

IV. Distribution and Abundance of *Acropora* Corals

Background

The declines in abundance of two of the principal Caribbean reef-building corals, staghorn coral (*Acropora cervicornis*) and elkhorn coral (*A. palmata*), are often-cited examples of the changes that have occurred on wider Caribbean reefs, including the Florida Keys, during the past several decades (Bruckner 2002; Gardner et al. 2003). The causes of these declines, which began in the late 1970s, include regional phenomena such as coral bleaching and disease, especially white band disease (Gladfelter 1982; Aronson and Precht 2001), as well as more localized effects from storms, cold fronts, and predation by corallivorous snails and damselfishes (Miller et al. 2002). Both coral species were under consideration for addition to the U.S. Endangered Species List (ESA) as of the early 1990s and were formally determined to be “threatened” on the ESA based upon range-wide population declines and poor recovery (*Acropora* Biological Review Team 2005).

Increased awareness of the fragility of Atlantic *Acropora* corals and the potential for further population decline, as well as recovery at some locations, stresses the need to gather information on habitat distribution, colony size, density, and population abundance estimates for wider Caribbean reefs. Population assessments of *A. palmata* in the U.S. Virgin Islands (Mayor et al. 2006), southern Caribbean (Zubillaga et al. 2008), at Looe Key in the Florida Keys (Miller et al. 2002) and by our program Keys-wide in 2007 and 2008 (see 2007 and 2008 Quick Look Reports at <http://people.uncw.edu/millers>) are recent examples. While some recovery is apparent in localized areas, populations of both species remain well-below historical levels, including those in the Florida Keys (Dustan and Halas 1987; Porter and Meier 1992). Moreover, localized and regional threats may inhibit population recovery (*Acropora* Biological Review Team 2005).

To document the current population status of stony corals, including *Acropora* spp., we conducted an assessment of the spatial distribution, colony abundance, size, and condition of these two corals in the upper Florida Keys during 2010. This effort is similar to the 2006 and 2007 field surveys, except that we were limited in 2010 to the geographic area between SW of Crocker Reef northwards to Turtle Reef (similar to 2006). Nevertheless, these efforts contribute to a temporal record dating back to 1999 on the abundance, size, and condition of *Acropora* corals. Using a stratified random sampling design, the goals of the 2010 surveys were to assess patterns in habitat distribution, colony abundance, size, and condition of *Acropora* corals in multiple habitat types, both inside and outside of FKNMS no-take zones. The data were used to construct population abundance estimates by size class and by habitat to provide comparisons to similar data collected in 2006 and 2007.

2010 *Acropora cervicornis* Survey Results

Both *Acropora* coral species surveyed in the upper Florida Keys during 2010 exhibited distribution and abundance patterns that were mostly similar to 2007-2009. While *Acropora cervicornis* (Figure 4-1) was encountered in all of the habitats sampled, frequency of occurrence and density continue to be greatest on patch reefs. Table 4-1 shows presence-absence and mean transect frequency of occurrence data, while Table 4-2 lists site-level mean densities, total surface area, and mean size. Figures 4-2 to 4-4 illustrate the spatial distribution of *A. cervicornis* densities in the upper Florida Keys, while Figures 4-5 and 4-6 illustrate mean colony densities by site for each of the habitats sampled. Overall, *A. cervicornis* was encountered within transects at 14 out of the 120 sites (12%) and in all of the habitats surveyed (Table 4-1). Mean (± 1 SE) transect frequency of occurrence was greater on offshore patch reefs ($9\% \pm 3\%$) and shallow (< 6 m) hard-bottom ($8\% \pm 6\%$) and relatively low ($5\% \pm 3\%$) on mid-channel patch reefs. From 84 transects surveyed at 21 mid-channel patch reefs, colonies were only found at three sites (14%) and only in reference areas. On the 17 offshore patch reefs sampled, *A. cervicornis* was present at three out of 17 sites (18%) and only found in reference sites. Staghorn coral was especially prevalent at a few patch reefs inshore of Conch Reef. As in previous years, frequency of occurrence of *A. cervicornis* was relatively low ($< 5\%$ of transects) on shallow spur and groove and deeper fore-reef habitats (Table 4-1).

A total of 131 colonies of *Acropora cervicornis* were surveyed in 480 belt transects (15-m x 1-m) among the 120 upper Keys sites, yielding a total surface area of 30,920 cm² (Table 4-2). On mid-channel patch reefs, 21 colonies were encountered (16% of total), yielding a mean density of 0.021 ± 0.017 colonies per m² and a total surface area of 5,564 cm². One mid-channel patch reef (site A73) west of Conch Reef contained several colonies. As in previous years, offshore patch reefs yielded the greatest densities of staghorn corals (66 colonies or 50%), even though offshore patch reefs represented only 14% of the total sampling effort in 2010 (Figure 4-2 to 4-4). Mean colony density on offshore patch reefs was 0.065 ± 0.039 per m², with a total colony surface area of 5,560 cm² among all colonies. Two sites inshore of Conch Reef (A801 and A802) and one site NW of French Reef on White Bank (643) contained several patches of staghorn corals (Figure 4-5). Shallow (< 6 m) hard-bottom sites also yielded relatively high numbers of larger colonies (Table 4-2). Other habitats such as back-reef rubble, shallow spur and groove, and deeper fore-reef habitats yielded relatively low densities of staghorn corals (Figure 4-6).

In addition to density and size assessments, the sampled staghorn colonies were also assessed for condition as related to evidence of bleaching, disease, predation, and overgrowth. Out of the 131 colonies

counted and measured in the upper Keys during 2010, a total of 21 colonies (16%) exhibited symptoms of bleaching (paling, partial or total bleaching) from late June to late August. Bleaching prevalence was relatively high in most of the habitats sampled, particularly on back-reef rubble sites (100% of colonies), high-relief spur and groove (36%), shallow hard-bottom (23%), mid-channel patch reefs (19%). Of the 131 *Acropora cervicornis* colonies sampled, none were observed with any evident signs of disease such as white-band disease. Overgrowth that was causing obvious tissue abrasion and partial mortality was documented on only four colonies (3%). Predation by *Coralliophila* snails, fireworms (*Hermodice carunculata*), or damselfishes (Pomacentridae) affected ~8% of the colonies assessed during 2010. The proportion of colonies with obvious signs of predation was greatest on back-reef rubble sites (67%), shallow hard-bottom (23%), and offshore patch reefs (6%).

2010 *Acropora palmata* Survey Results

Acropora palmata (Figure 4-7) was encountered at 13 of the 120 upper Keys sites (11%) (Table 4-1). Table 4-1 provides presence-absence and mean transect frequency of occurrence, while Table 4-3 lists site-level mean colony densities, total surface area, and mean colony sizes. Figures 4-8 to 4-10 illustrate site-level densities across the upper Florida Keys study area and Figures 4-11 and 4-12 illustrate mean site-level densities by habitat type. Elkhorn coral colonies were found only in three of the habitats surveyed: back-reef rubble, shallow hard-bottom, and high-relief spur and groove. Mean transect frequency of occurrence was low (2%) in two of these habitats. In back-reef rubble zones, *A. palmata* was only encountered at one out of 12 sites (8%); the one site is located in the back reef of Pickles Reef. On shallow hard-bottom, *A. palmata* was only found at one out of 12 sites (8%); the one site is at shallow Conch Reef SPA near mooring buoy C1 (site 554) (Table 4-3). As in previous years, high-relief spur and groove reefs yielded the greatest transect frequency of occurrence. *A. palmata* was found on $19\% \pm 5\%$ of the 96 transects sampled at 24 sites. Elkhorn coral was encountered at 11 of the 24 high-relief spur and groove sites (46%), seven of which are in no-take zones (Molasses Reef SPA, Grecian Rocks SPA, Dry Rocks SPA, Elbow Reef SPA, Carysfort/S. Carysfort SPA), while the remaining sites are reference areas such as Sand Island, Little Grecian, North-North Dry Rocks, and Turtle Reef (Figures 4-8 to 4-10).

A total of 129 *Acropora palmata* colonies were surveyed from 480 belt transects (15-m x 1-m), with a total surface area of 180,259 cm² measured among all colonies (Table 4-3). In back-reef rubble zones, two colonies (2% of the total) were encountered among all sites, yielding an overall habitat-level mean density of 0.003 ± 0.003 colonies per m² and a total surface area of 859 cm² (Table 4-3). On shallow hard-bottom, a total of five colonies from one site (site 554 at Conch Reef SPA) were encountered (4% of the total), with a mean density of 0.007 ± 0.007 colonies per m² and a total surface area of 495 cm². High-

relief spur and groove reefs yielded the most elkhorn corals and the greatest sizes. A total of 122 colonies were found (95% of total) on high-relief spur and groove reefs, even though only 20% of the total sampling effort was devoted to this habitat type. The mean colony density (0.085 ± 0.030 per m^2) and total surface area of $178,905 \text{ cm}^2$ were substantially greater than in other habitats. A maximum site-level density of 0.500 ± 0.250 colonies per m^2 was recorded at Sand Island (711), just north of Molasses Reef SPA, but relatively high densities and/or large colonies were also recorded at Grecian Rocks, Elbow Reef, and South Carysfort Reef.

In contrast to its congener, only three out of the 129 (2%) *Acropora palmata* colonies sampled during late June to late August exhibited any symptoms of bleaching such as paling, partial bleaching, or total bleaching. None of the elkhorn corals sampled exhibited any symptoms of disease. Active colony overgrowth by other organisms such as macroalgae was documented on four out of 131 colonies (3%). Predation by corallivorous snails, fireworms, and/or damselfishes was documented on ten out of 129 colonies (8%). On high-relief spur and groove reefs, where most (122) colonies were encountered, eight colonies (7%) exhibited obvious signs of predation.

Discussion

Results from the 2010 sampling effort add to a growing spatial and temporal data set on the status and changes in Florida Keys *Acropora palmata* and *A. cervicornis* populations. Subsequent analyses will yield domain-wide abundance estimates, structured by colony size that will provide for estimates of population size by habitat, region, and for individual no-take marine reserves. While earlier Keys-wide sampling in previous years was not optimized for *Acropora* corals, the benthic data still provide important opportunities to compare populations across multiple habitat types, including managed areas in the FKNMS. What is apparent from the *Acropora* surveys is that the distribution and abundance patterns of these two species are clearly different, perhaps necessitating different management approaches. Although 24 high-relief spur and groove sites were sampled in 2010, the results indicate that significant *A. palmata* stands remain at only a handful of sites, namely South Carysfort Reef, Elbow Reef, Grecian Rocks, and Sand Island. Although most of these sites are already within existing FKNMS no-take zones, predation by snails and damselfishes is still prevalent. In contrast, the distribution pattern of *A. cervicornis* reflects the importance of patch reefs to the possible recovery of this species. While there are over 5,000 patch reef sites on the south Florida shelf, staghorn is currently very patchily distributed, and the factors responsible for this pattern are not well known. In addition, patch reefs closer to shore are more susceptible to both hyper- and hypothermal events, best exemplified by the January 2010 cold-front, which apparently impacted many nearshore reefs, including those that support staghorn corals.

Figure 4-1. Examples of *Acropora cervicornis* in hard-bottom and coral reef habitats in the upper Florida Keys National Marine Sanctuary observed during June-August 2010.

