the east and west of each site, and along two transects within each site (Fig. 7). Three distances of 0 m, 50 m, and 100 m were selected to discern the impact of artificial reef associates as a function of distance away from the casita sites. Transects were to the east and west of the sites, and were therefore consistent with the east/west alignment of the sites.

Benthic samples were collected with a modified device similar to that illustrated in Orth & van Montfrans (1987). Suction over the sampling ring was created by the Venturi system in which water was forced through a smaller diameter pipe allowing the sample to be "vacuumed up" from within the ring (Fig. 8). A 54 cm diameter sampling ring was fitted with a 1 mm mesh covering to prevent shrimp, fish, and crabs from escaping. Ring size was determined in an efficiency study which determined that a 54 cm diameter ring was most efficient for quantifying resident fauna. A 1 mm mesh collection bag was chosen for comparative purposes with a previous study in south Florida (Brook 1978). Benthic samples were suctioned for 1 minute, and all 144 samples were collected between 26 July and 12 August 1991, one year after the casitas had been introduced. Benthic suction samples were taken because they provide a more quantitative estimate of infaunal and epibenthic

Figure 7. Schematic of six 100 m sampling transects per casita site. Transects were 0 m, 50 m, and 100 m away to the west and 0 m, 50 m, and 100 m to the east of each site.

Sampling Design

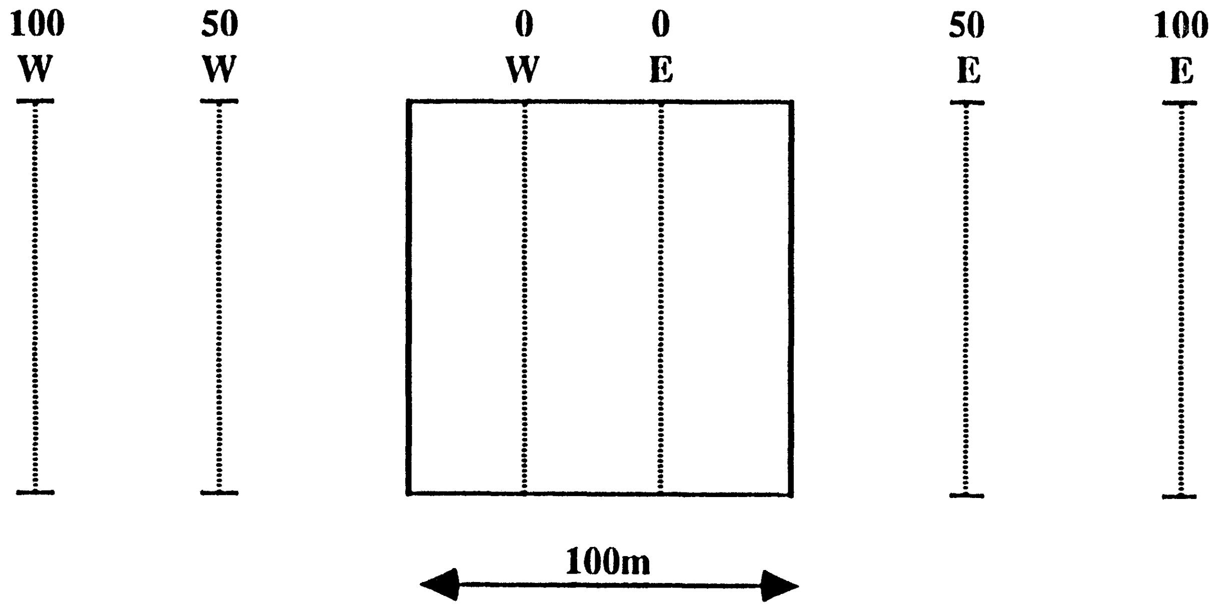
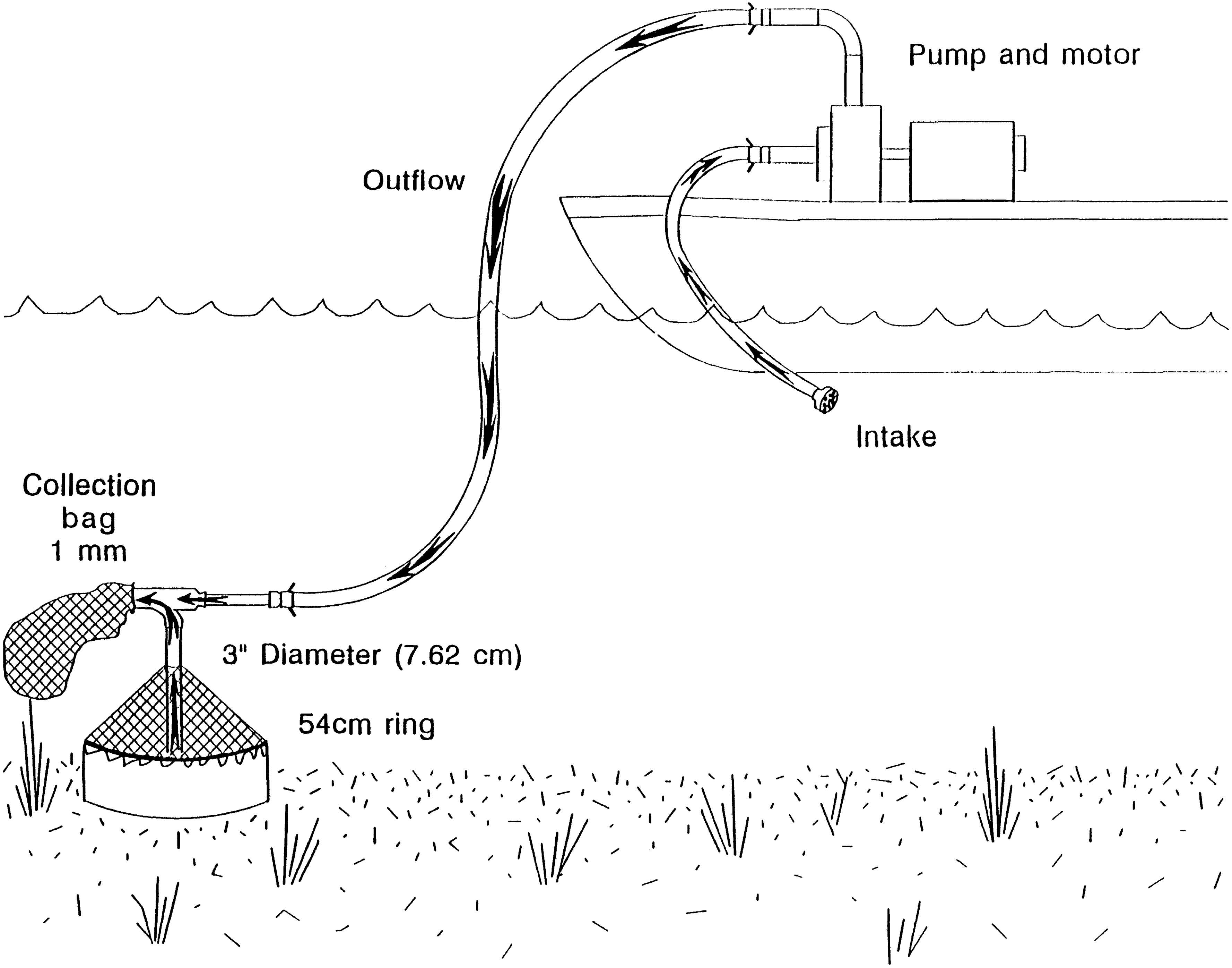


Figure 8. Macrobenthic suction sampling design diagramming the Venturi system in which water is forced through a smaller diameter pipe creating a vacuum.


Pump and motor
Outflow
Intake
Collection
bag
1 mm
3" Diameter (7.62 cm)
54cm ring

organisms than do core samples or grabs (Stoner et al. 1983) and suction devices have been suggested for study of benthic macrofauna in seagrass habitats (Brook 1978). Samples were visually sorted in the lab and organisms were preserved in 70% ethanol. Organisms were later identified to lowest practical taxon using the following keys: Warmke & Abbott (1962), Gosner (1971), Morris (1975), Williams (1984), Ruppert & Fox (1988), and Lyons (1989).

Data from the monthly visual casita survey was used in conjunction with published feeding habits of the resident predators to help identify the impact of artificial reef associates other than spiny lobster (i.e.fishes and crabs) on benthic community structure. To characterize the benthic flora and sediment characteristics of the control and casita sites, visual quadrats ($1m^2$) and 3 cm diameter cores were randomly taken along the 100 m transects to the west of each site, resulting in 18 samples at each location. Within each visual quadrat, percent cover of sand, seagrass, and algae was recorded and vegetation identified to species whenever possible. Sediment samples were fractionated to provide sediment composition of gravel (retained on a No. 10 USA standard testing sieve = 2 mm opening), sand (retained on a No. 60 USA standard testing sieve = .25 mm opening) and fine (that which passed through the No. 60 sieve).

Direction, east or west, was not a significant factor, and therefore a three-way

ANOVA was used to test the effects of *location*, *casita density*, and *distance* on the abundance of bivalves, gastropods, and a third group designated as "other" which included crustaceans, polychaetes, echinoderms, and fish. Levels of the ANOVA factors included: Arsnicker Keys and Twin Keys, 0, 8, and 16 casitas, and 0, 50, and 100 meters. Densities of organisms were log(x+1) transformed to standardize variances. In cases where the F-ratio was significant, lower-level ANOVA's or Tukey's (HSD) tests were used to compare means.

