

## V. Urchin Abundance and Size

### Background

The 1983-84 mass mortality of the long-spined sea urchin *Diadema antillarum* represents a spatially expansive and prolonged disturbance to coral reef ecosystems in the wider Caribbean region (Carpenter 1988; Lessios 1988, 2005). Prior to the mass mortality event, *D. antillarum* attained high ( $>20$  per  $m^2$ ) densities on many Caribbean reefs (Lessios 1988), but after the disease epidemic, abundances declined by several orders of magnitude and have largely remained in this state for over two decades (Lessios 2005; Weil et al. 2005; Debrot and Nagelkerken 2006). Together with physical impacts from storms, coral disease outbreaks, and severe bleaching episodes (Gardner et al. 2003), the reduction in urchin densities changed coral-algal dominance patterns (Carpenter 1988; Lessios 1988). In the Florida Keys, the few historical data available prior to 1983-84 indicate that *D. antillarum* densities were lower (up to 4 to 5 per  $m^2$ ) (Kier and Grant 1965; Bauer 1976, 1980) than values reported for the Caribbean. Historical densities of a few individuals per  $m^2$ , however, are still one to two orders of magnitude greater than current densities in the Florida Keys. A general trend of greater algal cover was reported after the urchin mortality at several Florida Keys offshore reefs in the late 1980s and early 1990s (Jaap et al. 1988; Porter and Meier 1992). However, identifying clear relationships between grazing and algae – and ultimately coral recovery – remains problematic for at least two reasons: 1) few (if any) specifically designed before-and-after studies were conducted in the Florida Keys related to urchin decline, and 2) the regional die-off of *Acropora* corals from white-band disease occurred at the same time, which opened up large amounts of dead coral substrate for algal recruitment. In contrast to the Caribbean, seven years after the 1983-84 event a second disease event in the Florida Keys, after initially modest recovery to 0.30-0.58 individuals per  $m^2$ , once again depressed *D. antillarum* densities to  $<0.01$  individuals per  $m^2$  (Forcucci 1994). With the exception of a few shallow-water areas in the Dry Tortugas (Chiappone et al. 2001), large-scale surveys of urchin densities across the south Florida during 1999-2001 confirm the continued pattern of poor recovery (Chiappone et al. 2002a,b).

Since the mass mortality, several investigators have reported limited or moderate recovery of *Diadema antillarum* populations for some Caribbean reef areas (Lessios 2005; Carpenter and Edmunds 2006; Debrot and Nagelkerken 2006), but recovery in the Florida Keys appears to be occurring slower (Chiappone et al. 2002a, in press; Lazar et al. 2005). Still, beginning in 2005 up to and including 2010, we have documented small increases in the frequency of occurrence, density, and the sizes of *D. antillarum* from surveys of hundreds of sites across the south Florida shelf. While some have suggested that *D. antillarum* recovery will help to promote coral recruitment and a return to pre-mortality baseline reef conditions (Carpenter and Edmunds 2006; Macia et al. 2007; Myhre and Acevedo-Gutierrez 2007),

diseases, bleaching episodes, and overfishing may counteract any positive influences of increased urchin grazing. Despite these uncertainties, and because of these uncertainties, there is keen interest in the spatial and temporal patterns of *D. antillarum* recovery in the Florida Keys. In addition, the slow and incomplete recovery of this urchin raises the question of what factors currently limit population recovery (Miller et al. in press).

Beginning in 1999, we have conducted intermittent, large-scale surveys of urchin density and size structure in a diversity of habitats across the south Florida shelf encompassing hundreds of sites (Chiappone et al. 2001, 2002a, b). We have recently described the population status of *Diadema antillarum* based upon surveys of 235 sites along ~200 km of the Florida reef tract during 2007 (Chiappone et al. 2009). Additional surveys were conducted Keyswide in 2008 (145 sites) and 2009 (160 sites). Below is a summary of the 2010 results for transect frequency of occurrence, density and sizes of all urchins encountered in surveys of 120 sites in the upper Florida Keys. To our knowledge, these are the only large-scale, repeated, surveys being conducted for urchins in the Sanctuary.

## 2010 Survey Results

During June-August, a total of 7,200 m<sup>2</sup> of benthic habitat among 120 sites was surveyed in the upper Florida Keys for urchin abundance and test sizes. Five species were encountered within transects: *Diadema antillarum*, *Echinometra lucunter*, *E. viridis*, *Eucidaris tribuloides*, and *Tripneustes ventricosus* (Figure 5-1). No individuals of *Lytechinus variegatus* or other species, except those above, were encountered. Tables 5-1 to 5-5 summarize site-level densities for each species and Table 5-6 provides the mean and ranges in test diameters (TD) by habitat and for the entire sampling effort. Of the five urchin species and 836 individuals encountered, the most abundant were *E. tribuloides* (455 individuals, 54.4% of all urchins) and *E. viridis* (261 individuals, 31.2%), followed by *D. antillarum* (75 individuals, 9.0%), *E. lucunter* (35 individuals, 4.2%), and *T. ventricosus* (10 individuals, 1.2%).

A total of 75 *Diadema antillarum* were recorded, with individuals distributed among all of the habitats sampled, albeit at different densities and sizes (Table 5-1). The maximum site-level density of 0.133 individuals per m<sup>2</sup> was recorded from the back-reef rubble zone at Conch Reef (site 555A). We have noticed since 2001 an increase in the number of sites where *D. antillarum* is found and a trend towards larger test sizes, especially on patch reefs. Figures 5-2 to 5-4 illustrate the spatial distribution of *D. antillarum* densities throughout the upper Florida Keys study area. Proportional station frequencies and habitat-level mean ( $\pm 1$  SE) densities were greatest in back-reef rubble zones (25%  $\pm$  10% of transects,  $0.029 \pm 0.014$  individuals per m<sup>2</sup>) and offshore patch reefs (21%  $\pm$  6% of transects,  $0.020 \pm 0.007$  per m<sup>2</sup>),

followed by high-relief spur and groove ( $13\% \pm 4\%$  of transects,  $0.010 \pm 0.004$  per  $m^2$ ) (Table 5-1). Among all habitats sampled, densities tended to be lower in no-take zones compared to reference areas, a trend evident since 2007 (Figures 5-5 and 5-6). On deeper (7-15 m) fore-reef habitats, *D. antillarum* continues to be absent at most locations (Figure 5-6). *D. antillarum* test sizes ranged from 0.4 to 10.0 cm and averaged  $4.1 \pm 0.3$  cm; this is slightly smaller than the mean size found Keyswide in 2009, at least partly due to the inclusion of back-reef rubble sites in 2010. The size range (0.6-2.5 cm) and mean test diameter in rubble zones ( $1.5 \pm 0.1$  cm) indicates the predominance of recently settled recruits in this habitat. If the back-reef rubble sites are excluded, the mean size for all other habitats was  $5.1 \pm 0.4$  cm, which is slightly greater than the 2009 average,  $\sim 1.5$  cm larger on average than the  $3.6 \pm 0.1$  cm documented in 2007 (Table 5-6), and over 3 cm greater than that reported in 1999-2001 (Chiappone et al. 2002a,b). The test sizes of the individuals in 2010 indicate a mixed distribution, with not only abundant recruits (35% of individuals), but also a large proportion (39%) of individuals greater than 5.0 cm TD (Figure 5-7). Patch reefs and shallow hard-bottom sites yielded the largest average size and maximum size, while back reef rubble sites and the deeper fore-reef yielded the lowest average test diameter (Figure 5-7, Table 5-6).

Two species of *Echinometra* were encountered during the 2010 surveys. *E. lucunter* was the less abundant of the two species (35 individuals) and was found among all habitats except shallow ( $< 6$  m) hard-bottom and the deeper (6-15 m) fore-reef (Table 5-2). Back-reef rubble sites yielded 69% of all individuals, with the balance recorded from patch reefs and high-relief spur and groove. *E. lucunter* test sizes ranged from 0.7 to 3.0 cm and averaged  $1.4 \pm 0.1$  cm. The size range (0.7-2.5 cm) and mean test diameter in rubble zones ( $1.1 \pm 0.1$  cm) indicates the predominance of recently settled recruits in this habitat (Table 5-6). Mean and maximum test diameters were greater on mid-channel and offshore patch reefs compared to rubble and high-relief spur and groove habitats.

*Echinometra viridis* was widely distributed among the habitats sampled, but exhibited habitat-specific patterns of abundance as documented in previous years (Table 5-3). *E. viridis* was especially abundant on mid-channel patch reefs, with 191 (73%) of the 261 individuals recorded from this habitat. Densities were especially high ( $> 1$  individual per  $m^2$ ) on patch reefs in the Basin Hill Shoals area west of Carysfort Reef (Table 5-3). Figures 5-8 to 5-10 illustrate the spatial distribution of *E. viridis* densities throughout the upper Florida Keys study area and clearly demonstrate relatively high densities on inshore and mid-channel patch reefs. A mean ( $\pm 1$  SE) habitat-level density of  $0.152 \pm 0.081$  individuals per  $m^2$  was recorded from mid-channel patch reefs, which was at least one order of magnitude greater than the other sampled habitats. Site-level densities of *E. viridis* were as high as 1.333 individuals per  $m^2$  (Figure 5-11

and 5-12). The test diameter (TD) of individuals ranged from 0.3 cm to 5.0 cm and averaged  $2.6 \pm 0.1$  cm among the 120 sites (Table 5-6). The combined size distribution indicated a modal size class of 2.0-2.9 cm. Inshore and mid-channel patch reefs yielded the largest average and maximum sizes compared to other habitats (Table 5-6 and Figure 5-13).

*Eucidaris tribuloides* was recorded from all habitats sampled, exhibited a habitat distribution pattern similar to historical surveys during 1999-2009 (Table 5-4), and was the most abundant (455 individuals) urchin species surveyed in the upper Keys during 2010. The greatest site-level density estimate of  $1.167 \pm 0.362$  individuals/m<sup>2</sup> was recorded from a back reef rubble site at Pickles Reef (site 688B) (Table 5-4). Figures 5-14 to 5-16 illustrate the spatial distribution of *E. tribuloides* densities throughout the upper Florida Keys study area. Back-reef rubble zones ( $56\% \pm 12\%$  of transects,  $0.258 \pm 0.110$  individuals per m<sup>2</sup>) and shallow (< 6 m) hard-bottom sites ( $71\% \pm 10\%$  of transects,  $0.115 \pm 0.032$  individuals per m<sup>2</sup>) yielded the greatest transect frequencies and densities (Table 5-4, Figures 5-17 and 5-18), followed by offshore patch reefs and high-relief spur and groove. For the 455 individuals encountered, test diameters ranged from 0.5 cm to 4.5 cm, averaged 2.1 cm (Table 5-6), and showed two modal size classes below 3.0 cm (Figure 5-19). A slightly larger average size was recorded from patch reefs compared to other habitats, especially back-reef rubble zones where recently settled juveniles predominated (Table 5-6 and Figure 5-19).

*Tripneustes ventricosus* was the least abundant urchin encountered in 2010, which is expected since the sampling effort did not include seagrass habitats. A total of 10 individuals were recorded from the 120 upper Keys sites, with a maximum site-level density of  $0.067 \pm 0.067$  individuals per m<sup>2</sup> recorded from a mid-channel patch reef (site A74) west of Conch Reef (Table 5-5). *T. ventricosus* was found in all habitats except shallow (< 6 m) hard-bottom, but was most commonly observed on mid-channel and offshore patch reefs. The size range of the 10 individuals sampled ranged from 2 to 10 cm, with a mean size of  $7.4 \pm 0.8$  cm. Larger individuals were found on patch reefs compared to other habitats.

## Discussion

Large-scale surveys encompassing hundreds of sites in the Florida Keys since 1999 indicate that the *Diadema antillarum* population continues to persist at densities well below values reported before the Caribbean-wide mass mortality in 1983-84 and the Florida Keys mortality event in 1991 (Kier and Grant 1965; Bauer 1980; Forcucci 1994). Despite this pattern, the Florida Keys population continues to exhibit an increase in the proportion of sites with *D. antillarum* present, as well as an increase in mean test size, with a greater proportion of larger individuals present. In addition, recruitment continues to occur

predominately in back-reef rubble zones. Earlier reports and recent observations indicate that other urchin species show density and habitat distribution patterns similar to pre-1983 observations, indicating that other urchin species have apparently not compensated for the loss of *D. antillarum* (Chiappone et al. 2002a). In areas with relatively high ( $> 0.1$  individuals/m<sup>2</sup>) and larger ( $> 5$  cm TD) *D. antillarum*, there are obvious effects of grazing on the substratum, particularly the removal of turf and macroalgae and exposure of the substratum (Chiappone et al. 2001). It remains unclear whether or not increasing urchin densities and sizes will lead to other changes to the benthos such as increased coral or urchin recruitment.

The slow and prolonged recovery of *Diadema antillarum* in the Florida Keys, especially compared to several recent studies in other Caribbean reef areas, raises several questions pertaining to factors that may inhibit recovery (Lessios 1988). Possible causes of slow recovery include poor larval survivorship, lack of adult conspecifics and hence protection from predators, suitable recruitment sites, and inter-specific competition. The sources of urchin larvae to the south Florida shelf are not known, but may include both local and regional sources (Lee et al. 1994). Nonetheless, it is apparent that *D. antillarum* have continually recruited to benthic habitats, especially rubble zones, but the fate of these recently settled juveniles is unknown (Chiappone et al. 2002a). A recent study of *D. antillarum* larval settlement rates in the Florida Keys, however, indicate that low larval supply may be one factor limiting recovery (Miller et al. in press). The predominance of relatively small test sizes from 1999-2005 indicated that recently settled individuals may have poor survivorship into larger size classes, perhaps due to predation or physical disturbance from storms. However, since 2005, there has been a notable shift in the size distribution towards larger individuals in the population. Because *D. antillarum* was historically significant as a grazer, it is anticipated that continued recovery will influence patterns in benthic community structure throughout the Florida Keys.

Figure 5-1. Urchin species surveyed for density and size (test diameter) in the Florida Keys during 2010. Not shown is *Lytechinus variegatus* (variegated urchin).

*Diadema antillarum*



Juvenile *Diadema antillarum*



*Echinometra lucunter*



*Echinometra viridis*



*Eucidaris tribuloides*



*Tripneustes ventricosus*



Figure 5-2. Densities (no. per m<sup>2</sup>) of long-spined sea urchins (*Diadema antillarum*) in the upper Florida Keys National Marine Sanctuary from the southern BNP boundary to Carysfort/S. Carysfort SPA.

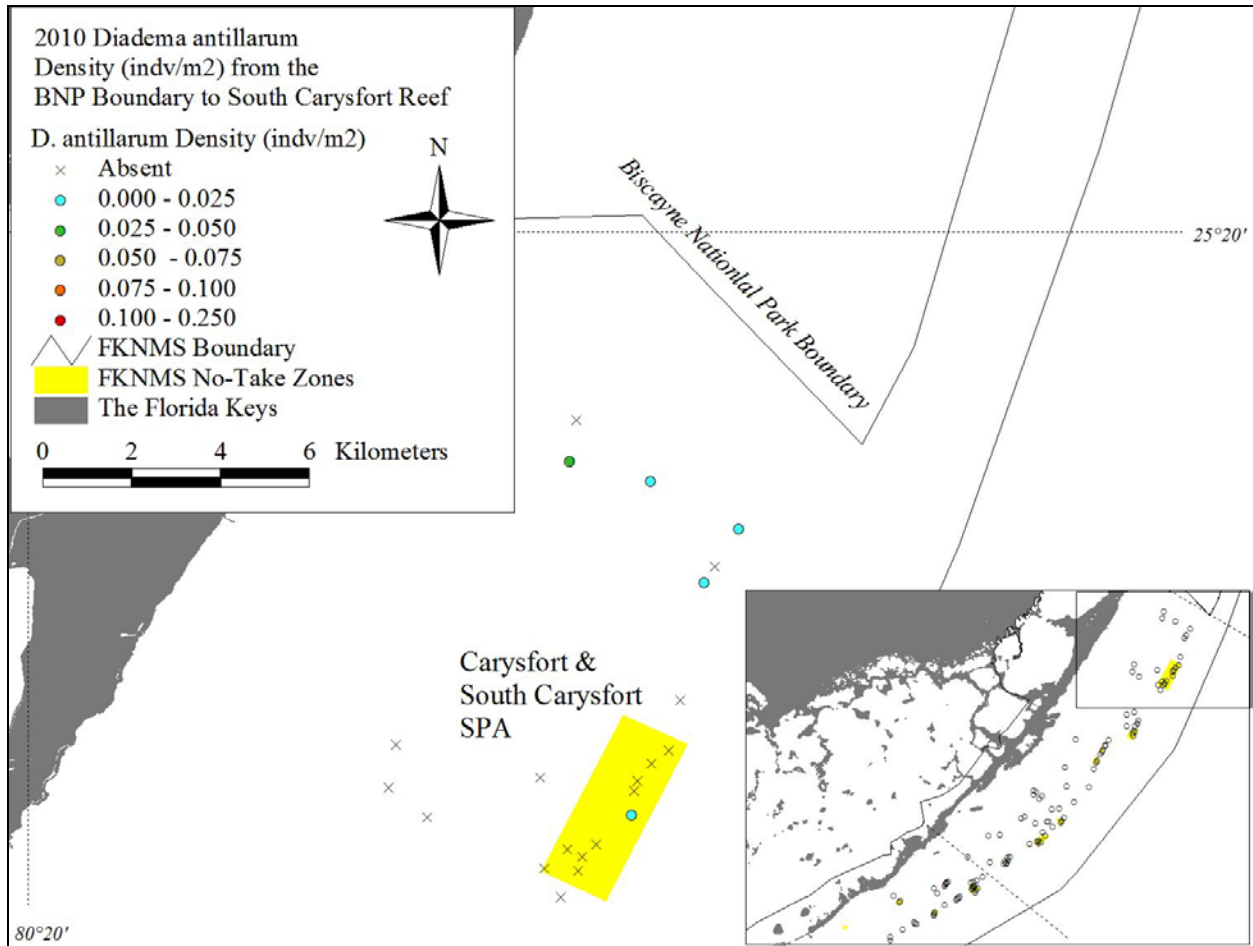




Figure 5-3. Densities (no. per m<sup>2</sup>) of long-spined sea urchins (*Diadema antillarum*) in the upper Florida Keys National Marine Sanctuary from Elbow Reef to Pickles Reef surveyed during June-August 2010.

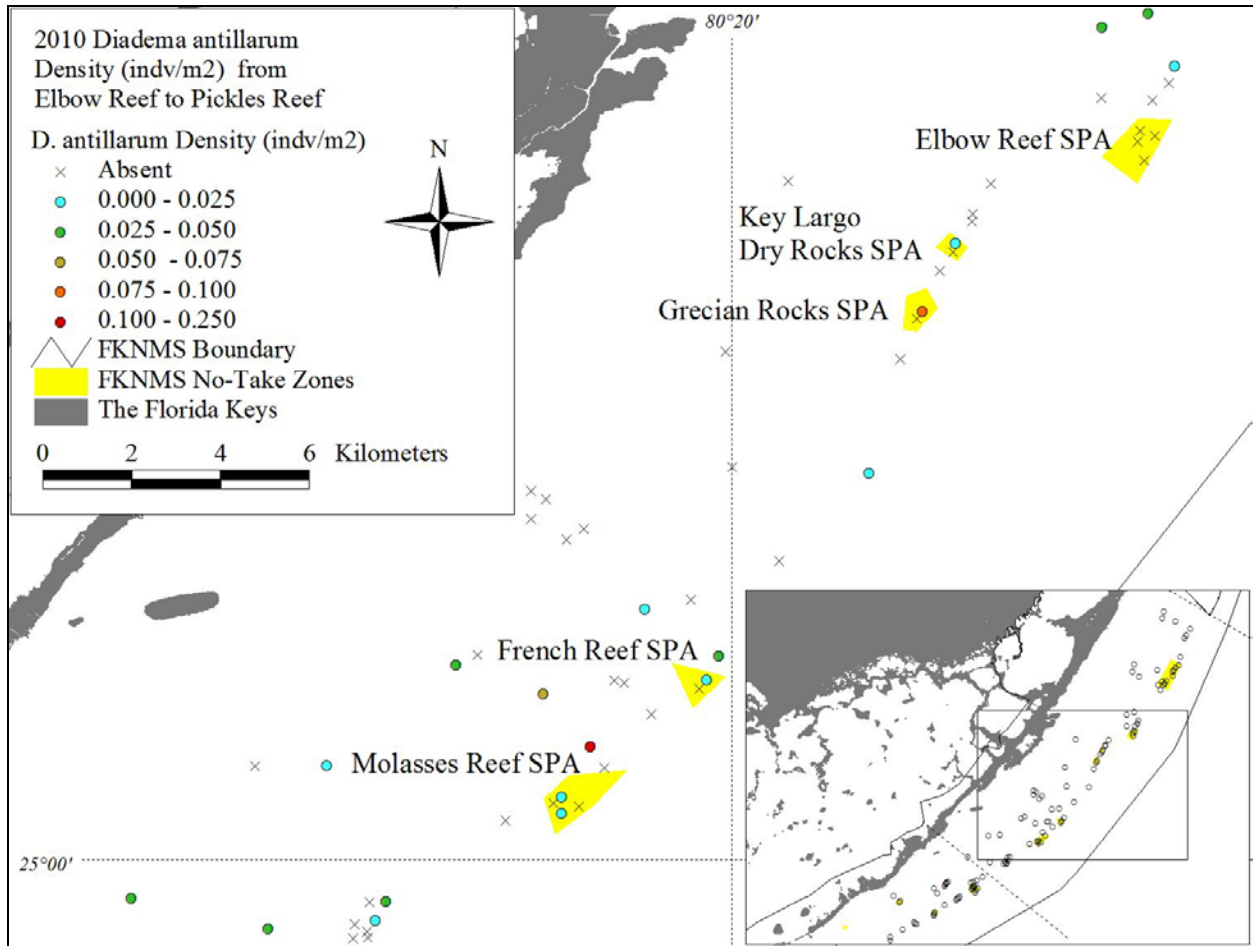




Figure 5-4. Densities (no. per m<sup>2</sup>) of long-spined sea urchins (*Diadema antillarum*) in the upper Florida Keys National Marine Sanctuary from Conch Reef SPA to Crocker Reef surveyed during June-August 2010.