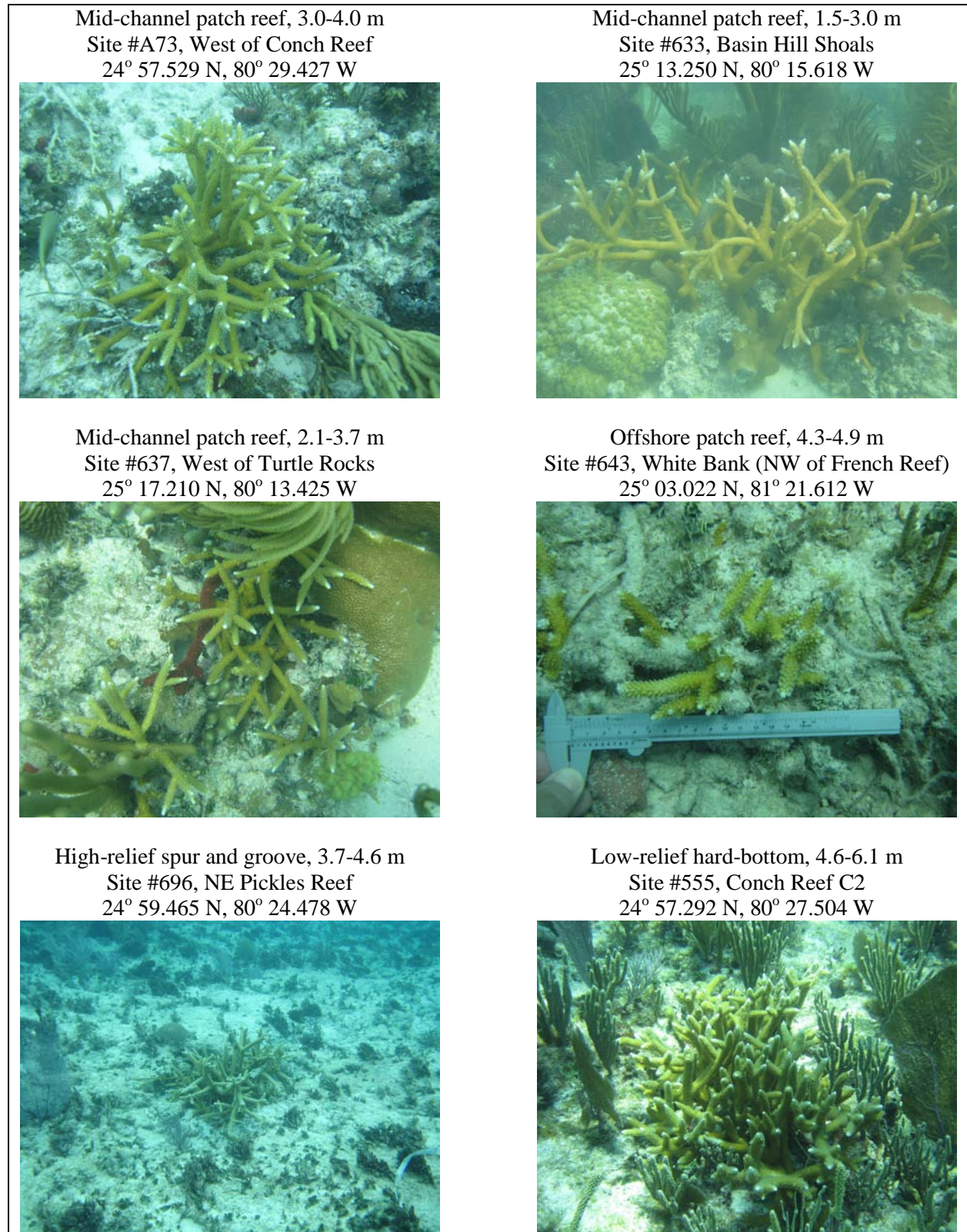


Figure 4-2. Staghorn coral (*Acropora cervicornis*) presence-absence and colony density (no. of colonies/m²) in the Florida Keys from the southern BNP boundary south to Carysfort/S. Carysfort Reef SPA surveyed during June-August 2010.

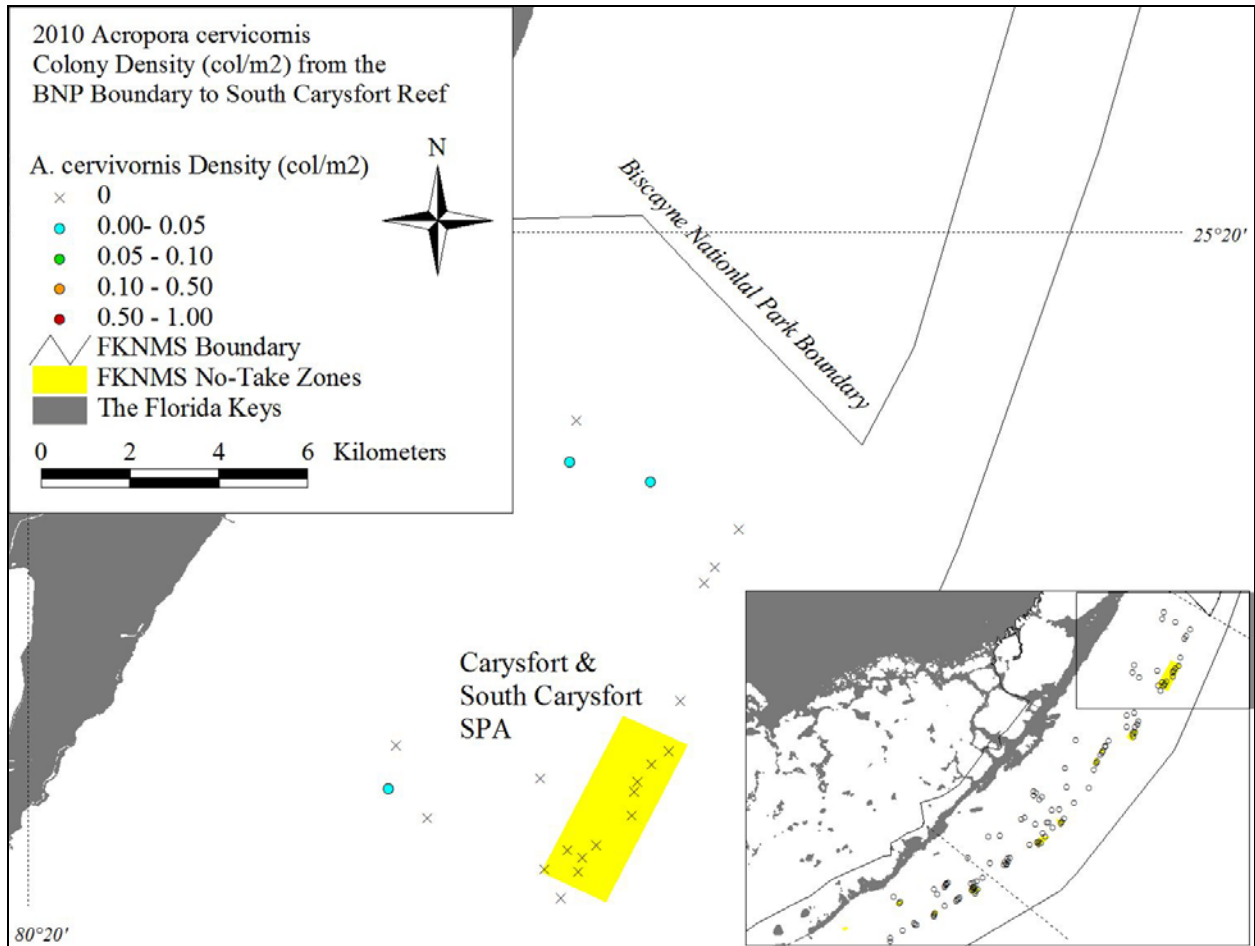


Figure 4-3. Staghorn coral (*Acropora cervicornis*) presence-absence and colony density (no. of colonies/m²) in the Florida Keys from Elbow Reef SPA to Pickles Reef surveyed during June-August 2010.

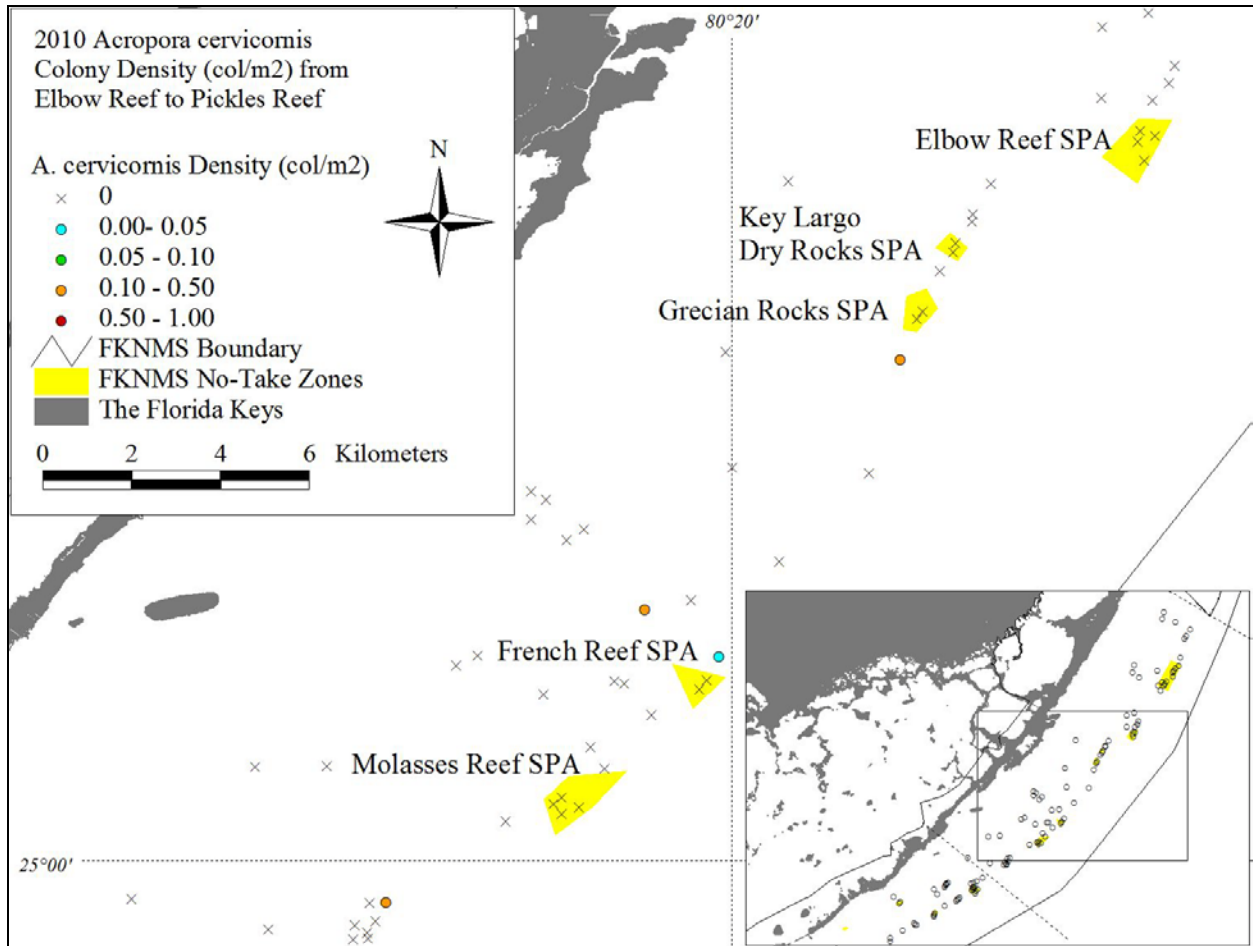


Figure 4-4. Staghorn coral (*Acropora cervicornis*) presence-absence and colony density (no. of colonies/m²) in the Florida Keys from Conch Reef SPA to Crocker Reef surveyed during June-August 2010.