RESULTS

Casitas, with their associated predators, had a significant negative impact on macrobenthic organism abundance, which, in some cases, diminished with distance from casitas (Figures 10, 13, and 16). The impact to bivalve, gastropod, and "other" (crustaceans, polychaetes, echinoderms, and fish) abundance was not the same in each experimental site and was most likely the result of predation intensity as modified by local micro-habitat complexity.

BIVALVES

There were significant *location*, *casita density*, and *distance* effects upon bivalve abundance and a significant *location x casita density* interaction effect (Table

1). When analyzed by *casita density*, *location* was a significant factor for both casita density = 8 (ANOVA, df = 1, F = 21.38, $P < 0.01$) and casita density = 16 (ANOVA, df = 1, F = 4.78, $P < 0.05$) (Fig. 9). When bivalve abundance was further analyzed within each location, Arsnicker Keys and Twin Keys, *casita density* and *distance* from the casitas were significant factors.

In both 8 casita sites, bivalve abundance was significantly lower at the 0 m distances than at 50 m and 100 m away (Arsnicker Keys; ANOVA, df = 2, F = 7.89, $P < 0.05$ and Tukey (HSD), critical Q = 3.57, comparison value = .310, $P < 0.05$) and (Twin Keys; ANOVA, df = 2, F = 4.87, $P < 0.05$ and Tukey (HSD), critical Q = 3.57, comparison value = .284, $P < 0.05$) (Fig. 10). In the 16 casita sites, no significant difference in bivalve abundance was determined at Arnsicker Keys (ANOVA, df = 2, F = 2.36, P = .119) while at Twin Keys bivalve abundance was significantly lower at 0 m than at 50 m and 100 m away (ANOVA, df = 2, F = 7.37, $P < 0.05$ and Tukey (HSD), critical Q = 3.57, comparison value = .252, $P < 0.05$) (Fig. 10). No significant differences in bivalve abundance occurred with distance at either control site (Arsnicker Keys; ANOVA, df = 2, F = .32, P = .732 and Twin Keys; ANOVA, df = 2, F = 0.7, P = .935) (Fig. 10).

No significant difference in bivalve abundance was found when the three 0 m distances from the control, 8 casita, and 16 casita site were compared from Arnsicker

Keys (Control; ANOVA, $df = 2$, $F = 2.13$, $P = .144$) (8 casita; ANOVA, $df = 2$, $F = .57$, $P = .573$) and (16 casita, ANOVA, $df = 2$, $F = 1.27$, $P = .301$) (Fig. 11). At Twin Keys, the bivalve abundance at the 0 m distance in the control site was significantly higher than the bivalve abundance at both the 8 and 16 casita sites (ANOVA, $df = 2$, $F = 14.61$, $P < 0.01$ and Tukey (HSD), critical $Q = 3.57$, comparison value $= .267$, $P < 0.05$) (Fig. 11). No significant difference in bivalve abundance was found in the three 50 m distances at Arsnicker Keys (ANOVA, $df = 2$, $F = .57$, $P = .573$) or the 100 m distances (ANOVA, $df = 2$, $F = 1.27$, $P = .301$) (Fig. 11). The same held true for the Twin Keys 50 m (ANOVA, $df = 2$, $F = .59$, $P = .565$) and 100 m distances (ANOVA, $df = 2$, $F = 1.27$, $P = .301$) (Fig. 11).

GASTROPODS

There were significant *location*, *casita density*, and *distance* effects upon gastropod abundance and a significant *location x casita density* interaction effect (Table 2). When analyzed by *casita density*, *location* was significant for the control (ANOVA, $df = 1$, $F = 2132.95$, $P < 0.01$) 8 casita (ANOVA, $df = 1$, $F = 148.55$, $P < 0.01$) and 16 casita sites (ANOVA, $df = 1$, $F = 33.88$, $P < 0.01$) (Fig 12). When gastropod abundance was further analyzed within each location, Arsnicker Keys and Twin Keys, *casita density* and *distance* from the casitas were significant factors.

In both 8 casita sites, gastropod abundance was significantly lower at the 0 m distances than the gastropod abundance 50 meters away. At the Arsnicker Keys 8 casita site, the 0 m gastropod abundance was also significantly lower than the abundance of gastropods 100 m away (Arsnicker Keys; ANOVA, $df = 2$, $F = 7.89$, $P < 0.05$ and Tukey (HSD), critical $Q = 3.57$, comparison value $= .243$, $P < 0.05$) and (Twin Keys; ANOVA, $df = 2$, $F = 5.39$, $P < 0.05$ and Tukey (HSD), critical $Q = 3.57$, comparison value $= .224$, $P < 0.05$) (Fig. 13).

In the 16 casita sites no significant difference in gastropod abundance was seen at Twin Keys (ANOVA, $df = 2$, $F = .50$, $P = .260$) while at Arsnicker Keys the gastropod abundance was significantly lower at 0 m than at 50 m and 100 m away (ANOVA, $df = 2$, $F = 6.31$, $P < 0.01$ and Tukey (HSD), critical $Q = 3.57$, comparison value $= .303$, $P < 0.05$) (Fig. 13). No significant difference in gastropod abundance occurred at either control site (Arsnicker Keys; ANOVA, $df = 2$, $F = 2.3$, $P = .123$) and (Twin Keys; ANOVA, $df = 2$, $F = .11$, $P = .894$) (Fig. 13).

The three distances, 0, 50, and 100 m were also compared to one another across all three casita densities within each location. At Arsnicker Keys, the gastropod abundance at the 0 m distance in the 16 casita site was significantly lower than the gastropod abundance in both the control and 8 casita sites (ANOVA, $df =$

2, F = 7.05, P < 0.01 and Tukey (HSD), critical Q = 3.57, comparison value = .323, P < 0.05) (Fig. 14). There was no significant difference in the 0 m gastropod abundance at Twin Keys (ANOVA, df =2, F = .79, P = .465) (Fig. 14). At Arsnicker Keys there was no significant difference in the 50 m gastropod abundances (ANOVA, df = 2, F = 3.32, P = .056) while at Twin Keys the 50 m gastropod abundance was significantly lower at the control site than at the 8 and 16 casita sites (ANOVA, df = 2, F = 6.62, P < 0.01 and Tukey (HSD), critical Q = 3.57, comparison value = .287, P < 0.05) (Fig. 14).

The 100 m comparisons both contained a significant difference in gastropod abundance. At Arsnicker Keys the gastropod abundance was significantly lower at the 16 casita site than at the control and 8 casita sites (ANOVA, df = 2, F = 5.32, P < 0.05 and Tukey (HSD), critical Q = 3.57, comparison value = .240, P < 0.05) (Fig. 14). At Twin Keys the gastropod abundance was significantly lower at the control site than at the 8 casita site (ANOVA, df = 2, F = 5.15, P < 0.05 and Tukey (HSD), critical Q = 3.57, comparison value = .344, P < 0.05) (Fig. 14).

OTHER

A third group of organisms containing crustaceans, polychaetes, echinoderms, and fish were designated as "other" and analyzed in the same manner as bivalves and gastropods. There were significant *location* and *casita density* effects upon abundance of "other" and a significant *location x casita density* interaction effect (Table 3). When analyzed by *casita density*, *location* was significant for the control (ANOVA, df = 1, F = 80.6, $P < 0.01$) and 8 casita sites (ANOVA, df = 1, F = 71.76, $P < 0.01$) (Fig. 15). When "other" abundance was further analyzed within each location, *casita density* and *distance* from the casitas were significant factors.

In the Twin Keys 8 casita site, "other" abundance was significantly lower at 0 m than at 100 m away (ANOVA, df = 2, F = 3.61, $P < 0.05$ and Tukey (HSD), critical Q = 3.57, comparison value = .277, $P < 0.05$) (Fig. 16). There was no significant difference in "other" abundance at the Arsnicker Keys 8 casita site (ANOVA, df = 2, F = 2.11, P = .146) (Fig. 16). No significant difference occurred in "other" abundance at either of the 16 casita sites (Arsnicker Keys; ANOVA, df = 2, F = 2.26, P = .129) and (Twin Keys; ANOVA, df = 2, F = .50, P = .613) (Fig. 16). No significant difference in "other" abundance occurred at either control site (Arsnicker Key; ANOVA, df = 2, F = .41, P = .672) and (Twin Keys; ANOVA, df = 2, F = .57, P = .572) (Fig. 16).

The abundances at three distances, 0, 50, and 100 m were also compared across all three casita densities within each location. At Arsnicker Keys the "other" abundance at the 0 m distance was significantly lower in the 16 casita site than the abundance in both the control and 8 casita sites (ANOVA, df = 2, F = 14.14, P <

0.01 and Tukey (HSD), critical Q = 3.57, comparison value = .333, $P < 0.05$) (Fig. 17). There were no significant differences in "other" abundance in the Arsnicker Keys 50 m samples (ANOVA, df = 2, F = 3.61, $P < 0.05$ but not detected Tukey (HSD)). At Arsnicker Keys the "other" abundance at the 100 m was significantly lower in the 16 casita site than the abundance in the control site (ANOVA, df = 2, F = 6.39, $P < 0.05$ and Tukey (HSD), critical Q = 3.57, comparison value = .386, $P < 0.05$) (Fig. 17). No significant differences were determined in "other" abundance in the Twin Keys three distance comparisons, (0 m; ANOVA, df = 2, F = 4.22, $P < 0.05$ but not detected in Tukey (HSD), 50 m; ANOVA, df = 2, F = .23, P = .799, and 100 m; ANOVA, df = 2, F = 1.49, P = .247) (Fig. 17).