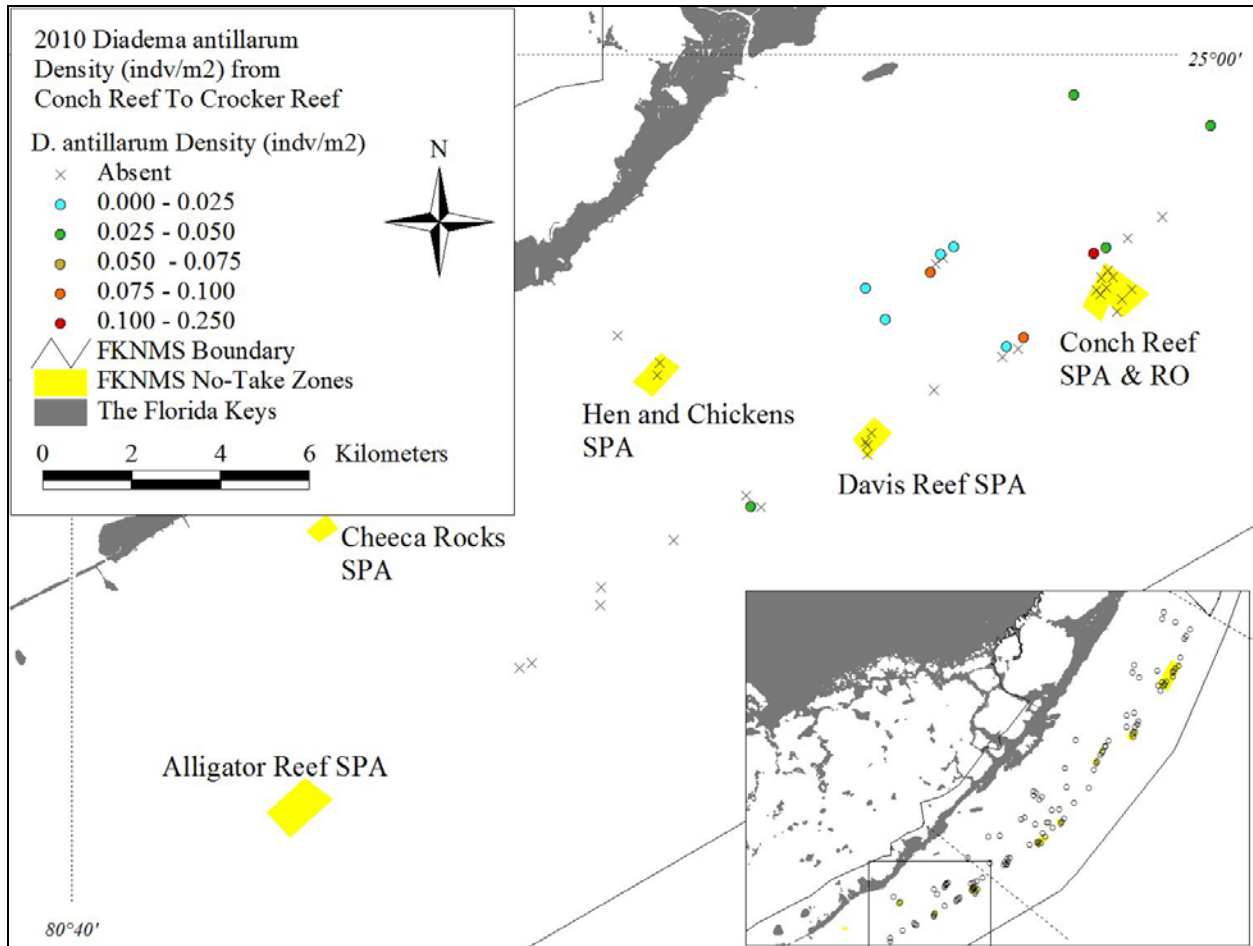


Figure 5-5. Mean (+ 1 SE) densities (no. per m<sup>2</sup>) of long-spined sea urchins (*Diadema antillarum*) on inshore and mid-channel patch reefs (top), offshore patch reefs (middle), and back reef rubble habitats (bottom) in the upper Florida Keys during June-August 2010. Open bars = FKNMS no-take zones; filled bars = reference areas.

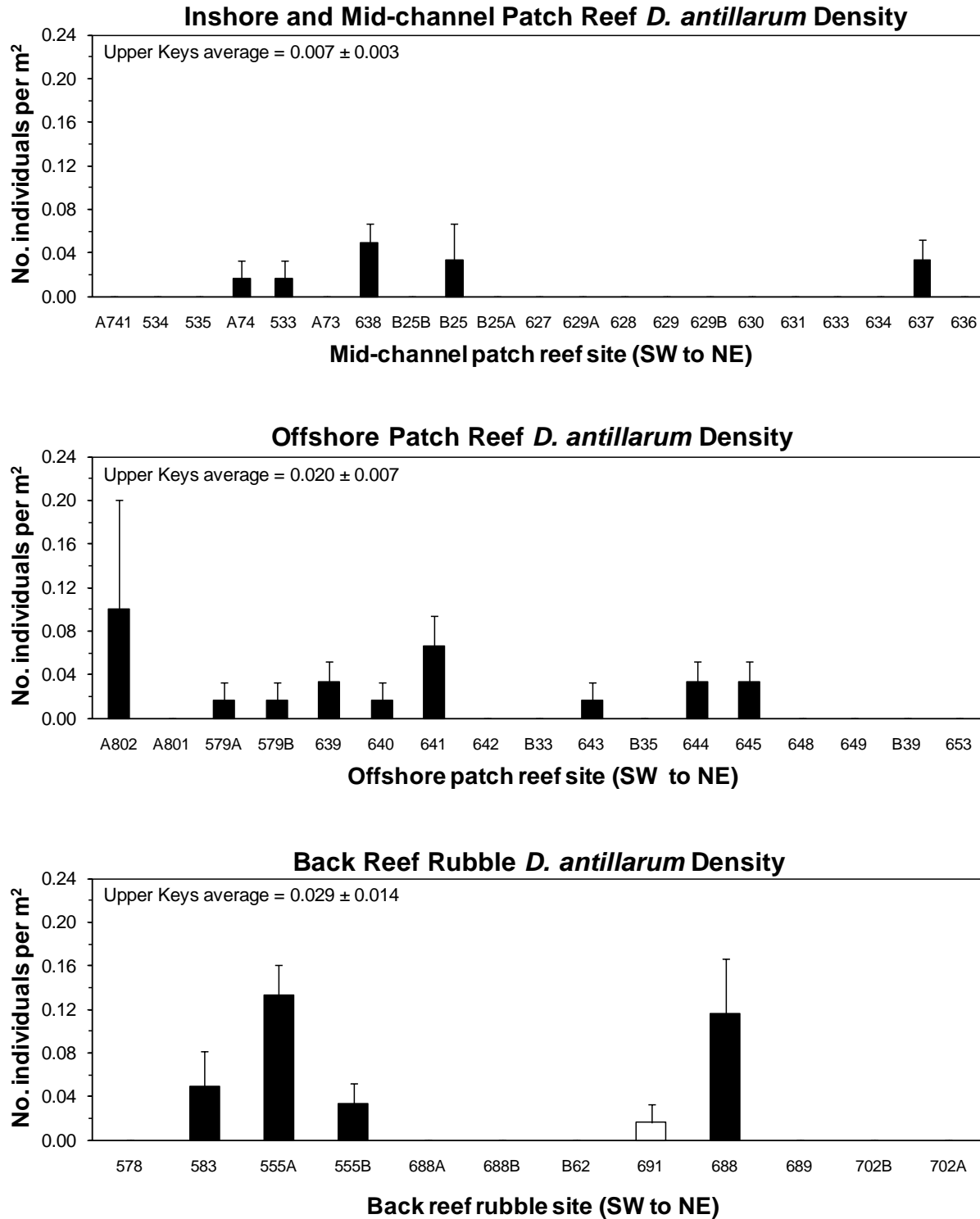


Figure 5-6. Mean (+ 1 SE) densities (no. per m<sup>2</sup>) of long-spined sea urchins (*Diadema antillarum*) on shallow (< 6 m) hard-bottom (top), high-relief spur and groove reefs (middle) and deeper (6-15 m) fore reef habitats (bottom) in the upper Florida Keys during June-August 2010. Open bars = FKNMS no-take zones; filled bars = reference areas.

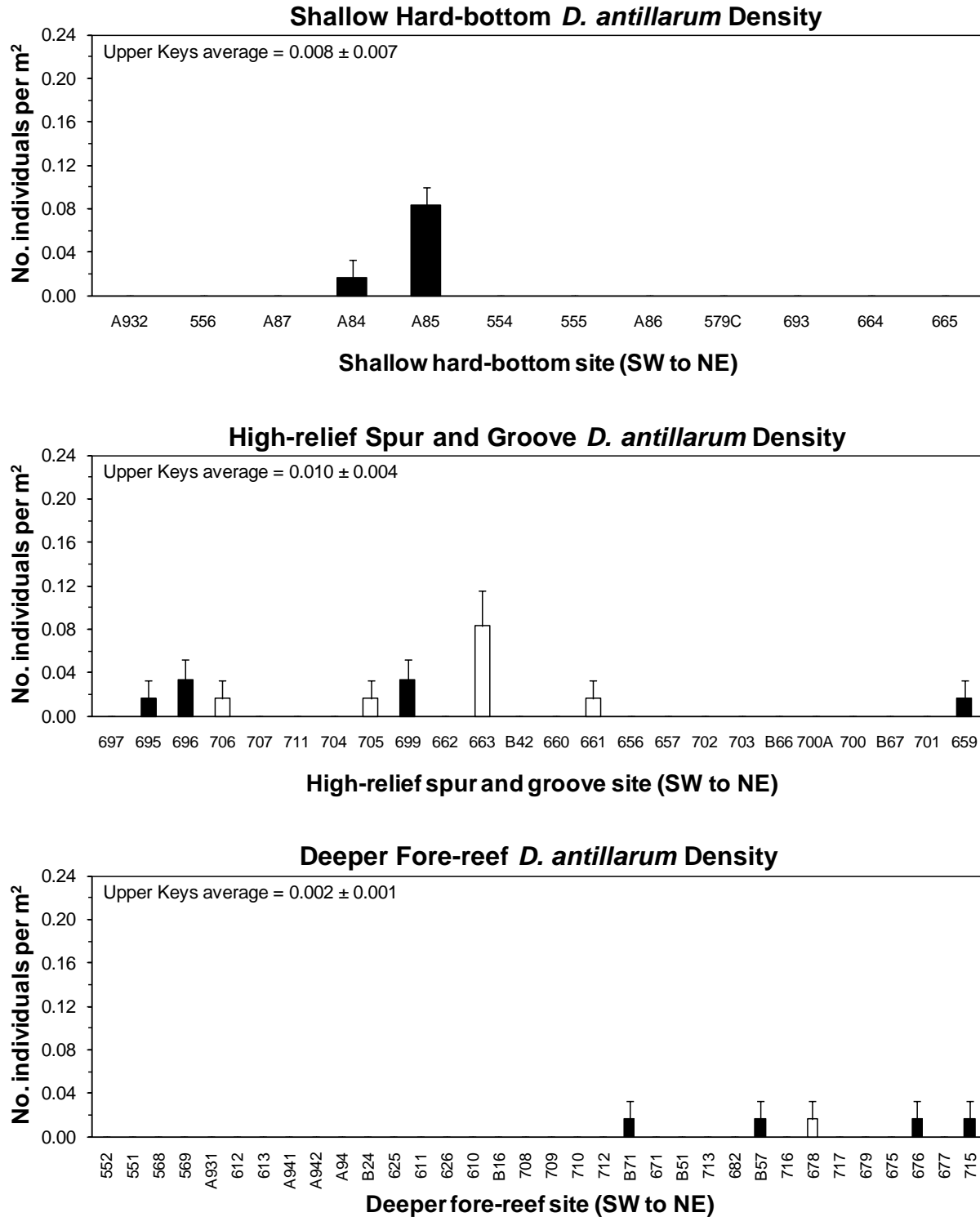


Figure 5-7. Distribution of urchin test diameter sizes (top) and mean ( $\pm 1$  SE) (filled circles) and maximum sizes (open circles) across habitats (bottom) for *Diadema antillarum* in the upper Florida Keys National Marine Sanctuary, as determined from surveys at 120 sites during June-August 2010. Habitat abbreviations in the bottom figure are: MPR = inshore and mid-channel patch reefs, OPR = offshore patch reefs, BRR = back reef rubble, SHB = shallow (< 6 m) hard-bottom, HSG = high-relief and groove, and DFR = deeper (6-15 m) fore-reef habitats.

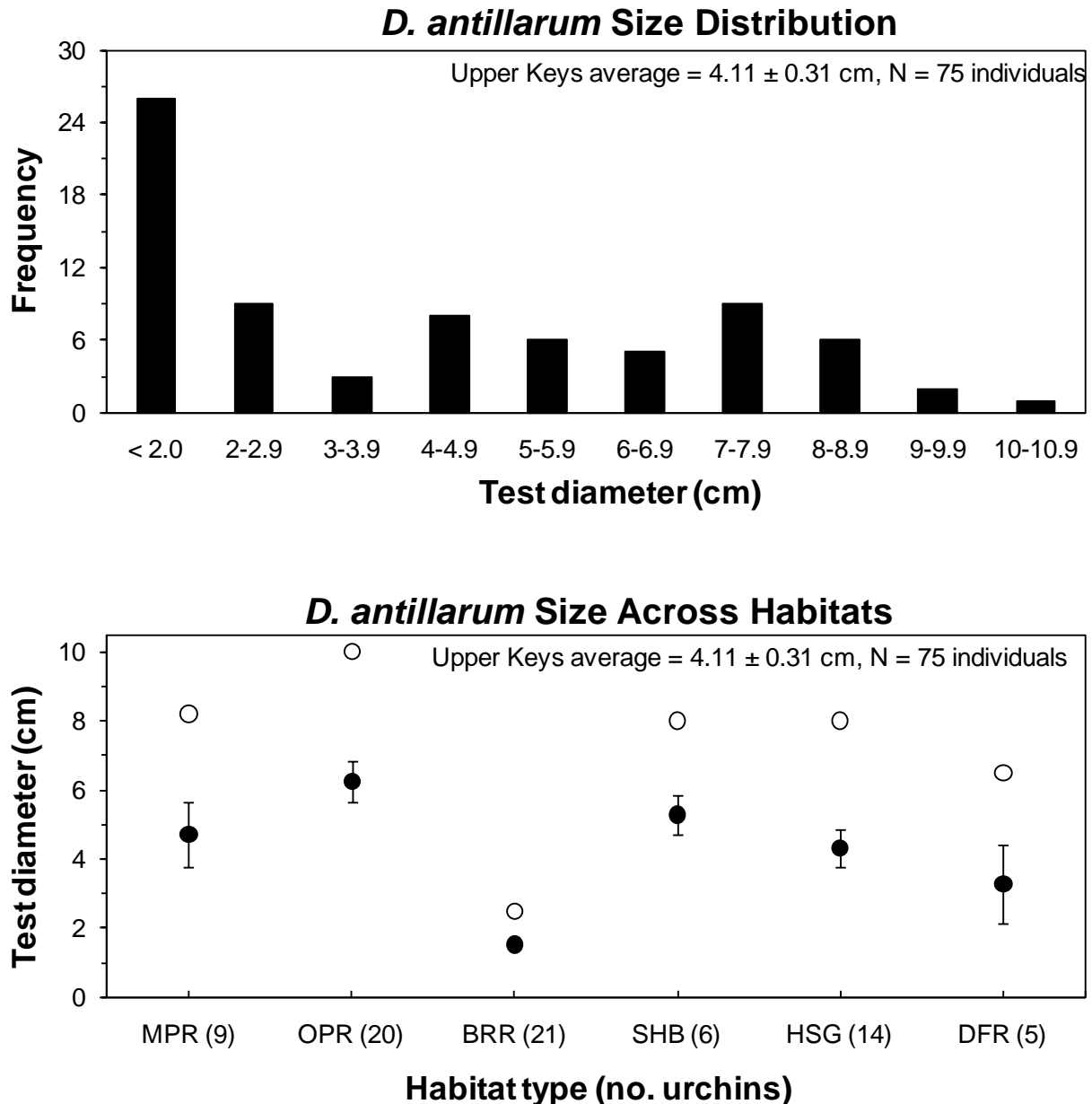


Figure 5-8. Densities (no. per m<sup>2</sup>) of green rock-boring urchins (*Echinometra viridis*) in the upper Florida Keys National Marine Sanctuary from the southern BNP boundary to Carysfort/S. Carysfort SPA surveyed during June-August 2010.