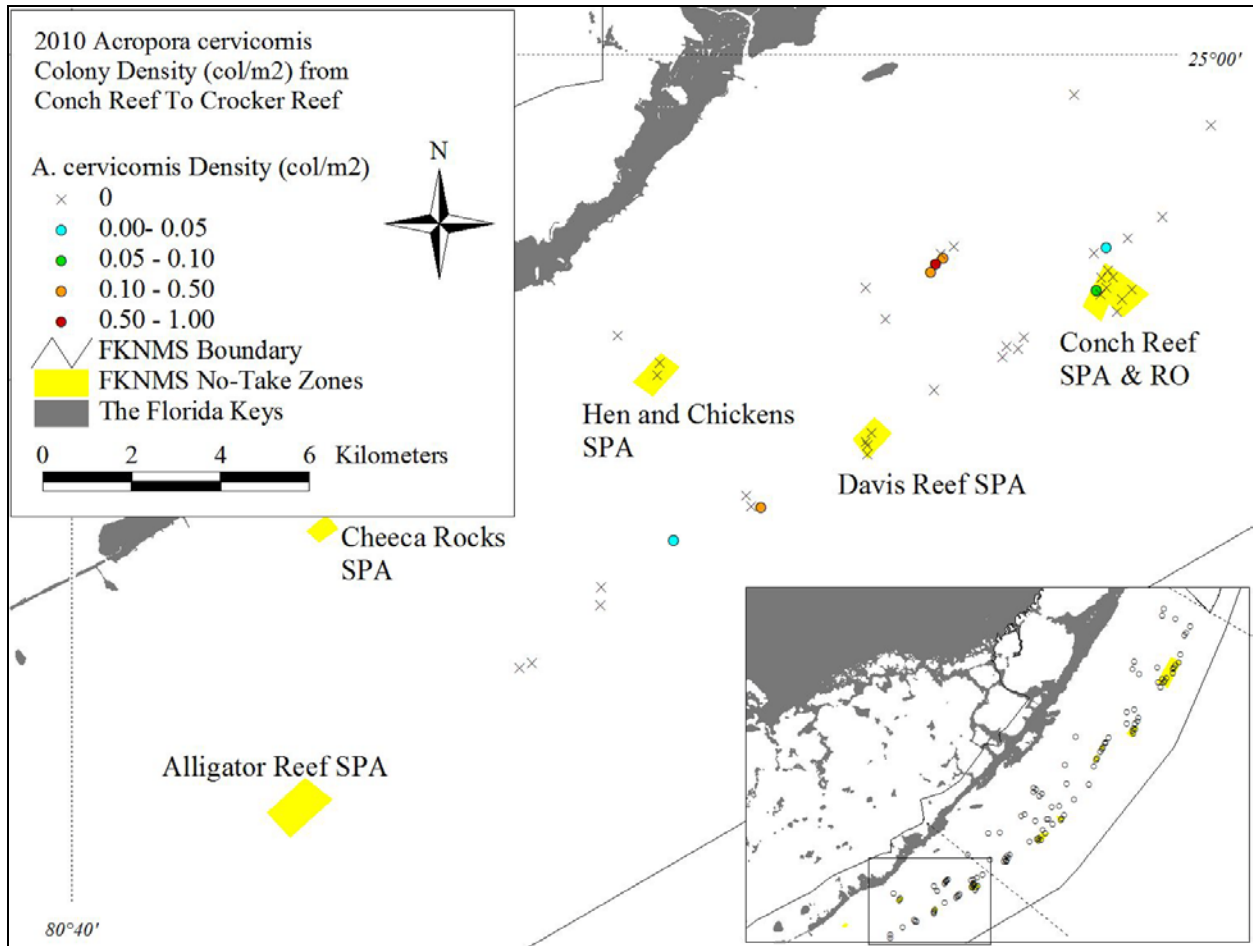


Figure 4-5. Mean (+ 1 SE) densities (no. colonies per m²) of staghorn corals (*Acropora cervicornis*) on inshore and mid-channel patch reefs (top), offshore patch reefs (middle), and back reef rubble habitats (bottom) in the upper Florida Keys during June-August 2010. Open bars = FKNMS no-take zones; filled bars = reference areas.

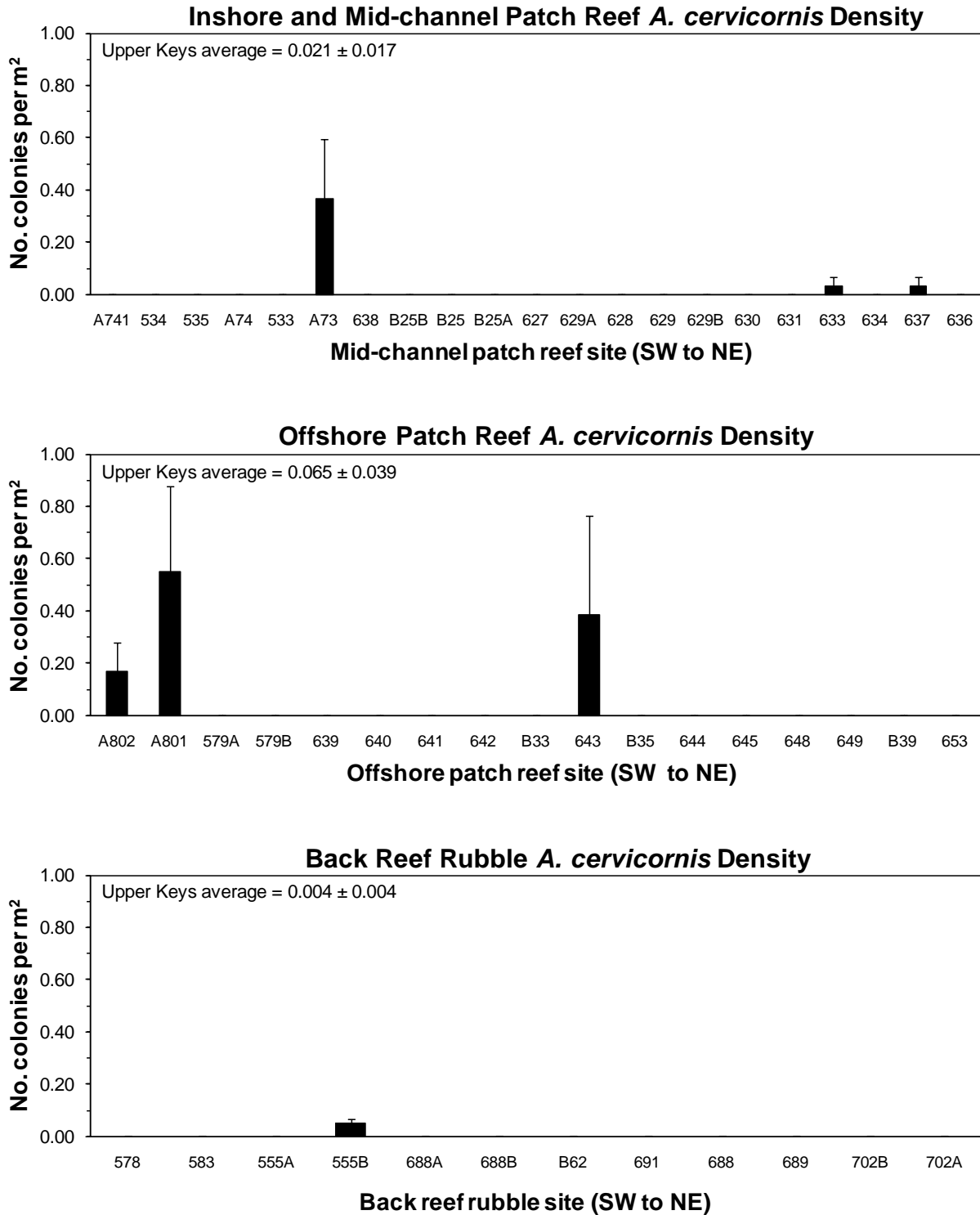


Figure 4-6. Mean (+ 1 SE) densities (no. colonies per m²) of staghorn corals (*Acropora cervicornis*) on shallow (< 6 m) hard-bottom (top), high-relief spur and groove reefs (middle) and deeper (6-15 m) fore reef habitats (bottom) in the upper Florida Keys during June-August 2010. Open bars = FKNMS no-take zones; filled bars = reference areas.

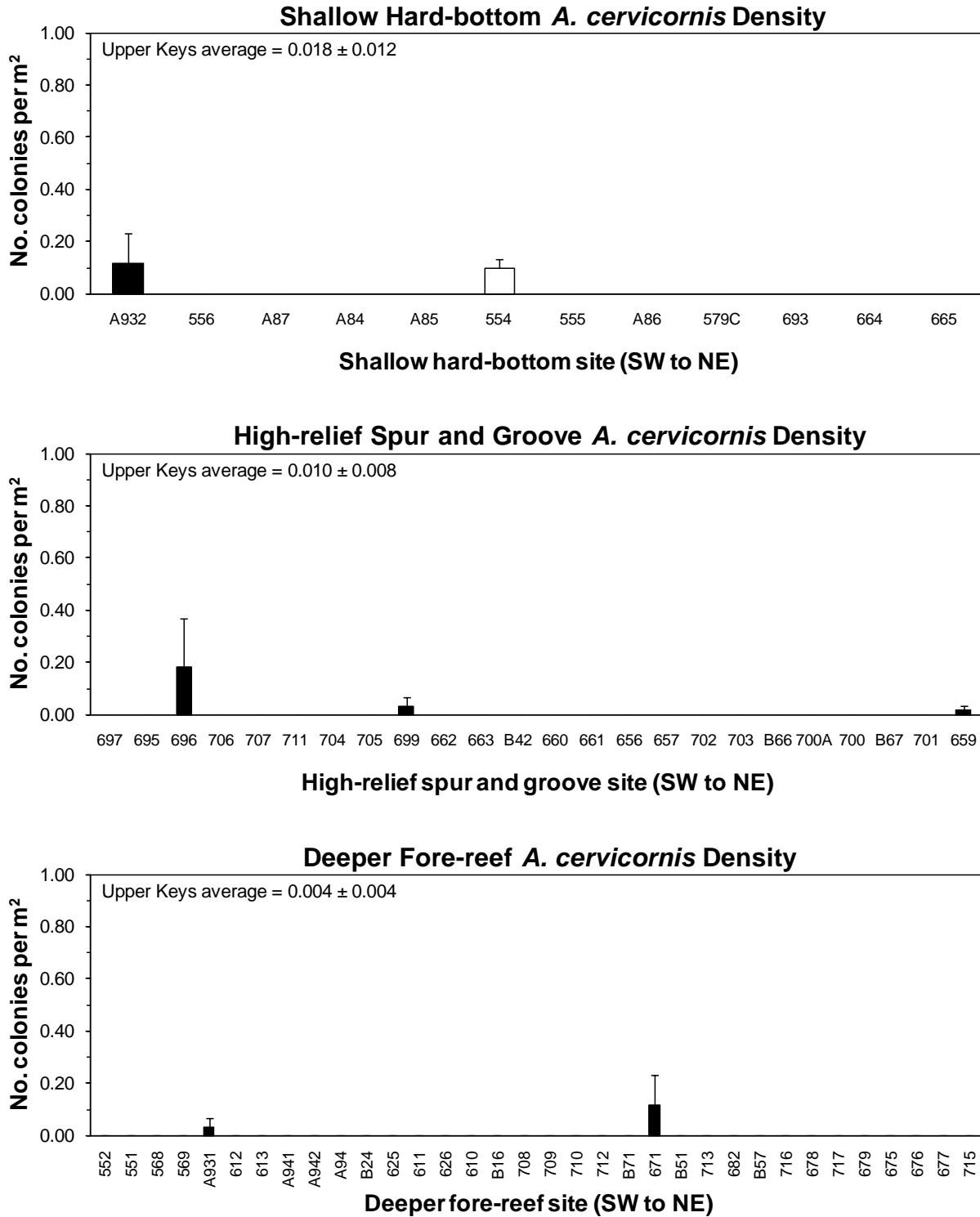


Figure 4-7. Examples of *Acropora palmata* in hard-bottom and coral reef habitats in the upper Florida Keys National Marine Sanctuary observed during June-August 2010.