A total of 24 benthic suction samples were taken at each site, revealing variable abundances of organisms (Appendix 1). Casita associates at the experimental sites during July and August 1991 were similar (Appendix 2). Sediment composition from the core samples was similar between Arsnicker and Twin Keys (Fig. 18), however the percent substrate from the ($1 m^2$) quadrats revealed the presence of red algae, *Laurencia spp.*, at Arsnicker Keys and not at Twin Keys (Fig. 19).

Table 1. Analysis of Variance of bivalve abundance at all three sites in both Arsnicker Keys and Twin Keys, Florida Bay.

Source of Variation	**df**	**SS**	**MS**	**F**
Location (A)	1	0.99986	0.99986	14.49 **
Casita Density (B)	2	1.09756	0.54878	7.96 **
Distance (C)	2	1.80147	0.90074	13.06 **
A*B	2	0.50122	0.25061	3.63 *
A*C	2	0.02729	0.01364	0.20 ns
B*C	4	0.59488	0.14872	2.16 ns
A*B*C	4	0.08948	0.02237	0.32 ns
Error	126	8.69214	0.06898	

** $P < 0.001$ * $P < 0.05$ ns $P > 0.05$

Figure 9. Bivalve abundance at three experimental sites (0, 8, and 16 casitas) within two locations (Arsnicker Keys and Twin Keys). Casita densities marked with an asterisk denote a significant difference at the 0.05 level.

Bivalves

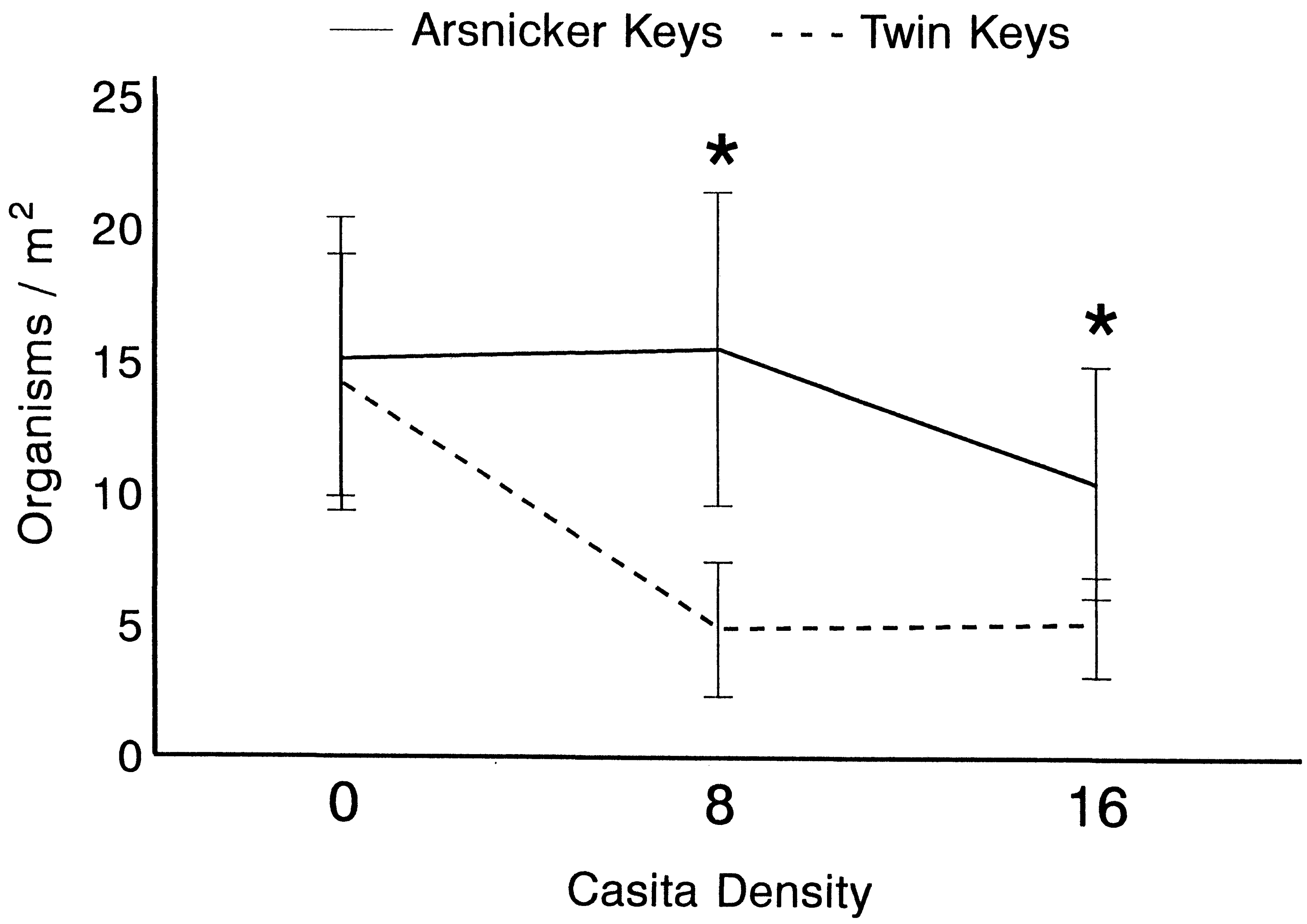

Arsnicker Keys
Twin Keys
Organisms / m2
25
20
15
10
5
0
0
8
16
*
*
Casita Density

Figure 10. Bivalve abundance at three experimental sites (0, 8, and 16 casitas) within two locations (Arsnicker Keys and Twin Keys). Distances marked with an asterisk denote a significant difference at the 0.05 level.

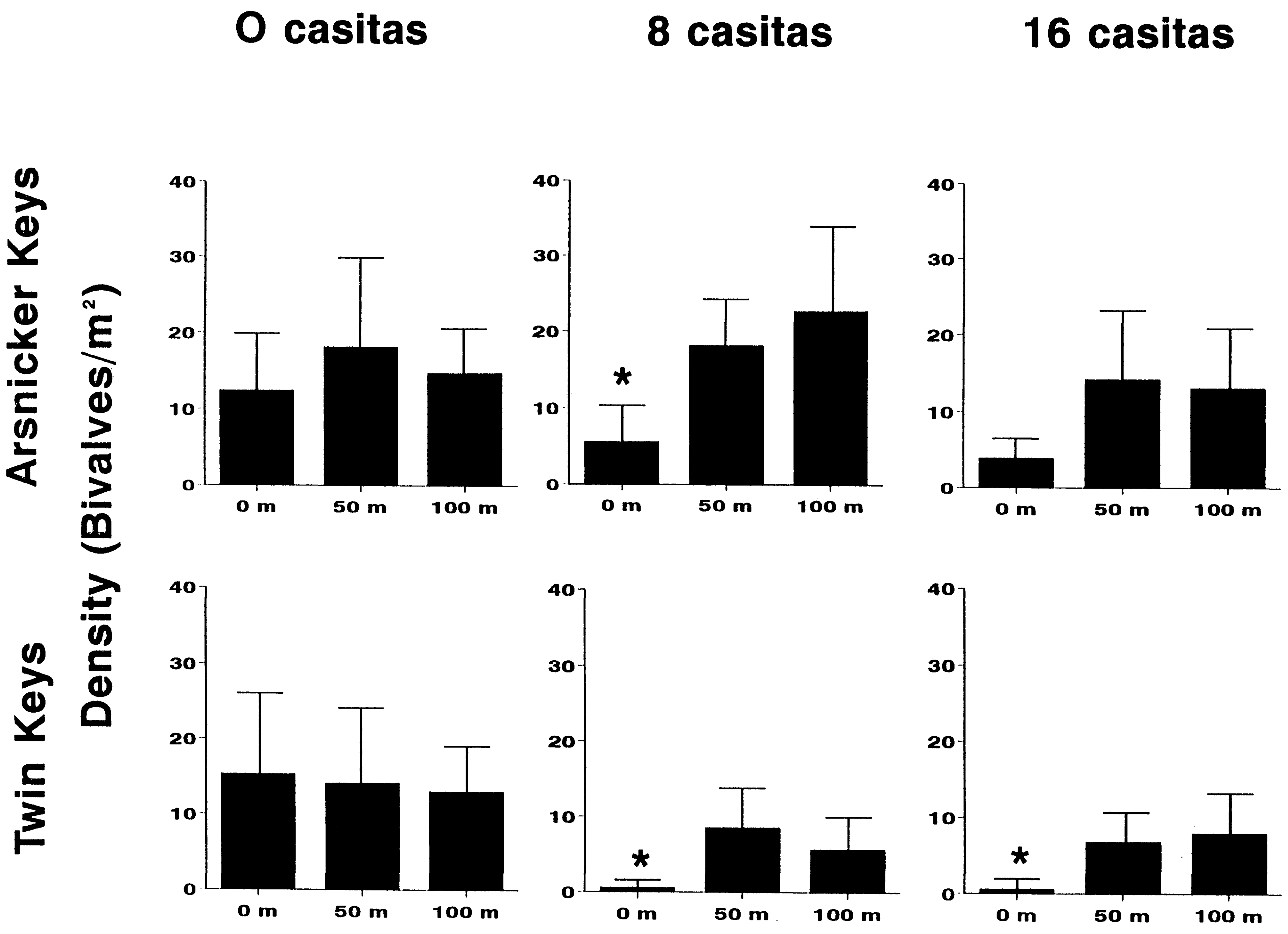

O casitas
8 casitas
16 casitas
Arsnicker Keys
Twin Keys
Density (Bivalves/m²)
40
30
20
10
0
0 m
50 m
100 m
*

Figure 11. Bivalve abundance at three experimental sites (0, 8, and 16 casitas) within two locations (Arsnicker Keys and Twin Keys). Casita densities marked with an asterisk denote a significant difference at the 0.05 level.