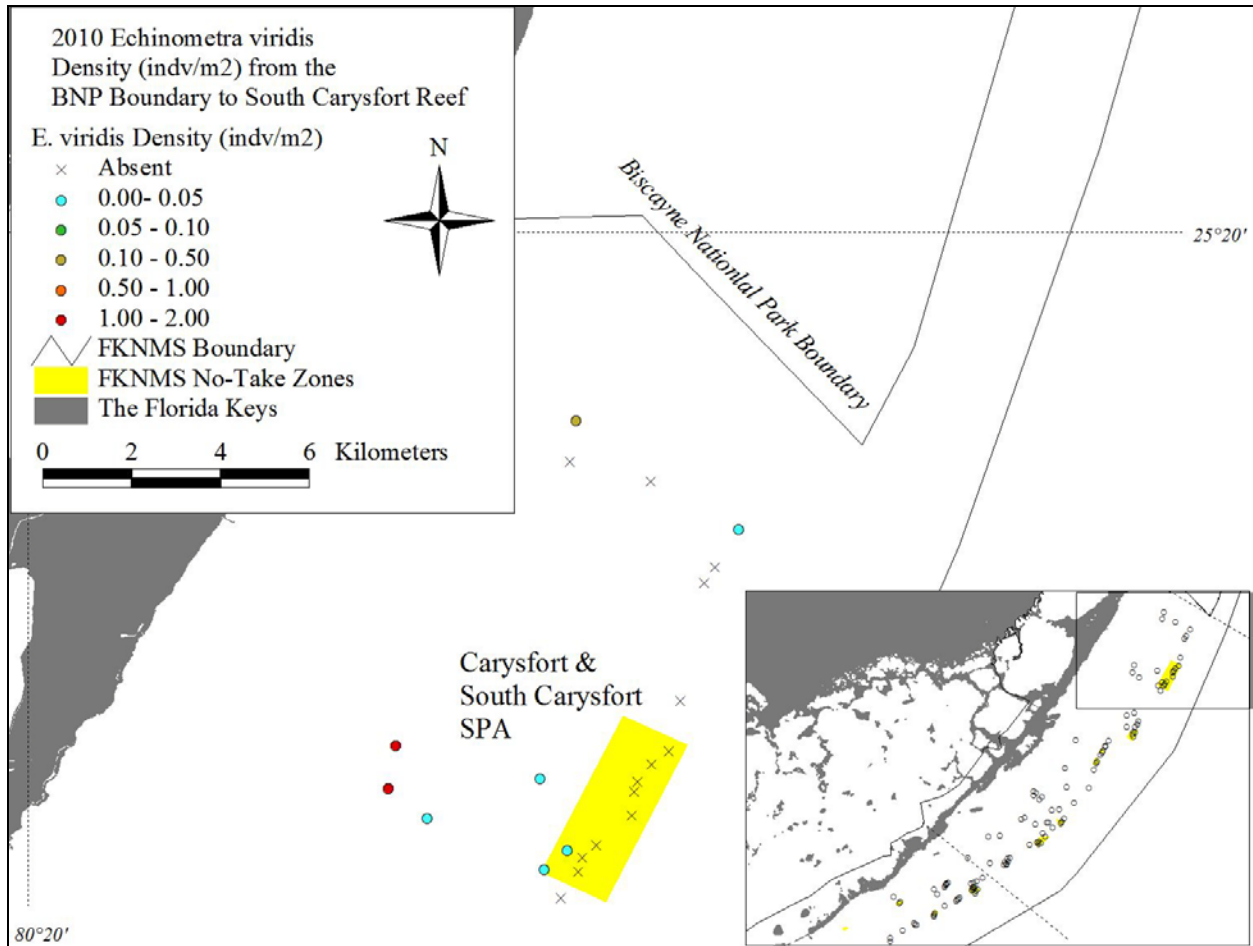


Figure 5-9. Densities (no. per m<sup>2</sup>) of green rock-boring urchins (*Echinometra viridis*) in the upper Florida Keys National Marine Sanctuary from Elbow Reef to Pickles Reef (bottom) surveyed during June-August 2010.

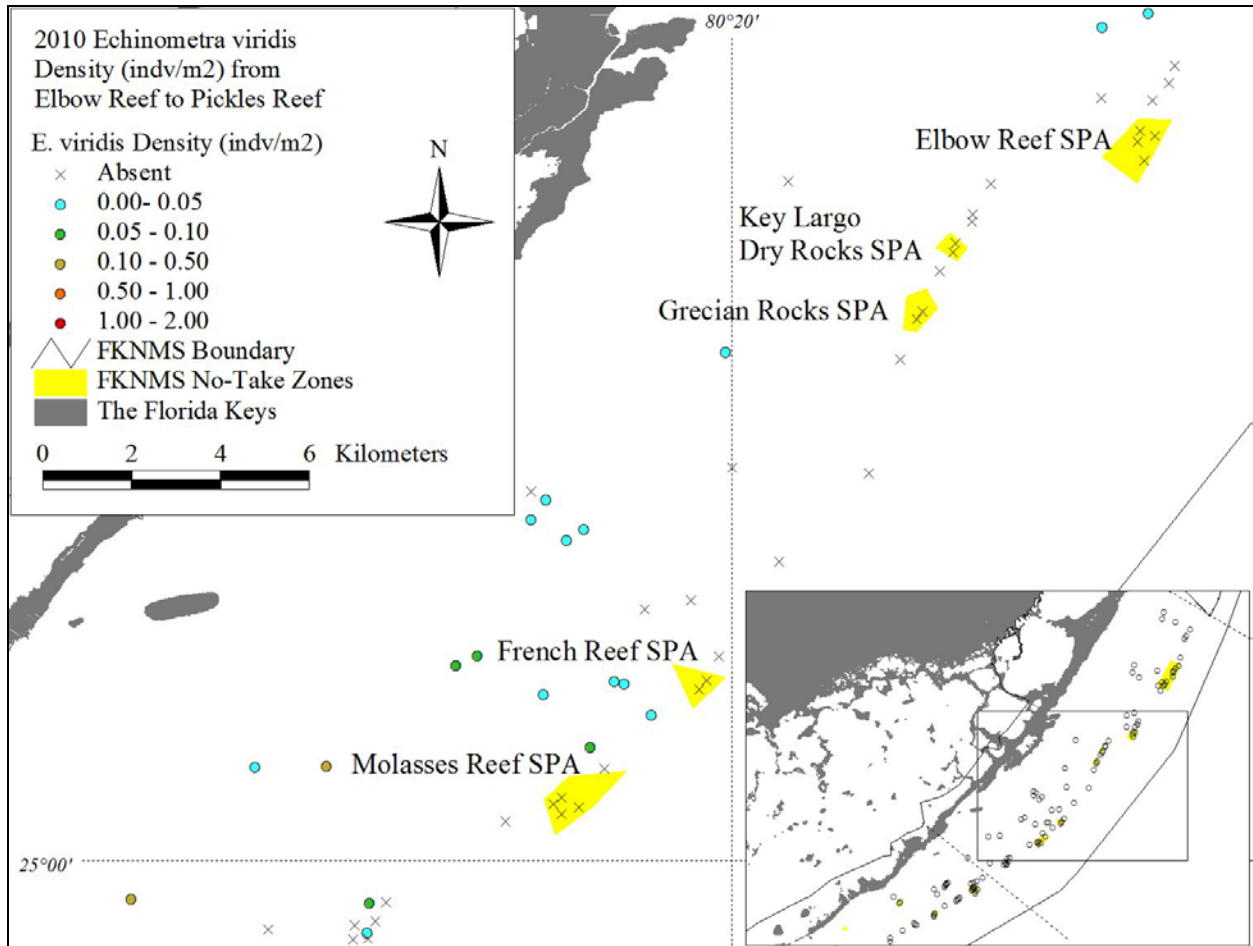


Figure 5-10. Densities (no. per m<sup>2</sup>) of green rock-boring urchins (*Echinometra viridis*) in the upper Florida Keys National Marine Sanctuary from Conch Reef SPA to Crocker Reef surveyed during June-August 2010.

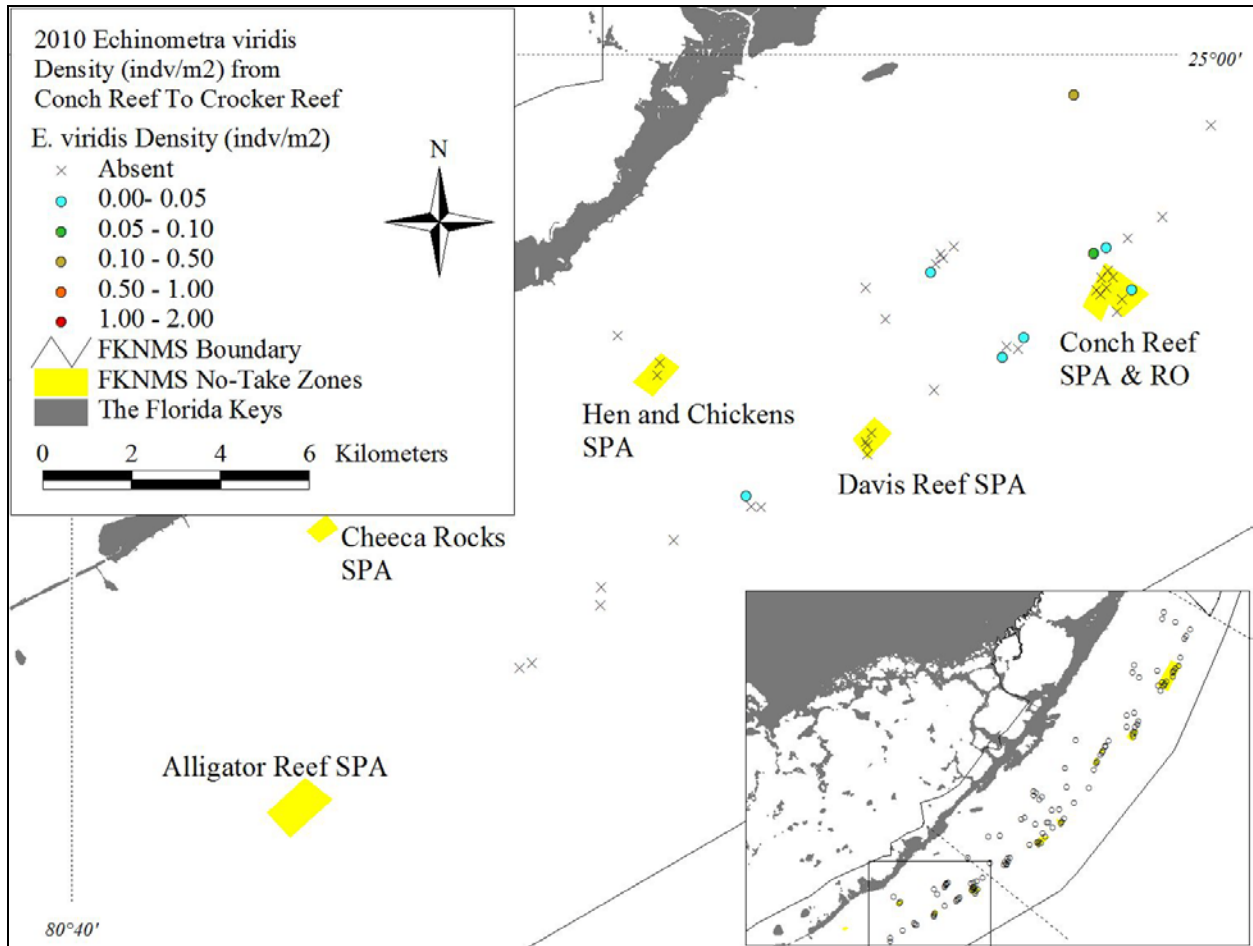




Figure 5-11. Mean (+ 1 SE) densities (no. per m<sup>2</sup>) of green rock-boring urchins (*Echinometra viridis*) on inshore and mid-channel patch reefs (top), offshore patch reefs (middle), and back reef rubble habitats (bottom) in the upper Florida Keys during June-August 2010. Open bars = FKNMS no-take zones; filled bars = reference areas.

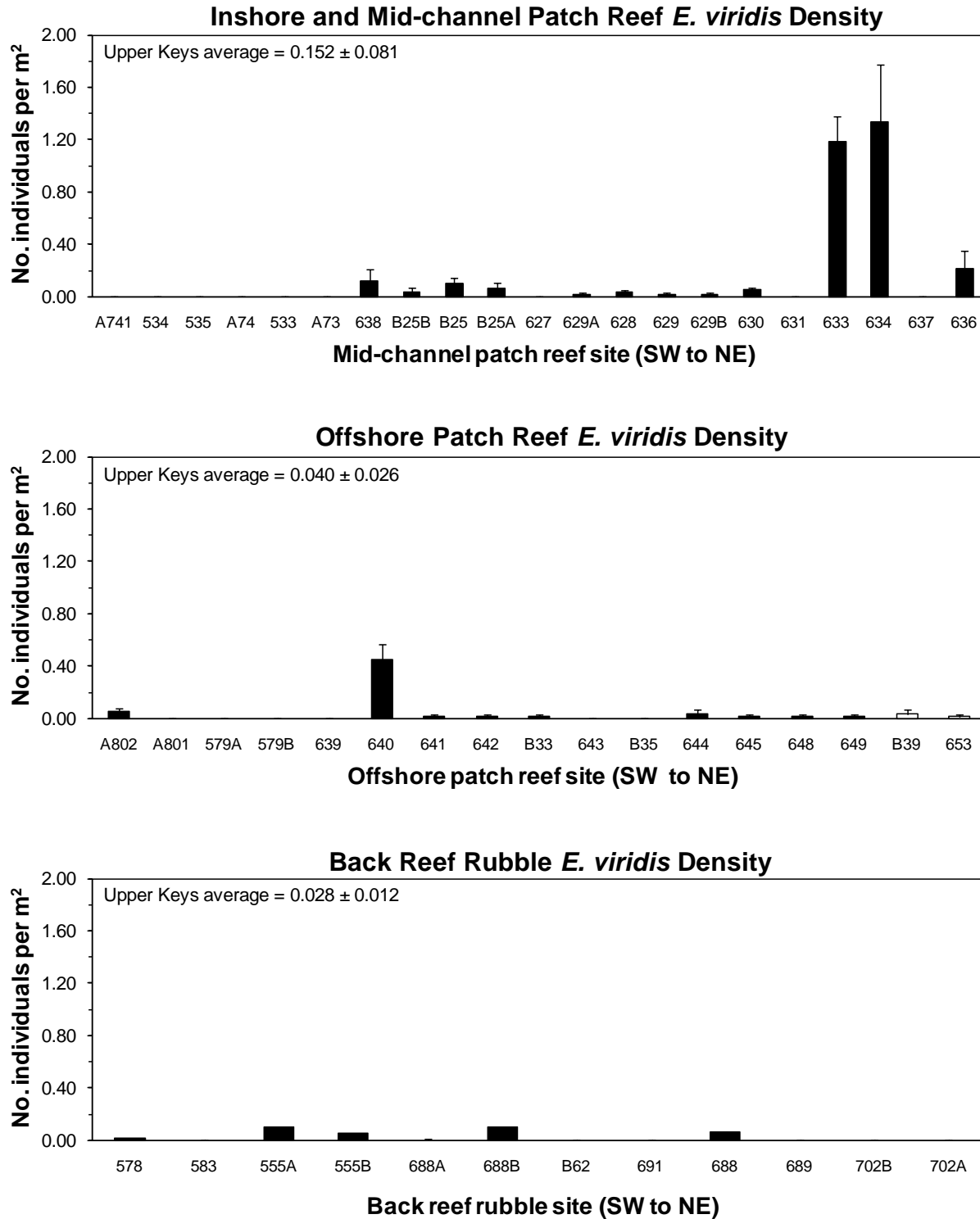


Figure 5-12. Mean (+ 1 SE) densities (no. per m<sup>2</sup>) of green rock-boring urchins (*Echinometra viridis*) on shallow (< 6 m) hard-bottom (top), high-relief spur and groove reefs (middle) and deeper (6-15 m) fore reef habitats (bottom) in the upper Florida Keys during June-August 2010. Open bars = FKNMS no-take zones; filled bars = reference areas.

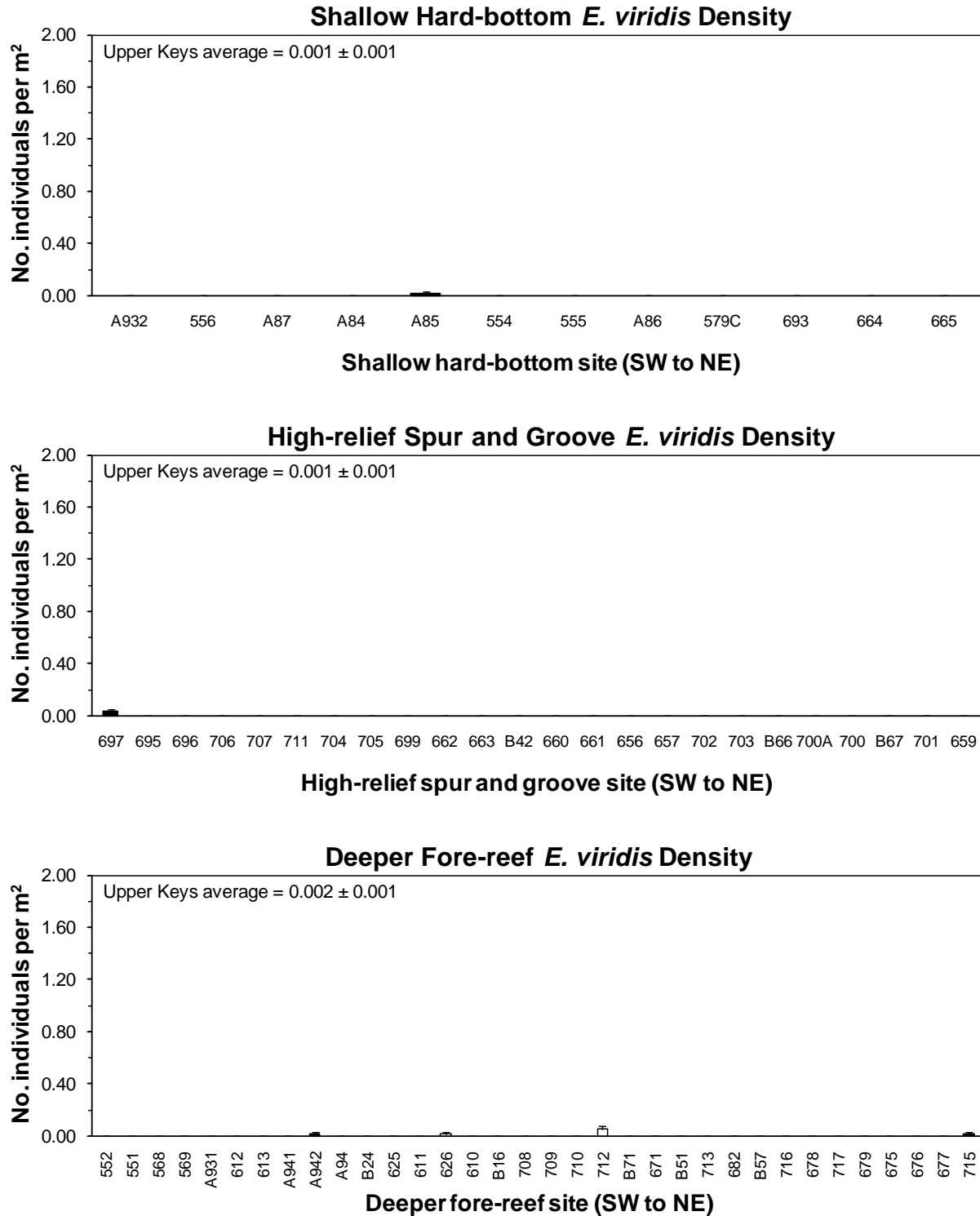


Figure 5-13. Distribution of urchin test diameter sizes (top) and mean ( $\pm 1$  SE) (filled circles) and maximum sizes (open circles) across habitats (bottom) for *Echinometra viridis* in the upper Florida Keys National Marine Sanctuary, as determined from surveys at 120 sites during June-August 2010. Habitat abbreviations in the bottom figure are: MPR = inshore and mid-channel patch reefs, OPR = offshore patch reefs, BRR = back reef rubble, SHB = shallow (< 6 m) hard-bottom, HSG = high-relief and groove, and DFR = deeper (6-15 m) fore-reef habitats.