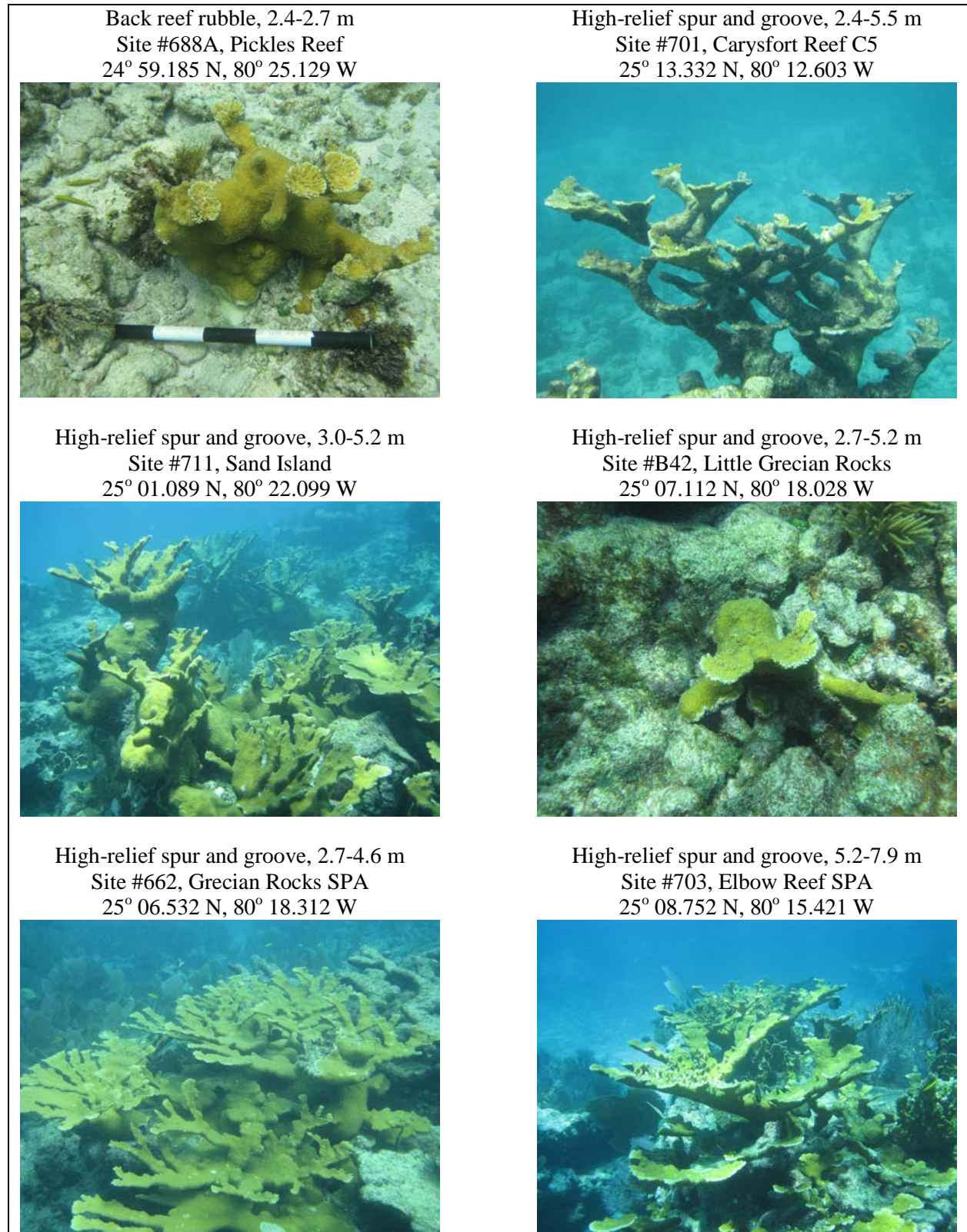


Figure 4-8. Elkhorn coral (*Acropora palmata*) presence-absence and colony density (no. of colonies/m²) in the Florida Keys from the southern BNP boundary south to Carysfort/S. Carysfort Reef SPA surveyed during June-August 2010.

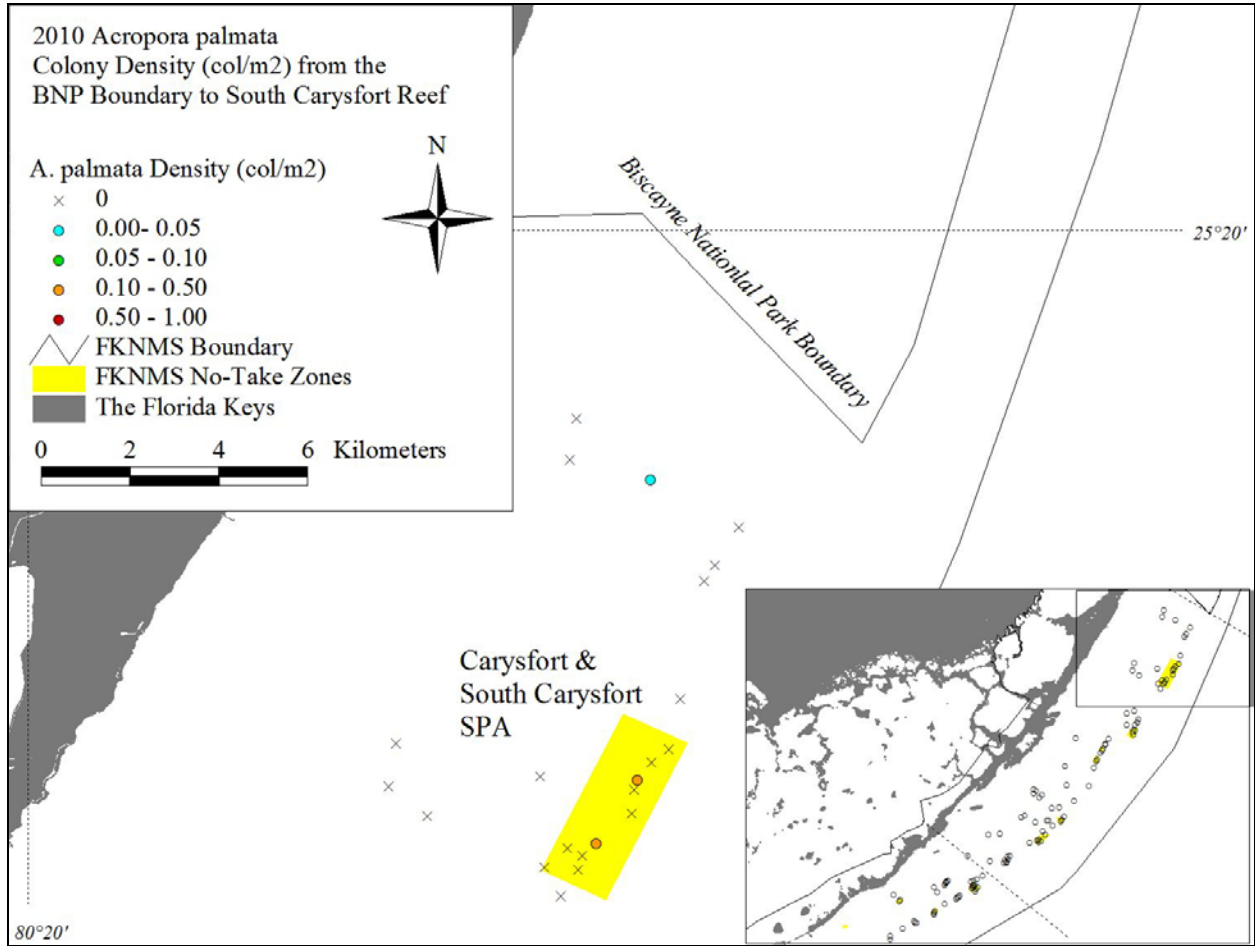


Figure 4-9. Elkhorn coral (*Acropora palmata*) presence-absence and colony density (no. of colonies/m²) in the Florida Keys from Elbow Reef SPA to Pickles Reef surveyed during June-August 2010.