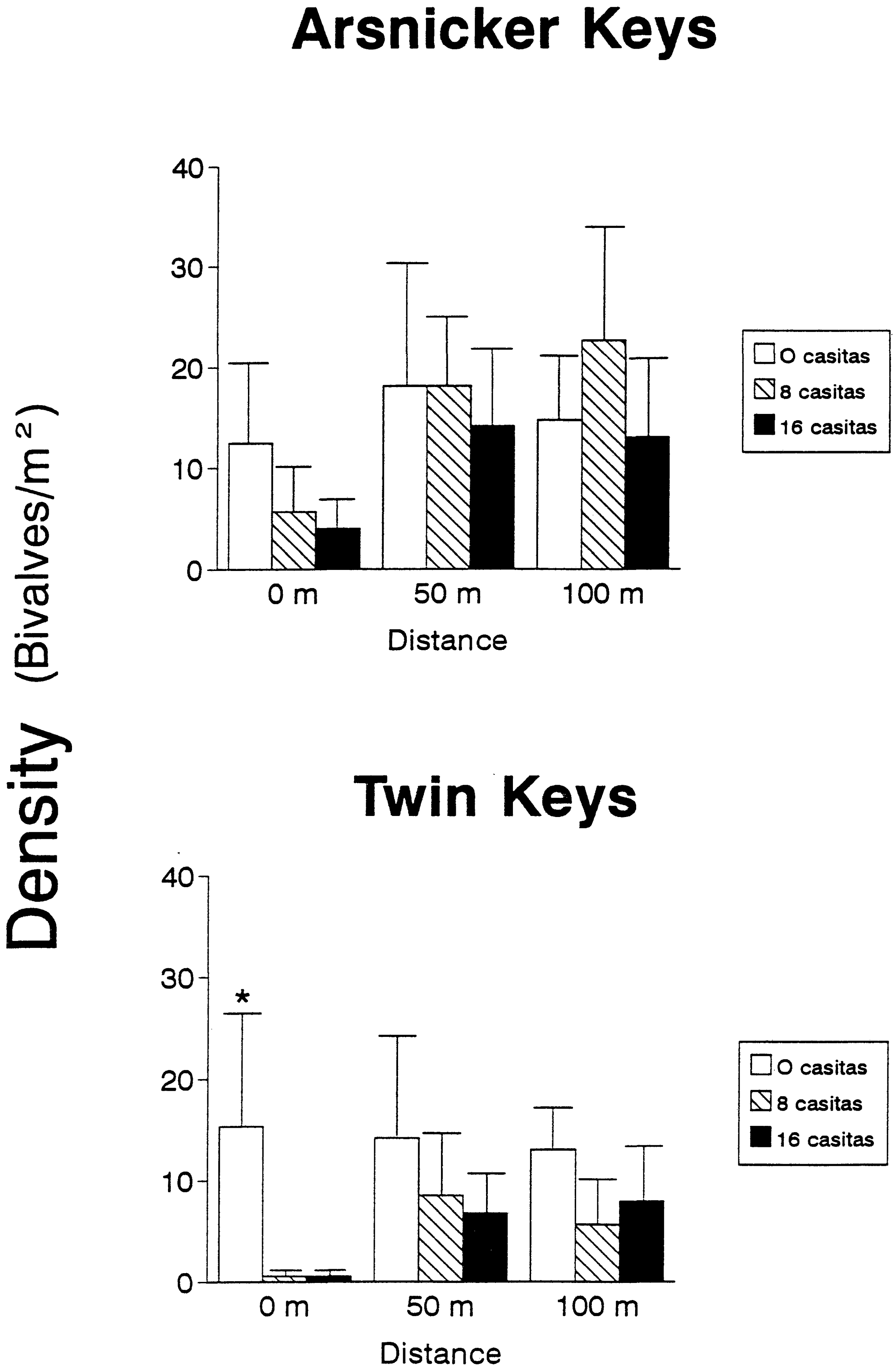

Arsnicker Keys
Density (Bivalves/m²)
40
30
20
10
0
0 m
50 m
100 m
Distance
O casitas
8 casitas
16 casitas
Twin Keys
40
30
20
10
0
*
0 m
50 m
100 m
Distance
O casitas
8 casitas
16 casitas

Table 2. Analysis of Variance on gastropod abundance at all three sites in both Arsnicker Keys and Twin Keys, Florida Bay.

Source of Variation	**df**	**SS**	**MS**	**F**
Location (A)	1	17.2403	17.2403	314.10 **
Casita Density (B)	2	1.2540	0.6270	11.42 **
Distance (C)	2	1.3760	0.6880	12.53 **
A*B	2	1.3860	0.6930	12.63 **
A*C	2	0.0877	0.4387	0.80 ns
B*C	4	0.4325	0.1081	1.97 ns
A*B*C	4	0.0860	0.0215	0.39 ns
Error	126	6.9158	0.0549	

** $P < 0.001$ ns $P > 0.05$

Figure 12. Gastropod abundance at three experimental sites (0, 8, and 16 casitas) within two locations (Arsnicker Keys and Twin Keys). Casita densities marked with an asterisk denote a significant difference at the 0.05 level.

Gastropods

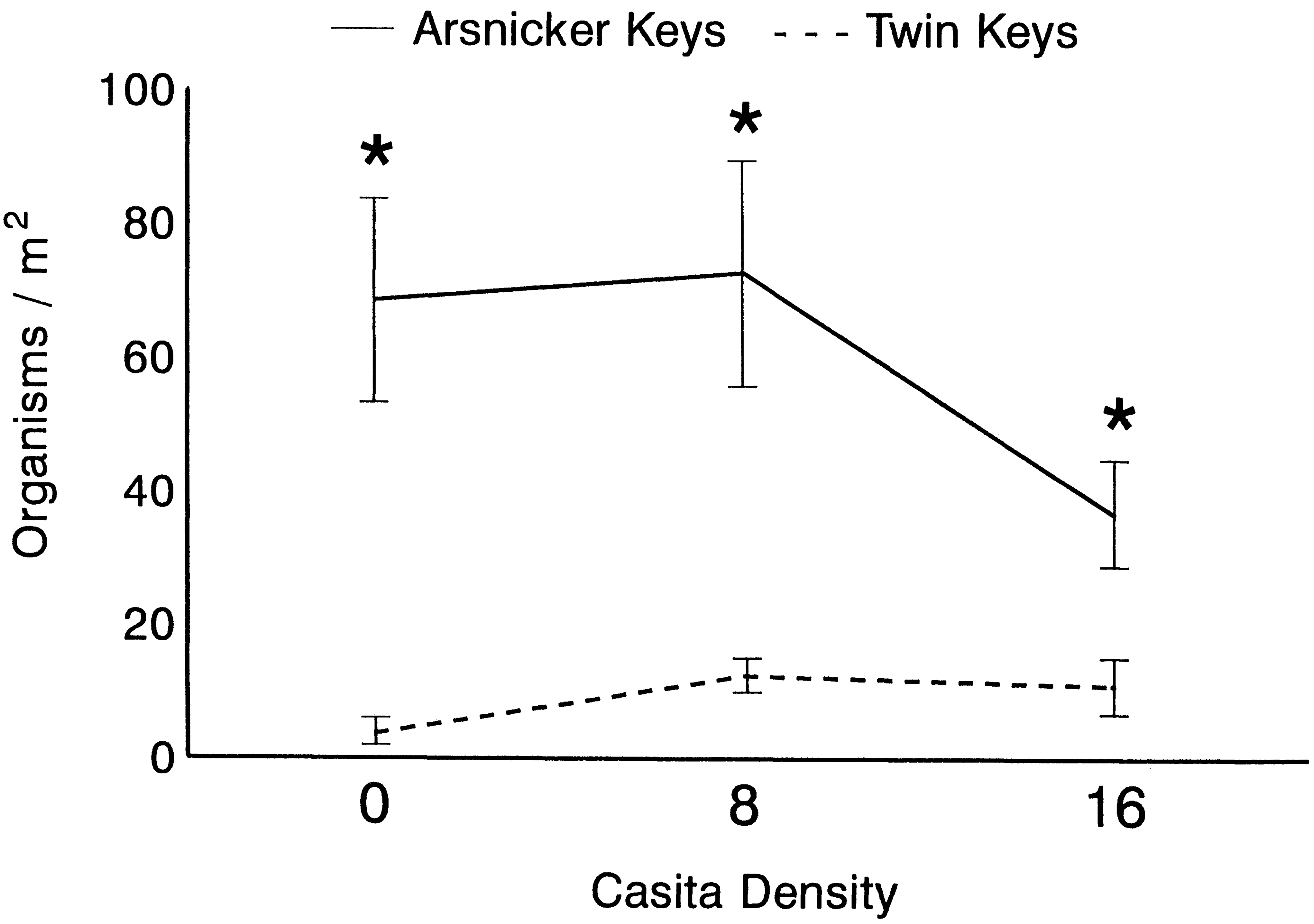

Arsnicker Keys
Twin Keys
100
80
60
40
20
0
Organisms / m2
*
*
*
0
8
16
Casita Density

Figure 13. Gastropod abundance at three experimental sites (0, 8, and 16 casitas) within two locations (Arsnicker Keys and Twin Keys). Distances marked with an asterisk denote a significant difference at the 0.05 level.