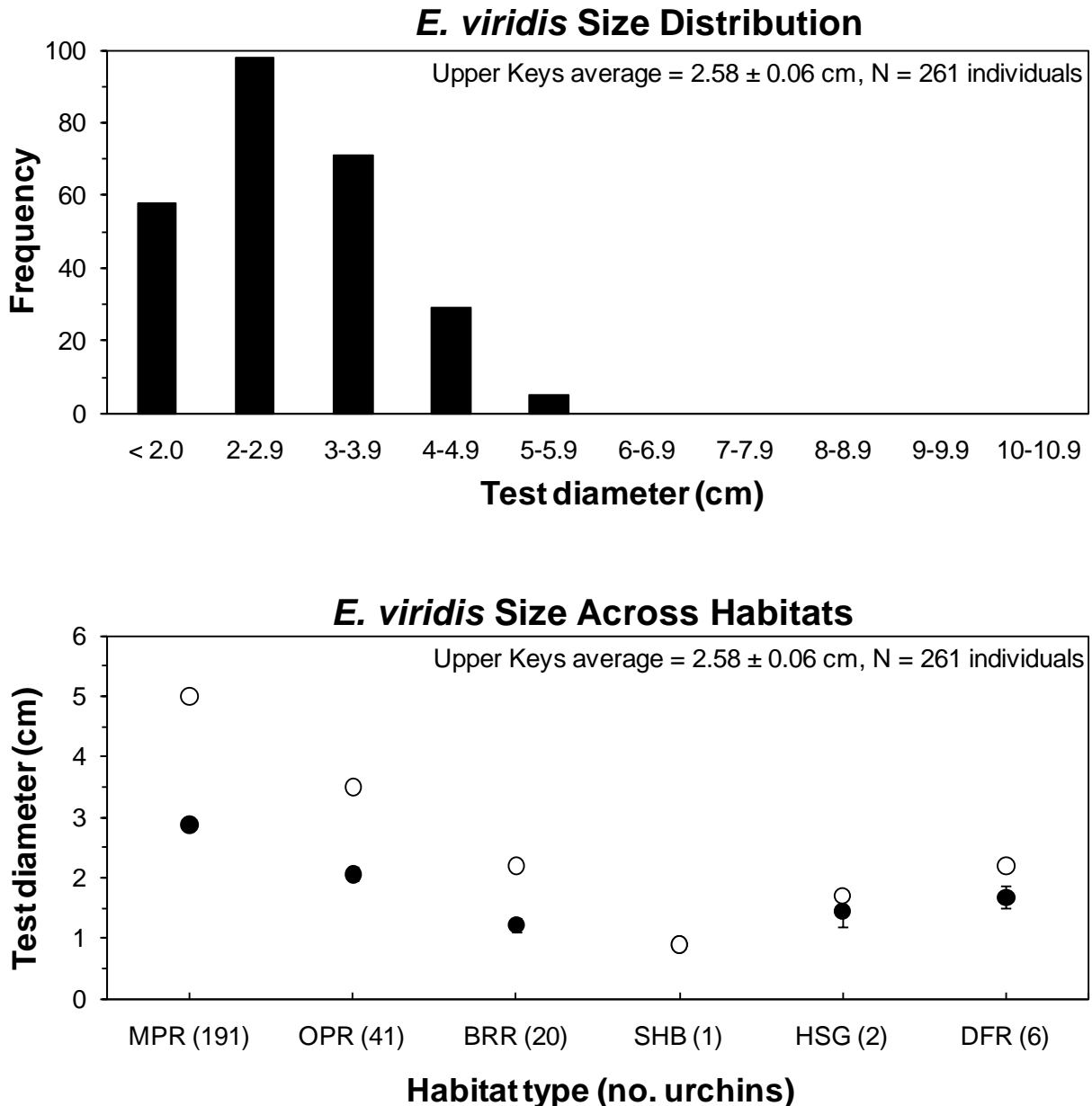


Figure 5-14. Densities (no. per m<sup>2</sup>) of slate pencil urchins (*Eucidaris tribuloides*) in the upper Florida Keys National Marine Sanctuary from the southern BNP boundary to Carysfort/S. Carysfort SPA surveyed during June-August 2010.

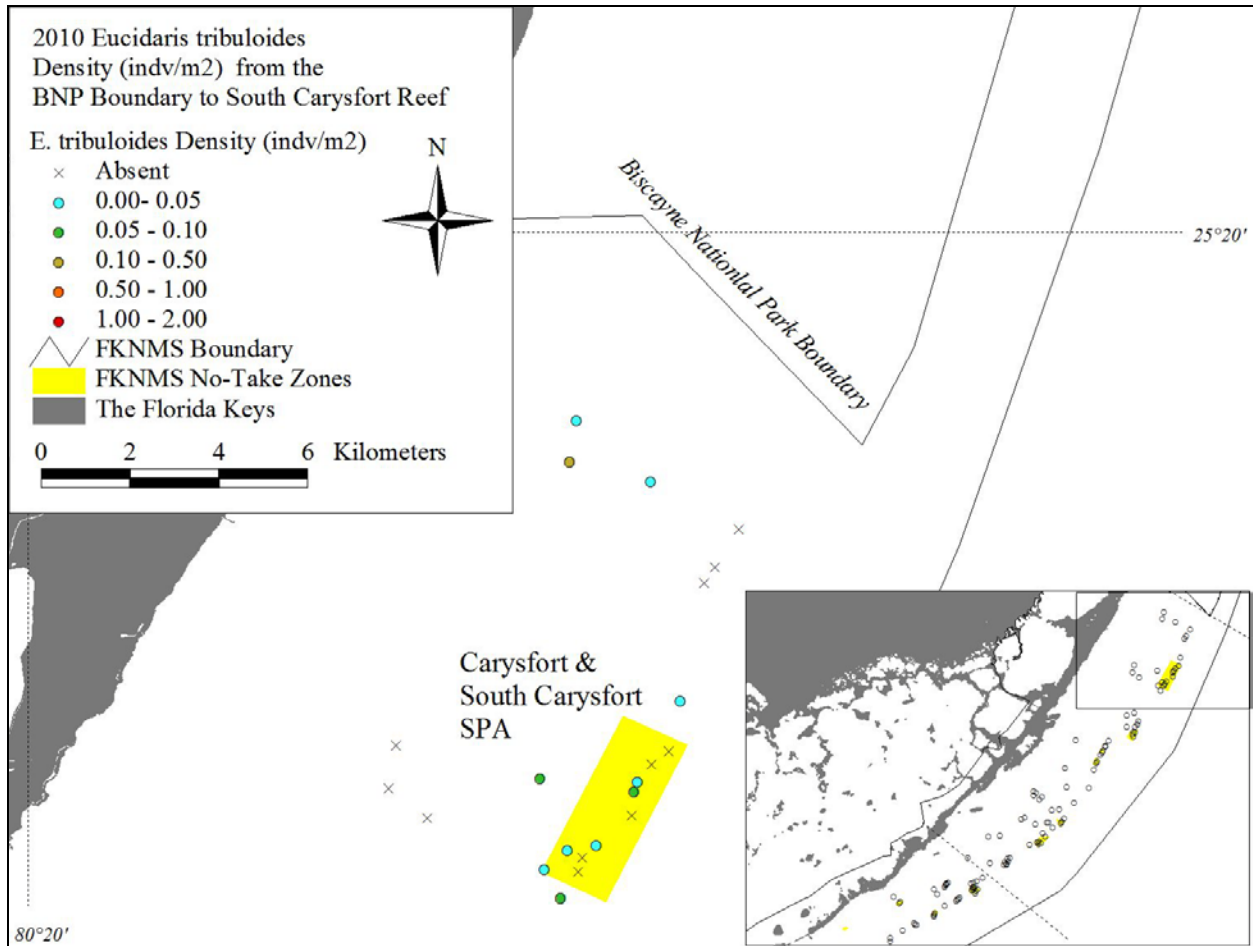


Figure 5-15. Densities (no. per m<sup>2</sup>) of slate pencil urchins (*Eucidaris tribuloides*) in the upper Florida Keys National Marine Sanctuary from Elbow Reef to Pickles Reef (bottom) surveyed during June-August 2010.

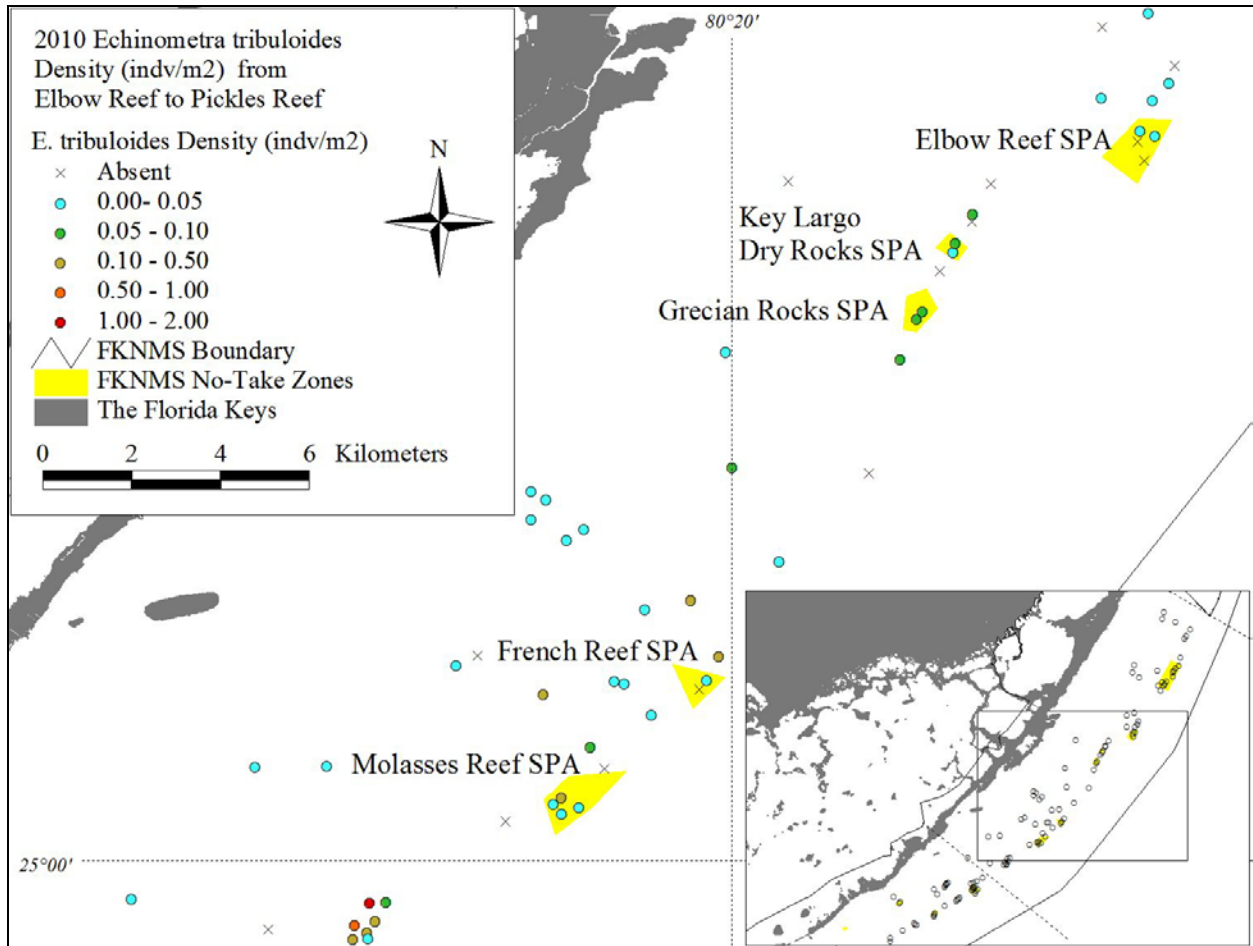


Figure 5-16. Densities (no. per m<sup>2</sup>) of slate pencil urchins (*Eucidaris tribuloides*) in the upper Florida Keys National Marine Sanctuary from Conch Reef SPA to Crocker Reef surveyed during June-August 2010.

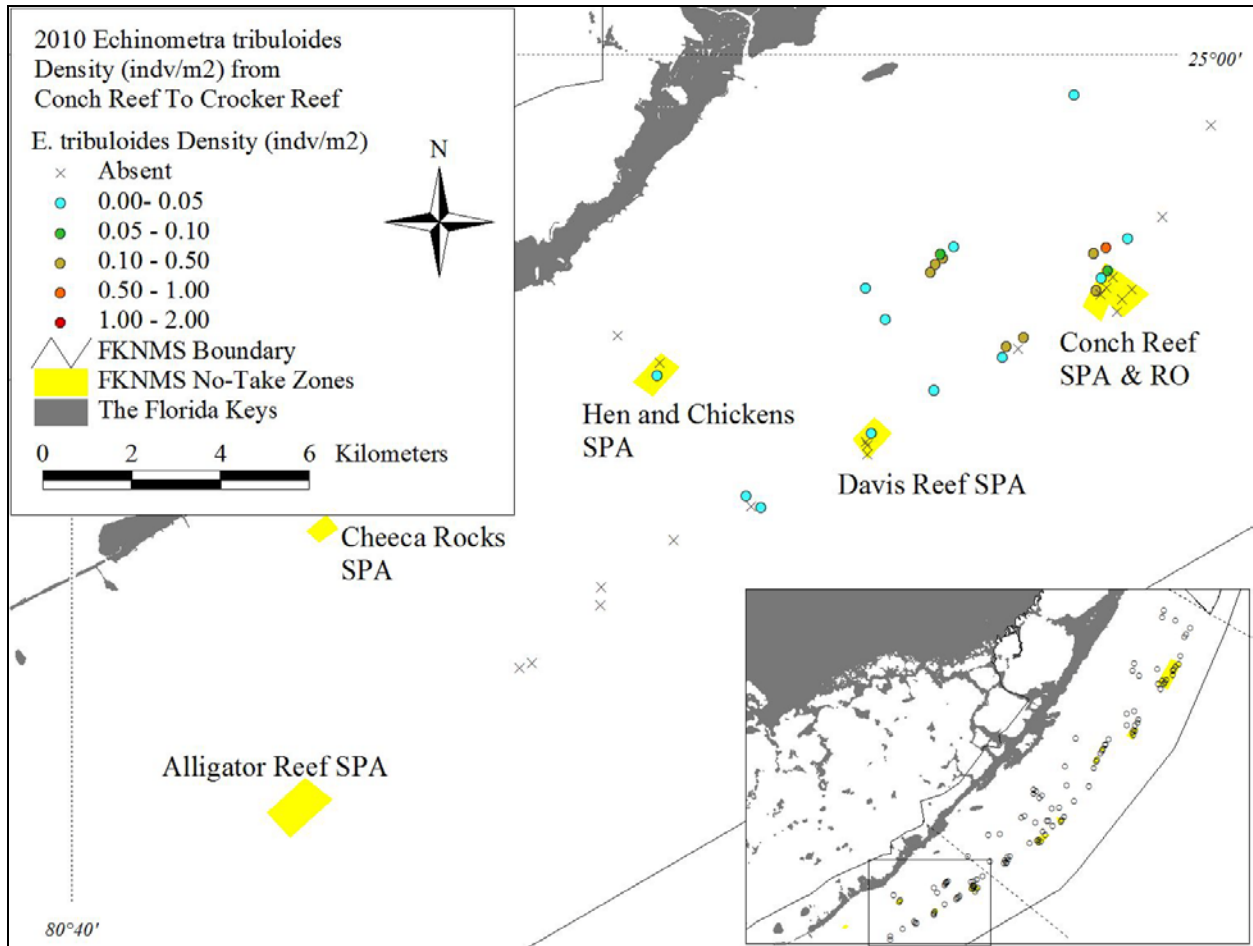


Figure 5-17. Mean ( $\pm 1$  SE) densities (no. per  $\text{m}^2$ ) of slate pencil urchins (*Eucidaris tribuloides*) on inshore and mid-channel patch reefs (top), offshore patch reefs (middle), and back reef rubble habitats (bottom) in the upper Florida Keys during June-August 2010. Open bars = FKNMS no-take zones; filled bars = reference areas.

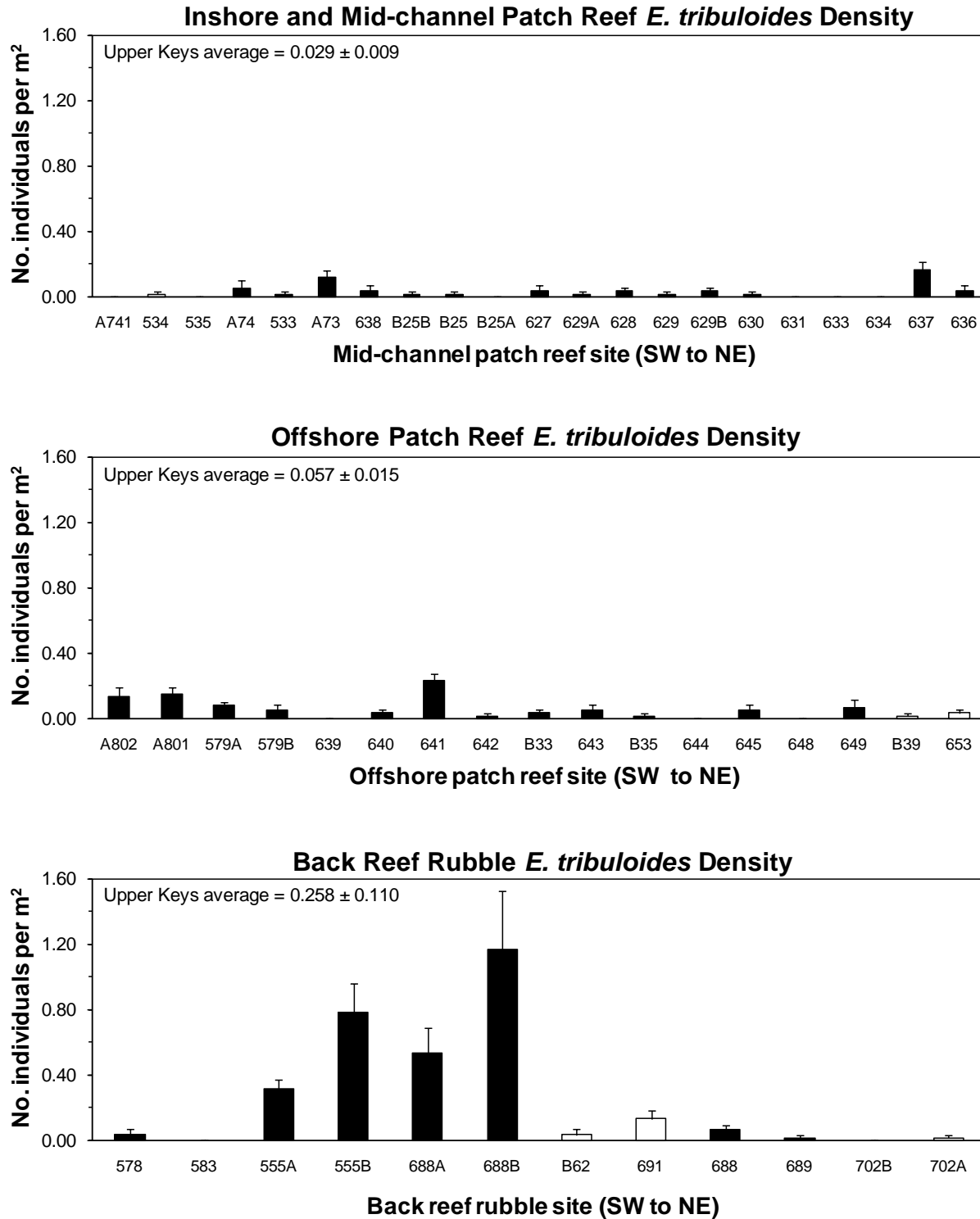




Figure 5-18. Mean (+ 1 SE) densities (no. per m<sup>2</sup>) of slate pencil urchins (*Eucidaris tribuloides*) on shallow (< 6 m) hard-bottom (top), high-relief spur and groove reefs (middle) and deeper (6-15 m) fore reef habitats (bottom) in the upper Florida Keys during June-August 2010. Open bars = FKNMS no-take zones; filled bars = reference areas.