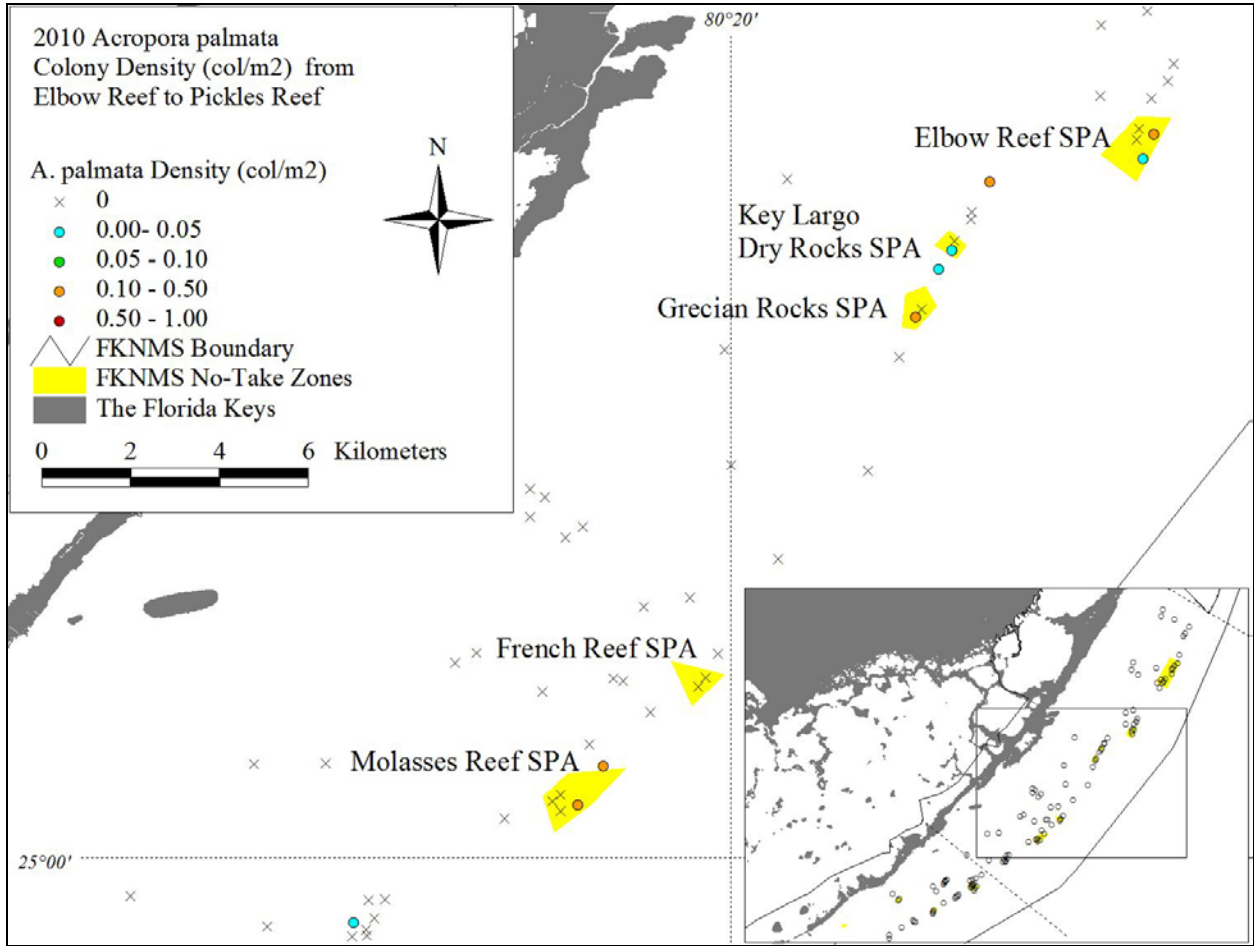


Figure 4-10. Elkhorn coral (*Acropora palmata*) presence-absence and colony density (no. of colonies/m²) in the Florida Keys from Conch Reef SPA to Crocker Reef surveyed during June-August 2010.

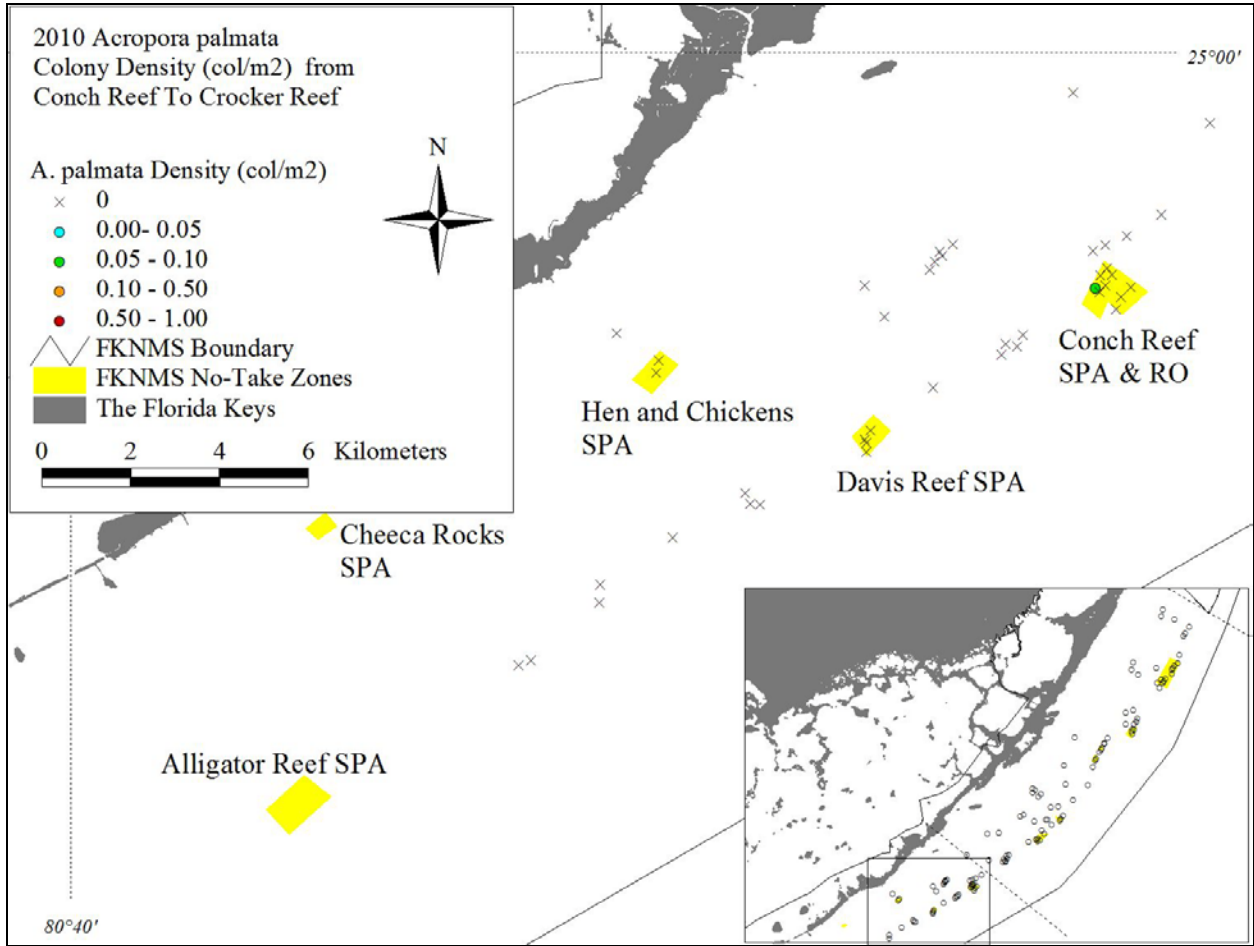


Figure 4-11. Mean (+ 1 SE) densities (no. colonies per m²) of elkhorn corals (*Acropora palmata*) on inshore and mid-channel patch reefs (top), offshore patch reefs (middle), and back reef rubble habitats (bottom) in the upper Florida Keys during June-August 2010. Open bars = FKNMS no-take zones; filled bars = reference areas.

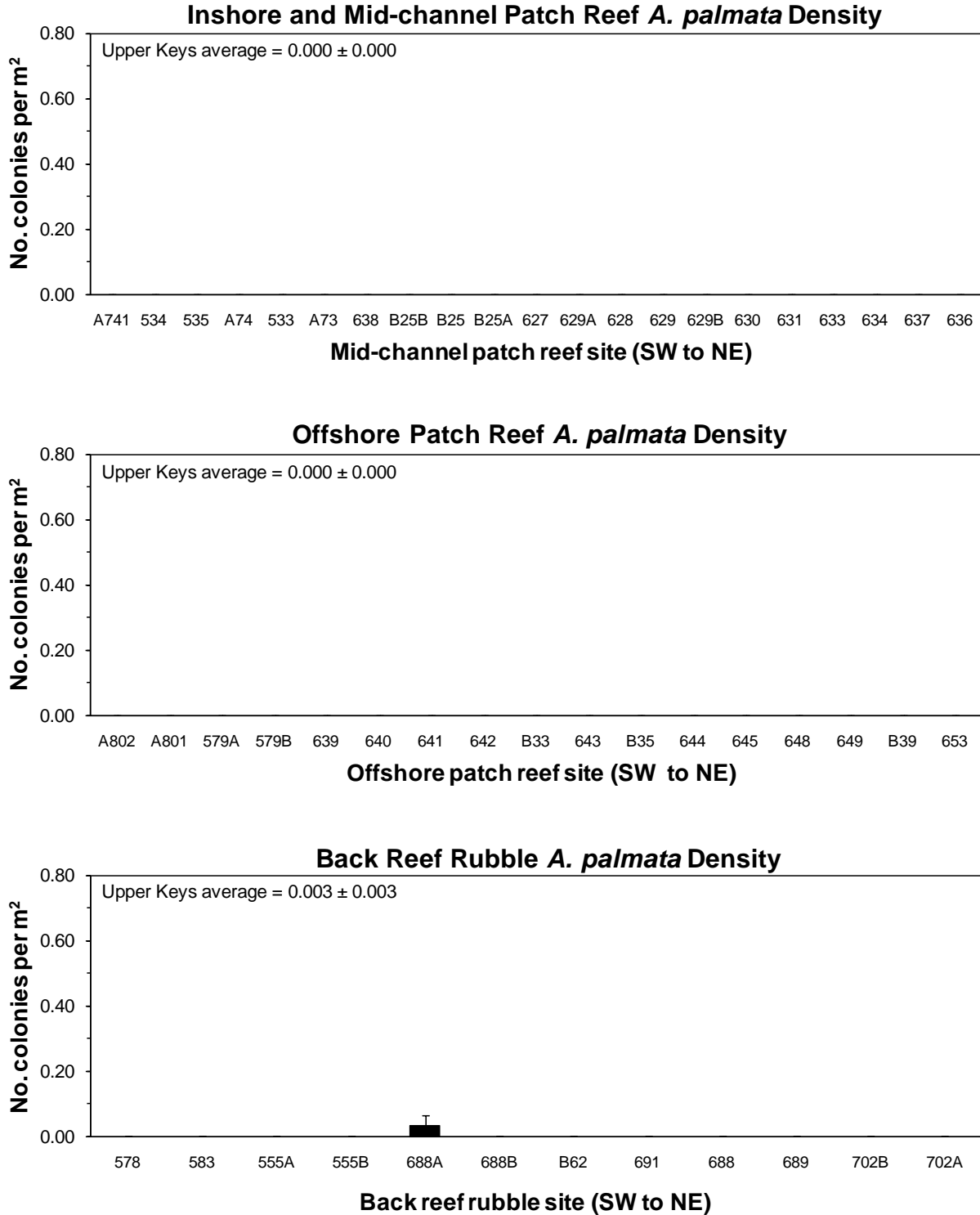


Figure 4-12. Mean (+ 1 SE) densities (no. colonies per m²) of elkhorn corals (*Acropora palmata*) on shallow (< 6 m) hard-bottom (top), high-relief spur and groove reefs (middle) and deeper (6-15 m) fore reef habitats (bottom) in the upper Florida Keys during June-August 2010. Open bars = FKNMS no-take zones; filled bars = reference areas.