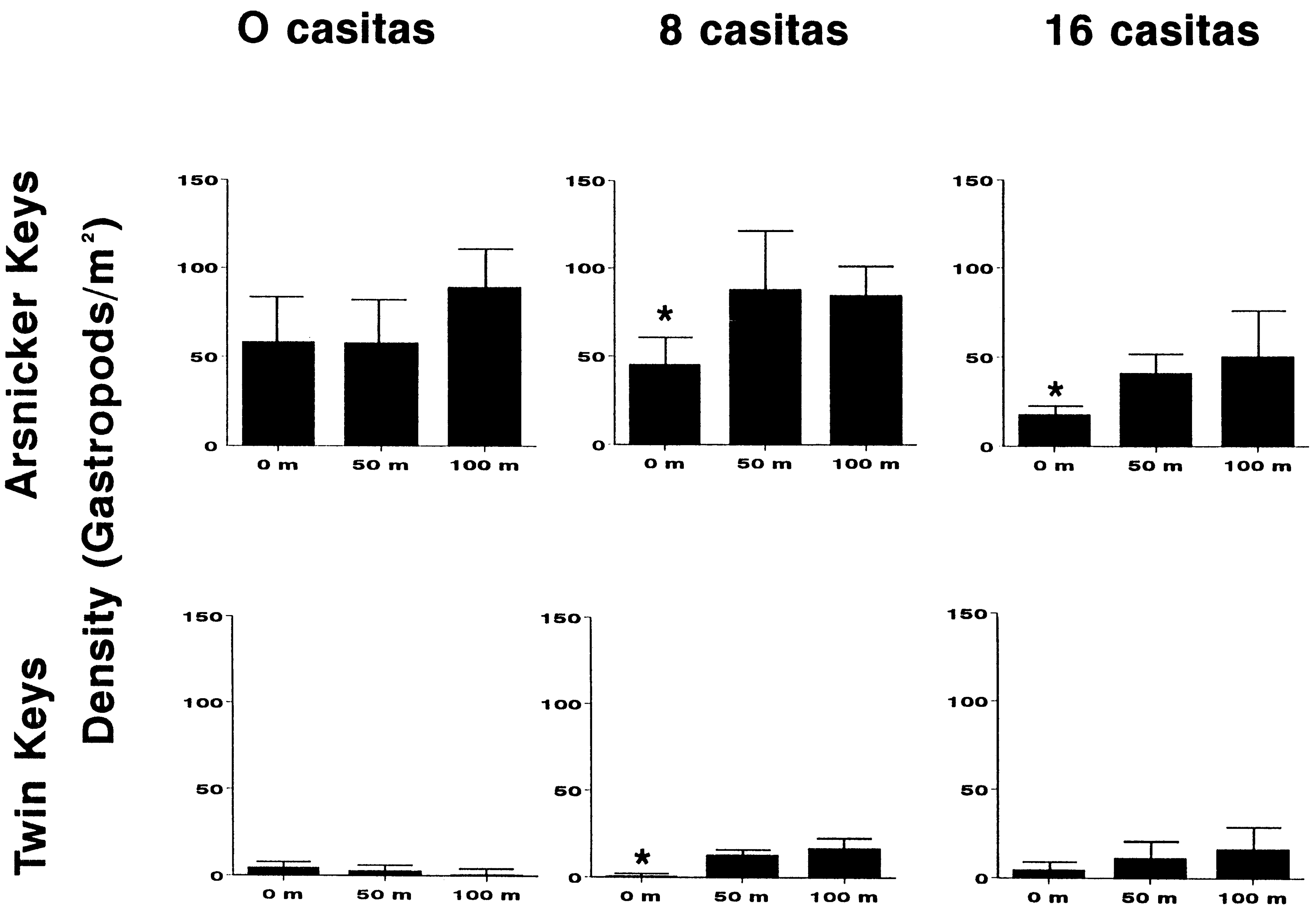

O casitas
8 casitas
16 casitas
Arsnicker Keys
Twin Keys
Density (Gastropods/m^2)
150
100
50
0
0 m
50 m
100 m
*

Figure 14. Gastropod abundance at three experimental sites (0, 8, and 16 casitas) within two locations (Arsnicker Keys and Twin Keys). Casita densities marked with an asterisk denote a significant difference at the 0.05 level.

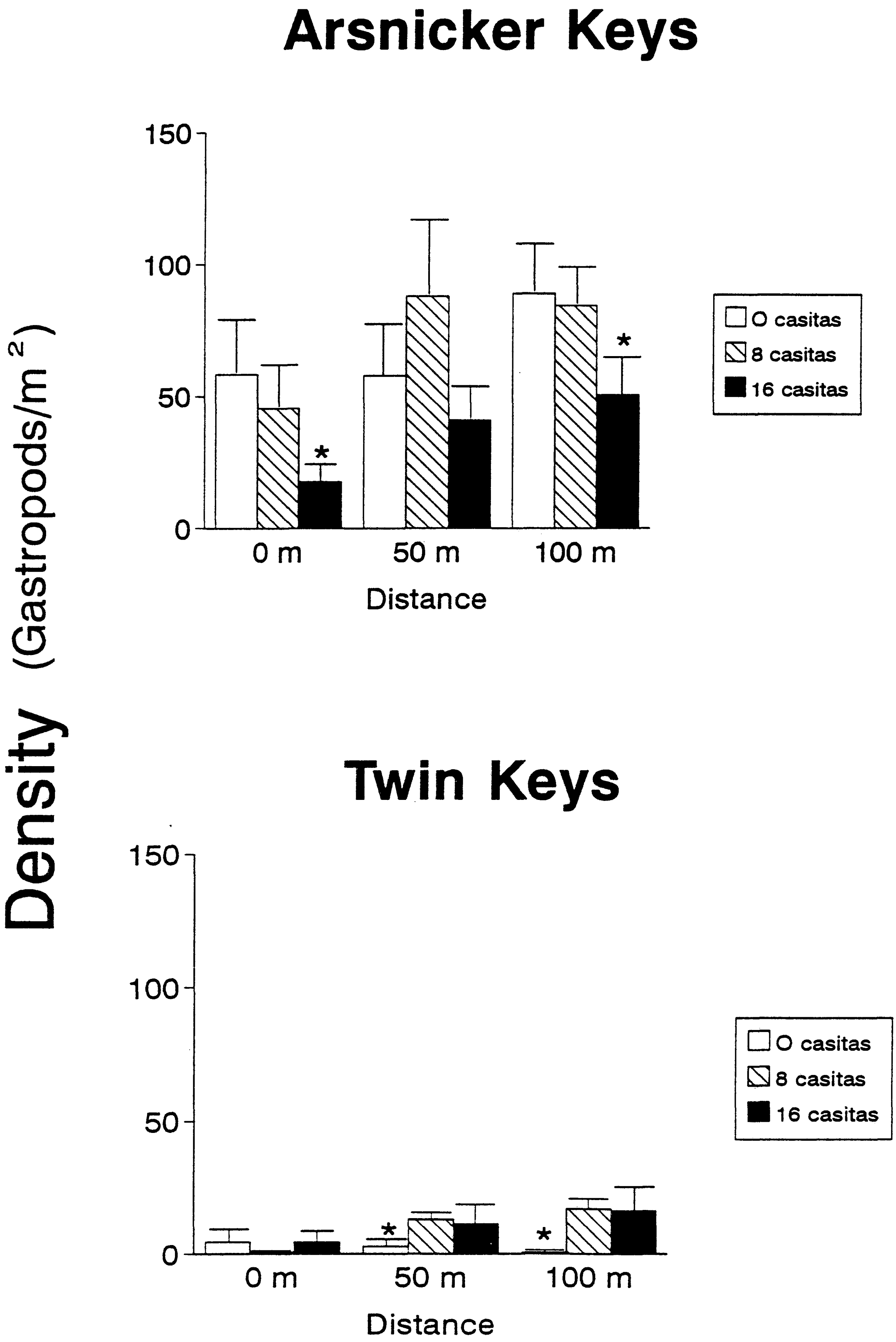

Arsnicker Keys
Density (Gastropods/m 2)
150
100
50
0
*
*
0 m
50 m
100 m
Distance
O casitas
8 casitas
16 casitas
Twin Keys
150
100
50
0
*
*
0 m
50 m
100 m
Distance
O casitas
8 casitas
16 casitas