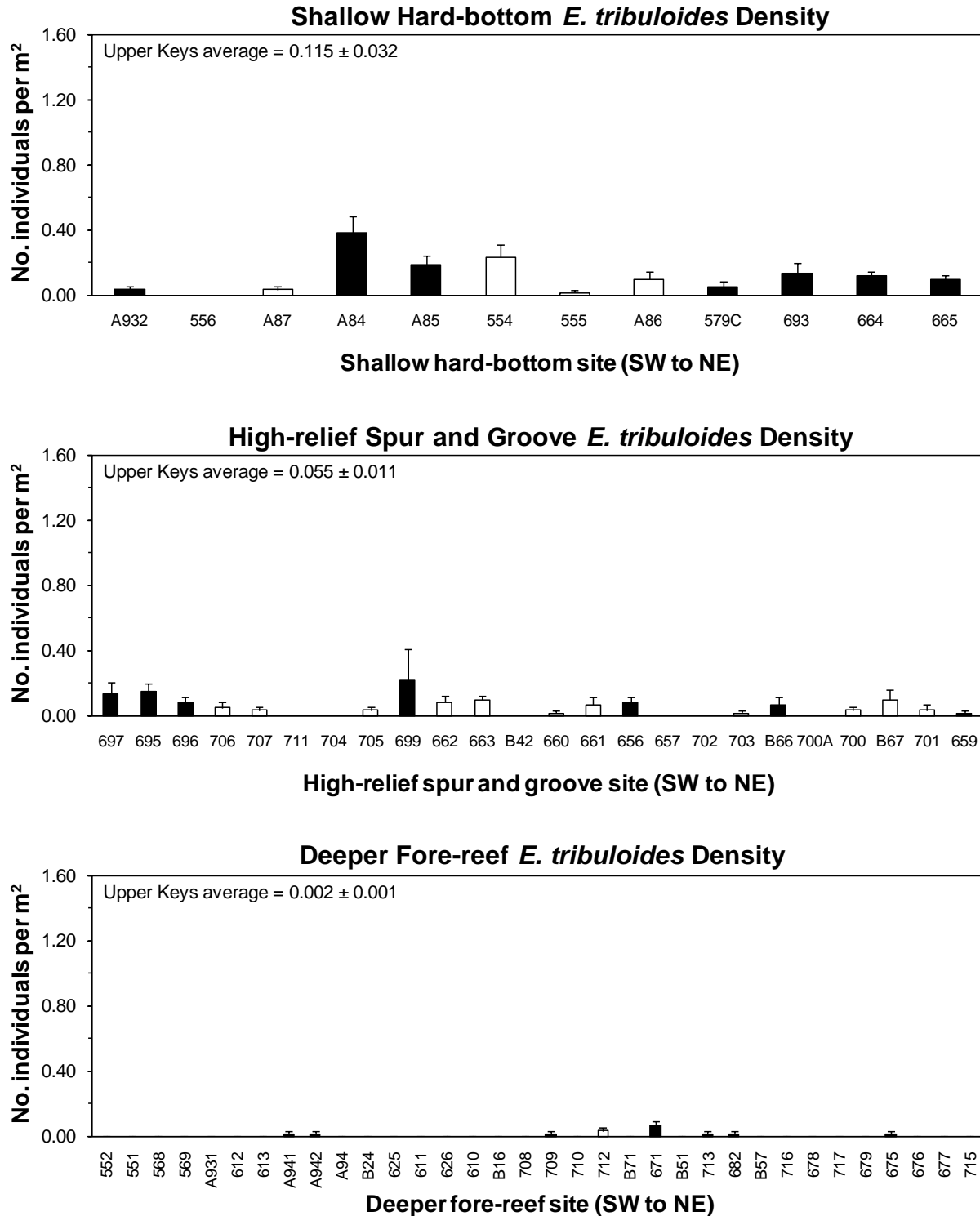


Figure 5-19. Distribution of urchin test diameter sizes (top) and mean ( $\pm 1$  SE) (filled circles) and maximum sizes (open circles) across habitats (bottom) for *Eucidaris tribuloides* in the upper Florida Keys National Marine Sanctuary, as determined from surveys at 120 sites during June-August 2010. Habitat abbreviations in the bottom figure are: MPR = inshore and mid-channel patch reefs, OPR = offshore patch reefs, BRR = back reef rubble, SHB = shallow (< 6 m) hard-bottom, HSG = high-relief and groove, and DFR = deeper (6-15 m) fore-reef habitats.

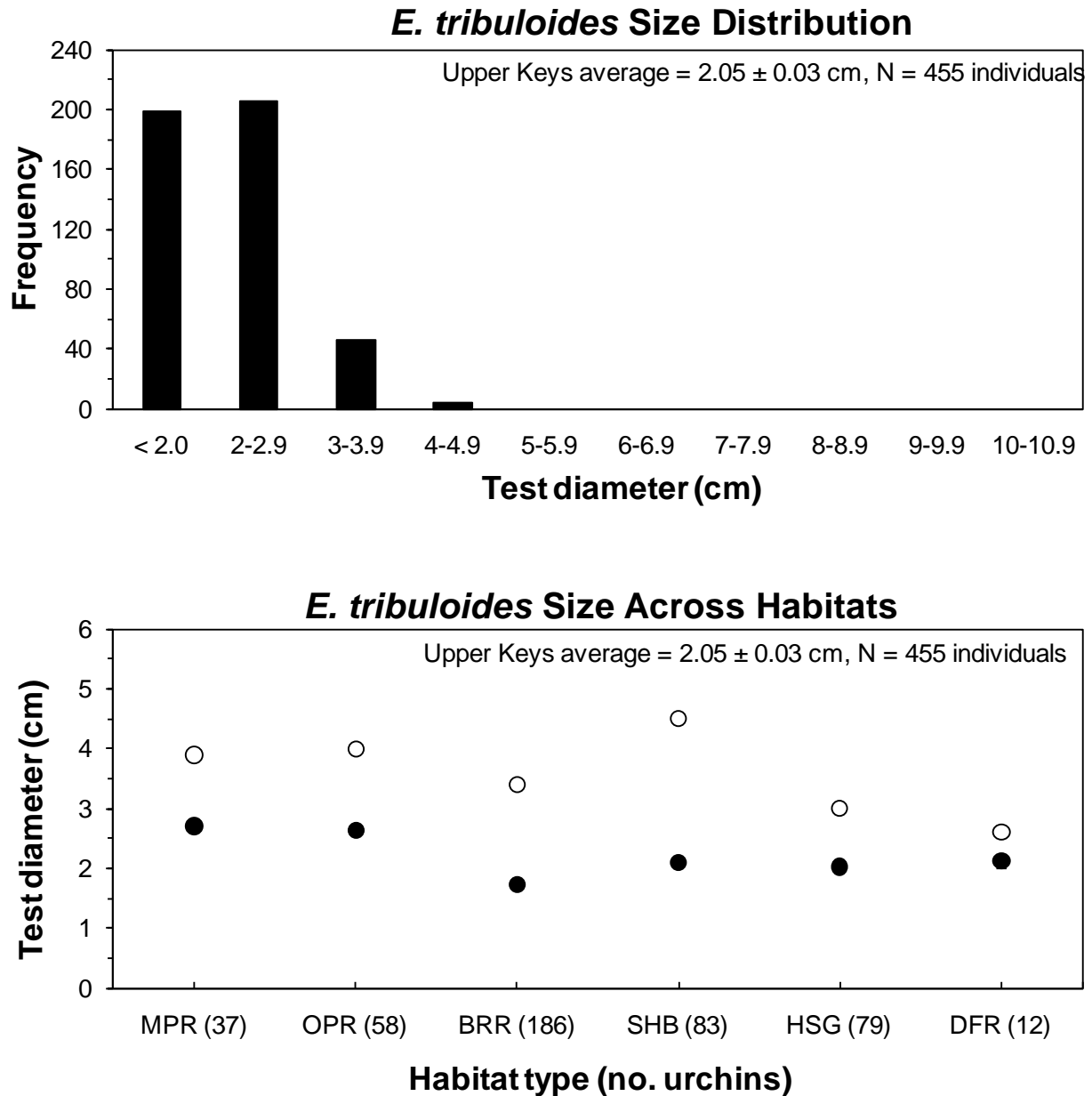


Table 5-1. Mean  $\pm$  1 SE transect frequencies (%), densities (no. individuals per m<sup>2</sup>), numbers of individuals (N), and test diameters of *Diadema antillarum* in the upper Florida Keys, as determined from surveys of four 15-m x 1-m belt transects per site at 120 sites during June-August 2010. Sites are arranged by habitat from SW to NE and asterisked locations (\*\*) are no-take zones.

Site number/site location	Transect frequency	N	Mean no. per m <sup>2</sup>	Mean size (cm)
<i>Inshore and mid-channel patch reefs</i>				
Middle Florida Keys				
A741 – Tavernier Rocks	0 $\pm$ 0	0	0 $\pm$ 0	
534 – Hen and Chickens SPA**	0 $\pm$ 0	0	0 $\pm$ 0	
535 – Hen and Chickens SPA**	0 $\pm$ 0	0	0 $\pm$ 0	
A74 – West of Conch Reef	25 $\pm$ 25	1	0.017 $\pm$ 0.017	5.7
533 – West of Conch Reef	25 $\pm$ 25	1	0.017 $\pm$ 0.017	7.2
A73 – West of Conch Reef	0 $\pm$ 0	0	0 $\pm$ 0	
Middle Florida Keys Total (6)	8 $\pm$ 5	2	0.006 $\pm$ 0.004	6.5 $\pm$ 0.8
Upper Florida Keys				
638 – Inshore of Pickles Reef	75 $\pm$ 25	3	0.050 $\pm$ 0.017	
B25B – Inshore of Molasses Reef	0 $\pm$ 0	0	0 $\pm$ 0	
B25 – Inshore of Molasses Reef	25 $\pm$ 25	2	0.033 $\pm$ 0.033	4.9 $\pm$ 3.4
B25A – Inshore of Molasses Reef	0 $\pm$ 0	0	0 $\pm$ 0	
627 – Mosquito Bank	0 $\pm$ 0	0	0 $\pm$ 0	
629A – Mosquito Bank	0 $\pm$ 0	0	0 $\pm$ 0	
628 – Mosquito Bank	0 $\pm$ 0	0	0 $\pm$ 0	
629 – Mosquito Bank	0 $\pm$ 0	0	0 $\pm$ 0	
629B – Mosquito Bank	0 $\pm$ 0	0	0 $\pm$ 0	
630 – SE of Cannon Patch Reef	0 $\pm$ 0	0	0 $\pm$ 0	
631 – Marker 33	0 $\pm$ 0	0	0 $\pm$ 0	
633 – Basin Hill Shoals	0 $\pm$ 0	0	0 $\pm$ 0	
634 – Basin Hill Shoals	0 $\pm$ 0	0	0 $\pm$ 0	
637 – West of Turtle Rocks	50 $\pm$ 29	2	0.033 $\pm$ 0.019	7.0 $\pm$ 0.9
636 – West of Turtle Rocks	0 $\pm$ 0	0	0 $\pm$ 0	
Upper Florida Keys Total (15)	10 $\pm$ 6	7	0.008 $\pm$ 0.004	4.2 $\pm$ 1.2
<b>Mid-channel Patch Reef Total (21)</b>	<b>10 <math>\pm</math> 4</b>	<b>9</b>	<b>0.007 <math>\pm</math> 0.003</b>	<b>4.7 <math>\pm</math> 0.9</b>
<i>Offshore patch reefs</i>				
Middle Florida Keys				
A802 – Inshore of Conch Reef	25 $\pm$ 25	6	0.100 $\pm$ 0.100	7.8 $\pm$ 0.2
A801 – Inshore of Conch Reef	0 $\pm$ 0	0	0 $\pm$ 0	
579A – Inshore of Conch Reef	25 $\pm$ 25	1	0.017 $\pm$ 0.017	6.4
579B – Inshore of Conch Reef	25 $\pm$ 25	1	0.017 $\pm$ 0.017	6.0
Middle Florida Keys Total (4)	19 $\pm$ 6	8	0.033 $\pm$ 0.023	7.4 $\pm$ 0.3
Upper Florida Keys				
639 – Inshore of Pickles Reef	50 $\pm$ 29	2	0.033 $\pm$ 0.019	
640 – White Bank (West of Molasses)	25 $\pm$ 25	1	0.017 $\pm$ 0.017	1.2
641 – White Bank (West of Molasses)	75 $\pm$ 25	4	0.067 $\pm$ 0.027	4.0 $\pm$ 1.0
642 – SE of White Bank Dry Rocks	0 $\pm$ 0	0	0 $\pm$ 0	
B33 – East of White Bank Dry Rocks	0 $\pm$ 0	0	0 $\pm$ 0	
643 – White Bank (NW of French)	25 $\pm$ 25	1	0.017 $\pm$ 0.017	5.0
B35 – West of Elbow Reef	0 $\pm$ 0	0	0 $\pm$ 0	
644 – Watson’s Reef	50 $\pm$ 29	2	0.033 $\pm$ 0.019	9.1 $\pm$ 0.0
645 – Watson’s Reef	50 $\pm$ 29	2	0.033 $\pm$ 0.019	5.4 $\pm$ 4.7
648 – East of Basin Hill Shoals	0 $\pm$ 0	0	0 $\pm$ 0	
649 – West of Carysfort Reef	0 $\pm$ 0	0	0 $\pm$ 0	
B39 – Carysfort Reef SPA**	0 $\pm$ 0	0	0 $\pm$ 0	
653 – Carysfort Reef SPA**	0 $\pm$ 0	0	0 $\pm$ 0	
Upper Florida Keys Total (13)	21 $\pm$ 7	12	0.015 $\pm$ 0.006	5.5 $\pm$ 0.9

Site number/site location	Transect frequency	N	Mean no. per m <sup>2</sup>	Mean size (cm)
<b>Offshore Patch Reef Total (17)</b>	<b>21 ± 6</b>	<b>20</b>	<b>0.020 ± 0.007</b>	<b>6.3 ± 0.6</b>
<i>Back reef rubble</i>				
Middle Florida Keys				
578 – Crocker Reef	0 ± 0	0	0 ± 0	
583 – Crocker Reef	50 ± 29	3	0.050 ± 0.032	1.5 ± 0.1
555A – Conch Reef	100 ± 0	8	0.133 ± 0.027	1.6 ± 0.2
555B – Conch Reef	50 ± 29	2	0.033 ± 0.019	1.3 ± 0.4
Middle Florida Keys Total (4)	50 ± 20	13	0.054 ± 0.028	1.5 ± 0.1
Upper Florida Keys				
688A – Pickles Reef	0 ± 0	0	0 ± 0	
688B – Pickles Reef	0 ± 0	0	0 ± 0	
B62 – Molasses Reef SPA**	0 ± 0	0	0 ± 0	
691 – Molasses Reef SPA**	25 ± 25	1	0.017 ± 0.017	2.0
688 – Sand Island	75 ± 25	7	0.117 ± 0.050	1.5 ± 0.2
689 – Inshore of Dixie Shoal	0 ± 0	0	0 ± 0	
702B – Elbow Reef SPA**	0 ± 0	0	0 ± 0	
702A – Elbow Reef SPA**	0 ± 0	0	0 ± 0	
Upper Florida Keys Total (8)	13 ± 9	8	0.017 ± 0.014	1.6 ± 0.2
<b>Back Reef Rubble Total (12)</b>	<b>25 ± 10</b>	<b>21</b>	<b>0.029 ± 0.014</b>	<b>1.5 ± 0.2</b>
<i>Low-relief hard-bottom (&lt; 6 m)</i>				
Middle Florida Keys				
A932 – Crocker Reef	0 ± 0	0	0 ± 0	
556 – Davis Reef SPA**	0 ± 0	0	0 ± 0	
A87 – Davis Reef SPA**	0 ± 0	0	0 ± 0	
A84 – Little Conch Reef	25 ± 25	1	0.017 ± 0.017	4.5
A85 – Little Conch Reef	100 ± 0	5	0.083 ± 0.017	5.4 ± 0.6
554 – Conch Reef C1**	0 ± 0	0	0 ± 0	
555 – Conch Reef C2**	0 ± 0	0	0 ± 0	
A86 – Conch Reef C3**	0 ± 0	0	0 ± 0	
579C – NE of Conch Reef	0 ± 0	0	0 ± 0	
Middle Florida Keys Total (9)	14 ± 11	6	0.011 ± 0.009	5.3 ± 0.6
Upper Florida Keys				
693 – Little Pickles Reef	0 ± 0	0	0 ± 0	
664 – North of French Reef	0 ± 0	0	0 ± 0	
665 – Inshore of Dixie Shoal	0 ± 0	0	0 ± 0	
Upper Florida Keys Total (3)	0 ± 0	0	0 ± 0	
<b>Shallow Hard-bottom Total (17)</b>	<b>10 ± 8</b>	<b>6</b>	<b>0.008 ± 0.007</b>	<b>5.3 ± 0.6</b>
<i>High-relief spur &amp; groove</i>				
Upper Florida Keys				
697 – Pickles Reef P1	0 ± 0	0	0 ± 0	
695 – Pickles Reef P3	25 ± 25	1	0.017 ± 0.017	
696 – NE Pickles Reef	50 ± 29	2	0.033 ± 0.019	
706 – Molasses Reef SPA**	25 ± 25	1	0.017 ± 0.017	2.7
707 – Molasses Reef SPA**	0 ± 0	0	0 ± 0	
711 – Sand Island	0 ± 0	0	0 ± 0	
704 – French Reef SPA**	0 ± 0	0	0 ± 0	
705 – French Reef SPA**	25 ± 25	1	0.017 ± 0.017	4.0
699 – North of French Reef	50 ± 29	2	0.033 ± 0.019	3.2 ± 0.7
662 – Grecian Rocks SPA**	0 ± 0	0	0 ± 0	
663 – Grecian Rocks SPA**	75 ± 25	5	0.083 ± 0.032	4.3 ± 1.0
B42 – Little Grecian Rocks	0 ± 0	0	0 ± 0	
660 – Key Largo Dry Rocks**	0 ± 0	0	0 ± 0	
661 – Key Largo Dry Rocks**	25 ± 25	1	0.017 ± 0.017	3.9

Site number/site location	Transect frequency	N	Mean no. per m <sup>2</sup>	Mean size (cm)
656 – North Dry Rocks	0 ± 0	0	0 ± 0	
657 – North-North Dry Rocks	0 ± 0	0	0 ± 0	
702 – Elbow Reef SPA**	0 ± 0	0	0 ± 0	
703 – Elbow Reef SPA**	0 ± 0	0	0 ± 0	
B66 – South of S. Carysfort	0 ± 0	0	0 ± 0	
700A – South Carysfort Reef**	0 ± 0	0	0 ± 0	
700 – South Carysfort Reef**	0 ± 0	0	0 ± 0	
B67 – Carysfort Reef C2**	0 ± 0	0	0 ± 0	
701 – Carysfort Reef C5**	0 ± 0	0	0 ± 0	
659 – Turtle Reef	25 ± 25	1	0.017 ± 0.017	7.0
Upper Florida Keys Total (24)	13 ± 4	14	0.010 ± 0.004	4.3 ± 0.5
<b>High-relief Spur &amp; Groove Total (42)</b>	<b>13 ± 4</b>	<b>14</b>	<b>0.010 ± 0.004</b>	<b>4.3 ± 0.5</b>
<i>Deeper Fore-reef (6-15 m)</i>				
Middle Florida Keys				
552 – SW of Crocker Reef	0 ± 0	0	0 ± 0	
551 – SW of Crocker Reef	0 ± 0	0	0 ± 0	
568 – SW of Crocker Reef	0 ± 0	0	0 ± 0	
569 – SW of Crocker Reef	0 ± 0	0	0 ± 0	
A931 – SW of Crocker Reef	0 ± 0	0	0 ± 0	
612 – Davis Reef SPA**	0 ± 0	0	0 ± 0	
613 – Davis Reef SPA**	0 ± 0	0	0 ± 0	
A941 – North of Davis Reef	0 ± 0	0	0 ± 0	
A942 – Little Conch Reef	0 ± 0	0	0 ± 0	
A94 – Little Conch Reef	0 ± 0	0	0 ± 0	
B24 – Conch Reef RO**	0 ± 0	0	0 ± 0	
625 – Conch Reef RO**	0 ± 0	0	0 ± 0	
611 – Conch Reef SPA**	0 ± 0	0	0 ± 0	
626 – Conch Reef RO**	0 ± 0	0	0 ± 0	
610 – Conch Reef SPA**	0 ± 0	0	0 ± 0	
B16 – Conch Reef SPA**	0 ± 0	0	0 ± 0	
Middle Florida Keys Total (16)	0 ± 0	0	0 ± 0	
Upper Florida Keys				
708 – NE of Conch Reef	0 ± 0	0	0 ± 0	
709 – Pickles Reef	0 ± 0	0	0 ± 0	
710 – SW of Molasses Reef SPA	0 ± 0	0	0 ± 0	
712 – SW of French Reef	0 ± 0	0	0 ± 0	
B71 – Dixie Shoal	25 ± 25	1	0.017 ± 0.017	1.5
671 – South of Grecian Rocks	0 ± 0	0	0 ± 0	
B51 – East of Dry Rocks	0 ± 0	0	0 ± 0	
713 – North of Elbow Reef	0 ± 0	0	0 ± 0	
682 – North of Elbow Reef	0 ± 0	0	0 ± 0	
B57 – SE of Watson's Reef	25 ± 25	1	0.017 ± 0.017	6.5
716 – South Carysfort Reef**	0 ± 0	0	0 ± 0	
678 – North Carysfort Reef**	25 ± 25	1	0.017 ± 0.017	0.4
717 – North Carysfort Reef**	0 ± 0	0	0 ± 0	
679 – North Carysfort Reef**	0 ± 0	0	0 ± 0	
675 – North of Carysfort Reef	0 ± 0	0	0 ± 0	
676 – North of Carysfort Reef	25 ± 25	1	0.017 ± 0.017	2.7
677 – North of Carysfort Reef	0 ± 0	0	0 ± 0	
715 – North of Carysfort Reef	25 ± 25	1	0.017 ± 0.017	5.3
Upper Florida Keys Total (18)	7 ± 3	5	0.005 ± 0.002	3.3 ± 1.2
<b>Deeper Fore-reef Total (34)</b>	<b>4 ± 2</b>	<b>5</b>	<b>0.002 ± 0.001</b>	<b>3.3 ± 1.2</b>

Table 5-2. Mean  $\pm$  1 SE transect frequencies (%), densities (no. individuals per m<sup>2</sup>), numbers of individuals (N), and test diameters of *Echinometra lucunter* in the upper Florida Keys, as determined from surveys of four 15-m x 1-m belt transects per site at 120 sites during June-August 2010. Sites are arranged by habitat from SW to NE and asterisked locations (\*\*) are no-take zones.