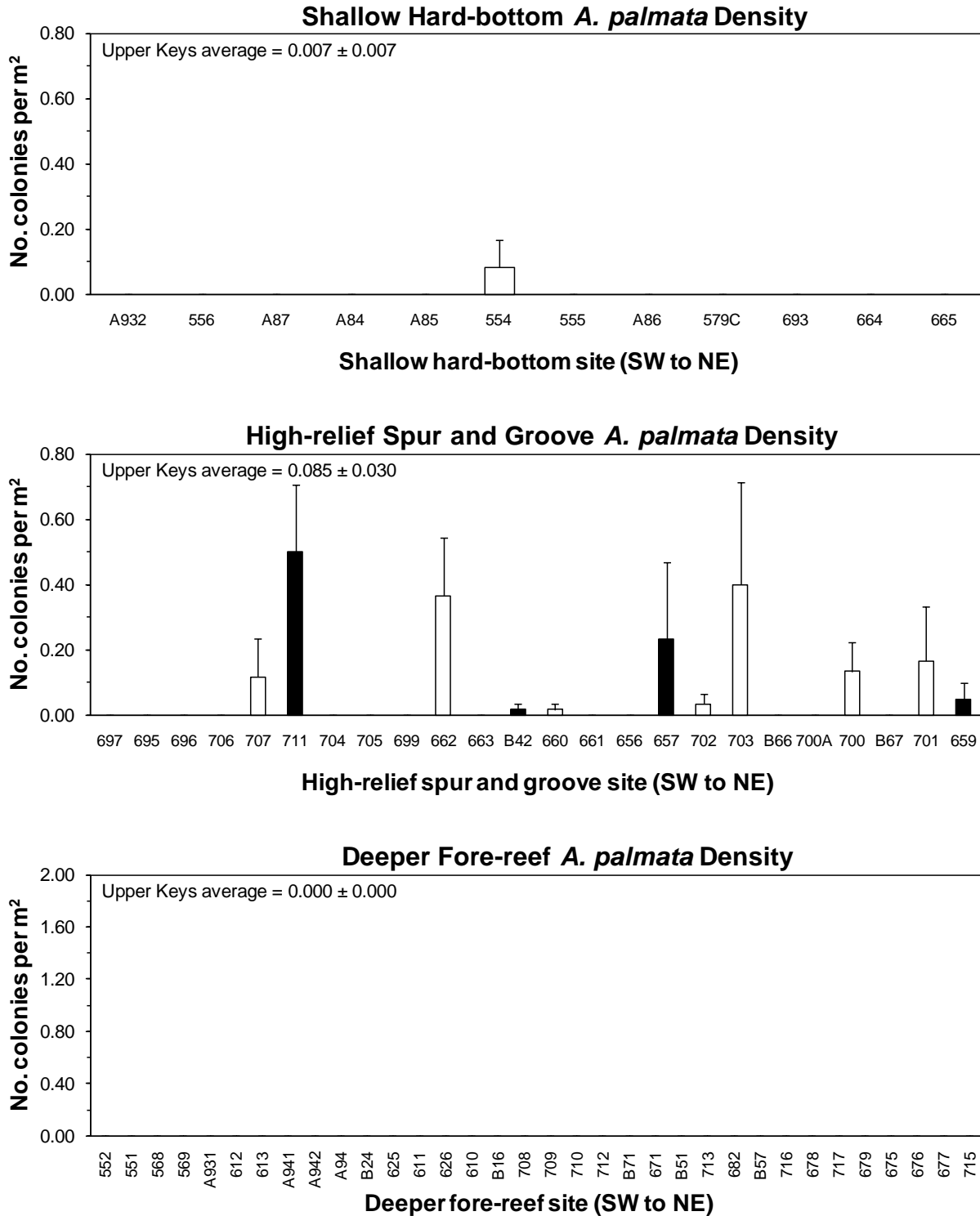


Table 4-1. Presence-absence and mean \pm 1 SE transect frequencies (%) for staghorn (*Acropora cervicornis*) and elkhorn (*A. palmata*) corals in the upper Florida Keys National Marine Sanctuary, as determined from surveys of four 15-m x 1-m belt transects per site at 120 sites during June-August 2010. Sites are arranged by habitat from SW to NE and asterisked locations (**) are no-take zones.

Site number/site location	<i>Acropora cervicornis</i>		<i>Acropora palmata</i>	
	Present	Transect frequency (%)	Present	Transect frequency (%)
<i>Inshore and mid-channel patch reefs</i>				
Middle Florida Keys				
A741 – Tavernier Rocks		0 \pm 0		0 \pm 0
534 – Hen and Chickens SPA**		0 \pm 0		0 \pm 0
535 – Hen and Chickens SPA**		0 \pm 0		0 \pm 0
A74 – West of Conch Reef		0 \pm 0		0 \pm 0
533 – West of Conch Reef		0 \pm 0		0 \pm 0
A73 – West of Conch Reef	**	50 \pm 29		0 \pm 0
Middle Florida Keys Total (6)	**	8 \pm 8		0 \pm 0
Upper Florida Keys				
638 – Inshore of Pickles Reef		0 \pm 0		0 \pm 0
B25B – Inshore of Molasses Reef		0 \pm 0		0 \pm 0
B25 – Inshore of Molasses Reef		0 \pm 0		0 \pm 0
B25A – Inshore of Molasses Reef		0 \pm 0		0 \pm 0
627 – Mosquito Bank		0 \pm 0		0 \pm 0
629A – Mosquito Bank		0 \pm 0		0 \pm 0
628 – Mosquito Bank		0 \pm 0		0 \pm 0
629 – Mosquito Bank		0 \pm 0		0 \pm 0
629B – Mosquito Bank		0 \pm 0		0 \pm 0
630 – SE of Cannon Patch Reef		0 \pm 0		0 \pm 0
631 – Marker 33		0 \pm 0		0 \pm 0
633 – Basin Hill Shoals	**	25 \pm 25		0 \pm 0
634 – Basin Hill Shoals		0 \pm 0		0 \pm 0
637 – West of Turtle Rocks	**	25 \pm 25		0 \pm 0
636 – West of Turtle Rocks		0 \pm 0		0 \pm 0
Upper Florida Keys Total (15)	**	3 \pm 2		0 \pm 0
Mid-channel Patch Reef Total (21)	**	5 \pm 3		0 \pm 0
<i>Offshore patch reefs</i>				
Middle Florida Keys				
A802 – Inshore of Conch Reef		0 \pm 0		0 \pm 0
A801 – Inshore of Conch Reef	**	75 \pm 25		0 \pm 0
579A – Inshore of Conch Reef		0 \pm 0		0 \pm 0
579B – Inshore of Conch Reef		0 \pm 0		0 \pm 0
Middle Florida Keys Total (4)	**	19 \pm 19		0 \pm 0
Upper Florida Keys				
639 – Inshore of Pickles Reef		0 \pm 0		0 \pm 0
640 – White Bank (West of Molasses)		0 \pm 0		0 \pm 0
641 – White Bank (West of Molasses)		0 \pm 0		0 \pm 0
642 – SE of White Bank Dry Rocks		0 \pm 0		0 \pm 0
B33 – East of White Bank Dry Rocks		0 \pm 0		0 \pm 0
643 – White Bank (NW of French)	**	25 \pm 25		0 \pm 0
B35 – West of Elbow Reef		0 \pm 0		0 \pm 0
644 – Watson’s Reef		0 \pm 0		0 \pm 0
645 – Watson’s Reef		0 \pm 0		0 \pm 0
648 – East of Basin Hill Shoals		0 \pm 0		0 \pm 0
649 – West of Carysfort Reef		0 \pm 0		0 \pm 0
B39 – Carysfort Reef SPA**		0 \pm 0		0 \pm 0
653 – Carysfort Reef SPA**		0 \pm 0		0 \pm 0

Site number/site location	<i>Acropora cervicornis</i>		<i>Acropora palmata</i>	
	Present	Transect frequency (%)	Present	Transect frequency (%)
Upper Florida Keys Total (13)	**	2 ± 2		0 ± 0
Offshore Patch Reef Total (17)	**	6 ± 5		0 ± 0
<i>Back reef rubble</i>				
Middle Florida Keys				
578 – Crocker Reef		0 ± 0		0 ± 0
583 – Crocker Reef		0 ± 0		0 ± 0
555A – Conch Reef		0 ± 0		0 ± 0
555B – Conch Reef	**	75 ± 25		0 ± 0
Middle Florida Keys Total (4)	**	19 ± 19		0 ± 0
Upper Florida Keys				
688A – Pickles Reef		0 ± 0	**	25 ± 25
688B – Pickles Reef		0 ± 0		0 ± 0
B62 – Molasses Reef SPA**		0 ± 0		0 ± 0
691 – Molasses Reef SPA**		0 ± 0		0 ± 0
688 – Sand Island		0 ± 0		0 ± 0
689 – Inshore of Dixie Shoal		0 ± 0		0 ± 0
702B – Elbow Reef SPA**		0 ± 0		0 ± 0
702A – Elbow Reef SPA**		0 ± 0		0 ± 0
Upper Florida Keys Total (8)		0 ± 0	**	3 ± 3
Back Reef Rubble Total (12)	**	6 ± 6	**	2 ± 2
<i>Low-relief hard-bottom (< 6 m)</i>				
Middle Florida Keys				
A932 – Crocker Reef	**	25 ± 25		0 ± 0
556 – Davis Reef SPA**		0 ± 0		0 ± 0
A87 – Davis Reef SPA**		0 ± 0		0 ± 0
A84 – Little Conch Reef		0 ± 0		0 ± 0
A85 – Little Conch Reef		0 ± 0		0 ± 0
554 – Conch Reef C1**	**	75 ± 25	**	25 ± 25
555 – Conch Reef C2**		0 ± 0		0 ± 0
A86 – Conch Reef C3**		0 ± 0		0 ± 0
579C – NE of Conch Reef		0 ± 0		0 ± 0
Middle Florida Keys Total (9)	**	11 ± 8	**	3 ± 3
Upper Florida Keys				
693 – Little Pickles Reef		0 ± 0		0 ± 0
664 – North of French Reef		0 ± 0		0 ± 0
665 – Inshore of Dixie Shoal		0 ± 0		0 ± 0
Upper Florida Keys Total (3)		0 ± 0		0 ± 0
Shallow Hard-bottom Total (17)	**	8 ± 6	**	2 ± 2
<i>High-relief spur & groove</i>				
Upper Florida Keys				
697 – Pickles Reef P1		0 ± 0		0 ± 0
695 – Pickles Reef P3		0 ± 0		0 ± 0
696 – NE Pickles Reef	**	25 ± 25		0 ± 0
706 – Molasses Reef SPA**		0 ± 0	**	25 ± 25
707 – Molasses Reef SPA**		0 ± 0	**	75 ± 25
711 – Sand Island		0 ± 0		0 ± 0
704 – French Reef SPA**		0 ± 0		0 ± 0
705 – French Reef SPA**		0 ± 0		0 ± 0
699 – North of French Reef	**	25 ± 25	**	50 ± 29
662 – Grecian Rocks SPA**		0 ± 0		0 ± 0
663 – Grecian Rocks SPA**		0 ± 0	**	25 ± 25
B42 – Little Grecian Rocks		0 ± 0		0 ± 0