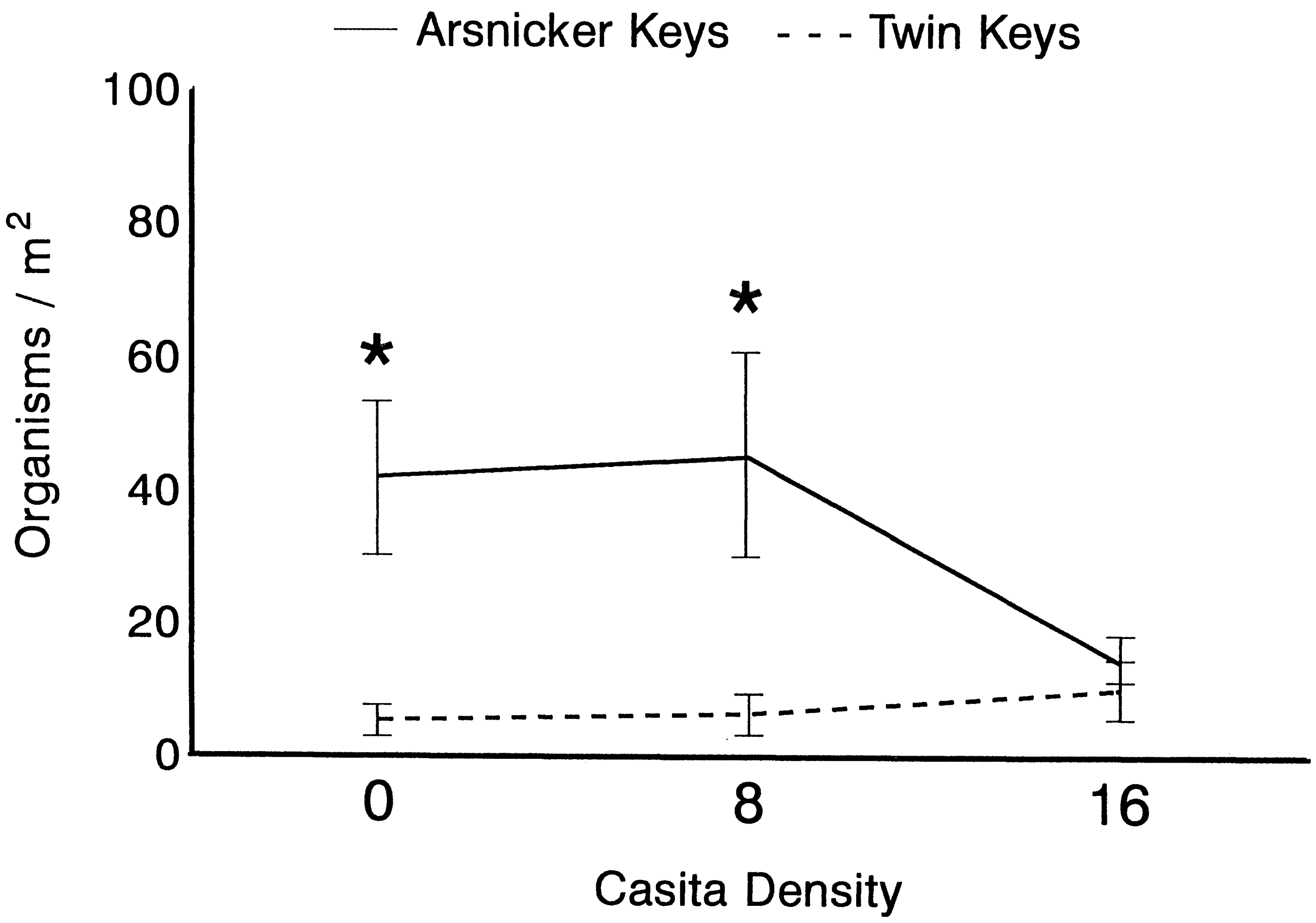
Table 3. Analysis of Variance on Other organism abundance at all three sites in both Arsnicker Keys and Twin Keys, Florida Bay.

Source of Variation	**df**	**SS**	**MS**	**F**
Location (A)	1	7.62080	7.62080	98.28 **
Casita Density (B)	2	0.92872	0.46436	5.99 **
Distance (C)	2	0.34534	0.17267	2.23 ns
A*B	2	2.73221	1.36610	17.62 **
A*C	2	0.12050	0.06025	0.78 ns
B*C	4	0.50008	0.12502	1.61 ns
A*B*C	4	0.42480	0.10620	1.37 ns
Error	126	9.77072	0.7754	

** $P < 0.001$ ns $P > 0.05$

Figure 15. Other organism abundance at three experimental sites (0, 8, and 16 casitas) within two locations (Arsnicker Keys and Twin Keys). Casita densities marked with an asterisk denote a significant difference at the 0.05 level.

Other



— Arsnicker Keys
- - - Twin Keys
Organisms / m²
100
80
60
40
20
0
*
*
0
8
16
Casita Density

Figure 16. Other organism abundance at three experimental sites (0, 8, and 16 casitas) within two locations (Arsnicker Keys and Twin Keys). Distances marked with an asterisk denote a significant difference at the 0.05 level.

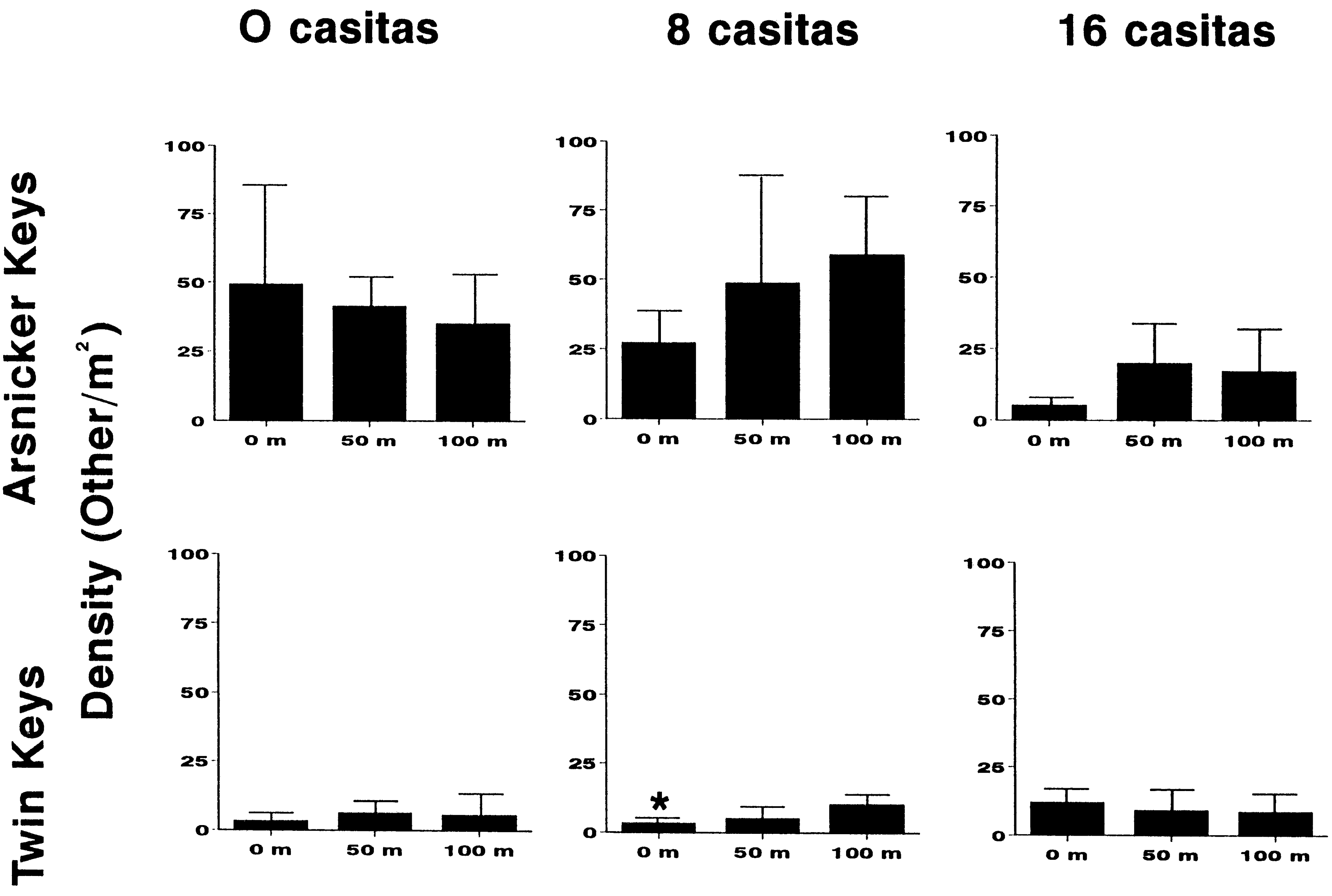

O casitas
8 casitas
16 casitas
Arsnicker Keys
Twin Keys
Density (Other/m^2)
100
75
50
25
0
0 m
50 m
100 m
*

Figure 17. Other organism abundance at three experimental sites (0, 8, and 16 casitas) within two locations (Arsnicker Keys and Twin keys). Casita densities marked with an asterisk denote a significant difference at the 0.05 level.