Site number/site location	Transect frequency	N	Mean no. per m <sup>2</sup>	Mean size (cm)
<i>Inshore and mid-channel patch reefs</i>				
Middle Florida Keys				
A741 – Tavernier Rocks	0 $\pm$ 0	0	0 $\pm$ 0	
534 – Hen and Chickens SPA**	0 $\pm$ 0	0	0 $\pm$ 0	
535 – Hen and Chickens SPA**	0 $\pm$ 0	0	0 $\pm$ 0	
A74 – West of Conch Reef	0 $\pm$ 0	0	0 $\pm$ 0	
533 – West of Conch Reef	0 $\pm$ 0	0	0 $\pm$ 0	
A73 – West of Conch Reef	0 $\pm$ 0	0	0 $\pm$ 0	
Middle Florida Keys Total (6)	0 $\pm$ 0	0	0 $\pm$ 0	
Upper Florida Keys				
638 – Inshore of Pickles Reef	0 $\pm$ 0	0	0 $\pm$ 0	
B25B – Inshore of Molasses Reef	0 $\pm$ 0	0	0 $\pm$ 0	
B25 – Inshore of Molasses Reef	0 $\pm$ 0	0	0 $\pm$ 0	
B25A – Inshore of Molasses Reef	50 $\pm$ 29	2	0.033 $\pm$ 0.019	1.8 $\pm$ 0.0
627 – Mosquito Bank	25 $\pm$ 25	1	0.017 $\pm$ 0.017	1.9
629A – Mosquito Bank	0 $\pm$ 0	0	0 $\pm$ 0	
628 – Mosquito Bank	0 $\pm$ 0	0	0 $\pm$ 0	
629 – Mosquito Bank	0 $\pm$ 0	0	0 $\pm$ 0	
629B – Mosquito Bank	0 $\pm$ 0	0	0 $\pm$ 0	
630 – SE of Cannon Patch Reef	0 $\pm$ 0	0	0 $\pm$ 0	
631 – Marker 33	0 $\pm$ 0	0	0 $\pm$ 0	
633 – Basin Hill Shoals	0 $\pm$ 0	0	0 $\pm$ 0	
634 – Basin Hill Shoals	0 $\pm$ 0	0	0 $\pm$ 0	
637 – West of Turtle Rocks	0 $\pm$ 0	0	0 $\pm$ 0	
636 – West of Turtle Rocks	25 $\pm$ 25	1	0.017 $\pm$ 0.017	2.6
Upper Florida Keys Total (15)	7 $\pm$ 4	4	0.004 $\pm$ 0.003	2.0 $\pm$ 0.2
<b>Mid-channel Patch Reef Total (21)</b>	<b>5 <math>\pm</math> 3</b>	<b>4</b>	<b>0.003 <math>\pm</math> 0.002</b>	<b>2.0 <math>\pm</math> 0.2</b>
<i>Offshore patch reefs</i>				
Middle Florida Keys				
A802 – Inshore of Conch Reef	0 $\pm$ 0	0	0 $\pm$ 0	
A801 – Inshore of Conch Reef	0 $\pm$ 0	0	0 $\pm$ 0	
579A – Inshore of Conch Reef	0 $\pm$ 0	0	0 $\pm$ 0	
579B – Inshore of Conch Reef	0 $\pm$ 0	0	0 $\pm$ 0	
Middle Florida Keys Total (4)	0 $\pm$ 0	0	0 $\pm$ 0	
Upper Florida Keys				
639 – Inshore of Pickles Reef	0 $\pm$ 0	0	0 $\pm$ 0	
640 – White Bank (West of Molasses)	0 $\pm$ 0	0	0 $\pm$ 0	
641 – White Bank (West of Molasses)	0 $\pm$ 0	0	0 $\pm$ 0	
642 – SE of White Bank Dry Rocks	0 $\pm$ 0	0	0 $\pm$ 0	
B33 – East of White Bank Dry Rocks	0 $\pm$ 0	0	0 $\pm$ 0	
643 – White Bank (NW of French)	0 $\pm$ 0	0	0 $\pm$ 0	
B35 – West of Elbow Reef	0 $\pm$ 0	0	0 $\pm$ 0	
644 – Watson’s Reef	0 $\pm$ 0	0	0 $\pm$ 0	
645 – Watson’s Reef	0 $\pm$ 0	0	0 $\pm$ 0	
648 – East of Basin Hill Shoals	0 $\pm$ 0	0	0 $\pm$ 0	
649 – West of Carysfort Reef	75 $\pm$ 25	5	0.083 $\pm$ 0.042	2.0 $\pm$ 0.3
B39 – Carysfort Reef SPA**	0 $\pm$ 0	0	0 $\pm$ 0	
653 – Carysfort Reef SPA**	0 $\pm$ 0	0	0 $\pm$ 0	
Upper Florida Keys Total (13)	6 $\pm$ 6	5	0.006 $\pm$ 0.006	2.0 $\pm$ 0.3

Site number/site location	Transect frequency	N	Mean no. per m <sup>2</sup>	Mean size (cm)
<b>Offshore Patch Reef Total (17)</b>	<b>4 ± 4</b>	<b>5</b>	<b>0.005 ± 0.005</b>	<b>2.0 ± 0.3</b>
<i>Back reef rubble</i>				
Middle Florida Keys				
578 – Crocker Reef	0 ± 0	0	0 ± 0	
583 – Crocker Reef	0 ± 0	0	0 ± 0	
555A – Conch Reef	100 ± 0	22	0.367 ± 0.088	1.1 ± 0.1
555B – Conch Reef	0 ± 0	0	0 ± 0	
Middle Florida Keys Total (4)	25 ± 25	22	0.092 ± 0.092	1.1 ± 0.1
Upper Florida Keys				
688A – Pickles Reef	0 ± 0	0	0 ± 0	
688B – Pickles Reef	0 ± 0	0	0 ± 0	
B62 – Molasses Reef SPA**	0 ± 0	0	0 ± 0	
691 – Molasses Reef SPA**	0 ± 0	0	0 ± 0	
688 – Sand Island	50 ± 29	2	0.033 ± 0.019	1.0 ± 0.1
689 – Inshore of Dixie Shoal	0 ± 0	0	0 ± 0	
702B – Elbow Reef SPA**	0 ± 0	0	0 ± 0	
702A – Elbow Reef SPA**	0 ± 0	0	0 ± 0	
Upper Florida Keys Total (8)	6 ± 6	2	0.004 ± 0.004	1.0 ± 0.1
<b>Back Reef Rubble Total (12)</b>	<b>13 ± 9</b>	<b>24</b>	<b>0.033 ± 0.030</b>	<b>1.1 ± 0.1</b>
<i>Low-relief hard-bottom (&lt; 6 m)</i>				
Middle Florida Keys				
A932 – Crocker Reef	0 ± 0	0	0 ± 0	
556 – Davis Reef SPA**	0 ± 0	0	0 ± 0	
A87 – Davis Reef SPA**	0 ± 0	0	0 ± 0	
A84 – Little Conch Reef	0 ± 0	0	0 ± 0	
A85 – Little Conch Reef	0 ± 0	0	0 ± 0	
554 – Conch Reef C1**	0 ± 0	0	0 ± 0	
555 – Conch Reef C2**	0 ± 0	0	0 ± 0	
A86 – Conch Reef C3**	0 ± 0	0	0 ± 0	
579C – NE of Conch Reef	0 ± 0	0	0 ± 0	
Middle Florida Keys Total (9)	0 ± 0	0	0 ± 0	
Upper Florida Keys				
693 – Little Pickles Reef	0 ± 0	0	0 ± 0	
664 – North of French Reef	0 ± 0	0	0 ± 0	
665 – Inshore of Dixie Shoal	0 ± 0	0	0 ± 0	
Upper Florida Keys Total (3)	0 ± 0	0	0 ± 0	
<b>Shallow Hard-bottom Total (17)</b>	<b>0 ± 0</b>	<b>0</b>	<b>0 ± 0</b>	
<i>High-relief spur &amp; groove</i>				
Upper Florida Keys				
697 – Pickles Reef P1	0 ± 0	0	0 ± 0	
695 – Pickles Reef P3	0 ± 0	0	0 ± 0	
696 – NE Pickles Reef	0 ± 0	0	0 ± 0	
706 – Molasses Reef SPA**	25 ± 25	1	0.017 ± 0.017	1.6
707 – Molasses Reef SPA**	0 ± 0	0	0 ± 0	
711 – Sand Island	0 ± 0	0	0 ± 0	
704 – French Reef SPA**	0 ± 0	0	0 ± 0	
705 – French Reef SPA**	0 ± 0	0	0 ± 0	
699 – North of French Reef	0 ± 0	0	0 ± 0	
662 – Grecian Rocks SPA**	0 ± 0	0	0 ± 0	
663 – Grecian Rocks SPA**	25 ± 25	1	0.017 ± 0.017	1.8
B42 – Little Grecian Rocks	0 ± 0	0	0 ± 0	
660 – Key Largo Dry Rocks**	0 ± 0	0	0 ± 0	
661 – Key Largo Dry Rocks**	0 ± 0	0	0 ± 0	



Site number/site location	Transect frequency	N	Mean no. per m <sup>2</sup>	Mean size (cm)
656 – North Dry Rocks	0 ± 0	0	0 ± 0	
657 – North-North Dry Rocks	0 ± 0	0	0 ± 0	
702 – Elbow Reef SPA**	0 ± 0	0	0 ± 0	
703 – Elbow Reef SPA**	0 ± 0	0	0 ± 0	
B66 – South of S. Carysfort	0 ± 0	0	0 ± 0	
700A – South Carysfort Reef**	0 ± 0	0	0 ± 0	
700 – South Carysfort Reef**	0 ± 0	0	0 ± 0	
B67 – Carysfort Reef C2**	0 ± 0	0	0 ± 0	
701 – Carysfort Reef C5**	0 ± 0	0	0 ± 0	
659 – Turtle Reef	0 ± 0	0	0 ± 0	
Upper Florida Keys Total (24)	2 ± 1	2	0.001 ± 0.001	1.7 ± 0.1
<b>High-relief Spur &amp; Groove Total (42)</b>	<b>2 ± 1</b>	<b>2</b>	<b>0.001 ± 0.001</b>	<b>1.7 ± 0.1</b>
<i>Deeper Fore-reef (6-15 m)</i>				
Middle Florida Keys				
552 – SW of Crocker Reef	0 ± 0	0	0 ± 0	
551 – SW of Crocker Reef	0 ± 0	0	0 ± 0	
568 – SW of Crocker Reef	0 ± 0	0	0 ± 0	
569 – SW of Crocker Reef	0 ± 0	0	0 ± 0	
A931 – SW of Crocker Reef	0 ± 0	0	0 ± 0	
612 – Davis Reef SPA**	0 ± 0	0	0 ± 0	
613 – Davis Reef SPA**	0 ± 0	0	0 ± 0	
A941 – North of Davis Reef	0 ± 0	0	0 ± 0	
A942 – Little Conch Reef	0 ± 0	0	0 ± 0	
A94 – Little Conch Reef	0 ± 0	0	0 ± 0	
B24 – Conch Reef RO**	0 ± 0	0	0 ± 0	
625 – Conch Reef RO**	0 ± 0	0	0 ± 0	
611 – Conch Reef SPA**	0 ± 0	0	0 ± 0	
626 – Conch Reef RO**	0 ± 0	0	0 ± 0	
610 – Conch Reef SPA**	0 ± 0	0	0 ± 0	
B16 – Conch Reef SPA**	0 ± 0	0	0 ± 0	
Middle Florida Keys Total (16)	0 ± 0	0	0 ± 0	
Upper Florida Keys				
708 – NE of Conch Reef	0 ± 0	0	0 ± 0	
709 – Pickles Reef	0 ± 0	0	0 ± 0	
710 – SW of Molasses Reef SPA	0 ± 0	0	0 ± 0	
712 – SW of French Reef	0 ± 0	0	0 ± 0	
B71 – Dixie Shoal	0 ± 0	0	0 ± 0	
671 – South of Grecian Rocks	0 ± 0	0	0 ± 0	
B51 – East of Dry Rocks	0 ± 0	0	0 ± 0	
713 – North of Elbow Reef	0 ± 0	0	0 ± 0	
682 – North of Elbow Reef	0 ± 0	0	0 ± 0	
B57 – SE of Watson's Reef	0 ± 0	0	0 ± 0	
716 – South Carysfort Reef**	0 ± 0	0	0 ± 0	
678 – North Carysfort Reef**	0 ± 0	0	0 ± 0	
717 – North Carysfort Reef**	0 ± 0	0	0 ± 0	
679 – North Carysfort Reef**	0 ± 0	0	0 ± 0	
675 – North of Carysfort Reef	0 ± 0	0	0 ± 0	
676 – North of Carysfort Reef	0 ± 0	0	0 ± 0	
677 – North of Carysfort Reef	0 ± 0	0	0 ± 0	
715 – North of Carysfort Reef	0 ± 0	0	0 ± 0	
Upper Florida Keys Total (18)	0 ± 0	0	0 ± 0	
<b>Deeper Fore-reef Total (34)</b>	<b>0 ± 0</b>	<b>0</b>	<b>0 ± 0</b>	

Table 5-3. Mean  $\pm$  1 SE transect frequencies (%), densities (no. individuals per m<sup>2</sup>), numbers of individuals (N), and test diameters of *Echinometra viridis* in the upper Florida Keys, as determined from surveys of four 15-m x 1-m belt transects per site at 120 sites during June-August 2010. Sites are arranged by habitat from SW to NE and asterisked locations (\*\*) are no-take zones.

Site number/site location	Transect frequency	N	Mean no. per m <sup>2</sup>	Mean size (cm)
<i>Inshore and mid-channel patch reefs</i>				
Middle Florida Keys				
A741 – Tavernier Rocks	0 $\pm$ 0	0	0 $\pm$ 0	
534 – Hen and Chickens SPA**	0 $\pm$ 0	0	0 $\pm$ 0	
535 – Hen and Chickens SPA**	0 $\pm$ 0	0	0 $\pm$ 0	
A74 – West of Conch Reef	0 $\pm$ 0	0	0 $\pm$ 0	
533 – West of Conch Reef	0 $\pm$ 0	0	0 $\pm$ 0	
A73 – West of Conch Reef	0 $\pm$ 0	0	0 $\pm$ 0	
Middle Florida Keys Total (6)	0 $\pm$ 0	0	0 $\pm$ 0	
Upper Florida Keys				
638 – Inshore of Pickles Reef	50 $\pm$ 29	7	0.117 $\pm$ 0.096	2.4 $\pm$ 0.2
B25B – Inshore of Molasses Reef	25 $\pm$ 25	2	0.033 $\pm$ 0.033	2.6 $\pm$ 0.1
B25 – Inshore of Molasses Reef	75 $\pm$ 25	6	0.100 $\pm$ 0.043	2.6 $\pm$ 0.3
B25A – Inshore of Molasses Reef	50 $\pm$ 29	4	0.067 $\pm$ 0.038	2.1 $\pm$ 0.3
627 – Mosquito Bank	0 $\pm$ 0	0	0 $\pm$ 0	
629A – Mosquito Bank	25 $\pm$ 25	1	0.017 $\pm$ 0.017	2.0
628 – Mosquito Bank	50 $\pm$ 29	2	0.033 $\pm$ 0.019	2.0 $\pm$ 1.6
629 – Mosquito Bank	25 $\pm$ 25	1	0.017 $\pm$ 0.017	2.5
629B – Mosquito Bank	25 $\pm$ 25	1	0.017 $\pm$ 0.017	3.2
630 – SE of Cannon Patch Reef	75 $\pm$ 25	3	0.050 $\pm$ 0.017	2.3 $\pm$ 1.0
631 – Marker 33	0 $\pm$ 0	0	0 $\pm$ 0	
633 – Basin Hill Shoals	100 $\pm$ 0	71	1.183 $\pm$ 0.199	3.0 $\pm$ 0.1
634 – Basin Hill Shoals	100 $\pm$ 0	80	1.333 $\pm$ 0.446	3.0 $\pm$ 0.1
637 – West of Turtle Rocks	0 $\pm$ 0	0	0 $\pm$ 0	
636 – West of Turtle Rocks	50 $\pm$ 29	13	0.217 $\pm$ 0.132	2.2 $\pm$ 0.2
Upper Florida Keys Total (15)	43 $\pm$ 9	191	0.212 $\pm$ 0.111	2.9 $\pm$ 0.1
<b>Mid-channel Patch Reef Total (21)</b>	<b>31 <math>\pm</math> 8</b>	<b>191</b>	<b>0.152 <math>\pm</math> 0.081</b>	<b>2.9 <math>\pm</math> 0.1</b>
<i>Offshore patch reefs</i>				
Middle Florida Keys				
A802 – Inshore of Conch Reef	50 $\pm$ 29	3	0.050 $\pm$ 0.032	2.5 $\pm$ 0.5
A801 – Inshore of Conch Reef	0 $\pm$ 0	0	0 $\pm$ 0	
579A – Inshore of Conch Reef	0 $\pm$ 0	0	0 $\pm$ 0	
579B – Inshore of Conch Reef	0 $\pm$ 0	0	0 $\pm$ 0	
Middle Florida Keys Total (4)	13 $\pm$ 13	3	0.013 $\pm$ 0.013	2.5 $\pm$ 0.5
Upper Florida Keys				
639 – Inshore of Pickles Reef	0 $\pm$ 0	0	0 $\pm$ 0	
640 – White Bank (West of Molasses)	100 $\pm$ 0	27	0.450 $\pm$ 0.113	2.1 $\pm$ 0.1
641 – White Bank (West of Molasses)	25 $\pm$ 25	1	0.017 $\pm$ 0.017	2.0
642 – SE of White Bank Dry Rocks	25 $\pm$ 25	1	0.017 $\pm$ 0.017	2.1
B33 – East of White Bank Dry Rocks	25 $\pm$ 25	1	0.017 $\pm$ 0.017	1.3
643 – White Bank (NW of French)	0 $\pm$ 0	0	0 $\pm$ 0	
B35 – West of Elbow Reef	0 $\pm$ 0	0	0 $\pm$ 0	
644 – Watson's Reef	25 $\pm$ 25	2	0.033 $\pm$ 0.033	1.2 $\pm$ 0.2
645 – Watson's Reef	25 $\pm$ 25	1	0.017 $\pm$ 0.017	2.2
648 – East of Basin Hill Shoals	25 $\pm$ 25	1	0.017 $\pm$ 0.017	3.2
649 – West of Carysfort Reef	25 $\pm$ 25	1	0.017 $\pm$ 0.017	1.9
B39 – Carysfort Reef SPA**	25 $\pm$ 25	2	0.033 $\pm$ 0.033	1.5 $\pm$ 0.8
653 – Carysfort Reef SPA**	25 $\pm$ 25	1	0.017 $\pm$ 0.017	2.2
Upper Florida Keys Total (13)	25 $\pm$ 7	38	0.049 $\pm$ 0.034	2.0 $\pm$ 0.1