Site number/site location	<i>Acropora cervicornis</i>		<i>Acropora palmata</i>	
	Present	Transect frequency (%)	Present	Transect frequency (%)
660 – Key Largo Dry Rocks**		0 ± 0	**	25 ± 25
661 – Key Largo Dry Rocks**		0 ± 0		0 ± 0
656 – North Dry Rocks		0 ± 0		0 ± 0
657 – North-North Dry Rocks		0 ± 0	**	25 ± 25
702 – Elbow Reef SPA**		0 ± 0	**	25 ± 25
703 – Elbow Reef SPA**		0 ± 0	**	75 ± 25
B66 – South of S. Carysfort		0 ± 0		0 ± 0
700A – South Carysfort Reef**		0 ± 0		0 ± 0
700 – South Carysfort Reef**		0 ± 0	**	75 ± 25
B67 – Carysfort Reef C2**		0 ± 0		0 ± 0
701 – Carysfort Reef C5**		0 ± 0	**	25 ± 25
659 – Turtle Reef	**	25 ± 25	**	25 ± 25
Upper Florida Keys Total (24)	**	3 ± 2	**	19 ± 5
High-relief Spur & Groove Total (42)	**	3 ± 2	**	19 ± 5
<i>Deeper Fore-reef (6-15 m)</i>				
Middle Florida Keys				
552 – SW of Crocker Reef		0 ± 0		0 ± 0
551 – SW of Crocker Reef		0 ± 0		0 ± 0
568 – SW of Crocker Reef		0 ± 0		0 ± 0
569 – SW of Crocker Reef		0 ± 0		0 ± 0
A931 – SW of Crocker Reef	**	25 ± 25		0 ± 0
612 – Davis Reef SPA**		0 ± 0		0 ± 0
613 – Davis Reef SPA**		0 ± 0		0 ± 0
A941 – North of Davis Reef		0 ± 0		0 ± 0
A942 – Little Conch Reef		0 ± 0		0 ± 0
A94 – Little Conch Reef		0 ± 0		0 ± 0
B24 – Conch Reef RO**		0 ± 0		0 ± 0
625 – Conch Reef RO**		0 ± 0		0 ± 0
611 – Conch Reef SPA**		0 ± 0		0 ± 0
626 – Conch Reef RO**		0 ± 0		0 ± 0
610 – Conch Reef SPA**		0 ± 0		0 ± 0
B16 – Conch Reef SPA**		0 ± 0		0 ± 0
Middle Florida Keys Total (16)	**	2 ± 2		0 ± 0
Upper Florida Keys				
708 – NE of Conch Reef		0 ± 0		0 ± 0
709 – Pickles Reef		0 ± 0		0 ± 0
710 – SW of Molasses Reef SPA		0 ± 0		0 ± 0
712 – SW of French Reef		0 ± 0		0 ± 0
B71 – Dixie Shoal		0 ± 0		0 ± 0
671 – South of Grecian Rocks	**	25 ± 25		0 ± 0
B51 – East of Dry Rocks		0 ± 0		0 ± 0
713 – North of Elbow Reef		0 ± 0		0 ± 0
682 – North of Elbow Reef		0 ± 0		0 ± 0
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		0 ± 0		0 ± 0
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)	**	1 ± 1		0 ± 0
Deeper Fore-reef Total (34)	**	1 ± 1		0 ± 0

Table 4-2. Mean (± 1 SE) densities (no. colonies per m²), numbers of colonies sampled, total colony tissue surface area, and mean (± 1 SE) colony (ramet) surface area size of *Acropora cervicornis* 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	No. colonies per m ²	N	Total surface area (cm ²)	Mean size (cm ²)
<i>Inshore and mid-channel patch reefs</i>				
Middle Florida Keys				
A741 – Tavernier Rocks	0 \pm 0	0	0	
534 – Hen and Chickens SPA**	0 \pm 0	0	0	
535 – Hen and Chickens SPA**	0 \pm 0	0	0	
A74 – West of Conch Reef	0 \pm 0	0	0	
533 – West of Conch Reef	0 \pm 0	0	0	
A73 – West of Conch Reef	0.367 \pm 0.227	22	4,692	224 \pm 27
Middle Florida Keys Total (6)	0.061 \pm 0.061	22	4,692	224 \pm 27
Upper Florida Keys				
638 – Inshore of Pickles Reef	0 \pm 0	0	0	
B25B – Inshore of Molasses Reef	0 \pm 0	0	0	
B25 – Inshore of Molasses Reef	0 \pm 0	0	0	
B25A – Inshore of Molasses Reef	0 \pm 0	0	0	
627 – Mosquito Bank	0 \pm 0	0	0	
629A – Mosquito Bank	0 \pm 0	0	0	
628 – Mosquito Bank	0 \pm 0	0	0	
629 – Mosquito Bank	0 \pm 0	0	0	
629B – Mosquito Bank	0 \pm 0	0	0	
630 – SE of Cannon Patch Reef	0 \pm 0	0	0	
631 – Marker 33	0 \pm 0	0	0	
633 – Basin Hill Shoals	0.033 \pm 0.033	2	499	250 \pm 0
634 – Basin Hill Shoals	0 \pm 0	0	0	
637 – West of Turtle Rocks	0.033 \pm 0.033	2	373	186 \pm 0
636 – West of Turtle Rocks	0 \pm 0	0	0	
Upper Florida Keys Total (15)	0.004 \pm 0.004	4	872	218 \pm 32
Mid-channel Patch Reef Total (21)	0.021 \pm 0.017	26	5,564	220 \pm 18
<i>Offshore patch reefs</i>				
Middle Florida Keys				
A802 – Inshore of Conch Reef	0.167 \pm 0.111	10	508	64 \pm 23
A801 – Inshore of Conch Reef	0.550 \pm 0.328	33	4,629	420 \pm 257
579A – Inshore of Conch Reef	0 \pm 0	0	0	
579B – Inshore of Conch Reef	0 \pm 0	0	0	
Middle Florida Keys Total (4)	0.179 \pm 0.130	0	5,137	242 \pm 178
Upper Florida Keys				
639 – Inshore of Pickles Reef	0 \pm 0	0	0	
640 – White Bank (West of Molasses)	0 \pm 0	0	0	
641 – White Bank (West of Molasses)	0 \pm 0	0	0	
642 – SE of White Bank Dry Rocks	0 \pm 0	0	0	
B33 – East of White Bank Dry Rocks	0 \pm 0	0	0	
643 – White Bank (NW of French)	0.383 \pm 0.383	23	422	25 \pm 0
B35 – West of Elbow Reef	0 \pm 0	0	0	
644 – Watson’s Reef	0 \pm 0	0	0	
645 – Watson’s Reef	0 \pm 0	0	0	
648 – East of Basin Hill Shoals	0 \pm 0	0	0	
649 – West of Carysfort Reef	0 \pm 0	0	0	
B39 – Carysfort Reef SPA**	0 \pm 0	0	0	
653 – Carysfort Reef SPA**	0 \pm 0	0	0	

Site number/site location	No. colonies per m ²	N	Total surface area (cm ²)	Mean size (cm ²)
Upper Florida Keys Total (13)	0.029 ± 0.029	23	565	25 ± 0
Offshore Patch Reef Total (17)	0.065 ± 0.039	66	5,702	169 ± 26
<i>Back reef rubble</i>				
Middle Florida Keys				
578 – Crocker Reef	0 ± 0	0	0	
583 – Crocker Reef	0 ± 0	0	0	
555A – Conch Reef	0 ± 0	0	0	
555B – Conch Reef	0.050 ± 0.017	3	594	198 ± 79
Middle Florida Keys Total (4)	0.013 ± 0.013	3	594	198 ± 79
Upper Florida Keys				
688A – Pickles Reef	0 ± 0	0	0	
688B – Pickles Reef	0 ± 0	0	0	
B62 – Molasses Reef SPA**	0 ± 0	0	0	
691 – Molasses Reef SPA**	0 ± 0	0	0	
688 – Sand Island	0 ± 0	0	0	
689 – Inshore of Dixie Shoal	0 ± 0	0	0	
702B – Elbow Reef SPA**	0 ± 0	0	0	
702A – Elbow Reef SPA**	0 ± 0	0	0	
Upper Florida Keys Total (8)	0 ± 0	0	0	
Back Reef Rubble Total (12)	0.004 ± 0.004	3	594	198 ± 79
<i>Low-relief hard-bottom (< 6 m)</i>				
Middle Florida Keys				
A932 – Crocker Reef	0.117 ± 0.117	7	2,771	396 ± 0
556 – Davis Reef SPA**	0 ± 0	0	0	
A87 – Davis Reef SPA**	0 ± 0	0	0	
A84 – Little Conch Reef	0 ± 0	0	0	
A85 – Little Conch Reef	0 ± 0	0	0	
554 – Conch Reef C1**	0.100 ± 0.033	6	4,406	734 ± 310
555 – Conch Reef C2**	0 ± 0	0	0	
A86 – Conch Reef C3**	0 ± 0	0	0	
579C – NE of Conch Reef	0 ± 0	0	0	
Middle Florida Keys Total (9)	0.024 ± 0.016	13	7,177	565 ± 169
Upper Florida Keys				
693 – Little Pickles Reef	0 ± 0	0	0	
664 – North of French Reef	0 ± 0	0	0	
665 – Inshore of Dixie Shoal	0 ± 0	0	0	
Upper Florida Keys Total (3)	0 ± 0	0	0	
Shallow Hard-bottom Total (17)	0.018 ± 0.012	0	0	565 ± 169
<i>High-relief spur & groove</i>				
Upper Florida Keys				
697 – Pickles Reef P1	0 ± 0	0	0	
695 – Pickles Reef P3	0 ± 0	0	0	
696 – NE Pickles Reef	0.183 ± 0.183	11	9,490	863 ± 0
706 – Molasses Reef SPA**	0 ± 0	0	0	
707 – Molasses Reef SPA**	0 ± 0	0	0	
711 – Sand Island	0 ± 0	0	0	
704 – French Reef SPA**	0 ± 0	0	0	
705 – French Reef SPA**	0 ± 0	0	0	
699 – North of French Reef	0.033 ± 0.033	2	286	143 ± 0
662 – Grecian Rocks SPA**	0 ± 0	0	0	
663 – Grecian Rocks SPA**	0 ± 0	0	0	
B42 – Little Grecian Rocks	0 ± 0	0	0	
660 – Key Largo Dry Rocks**	0 ± 0	0	0	

Site number/site location	No. colonies per m ²	N	Total surface area (cm ²)	Mean size (cm ²)
661 – Key Largo Dry Rocks**	0 ± 0	0	0	
656 – North Dry Rocks	0 ± 0	0	0	
657 – North-North Dry Rocks	0 ± 0	0	0	
702 – Elbow Reef SPA**	0 ± 0	0	0	
703 – Elbow Reef SPA**	0 ± 0	0	0	
B66 – South of S. Carysfort	0 ± 0	0	0	
700A – South Carysfort Reef**	0 ± 0	0	0	
700 – South Carysfort Reef**	0 ± 0	0	0	
B67 – Carysfort Reef C2**	0 ± 0	0	0	
701 – Carysfort Reef C5**	0 ± 0	0	0	
659 – Turtle Reef	0.017 ± 0.017	1	1,248	1,248
Upper Florida Keys Total (24)	0.010 ± 0.008	14	11,023	751 ± 324
High-relief Spur & Groove Total (42)	0.010 ± 0.0080	14	11,023	751 ± 324
<i>Deeper Fore-reef (6-15 m)</i>				
Middle Florida Keys				
552 – SW of Crocker Reef	0 ± 0	0	0	
551 – SW of Crocker Reef	0 ± 0	0	0	
568 – SW of Crocker Reef	0 ± 0	0	0	
569 – SW of Crocker Reef	0 ± 0	0	0	
A931 – SW of Crocker Reef	0.033 ± 0.033	2	116	58 ± 0
612 – Davis Reef SPA**	0 ± 0	0	0	
613 – Davis Reef SPA**	0 ± 0	0	0	
A941 – North of Davis Reef	0 ± 0	0	0	
A942 – Little Conch Reef	0 ± 0	0	0	
A94 – Little Conch Reef	0 ± 0	0	0	
B24 – Conch Reef RO**	0 ± 0	0	0	
625 – Conch Reef RO**	0 ± 0	0	0	
611 – Conch Reef SPA**	0 ± 0	0	0	
626 – Conch Reef RO**	0 ± 0	0	0	
610 – Conch Reef SPA**	0 ± 0	0	0	
B16 – Conch Reef SPA**	0 ± 0	0	0	
Middle Florida Keys Total (16)	0.002 ± 0.002	2	116	58 ± 0
Upper Florida Keys				
708 – NE of Conch Reef	0 ± 0	0	0	
709 – Pickles Reef	0 ± 0	0	0	
710 – SW of Molasses Reef SPA	0 ± 0	0	0	
712 – SW of French Reef	0 ± 0	0	0	
B71 – Dixie Shoal	0 ± 0	0	0	
671 – South of Grecian Rocks	0.117 ± 0.117	7	886	127 ± 0
B51 – East of Dry Rocks	0 ± 0	0	0	
713 – North of Elbow Reef	0 ± 0	0	0	
682 – North of Elbow Reef	0 ± 0	0	0	
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	0 ± 0	0	0	
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)	0.006 ± 0.006	7	886	127 ± 0
Deeper Fore-reef Total (34)	0.004 ± 0.004	9	1,002	92 ± 34