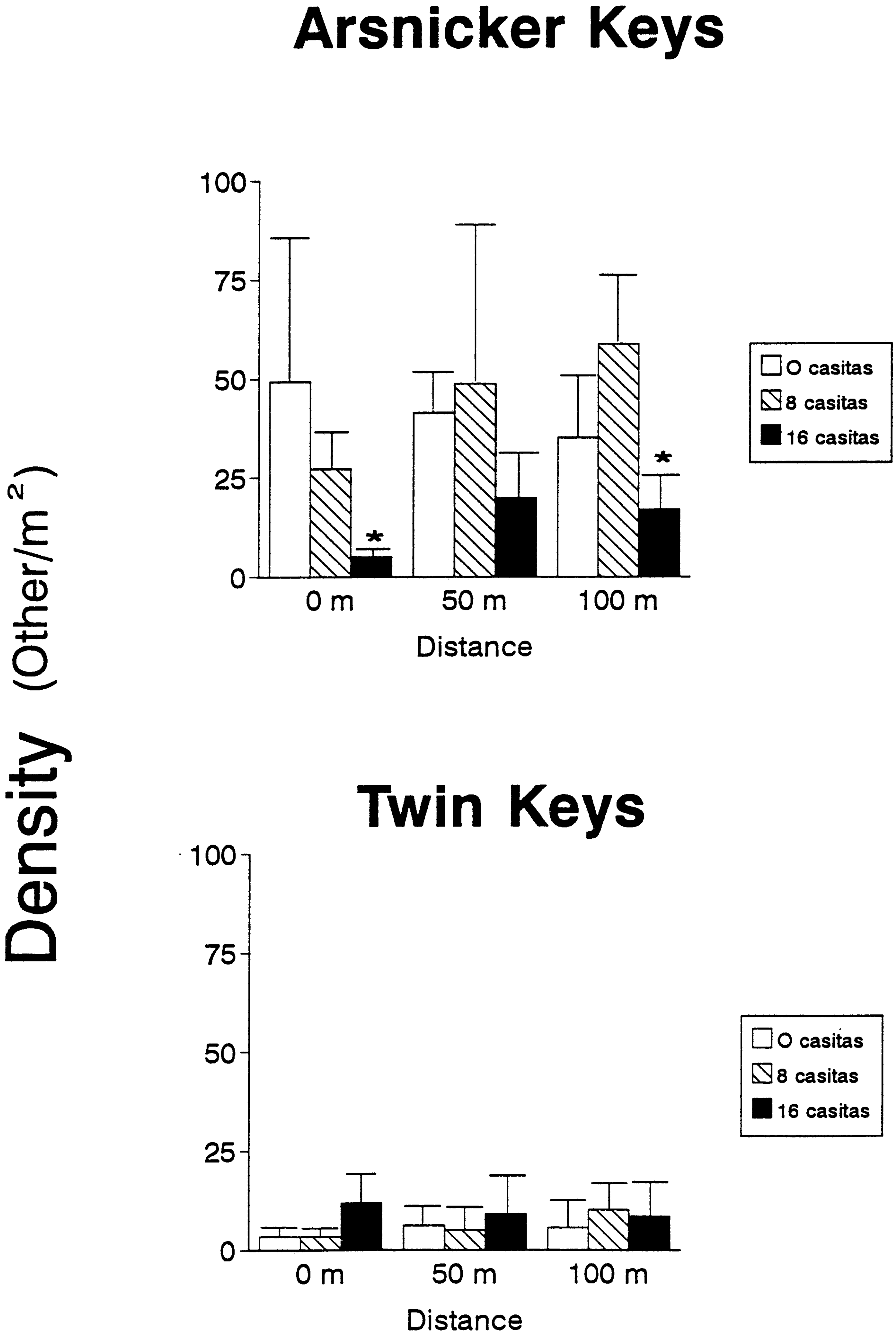
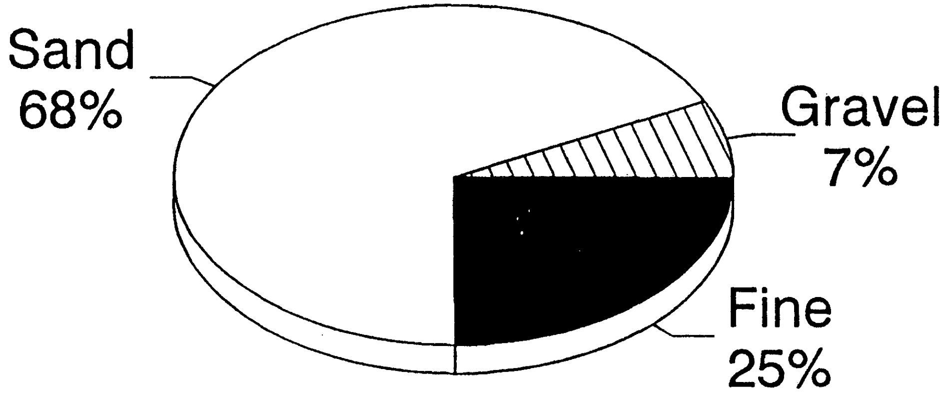

Arsnicker Keys
100
75
50
25
0
*
*
0 m
50 m
100 m
Distance
O casitas
8 casitas
16 casitas
Density (Other/m 2)
Twin Keys
100
75
50
25
0
0 m
50 m
100 m
Distance
O casitas
8 casitas
16 casitas

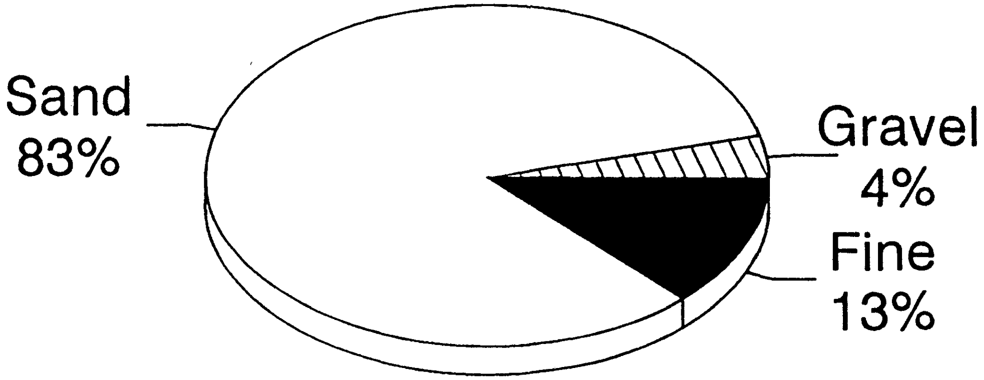
Figure 18. Sediment composition from core samples taken at Arsnicker Keys and Twin Keys, Florida Bay.

Sediment Composition

Florida Bay 1991



Arsnicker Keys

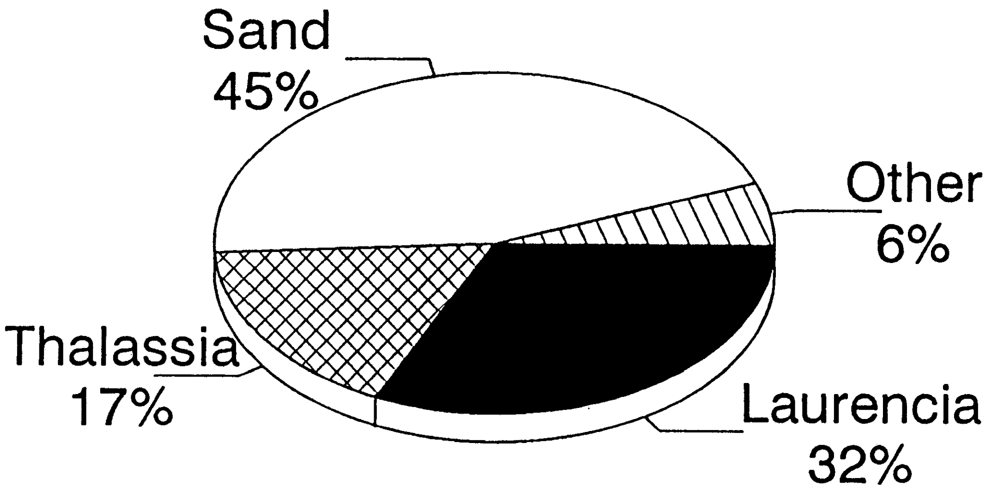


Twin Keys

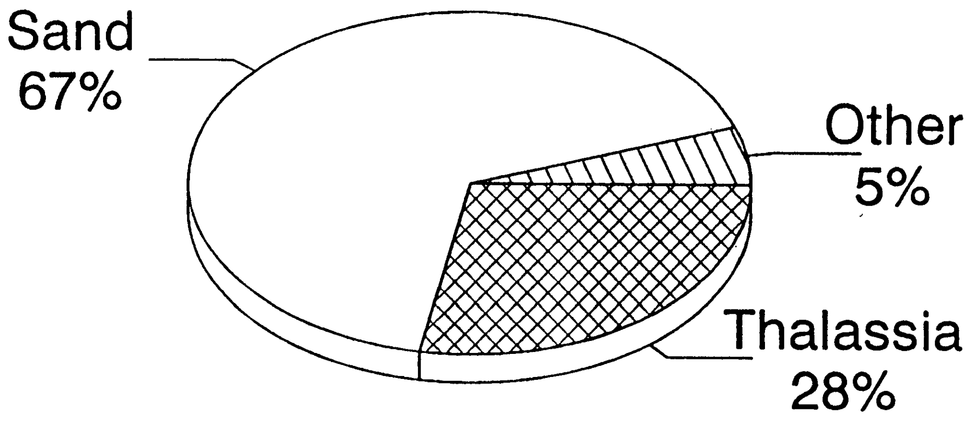
Figure 19. Percent substrate cover at Arsnicker Keys and Twin Keys, Florida Bay.