Site number/site location	Transect frequency	N	Mean no. per m <sup>2</sup>	Mean size (cm)
<b>Offshore Patch Reef Total (17)</b>	<b>22 ± 6</b>	<b>41</b>	<b>0.040 ± 0.026</b>	<b>2.1 ± 0.1</b>
<i>Back reef rubble</i>				
Middle Florida Keys				
578 – Crocker Reef	25 ± 25	1	0.017 ± 0.017	1.1
583 – Crocker Reef	0 ± 0	0	0 ± 0	
555A – Conch Reef	75 ± 25	6	0.100 ± 0.043	1.2 ± 0.1
555B – Conch Reef	50 ± 29	3	0.050 ± 0.032	1.3 ± 0.0
Middle Florida Keys Total (4)	38 ± 16	10	0.042 ± 0.022	1.1 ± 0.1
Upper Florida Keys				
688A – Pickles Reef	0 ± 0	0	0 ± 0	
688B – Pickles Reef	50 ± 29	6	0.100 ± 0.079	1.4 ± 0.3
B62 – Molasses Reef SPA**	0 ± 0	0	0 ± 0	
691 – Molasses Reef SPA**	0 ± 0	0	0 ± 0	
688 – Sand Island	75 ± 25	4	0.067 ± 0.027	1.4 ± 0.2
689 – Inshore of Dixie Shoal	0 ± 0	0	0 ± 0	
702B – Elbow Reef SPA**	0 ± 0	0	0 ± 0	
702A – Elbow Reef SPA**	0 ± 0	0	0 ± 0	
Upper Florida Keys Total (8)	16 ± 10	10	0.021 ± 0.014	1.4 ± 0.2
<b>Back Reef Rubble Total (12)</b>	<b>23 ± 9</b>	<b>20</b>	<b>0.028 ± 0.012</b>	<b>1.2 ± 0.1</b>
<i>Low-relief hard-bottom (&lt; 6 m)</i>				
Middle Florida Keys				
A932 – Crocker Reef	0 ± 0	0	0 ± 0	
556 – Davis Reef SPA**	0 ± 0	0	0 ± 0	
A87 – Davis Reef SPA**	0 ± 0	0	0 ± 0	
A84 – Little Conch Reef	0 ± 0	0	0 ± 0	
A85 – Little Conch Reef	25 ± 25	1	0.017 ± 0.017	0.9
554 – Conch Reef C1**	0 ± 0	0	0 ± 0	
555 – Conch Reef C2**	0 ± 0	0	0 ± 0	
A86 – Conch Reef C3**	0 ± 0	0	0 ± 0	
579C – NE of Conch Reef	0 ± 0	0	0 ± 0	
Middle Florida Keys Total (9)	3 ± 3	1	0.002 ± 0.002	0.9
Upper Florida Keys				
693 – Little Pickles Reef	0 ± 0	0	0 ± 0	
664 – North of French Reef	0 ± 0	0	0 ± 0	
665 – Inshore of Dixie Shoal	0 ± 0	0	0 ± 0	
Upper Florida Keys Total (3)	0 ± 0	0	0 ± 0	
<b>Shallow Hard-bottom Total (17)</b>	<b>2 ± 2</b>	<b>1</b>	<b>0.001 ± 0.001</b>	<b>0.9</b>
<i>High-relief spur &amp; groove</i>				
Upper Florida Keys				
697 – Pickles Reef P1	50 ± 29	2	0.033 ± 0.019	1.5 ± 0.3
695 – Pickles Reef P3	0 ± 0	0	0 ± 0	
696 – NE Pickles Reef	0 ± 0	0	0 ± 0	
706 – Molasses Reef SPA**	0 ± 0	0	0 ± 0	
707 – Molasses Reef SPA**	0 ± 0	0	0 ± 0	
711 – Sand Island	0 ± 0	0	0 ± 0	
704 – French Reef SPA**	0 ± 0	0	0 ± 0	
705 – French Reef SPA**	0 ± 0	0	0 ± 0	
699 – North of French Reef	0 ± 0	0	0 ± 0	
662 – Grecian Rocks SPA**	0 ± 0	0	0 ± 0	
663 – Grecian Rocks SPA**	0 ± 0	0	0 ± 0	
B42 – Little Grecian Rocks	0 ± 0	0	0 ± 0	
660 – Key Largo Dry Rocks**	0 ± 0	0	0 ± 0	
661 – Key Largo Dry Rocks**	0 ± 0	0	0 ± 0	

Site number/site location	Transect frequency	N	Mean no. per m <sup>2</sup>	Mean size (cm)
656 – North Dry Rocks	0 ± 0	0	0 ± 0	
657 – North-North Dry Rocks	0 ± 0	0	0 ± 0	
702 – Elbow Reef SPA**	0 ± 0	0	0 ± 0	
703 – Elbow Reef SPA**	0 ± 0	0	0 ± 0	
B66 – South of S. Carysfort	0 ± 0	0	0 ± 0	
700A – South Carysfort Reef**	0 ± 0	0	0 ± 0	
700 – South Carysfort Reef**	0 ± 0	0	0 ± 0	
B67 – Carysfort Reef C2**	0 ± 0	0	0 ± 0	
701 – Carysfort Reef C5**	0 ± 0	0	0 ± 0	
659 – Turtle Reef	0 ± 0	0	0 ± 0	
Upper Florida Keys Total (24)	2 ± 2	2	0.001 ± 0.001	1.5 ± 0.3
<b>High-relief Spur &amp; Groove Total (42)</b>	<b>2 ± 2</b>	<b>2</b>	<b>0.001 ± 0.001</b>	<b>1.5 ± 0.3</b>
<i>Deeper Fore-reef (6-15 m)</i>				
Middle Florida Keys				
552 – SW of Crocker Reef	0 ± 0	0	0 ± 0	
551 – SW of Crocker Reef	0 ± 0	0	0 ± 0	
568 – SW of Crocker Reef	0 ± 0	0	0 ± 0	
569 – SW of Crocker Reef	0 ± 0	0	0 ± 0	
A931 – SW of Crocker Reef	0 ± 0	0	0 ± 0	
612 – Davis Reef SPA**	0 ± 0	0	0 ± 0	
613 – Davis Reef SPA**	0 ± 0	0	0 ± 0	
A941 – North of Davis Reef	0 ± 0	0	0 ± 0	
A942 – Little Conch Reef	25 ± 25	1	0.017 ± 0.017	2.0
A94 – Little Conch Reef	0 ± 0	0	0 ± 0	
B24 – Conch Reef RO**	0 ± 0	0	0 ± 0	
625 – Conch Reef RO**	0 ± 0	0	0 ± 0	
611 – Conch Reef SPA**	0 ± 0	0	0 ± 0	
626 – Conch Reef RO**	25 ± 25	1	0.017 ± 0.017	1.2
610 – Conch Reef SPA**	0 ± 0	0	0 ± 0	
B16 – Conch Reef SPA**	0 ± 0	0	0 ± 0	
Middle Florida Keys Total (16)	3 ± 2	2	0.002 ± 0.001	1.6 ± 0.4
Upper Florida Keys				
708 – NE of Conch Reef	0 ± 0	0	0 ± 0	
709 – Pickles Reef	0 ± 0	0	0 ± 0	
710 – SW of Molasses Reef SPA	0 ± 0	0	0 ± 0	
712 – SW of French Reef	50 ± 29	3	0.050 ± 0.032	1.9 ± 0.2
B71 – Dixie Shoal	0 ± 0	0	0 ± 0	
671 – South of Grecian Rocks	0 ± 0	0	0 ± 0	
B51 – East of Dry Rocks	0 ± 0	0	0 ± 0	
713 – North of Elbow Reef	0 ± 0	0	0 ± 0	
682 – North of Elbow Reef	0 ± 0	0	0 ± 0	
B57 – SE of Watson's Reef	0 ± 0	0	0 ± 0	
716 – South Carysfort Reef**	0 ± 0	0	0 ± 0	
678 – North Carysfort Reef**	0 ± 0	0	0 ± 0	
717 – North Carysfort Reef**	0 ± 0	0	0 ± 0	
679 – North Carysfort Reef**	0 ± 0	0	0 ± 0	
675 – North of Carysfort Reef	0 ± 0	0	0 ± 0	
676 – North of Carysfort Reef	0 ± 0	0	0 ± 0	
677 – North of Carysfort Reef	0 ± 0	0	0 ± 0	
715 – North of Carysfort Reef	25 ± 25	1	0.017 ± 0.017	1.1
Upper Florida Keys Total (18)	4 ± 3	4	0.004 ± 0.003	1.7 ± 0.2
<b>Deeper Fore-reef Total (34)</b>	<b>4 ± 2</b>	<b>6</b>	<b>0.003 ± 0.002</b>	<b>1.7 ± 0.2</b>

Table 5-4. Mean  $\pm$  1 SE transect frequencies (%), densities (no. individuals per m<sup>2</sup>), numbers of individuals (N), and test diameters of *Eucidaris tribuloides* in the upper Florida Keys, as determined from surveys of four 15-m x 1-m belt transects per site at 120 sites during June-August 2010. Sites are arranged by habitat from SW to NE and asterisked locations (\*\*) are no-take zones.

Site number/site location	Transect frequency	N	Mean no. per m <sup>2</sup>	Mean size (cm)
<i>Inshore and mid-channel patch reefs</i>				
Middle Florida Keys				
A741 – Tavernier Rocks	0 $\pm$ 0	0	0 $\pm$ 0	
534 – Hen and Chickens SPA**	25 $\pm$ 25	1	0.017 $\pm$ 0.017	2.0
535 – Hen and Chickens SPA**	0 $\pm$ 0	0	0 $\pm$ 0	
A74 – West of Conch Reef	25 $\pm$ 25	3	0.050 $\pm$ 0.050	2.6 $\pm$ 0.2
533 – West of Conch Reef	25 $\pm$ 25	1	0.017 $\pm$ 0.017	2.3
A73 – West of Conch Reef	75 $\pm$ 25	7	0.117 $\pm$ 0.042	2.6 $\pm$ 0.1
Middle Florida Keys Total (6)	25 $\pm$ 11	12	0.033 $\pm$ 0.018	2.5 $\pm$ 0.1
Upper Florida Keys				
638 – Inshore of Pickles Reef	25 $\pm$ 25	2	0.033 $\pm$ 0.033	2.3 $\pm$ 0.2
B25B – Inshore of Molasses Reef	25 $\pm$ 25	1	0.017 $\pm$ 0.017	2.5
B25 – Inshore of Molasses Reef	25 $\pm$ 25	1	0.017 $\pm$ 0.017	2.4
B25A – Inshore of Molasses Reef	0 $\pm$ 0	0	0 $\pm$ 0	
627 – Mosquito Bank	25 $\pm$ 25	2	0.033 $\pm$ 0.033	3.3 $\pm$ 0.1
629A – Mosquito Bank	25 $\pm$ 25	1	0.017 $\pm$ 0.017	3.5
628 – Mosquito Bank	50 $\pm$ 29	2	0.033 $\pm$ 0.019	3.2 $\pm$ 0.7
629 – Mosquito Bank	25 $\pm$ 25	1	0.017 $\pm$ 0.017	3.0
629B – Mosquito Bank	50 $\pm$ 29	2	0.033 $\pm$ 0.019	3.3 $\pm$ 0.4
630 – SE of Cannon Patch Reef	25 $\pm$ 25	1	0.017 $\pm$ 0.017	3.1
631 – Marker 33	0 $\pm$ 0	0	0 $\pm$ 0	
633 – Basin Hill Shoals	0 $\pm$ 0	0	0 $\pm$ 0	
634 – Basin Hill Shoals	0 $\pm$ 0	0	0 $\pm$ 0	
637 – West of Turtle Rocks	100 $\pm$ 0	10	0.167 $\pm$ 0.043	2.7 $\pm$ 0.2
636 – West of Turtle Rocks	25 $\pm$ 25	2	0.033 $\pm$ 0.033	2.4 $\pm$ 0.1
Upper Florida Keys Total (15)	27 $\pm$ 7	25	0.028 $\pm$ 0.010	2.8 $\pm$ 0.1
<b>Mid-channel Patch Reef Total (21)</b>	<b>26 <math>\pm</math> 6</b>	<b>37</b>	<b>0.029 <math>\pm</math> 0.009</b>	<b>2.7 <math>\pm</math> 0.1</b>
<i>Offshore patch reefs</i>				
Middle Florida Keys				
A802 – Inshore of Conch Reef	75 $\pm$ 25	8	0.133 $\pm$ 0.061	2.5 $\pm$ 0.2
A801 – Inshore of Conch Reef	100 $\pm$ 0	9	0.150 $\pm$ 0.042	2.7 $\pm$ 0.2
579A – Inshore of Conch Reef	100 $\pm$ 0	5	0.083 $\pm$ 0.017	2.8 $\pm$ 0.3
579B – Inshore of Conch Reef	50 $\pm$ 29	3	0.050 $\pm$ 0.032	2.6 $\pm$ 0.2
Middle Florida Keys Total (4)	81 $\pm$ 12	25	0.104 $\pm$ 0.023	2.7 $\pm$ 0.1
Upper Florida Keys				
639 – Inshore of Pickles Reef	0 $\pm$ 0	0	0 $\pm$ 0	
640 – White Bank (West of Molasses)	50 $\pm$ 29	2	0.033 $\pm$ 0.019	2.8 $\pm$ 0.3
641 – White Bank (West of Molasses)	100 $\pm$ 0	14	0.233 $\pm$ 0.043	2.7 $\pm$ 0.1
642 – SE of White Bank Dry Rocks	25 $\pm$ 25	1	0.017 $\pm$ 0.017	2.0
B33 – East of White Bank Dry Rocks	50 $\pm$ 29	2	0.033 $\pm$ 0.019	2.4 $\pm$ 0.1
643 – White Bank (NW of French)	50 $\pm$ 29	3	0.050 $\pm$ 0.032	2.8 $\pm$ 0.4
B35 – West of Elbow Reef	25 $\pm$ 25	1	0.017 $\pm$ 0.017	2.6
644 – Watson's Reef	0 $\pm$ 0	0	0 $\pm$ 0	
645 – Watson's Reef	50 $\pm$ 29	3	0.050 $\pm$ 0.032	2.6 $\pm$ 0.3
648 – East of Basin Hill Shoals	0 $\pm$ 0	0	0 $\pm$ 0	
649 – West of Carysfort Reef	50 $\pm$ 29	4	0.067 $\pm$ 0.047	3.0 $\pm$ 0.4
B39 – Carysfort Reef SPA**	25 $\pm$ 25	1	0.017 $\pm$ 0.017	2.5
653 – Carysfort Reef SPA**	50 $\pm$ 29	2	0.033 $\pm$ 0.019	1.6 $\pm$ 0.3
Upper Florida Keys Total (13)	37 $\pm$ 8	33	0.042 $\pm$ 0.017	2.6 $\pm$ 0.1

Site number/site location	Transect frequency	N	Mean no. per m <sup>2</sup>	Mean size (cm)
<b>Offshore Patch Reef Total (17)</b>	<b>47 ± 8</b>	<b>58</b>	<b>0.057 ± 0.015</b>	<b>2.6 ± 0.1</b>
<i>Back reef rubble</i>				
Middle Florida Keys				
578 – Crocker Reef	50 ± 29	2	0.033 ± 0.033	1.2 ± 0.2
583 – Crocker Reef	0 ± 0	0	0 ± 0	
555A – Conch Reef	100 ± 0	19	0.317 ± 0.057	1.3 ± 0.1
555B – Conch Reef	100 ± 0	47	0.783 ± 0.175	2.6 ± 0.1
Middle Florida Keys Total (4)	63 ± 24	68	0.283 ± 0.181	1.5 ± 0.1
Upper Florida Keys				
688A – Pickles Reef	100 ± 0	32	0.533 ± 0.156	2.1 ± 0.1
688B – Pickles Reef	100 ± 0	70	1.167 ± 0.362	1.8 ± 0.1
B62 – Molasses Reef SPA**	25 ± 25	2	0.033 ± 0.033	1.0 ± 0.1
691 – Molasses Reef SPA**	75 ± 25	8	0.133 ± 0.047	1.1 ± 0.1
688 – Sand Island	75 ± 25	4	0.067 ± 0.027	1.4 ± 0.1
689 – Inshore of Dixie Shoal	25 ± 25	1	0.017 ± 0.017	1.0
702B – Elbow Reef SPA**	0 ± 0	0	0 ± 0	
702A – Elbow Reef SPA**	25 ± 25	1	0.017 ± 0.017	1.0
Upper Florida Keys Total (8)	53 ± 14	118	0.246 ± 0.146	1.8 ± 0.1
<b>Back Reef Rubble Total (12)</b>	<b>56 ± 12</b>	<b>186</b>	<b>0.258 ± 0.110</b>	<b>1.7 ± 0.1</b>
<i>Low-relief hard-bottom (&lt; 6 m)</i>				
Middle Florida Keys				
A932 – Crocker Reef	50 ± 29	2	0.033 ± 0.019	1.7 ± 0.0
556 – Davis Reef SPA**	0 ± 0	0	0 ± 0	
A87 – Davis Reef SPA**	50 ± 29	2	0.033 ± 0.019	1.8 ± 0.2
A84 – Little Conch Reef	100 ± 0	23	0.383 ± 0.100	2.2 ± 0.1
A85 – Little Conch Reef	100 ± 0	11	0.183 ± 0.057	1.9 ± 0.3
554 – Conch Reef C1**	100 ± 0	14	0.233 ± 0.079	2.1 ± 0.1
555 – Conch Reef C2**	25 ± 25	1	0.017 ± 0.017	2.6
A86 – Conch Reef C3**	75 ± 25	6	0.100 ± 0.043	2.1 ± 0.2
579C – NE of Conch Reef	50 ± 29	3	0.050 ± 0.032	2.1 ± 0.1
Middle Florida Keys Total (9)	61 ± 12	62	0.115 ± 0.043	2.1 ± 0.1
Upper Florida Keys				
693 – Little Pickles Reef	100 ± 0	8	0.133 ± 0.067	1.7 ± 0.2
664 – North of French Reef	100 ± 0	7	0.117 ± 0.032	2.4 ± 0.1
665 – Inshore of Dixie Shoal	100 ± 0	6	0.100 ± 0.019	2.5 ± 0.1
Upper Florida Keys Total (3)	100 ± 100	21	0.117 ± 0.010	2.1 ± 0.1
<b>Shallow Hard-bottom Total (17)</b>	<b>71 ± 10</b>	<b>83</b>	<b>0.115 ± 0.032</b>	<b>2.1 ± 0.1</b>
<i>High-relief spur &amp; groove</i>				
Upper Florida Keys				
697 – Pickles Reef P1	75 ± 25	8	0.133 ± 0.072	2.2 ± 0.1
695 – Pickles Reef P3	100 ± 0	9	0.150 ± 0.050	1.9 ± 0.1
696 – NE Pickles Reef	75 ± 25	5	0.083 ± 0.032	2.0 ± 0.2
706 – Molasses Reef SPA**	50 ± 29	3	0.050 ± 0.032	2.0 ± 0.4
707 – Molasses Reef SPA**	50 ± 29	2	0.033 ± 0.019	2.5 ± 0.5
711 – Sand Island	0 ± 0	0	0 ± 0	
704 – French Reef SPA**	0 ± 0	0	0 ± 0	
705 – French Reef SPA**	50 ± 29	2	0.033 ± 0.019	2.0 ± 0.2
699 – North of French Reef	50 ± 29	13	0.217 ± 0.195	2.0 ± 0.1
662 – Grecian Rocks SPA**	75 ± 25	5	0.083 ± 0.042	2.4 ± 0.2
663 – Grecian Rocks SPA**	100 ± 0	6	0.100 ± 0.019	2.2 ± 0.1
B42 – Little Grecian Rocks	0 ± 0	0	0 ± 0	
660 – Key Largo Dry Rocks**	25 ± 25	1	0.017 ± 0.017	2.0
661 – Key Largo Dry Rocks**	50 ± 29	4	0.067 ± 0.047	1.9 ± 0.1