Table 4-3. Mean (± 1 SE) densities (no. colonies per m²), numbers of colonies sampled, total colony tissue surface area, and mean (± 1 SE) colony (ramet) surface area size of *Acropora palmata* 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	No. colonies per m ²	N	Total surface area (cm ²)	Mean size (cm ²)
<i>Inshore and mid-channel patch reefs</i>				
Middle Florida Keys				
A741 – Tavernier Rocks	0 \pm 0	0	0	
534 – Hen and Chickens SPA**	0 \pm 0	0	0	
535 – Hen and Chickens SPA**	0 \pm 0	0	0	
A74 – West of Conch Reef	0 \pm 0	0	0	
533 – West of Conch Reef	0 \pm 0	0	0	
A73 – West of Conch Reef	0 \pm 0	0	0	
Middle Florida Keys Total (6)	0 \pm 0	0	0	
Upper Florida Keys				
638 – Inshore of Pickles Reef	0 \pm 0	0	0	
B25B – Inshore of Molasses Reef	0 \pm 0	0	0	
B25 – Inshore of Molasses Reef	0 \pm 0	0	0	
B25A – Inshore of Molasses Reef	0 \pm 0	0	0	
627 – Mosquito Bank	0 \pm 0	0	0	
629A – Mosquito Bank	0 \pm 0	0	0	
628 – Mosquito Bank	0 \pm 0	0	0	
629 – Mosquito Bank	0 \pm 0	0	0	
629B – Mosquito Bank	0 \pm 0	0	0	
630 – SE of Cannon Patch Reef	0 \pm 0	0	0	
631 – Marker 33	0 \pm 0	0	0	
633 – Basin Hill Shoals	0 \pm 0	0	0	
634 – Basin Hill Shoals	0 \pm 0	0	0	
637 – West of Turtle Rocks	0 \pm 0	0	0	
636 – West of Turtle Rocks	0 \pm 0	0	0	
Upper Florida Keys Total (15)	0 \pm 0	0	0	
Mid-channel Patch Reef Total (21)	0 \pm 0	0	0	
<i>Offshore patch reefs</i>				
Middle Florida Keys				
A802 – Inshore of Conch Reef	0 \pm 0	0	0	
A801 – Inshore of Conch Reef	0 \pm 0	0	0	
579A – Inshore of Conch Reef	0 \pm 0	0	0	
579B – Inshore of Conch Reef	0 \pm 0	0	0	
Middle Florida Keys Total (4)	0 \pm 0	0	0	
Upper Florida Keys				
639 – Inshore of Pickles Reef	0 \pm 0	0	0	
640 – White Bank (West of Molasses)	0 \pm 0	0	0	
641 – White Bank (West of Molasses)	0 \pm 0	0	0	
642 – SE of White Bank Dry Rocks	0 \pm 0	0	0	
B33 – East of White Bank Dry Rocks	0 \pm 0	0	0	
643 – White Bank (NW of French)	0 \pm 0	0	0	
B35 – West of Elbow Reef	0 \pm 0	0	0	
644 – Watson’s Reef	0 \pm 0	0	0	
645 – Watson’s Reef	0 \pm 0	0	0	
648 – East of Basin Hill Shoals	0 \pm 0	0	0	
649 – West of Carysfort Reef	0 \pm 0	0	0	
B39 – Carysfort Reef SPA**	0 \pm 0	0	0	
653 – Carysfort Reef SPA**	0 \pm 0	0	0	

Site number/site location	No. colonies per m ²	N	Total surface area (cm ²)	Mean size (cm ²)
Upper Florida Keys Total (13)	0 ± 0	0	0	
Offshore Patch Reef Total (17)	0 ± 0	0	0	
<i>Back reef rubble</i>				
Middle Florida Keys				
578 – Crocker Reef	0 ± 0	0	0	
583 – Crocker Reef	0 ± 0	0	0	
555A – Conch Reef	0 ± 0	0	0	
555B – Conch Reef	0 ± 0	0	0	
Middle Florida Keys Total (4)	0 ± 0	0	0	
Upper Florida Keys				
688A – Pickles Reef	0.033 ± 0.033	2	859	429 ± 0
688B – Pickles Reef	0 ± 0	0	0	
B62 – Molasses Reef SPA**	0 ± 0	0	0	
691 – Molasses Reef SPA**	0 ± 0	0	0	
688 – Sand Island	0 ± 0	0	0	
689 – Inshore of Dixie Shoal	0 ± 0	0	0	
702B – Elbow Reef SPA**	0 ± 0	0	0	
702A – Elbow Reef SPA**	0 ± 0	0	0	
Upper Florida Keys Total (8)	0.004 ± 0.004	2	859	429 ± 0
Back Reef Rubble Total (12)	0.004 ± 0.004	2	859	429 ± 0
<i>Low-relief hard-bottom (< 6 m)</i>				
Middle Florida Keys				
A932 – Crocker Reef	0 ± 0	0	0	
556 – Davis Reef SPA**	0 ± 0	0	0	
A87 – Davis Reef SPA**	0 ± 0	0	0	
A84 – Little Conch Reef	0 ± 0	0	0	
A85 – Little Conch Reef	0 ± 0	0	0	
554 – Conch Reef C1**	0 ± 0	0	0	
555 – Conch Reef C2**	0 ± 0	0	0	
A86 – Conch Reef C3**	0 ± 0	0	0	
579C – NE of Conch Reef	0 ± 0	0	0	
Middle Florida Keys Total (9)	0 ± 0	0	0	
Upper Florida Keys				
693 – Little Pickles Reef	0 ± 0	0	0	
664 – North of French Reef	0 ± 0	0	0	
665 – Inshore of Dixie Shoal	0 ± 0	0	0	
Upper Florida Keys Total (3)	0 ± 0	0	0	
Shallow Hard-bottom Total (17)	0 ± 0	0	0	0 ± 0
<i>High-relief spur & groove</i>				
Upper Florida Keys				
697 – Pickles Reef P1	0 ± 0	0	0	
695 – Pickles Reef P3	0 ± 0	0	0	
696 – NE Pickles Reef	0 ± 0	0	0	
706 – Molasses Reef SPA**	0 ± 0	0	0	
707 – Molasses Reef SPA**	0.117 ± 0.117	7	1,407	201 ± 0
711 – Sand Island	0.500 ± 0.205	30	26,818	728 ± 290
704 – French Reef SPA**	0 ± 0	0	0	
705 – French Reef SPA**	0 ± 0	0	0	
699 – North of French Reef	0 ± 0	0	0	
662 – Grecian Rocks SPA**	0.367 ± 0.177	22	65,071	3,711 ± 1,096
663 – Grecian Rocks SPA**	0 ± 0	0	0	
B42 – Little Grecian Rocks	0.017 ± 0.017	1	6,379	6,379
660 – Key Largo Dry Rocks**	0.017 ± 0.017	1	26	26

Site number/site location	No. colonies per m ²	N	Total surface area (cm ²)	Mean size (cm ²)
661 – Key Largo Dry Rocks**	0 ± 0	0	0	
656 – North Dry Rocks	0 ± 0	0	0	
657 – North-North Dry Rocks	0.233 ± 0.233	14	5,230	374 ± 0
702 – Elbow Reef SPA**	0.033 ± 0.0333	2	16,852	8,426 ± 0
703 – Elbow Reef SPA**	0.400 ± 0.314	24	43,395	6,238 ± 4,236
B66 – South of S. Carysfort	0 ± 0	0	0	
700A – South Carysfort Reef**	0 ± 0	0	0	
700 – South Carysfort Reef**	0.133 ± 0.090	8	4,428	1,080 ± 586
B67 – Carysfort Reef C2**	0 ± 0	0	0	
701 – Carysfort Reef C5**	0.167 ± 0.167	10	8,987	899 ± 0
659 – Turtle Reef	0.050 ± 0.050	3	312	104 ± 0
Upper Florida Keys Total (24)	0.085 ± 0.030	122	178,905	2,560 ± 929
High-relief Spur & Groove Total (42)	0.085 ± 0.030	122	178,905	2,560 ± 929
<i>Deeper Fore-reef (6-15 m)</i>				
Middle Florida Keys				
552 – SW of Crocker Reef	0 ± 0	0	0	
551 – SW of Crocker Reef	0 ± 0	0	0	
568 – SW of Crocker Reef	0 ± 0	0	0	
569 – SW of Crocker Reef	0 ± 0	0	0	
A931 – SW of Crocker Reef	0 ± 0	0	0	
612 – Davis Reef SPA**	0 ± 0	0	0	
613 – Davis Reef SPA**	0 ± 0	0	0	
A941 – North of Davis Reef	0 ± 0	0	0	
A942 – Little Conch Reef	0 ± 0	0	0	
A94 – Little Conch Reef	0 ± 0	0	0	
B24 – Conch Reef RO**	0 ± 0	0	0	
625 – Conch Reef RO**	0 ± 0	0	0	
611 – Conch Reef SPA**	0 ± 0	0	0	
626 – Conch Reef RO**	0 ± 0	0	0	
610 – Conch Reef SPA**	0 ± 0	0	0	
B16 – Conch Reef SPA**	0 ± 0	0	0	
Middle Florida Keys Total (16)	0 ± 0	0	0	
Upper Florida Keys				
708 – NE of Conch Reef	0 ± 0	0	0	
709 – Pickles Reef	0 ± 0	0	0	
710 – SW of Molasses Reef SPA	0 ± 0	0	0	
712 – SW of French Reef	0 ± 0	0	0	
B71 – Dixie Shoal	0 ± 0	0	0	
671 – South of Grecian Rocks	0 ± 0	0	0	
B51 – East of Dry Rocks	0 ± 0	0	0	
713 – North of Elbow Reef	0 ± 0	0	0	
682 – North of Elbow Reef	0 ± 0	0	0	
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	0 ± 0	0	0	
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)	0 ± 0	0	0	
Deeper Fore-reef Total (34)	0 ± 0	0	0	