Percent Substrate Type

Florida Bay 1991



Arsnicker Keys



Twin Keys

DISCUSSION

Since predation is a biological factor which can have a significant influence on seagrass community structure, it is possible that predation by casita associates on macrobenthic organisms was the cause for significant differences in macrobenthic organism abundance in the experimental sites. If predation by casita associates was the primary factor responsible for a significant difference in macrobenthic abundance, then the impact to bivalve and gastropod abundance was most likely due to the spiny lobster *Panulirus argus*. Not only was the spiny lobster the most abundant casita associate at both locations (Appendix 2), its foraging pattern and prey selection is closely linked to gastropod and bivalve abundance. The five most abundant finfish in both locations likely had little predatory impact on the gastropod and bivalve assemblage, but may have been the cause for a significant decrease in crustacean, polychaete, echinoderm, and fish abundance at Arsnicker Keys (Randall 1967).

A comprehensive study on the stomach contents of 5,526 specimens of 212 reef and inshore fishes was completed by (Randall 1967) in which principal plant and animal groups eaten by the fishes were calculated in percentage volume of the stomach contents. Gastropods comprised more than 40% of the diet of five of these fishes: spiny puffer, *Diodon holocanthus* (67.7%), bridled burrfish, *Chilomycterus antennatus* (56.6%), eagle ray, *Aetobatis narinari* (53.4%), sheepshead porgy, *Calamus penna* (50%), and permit, *Trachinotus falcatus* (47.8%). The most abundant finfish associated with casitas and their principal food items according to Randall were: Tomtate (33.6% shrimps and shrimp larvae, 31% polychaetes), Porkfish (16.5% ophiuroids, 16.2% crabs, 14.7% shrimps, and 14% polychaetes), Gray snapper (40% crabs, 39.1% fishes, and 13.2% shrimps), Doctorfish (93.9% algae and organic detritus), Highhat (73.2% shrimps and shrimp larvae, and 10.5% unidentified crustaceans), Bar Jack (91.5% fishes), Bluestriped grunt (26.9% crabs, 15% pelecypods, and 10% shrimps), and French grunt (39.6% polychaetes, 15.5% crabs, and 10.2% sipunculids). Gastropods were found in the stomachs of Gray snapper, Bluestriped grunt, and French grunt, however the percentage of volume was always less than 10%. Of the crabs found in the experimental sites, the stone crab, *Menippe mercenaria*, is an active predator on mollusks (Ortiz & Poll 1982), however due to their low abundance in the experimental sites (Appendix 2) their impact was considered negligible compared to that of the spiny lobster. Thus, spiny lobster are the most likely major predator on gastropods and bivalves in this study.

At both experimental locations, bivalve and gastropod abundances were lowest in sites containing the highest density of casitas (Figs. 10 and 13). Even though organism abundance was lower at sites with casitas, compared to the control sites without casitas (Figure 9), the trends in bivalve abundance were similar. The impact to bivalve abundance at the 8 casita sites and the Twin Keys 16 casita site was confined to the 1 ha area (0 meters). However at the Arsnicker 16 casita site, the impact appeared to extend to 50 m and 100 m away (Figure 10). This extending impact on bivalve abundance could be due to the lobsters foraging further from casitas at the 16 casita site than in the 8 casita site.

The greater density of spiny lobster at the casita sites could also account for the significant reduction in gastropod abundance at these sites (Figure 13). Again, the impact to the lobster prey was confined to the 0 m distances at both 8 casita sites, and 0 m at the Arsnicker 16 site. The result of greater casita density, ergo more spiny lobster, present in the same 1 ha area could account for a decrease in mollusc abundance and possibly an extended impact at the Twin Keys 16 casita site when spiny lobsters foraged further from the casitas.

The abundance of crustaceans, polychaetes, echinoderms, and fish was lower at 0 m within the Twin Keys 8 casita site than at 50 m or 100 m away (Figure 16). This pattern may be due to predations of high numbers of tomtates and french grunts present at Twin Keys feeding on polychaetes. There were no other significant differences within each casita site as was illustrated in bivalve and gastropod abundance, and therefore, the impact of finfish was probably not as great as the spiny lobster. In fact, spiny lobster abundance, at both locations, was more than double that of the next most abundant casita associate (Appendix 2).

In no instance did any of the control sites illustrate any significant change in macrobenthic abundance. It was only when samples from the experimental locations, sites which contained casitas, were analyzed that significant decreases in macrobenthic organism abundance were detected.

A second biological factor which can influence the distribution of macrobenthic organisms in seagrass systems is habitat complexity. Considerable evidence suggests that vulnerability of prey to predation decreases as habitat complexity increases (Coen et al. 1981, Heck & Thoman 1981, Savino & Stein 1982, Leber 1985). There is also evidence that in grassbed habitats, epifaunal abundances are strongly correlated with plant biomass (Orth 1973, Brook 1978, Stoner 1980, Gore et al. 1981). The total abundance of macrobenthic organisms was much lower at Twin Keys than at Arsnicker Keys (Figures 9, 12, 15, and Appendix 1). This difference was probably due to the large numbers of lobster and finfish, combined with low amounts of structural refuge (e.g.*Laurencia*). For example, the sediment characteristics were similar between Arsnicker Keys and Twin Keys (Fig. 18), however, the percent substrate cover and habitat complexity were higher at Arsnicker Keys (Fig. 19). The presence of red algae, *Laurencia spp.*, at Arsnicker Keys and not Twin Keys may have provided for greater habitat complexity, and therefore, greater abundances of macrofauna. Another possible explanation for reduced abundances of macrobenthos at Twin Keys is that species composition and abundance can vary widely in *Thalassia* communities, even in areas that are close geographically. (Brook 1978).

In the Brook 1978 study, five seagrass communities in south Florida were sampled and macrobenthic abundance ranged from 292 to 10,728 individuals/m^2. Molluscs were the most abundant taxa in three of the five communities. The macrobenthic organism abundance at Arsnicker Keys and Twin Keys ranged from 23 to 130 individuals/m^2. This also lends support to casitas, with their associated predators as modified by habitat complexity, having a significant impact on the macrobenthic abundance in the experimental sites within Florida Bay.

This study dealt with what was present in the experimental sites over a 13 day period approximately one year after artificial shelters were deployed. Although the data are more of a "snapshot" in time, some conclusions can be drawn. The casitas did provide shelter for a variety of artificial reef associates primarily spiny lobster. If in fact predation was the dominant factor controlling the macrobenthic community structure in the experimental sites, then the results implicate the spiny lobster as the dominant predator impacting macrobenthic abundance.

The 16 casita sites had lobster densities upwards of 1000 lobsters per ha which rarely occur naturally and only for short periods of time. The consequences of such densities over longer periods of time are unclear. It is possible that foraging distances could increase, food resources could become depleted, and lobsters could resort to alternative prey sources. Because there are many changes which take place over time, the results of this study should be used to augment the ongoing monitoring of artificial shelter associates and their ecological interactions with the surrounding macrobenthic community.

APPENDICES

Appendix 1. Abundance summary (individuals/m^2) of suction samples from three sites within two locations in Florida Bay. (AR) Arsnicker Keys; (TK) Twin Keys.

	AR 0	AR 8	AR 16	TK 0	TK 8	TK 16
Phylum Arthropoda						
Subphylum Crustacea						
Class Malacostraca						
Order Decapoda	18.01	11.52	5.29	1.13	0.94	1.32
Order Isopoda	0.75	0.94	0.38	0.00	0.00	0.00
Order Amphipoda	0.18	0.94	0.38	0.00	0.00	0.18
Phylum Mollusca						
Class Gastropoda	17.56	10.95	6.80	9.63	10.95	7.93
Class Bivalvia	15.11	15.48	10.39	3.59	4.72	4.53
Class Polyplacophora	0.00	0.17	0.38	0.00	0.00	0.00
Phylum Annelida						
Class Polychaeta	64.22	74.79	32.30	7.56	5.48	9.82
Phylum Echinodermata						
Class Stelleroidea	6.75	12.92	2.08	0.54	0.54	1.08
Class Holothuria	0.38	1.08	0.00	0.00	0.00	0.00
Fish	1.51	1.32	0.57	0.38	0.38	0.00
Total	**124.47**	**130.11**	**58.57**	**22.83**	**23.01**	**24.86**

Appendix 2. Casita Associates (Mean #) of most abundant casita associates at experimental sites within Florida Bay, July and August 1991.

Arsnicker Keys

Spiny lobster	*Panulirus argus*	**(915)**
Tomtate	*Haemulon aurolineatum*	(330)
Porkfish	*Anisotremus virginicus*	(203)
Gray Snapper	*Lutjanus griseus*	(200)
Doctorfish	*Acanthurus chirurgus*	(56)
Highhat	*Equetus acuminatus*	(36)
Spider crab	*Libinia sp.*	(38)
Decorator crab	*Microphryus bicornutus*	(5)
Stone crab	*Menippe mercenaria*	(4)

Twin Keys

Spiny lobster	*Panulirus argus*	**(1322)**
Gray Snapper	*Lutjanus griseus*	(657)
Tomtate	*Haemulon aurolineatum*	(276)
Bar Jack	*Caranx ruber*	(32)
Bluestriped grunt	*Haemulon sciurus*	(26)
French grunt	*Haemulon flavolineatum*	(20)
Spider crab	*Libinia sp.*	(14)
Stone crab	*Menippe mercenaria*	(7)

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