Site number/site location	Transect frequency	N	Mean no. per m <sup>2</sup>	Mean size (cm)
656 – North Dry Rocks	75 ± 25	5	0.083 ± 0.032	1.7 ± 0.1
657 – North-North Dry Rocks	0 ± 0	0	0 ± 0	
702 – Elbow Reef SPA**	0 ± 0	0	0 ± 0	
703 – Elbow Reef SPA**	25 ± 25	1	0.017 ± 0.017	2.2
B66 – South of S. Carysfort	50 ± 29	4	0.067 ± 0.047	2.1 ± 0.3
700A – South Carysfort Reef**	0 ± 0	0	0 ± 0	
700 – South Carysfort Reef**	50 ± 29	2	0.033 ± 0.019	2.3 ± 0.3
B67 – Carysfort Reef C2**	75 ± 25	6	0.100 ± 0.058	1.7 ± 0.2
701 – Carysfort Reef C5**	25 ± 25	2	0.033 ± 0.033	2.0 ± 0.1
659 – Turtle Reef	25 ± 25	1	0.017 ± 0.017	2.0
Upper Florida Keys Total (24)	43 ± 7	79	0.055 ± 0.011	2.1 ± 0.0
<b>High-relief Spur &amp; Groove Total (42)</b>	<b>43 ± 7</b>	<b>79</b>	<b>0.055 ± 0.011</b>	<b>2.1 ± 0.0</b>
<i>Deeper Fore-reef (6-15 m)</i>				
Middle Florida Keys				
552 – SW of Crocker Reef	0 ± 0	0	0 ± 0	
551 – SW of Crocker Reef	0 ± 0	0	0 ± 0	
568 – SW of Crocker Reef	0 ± 0	0	0 ± 0	
569 – SW of Crocker Reef	0 ± 0	0	0 ± 0	
A931 – SW of Crocker Reef	0 ± 0	0	0 ± 0	
612 – Davis Reef SPA**	0 ± 0	0	0 ± 0	
613 – Davis Reef SPA**	0 ± 0	0	0 ± 0	
A941 – North of Davis Reef	25 ± 25	1	0.017 ± 0.017	1.6
A942 – Little Conch Reef	25 ± 25	1	0.017 ± 0.017	2.1
A94 – Little Conch Reef	0 ± 0	0	0 ± 0	
B24 – Conch Reef RO**	0 ± 0	0	0 ± 0	
625 – Conch Reef RO**	0 ± 0	0	0 ± 0	
611 – Conch Reef SPA**	0 ± 0	0	0 ± 0	
626 – Conch Reef RO**	0 ± 0	0	0 ± 0	
610 – Conch Reef SPA**	0 ± 0	0	0 ± 0	
B16 – Conch Reef SPA**	0 ± 0	0	0 ± 0	
Middle Florida Keys Total (16)	3 ± 2	2	0.002 ± 0.001	1.9 ± 0.3
Upper Florida Keys				
708 – NE of Conch Reef	0	0	0 ± 0	
709 – Pickles Reef	25 ± 25	1	0.017 ± 0.017	1.9
710 – SW of Molasses Reef SPA	0	0	0 ± 0	
712 – SW of French Reef	50 ± 29	2	0.033 ± 0.019	2.1 ± 0.1
B71 – Dixie Shoal	0	0	0 ± 0	
671 – South of Grecian Rocks	75 ± 25	4	0.067 ± 0.027	2.4 ± 0.1
B51 – East of Dry Rocks	0	0	0 ± 0	
713 – North of Elbow Reef	25 ± 25	1	0.017 ± 0.017	2.5
682 – North of Elbow Reef	25 ± 25	1	0.017 ± 0.017	2.6
B57 – SE of Watson's Reef	0	0	0 ± 0	
716 – South Carysfort Reef**	0	0	0 ± 0	
678 – North Carysfort Reef**	0	0	0 ± 0	
717 – North Carysfort Reef**	0	0	0 ± 0	
679 – North Carysfort Reef**	0	0	0 ± 0	
675 – North of Carysfort Reef	25 ± 25	1	0.017 ± 0.017	1.3
676 – North of Carysfort Reef	0	0	0 ± 0	
677 – North of Carysfort Reef	0	0	0 ± 0	
715 – North of Carysfort Reef	0	0	0 ± 0	
Upper Florida Keys Total (18)	13 ± 5	10	0.009 ± 0.004	2.2 ± 0.1
<b>Deeper Fore-reef Total (34)</b>	<b>8 ± 3</b>	<b>12</b>	<b>0.006 ± 0.002</b>	<b>2.1 ± 0.1</b>



Table 5-5. Mean  $\pm$  1 SE transect frequencies (%), densities (no. individuals per m<sup>2</sup>), numbers of individuals (N), and test diameters of *Tripneustes ventricosus* in the upper Florida Keys, as determined from surveys of four 15-m x 1-m belt transects per site at 120 sites during June-August 2010. Sites are arranged by habitat from SW to NE and asterisked locations (\*\*) are no-take zones.

Site number/site location	Transect frequency	N	Mean no. per m <sup>2</sup>	Mean size (cm)
<i>Inshore and mid-channel patch reefs</i>				
Middle Florida Keys				
A741 – Tavernier Rocks	0 $\pm$ 0	0	0 $\pm$ 0	
534 – Hen and Chickens SPA**	0 $\pm$ 0	0	0 $\pm$ 0	
535 – Hen and Chickens SPA**	0 $\pm$ 0	0	0 $\pm$ 0	
A74 – West of Conch Reef	25 $\pm$ 25	1	0.067 $\pm$ 0.067	8.5 $\pm$ 0.7
533 – West of Conch Reef	0 $\pm$ 0	0	0 $\pm$ 0	
A73 – West of Conch Reef	0 $\pm$ 0	0	0 $\pm$ 0	
<b>Middle Florida Keys Total (6)</b>	<b>4 <math>\pm</math> 4</b>	<b>4</b>	<b>0.003 <math>\pm</math> 0.003</b>	<b>8.5 <math>\pm</math> 0.7</b>
Upper Florida Keys				
638 – Inshore of Pickles Reef	0 $\pm$ 0	0	0 $\pm$ 0	
B25B – Inshore of Molasses Reef	0 $\pm$ 0	0	0 $\pm$ 0	
B25 – Inshore of Molasses Reef	0 $\pm$ 0	0	0 $\pm$ 0	
B25A – Inshore of Molasses Reef	0 $\pm$ 0	0	0 $\pm$ 0	
627 – Mosquito Bank	0 $\pm$ 0	0	0 $\pm$ 0	
629A – Mosquito Bank	0 $\pm$ 0	0	0 $\pm$ 0	
628 – Mosquito Bank	0 $\pm$ 0	0	0 $\pm$ 0	
629 – Mosquito Bank	0 $\pm$ 0	0	0 $\pm$ 0	
629B – Mosquito Bank	0 $\pm$ 0	0	0 $\pm$ 0	
630 – SE of Cannon Patch Reef	0 $\pm$ 0	0	0 $\pm$ 0	
631 – Marker 33	0 $\pm$ 0	0	0 $\pm$ 0	
633 – Basin Hill Shoals	0 $\pm$ 0	0	0 $\pm$ 0	
634 – Basin Hill Shoals	0 $\pm$ 0	0	0 $\pm$ 0	
637 – West of Turtle Rocks	0 $\pm$ 0	0	0 $\pm$ 0	
636 – West of Turtle Rocks	0 $\pm$ 0	0	0 $\pm$ 0	
Upper Florida Keys Total (15)	0 $\pm$ 0	0	0 $\pm$ 0	
<b>Mid-channel Patch Reef Total (21)</b>	<b>1 <math>\pm</math> 1</b>	<b>4</b>	<b>0.003 <math>\pm</math> 0.003</b>	<b>8.5 <math>\pm</math> 0.7</b>
<i>Offshore patch reefs</i>				
Middle Florida Keys				
A802 – Inshore of Conch Reef	0 $\pm$ 0	0	0 $\pm$ 0	
A801 – Inshore of Conch Reef	0 $\pm$ 0	0	0 $\pm$ 0	
579A – Inshore of Conch Reef	0 $\pm$ 0	0	0 $\pm$ 0	
579B – Inshore of Conch Reef	0 $\pm$ 0	0	0 $\pm$ 0	
Middle Florida Keys Total (4)	0 $\pm$ 0	0	0 $\pm$ 0	
Upper Florida Keys				
639 – Inshore of Pickles Reef	0 $\pm$ 0	0	0 $\pm$ 0	
640 – White Bank (West of Molasses)	0 $\pm$ 0	0	0 $\pm$ 0	
641 – White Bank (West of Molasses)	25 $\pm$ 25	1	0.017 $\pm$ 0.017	8.0
642 – SE of White Bank Dry Rocks	0 $\pm$ 0	0	0 $\pm$ 0	
B33 – East of White Bank Dry Rocks	0 $\pm$ 0	0	0 $\pm$ 0	
643 – White Bank (NW of French)	0 $\pm$ 0	0	0 $\pm$ 0	
B35 – West of Elbow Reef	0 $\pm$ 0	0	0 $\pm$ 0	
644 – Watson's Reef	0 $\pm$ 0	0	0 $\pm$ 0	
645 – Watson's Reef	0 $\pm$ 0	0	0 $\pm$ 0	
648 – East of Basin Hill Shoals	0 $\pm$ 0	0	0 $\pm$ 0	
649 – West of Carysfort Reef	25 $\pm$ 25	2	0.033 $\pm$ 0.019	9.1 $\pm$ 0.9
B39 – Carysfort Reef SPA**	0 $\pm$ 0	0	0 $\pm$ 0	
653 – Carysfort Reef SPA**	0 $\pm$ 0	0	0 $\pm$ 0	
Upper Florida Keys Total (13)	6 $\pm$ 4	3	0.004 $\pm$ 0.003	8.7 $\pm$ 0.7

Site number/site location	Transect frequency	N	Mean no. per m <sup>2</sup>	Mean size (cm)
<b>Offshore Patch Reef Total (17)</b>	<b>4 ± 3</b>	<b>3</b>	<b>0.003 ± 0.002</b>	<b>8.7 ± 0.7</b>
<i>Back reef rubble</i>				
Middle Florida Keys				
578 – Crocker Reef	0 ± 0	0	0 ± 0	
583 – Crocker Reef	0 ± 0	0	0 ± 0	
555A – Conch Reef	0 ± 0	0	0 ± 0	
555B – Conch Reef	0 ± 0	0	0 ± 0	
Middle Florida Keys Total (4)	0 ± 0	0	0 ± 0	
Upper Florida Keys				
688A – Pickles Reef	25 ± 25	1	0.017 ± 0.017	2.0
688B – Pickles Reef	0 ± 0	0	0 ± 0	
B62 – Molasses Reef SPA**	0 ± 0	0	0 ± 0	
691 – Molasses Reef SPA**	0 ± 0	0	0 ± 0	
688 – Sand Island	0 ± 0	0	0 ± 0	
689 – Inshore of Dixie Shoal	0 ± 0	0	0 ± 0	
702B – Elbow Reef SPA**	0 ± 0	0	0 ± 0	
702A – Elbow Reef SPA**	0 ± 0	0	0 ± 0	
Upper Florida Keys Total (8)	3 ± 3	1	0.002 ± 0.002	2.0
<b>Back Reef Rubble Total (12)</b>	<b>2 ± 2</b>	<b>1</b>	<b>0.001 ± 0.001</b>	<b>2.0</b>
<i>Low-relief hard-bottom (&lt; 6 m)</i>				
Middle Florida Keys				
A932 – Crocker Reef	0 ± 0	0	0 ± 0	
556 – Davis Reef SPA**	0 ± 0	0	0 ± 0	
A87 – Davis Reef SPA**	0 ± 0	0	0 ± 0	
A84 – Little Conch Reef	0 ± 0	0	0 ± 0	
A85 – Little Conch Reef	0 ± 0	0	0 ± 0	
554 – Conch Reef C1**	0 ± 0	0	0 ± 0	
555 – Conch Reef C2**	0 ± 0	0	0 ± 0	
A86 – Conch Reef C3**	0 ± 0	0	0 ± 0	
579C – NE of Conch Reef	0 ± 0	0	0 ± 0	
Middle Florida Keys Total (9)	0 ± 0	0	0 ± 0	
Upper Florida Keys				
693 – Little Pickles Reef	0 ± 0	0	0 ± 0	
664 – North of French Reef	0 ± 0	0	0 ± 0	
665 – Inshore of Dixie Shoal	0 ± 0	0	0 ± 0	
Upper Florida Keys Total (3)	0 ± 0	0	0 ± 0	
<b>Shallow Hard-bottom Total (17)</b>	<b>0 ± 0</b>	<b>0</b>	<b>0 ± 0</b>	
<i>High-relief spur &amp; groove</i>				
Upper Florida Keys				
697 – Pickles Reef P1	0 ± 0	0	0 ± 0	
695 – Pickles Reef P3	0 ± 0	0	0 ± 0	
696 – NE Pickles Reef	25 ± 25	1	0.017 ± 0.017	6.7
706 – Molasses Reef SPA**	0 ± 0	0	0 ± 0	
707 – Molasses Reef SPA**	0 ± 0	0	0 ± 0	
711 – Sand Island	0 ± 0	0	0 ± 0	
704 – French Reef SPA**	0 ± 0	0	0 ± 0	
705 – French Reef SPA**	0 ± 0	0	0 ± 0	
699 – North of French Reef	0 ± 0	0	0 ± 0	
662 – Grecian Rocks SPA**	0 ± 0	0	0 ± 0	
663 – Grecian Rocks SPA**	0 ± 0	0	0 ± 0	
B42 – Little Grecian Rocks	0 ± 0	0	0 ± 0	
660 – Key Largo Dry Rocks**	0 ± 0	0	0 ± 0	
661 – Key Largo Dry Rocks**	0 ± 0	0	0 ± 0	

Site number/site location	Transect frequency	N	Mean no. per m <sup>2</sup>	Mean size (cm)
656 – North Dry Rocks	0 ± 0	0	0 ± 0	
657 – North-North Dry Rocks	0 ± 0	0	0 ± 0	
702 – Elbow Reef SPA**	0 ± 0	0	0 ± 0	
703 – Elbow Reef SPA**	0 ± 0	0	0 ± 0	
B66 – South of S. Carysfort	0 ± 0	0	0 ± 0	
700A – South Carysfort Reef**	0 ± 0	0	0 ± 0	
700 – South Carysfort Reef**	0 ± 0	0	0 ± 0	
B67 – Carysfort Reef C2**	0 ± 0	0	0 ± 0	
701 – Carysfort Reef C5**	0 ± 0	0	0 ± 0	
659 – Turtle Reef	0 ± 0	0	0 ± 0	
Upper Florida Keys Total (24)	1 ± 1	1	0.001 ± 0.001	6.7
<b>High-relief Spur &amp; Groove Total (42)</b>	<b>1 ± 1</b>	<b>1</b>	<b>0.001 ± 0.001</b>	<b>6.7</b>
<i>Deeper Fore-reef (6-15 m)</i>				
Middle Florida Keys				
552 – SW of Crocker Reef	0 ± 0	0	0 ± 0	
551 – SW of Crocker Reef	0 ± 0	0	0 ± 0	
568 – SW of Crocker Reef	0 ± 0	0	0 ± 0	
569 – SW of Crocker Reef	0 ± 0	0	0 ± 0	
A931 – SW of Crocker Reef	0 ± 0	0	0 ± 0	
612 – Davis Reef SPA**	0 ± 0	0	0 ± 0	
613 – Davis Reef SPA**	0 ± 0	0	0 ± 0	
A941 – North of Davis Reef	0 ± 0	0	0 ± 0	
A942 – Little Conch Reef	0 ± 0	0	0 ± 0	
A94 – Little Conch Reef	0 ± 0	0	0 ± 0	
B24 – Conch Reef RO**	0 ± 0	0	0 ± 0	
625 – Conch Reef RO**	0 ± 0	0	0 ± 0	
611 – Conch Reef SPA**	0 ± 0	0	0 ± 0	
626 – Conch Reef RO**	0 ± 0	0	0 ± 0	
610 – Conch Reef SPA**	0 ± 0	0	0 ± 0	
B16 – Conch Reef SPA**	0 ± 0	0	0 ± 0	
Middle Florida Keys Total (16)	0 ± 0	0	0 ± 0	
Upper Florida Keys				
708 – NE of Conch Reef	0 ± 0	0	0 ± 0	
709 – Pickles Reef	0 ± 0	0	0 ± 0	
710 – SW of Molasses Reef SPA	0 ± 0	0	0 ± 0	
712 – SW of French Reef	25 ± 25	1	0.017 ± 0.017	5.0
B71 – Dixie Shoal	0 ± 0	0	0 ± 0	
671 – South of Grecian Rocks	0 ± 0	0	0 ± 0	
B51 – East of Dry Rocks	0 ± 0	0	0 ± 0	
713 – North of Elbow Reef	0 ± 0	0	0 ± 0	
682 – North of Elbow Reef	0 ± 0	0	0 ± 0	
B57 – SE of Watson's Reef	0 ± 0	0	0 ± 0	
716 – South Carysfort Reef**	0 ± 0	0	0 ± 0	
678 – North Carysfort Reef**	0 ± 0	0	0 ± 0	
717 – North Carysfort Reef**	0 ± 0	0	0 ± 0	
679 – North Carysfort Reef**	0 ± 0	0	0 ± 0	
675 – North of Carysfort Reef	0 ± 0	0	0 ± 0	
676 – North of Carysfort Reef	0 ± 0	0	0 ± 0	
677 – North of Carysfort Reef	0 ± 0	0	0 ± 0	
715 – North of Carysfort Reef	0 ± 0	0	0 ± 0	
Upper Florida Keys Total (18)	1 ± 1	1	0.001 ± 0.001	5.0
<b>Deeper Fore-reef Total (34)</b>	<b>1 ± 1</b>	<b>1</b>	<b>&lt; 0.001 ± &lt; 0.001</b>	<b>5.0</b>

Table 5-6. Number of individuals (N), mean, standard error (SE), and range in sea urchin test diameters by species and habitat type in the upper Florida Keys National Marine Sanctuary, as determined from surveys of four 15-m x 1-m belt transects per site at 120 sites during June-August 2010.

Habitat type (no. sites)	Transect depth (m)	N	Mean test size (cm)	SE	Min. test size (cm)	Max. test size (cm)
<b><i>Diadema antillarum</i></b>						
Inshore and mid-channel patch reef (21)	1.2-6.7	9	4.7	0.9	1.5	8.2
Offshore patch reef (17)	1.8-8.2	20	6.3	0.6	0.7	10.0
Back reef rubble (12)	1.5-6.1	21	1.5	0.1	0.6	2.5
Shallow (< 6 m) hard-bottom (12)	3.0-7.3	6	5.3	0.6	4.5	8.0
High-relief spur and groove (24)	1.5-8.2	14	4.3	0.5	1.2	8.0
Deeper (6-15 m) fore-reef (34)	5.8-14.9	5	3.3	1.2	0.4	6.5
All habitats combined (120 sites)	1.2-14.9	75	4.1	0.3	0.4	10.0
<b><i>Echinometra lucunter</i></b>						
Inshore and mid-channel patch reef (21)	1.2-6.7	4	2.0	0.2	1.7	2.6
Offshore patch reef (17)	1.8-8.2	5	2.0	0.3	0.9	3.0
Back reef rubble (12)	1.5-6.1	24	1.1	0.1	0.7	2.5
Shallow (< 6 m) hard-bottom (12)	3.0-7.3	0				
High-relief spur and groove (24)	1.5-8.2	2	1.7	0.1	1.6	1.8
Deeper (6-15 m) fore-reef (34)	5.8-14.9	0				
All habitats combined (120 sites)	1.2-14.9	35	1.4	0.1	0.7	3.0
<b><i>Echinometra viridis</i></b>						
Inshore and mid-channel patch reef (21)	1.2-6.7	191	2.9	0.1	0.3	5.0
Offshore patch reef (17)	1.8-8.2	41	2.1	0.1	0.7	3.5
Back reef rubble (12)	1.5-6.1	20	1.2	0.1	0.6	2.2
Shallow (< 6 m) hard-bottom (12)	3.0-7.3	1	0.9		0.9	0.9
High-relief spur and groove (24)	1.5-8.2	2	1.5	0.3	1.2	1.7
Deeper (6-15 m) fore-reef (34)	5.8-14.9	6	1.7	0.2	1.1	2.2
All habitats combined (120 sites)	1.2-14.9	261	2.6	0.1	0.3	5.0
<b><i>Euclidaris tribuloides</i></b>						
Inshore and mid-channel patch reef (21)	1.2-6.7	37	2.7	0.1	1.9	3.9
Offshore patch reef (17)	1.8-8.2	58	2.6	0.1	1.3	4.0
Back reef rubble (12)	1.5-6.1	186	1.7	0.1	0.5	3.4
Shallow (< 6 m) hard-bottom (12)	3.0-7.3	83	2.1	0.4	1.0	4.5
High-relief spur and groove (24)	1.5-8.2	79	2.0	0.0	1.2	3.0
Deeper (6-15 m) fore-reef (34)	5.8-14.9	12	2.1	0.1	1.3	2.6
All habitats combined (120 sites)	1.2-14.9	455	2.1	0.0	0.5	4.5
<b><i>Tripneustes ventricosus</i></b>						
Inshore and mid-channel patch reef (21)	1.2-6.7	4	8.5	0.7	7.0	10.0
Offshore patch reef (17)	1.8-8.2	3	8.7	0.7	8.0	10.0
Back reef rubble (12)	1.5-6.1	1	2.0		2.0	2.0
Shallow (< 6 m) hard-bottom (12)	3.0-7.3	0				
High-relief spur and groove (24)	1.5-8.2	1	6.7		6.7	6.7
Deeper (6-15 m) fore-reef (34)	5.8-14.9	1	5.0		5.0	5.0
All habitats combined (120 sites)	1.2-14.9	10	7.4	0.8	2.0	10.0