

FINAL REPORT

Coral Reef Benthic Community Response to Ten Years of Management in Fully Protected Marine Zones of the Florida Keys

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Period covered by this Report: 1 June, 2007 to 30 Sept 2009.

Summary of Findings

Coral recruitment and juvenile coral mortality rates

The project continued with a successful field expedition in July 2008. The study was conducted at two depths, 7 m and 18 m, in Fully Protected Zones (FPZs) (Eastern Sambo Research Only; Western Sambo Ecological Reserve; South Carysfort and Molasses Reef) and reference sites (Middle Sambo, Pelican Shoal, Maitland and Pickles) in the Upper and Lower Keys. Thirty two permanent quadrats (95 x 65 cm) have been established at each depth. We were successful in relocating the study sites in July 2008. We did not attempt to work at the Molasses and Pickles reef sites, previously sampled in 2005, due to the limited funding available for the project.

The Smith team re-surveyed 93% (358/384) of the permanent quadrats at Western Sambo Ecological Reserve (WS), Middle Sambo Reference site (MS), Eastern Sambo Research only (ES), Pelican Shoal Reference site (PEL), Maitland Reference site (MA) and South Carysfort (SC). We could not locate several quadrats because of the destructive effects of the 2005 hurricanes that removed the permanent marking pins. The surveyors were using photographs of the quadrats from 2005 and 2007 to re-survey the quadrats. We were able to photograph all the relocated permanent quadrats at all the sites which was an important achievement considering the problems and time limitations encountered in 2007.

Coral recruitment

We were better able to estimate coral recruitment rates in 2008 because we had survey data from 80% of the quadrats in 2007. This is in contrast to the 2007 “recruitment” data, for which we lacked data from 2006 (due to lack of funding for that year). For the 2007 recruitment assessment it was ambiguous to categorize all “new” small colonies observed in 2007 as recruits as they could have settled as recruits in 2006, established as fragments in late 2005 (post-hurricanes Dennis, Rita, Wilma) or settled as recruits in early 2007. We established size criteria to exclude larger “new” corals as recruits, based on historic records of recruit sizes and growth over a 2-year period for each of the species observed. New colonies of the following species that were larger than

the cut-off criteria were not considered recruits. The intent was to exclude “new” colonies that may have established as fragments but to include corals that recruited in 2006 and grew.

Species	Cut-off colony diameter (mm)
<i>Porites</i> spp.	25
<i>Agaricia</i> spp.	25
<i>Siderastrea</i> spp.	20
<i>Montastraea cavernosa</i>	15
<i>Stephanocoenia intersepta</i>	20

Thus, the “recruits” observed in 2007 at each depth at each site represent a composite of two years of coral recruitment. Our surveys included colonies that settled in 2006 and survived to 2007, as well as new colonies that settled in early 2007 especially for *Porites* spp. and *Agaricia* spp., both genera that planulate in April and May. Thus we normalized the mean number of “recruits” per depth to an annual rate by dividing by 2. We are sure that these rates will underestimate recruitment because we cannot know the number of recruits in 2006 that did not survive until 2007. Our historic patterns of annual juvenile coral mortality range between 25-35 % and so our recruitment rates in 2007 are probably underestimated by this level of magnitude. The same issues were relevant for a smaller number of quadrats that we were not able to survey in 2007. It was very clear which of colonies in the quadrats surveyed for the first time in 2008 were recruits and which were not, based on their small size.

In terms of coral recruitment in the Upper Keys, the rates remained consistently low ($< 5 \text{ m}^{-2} \text{ yr}^{-1}$) at both the shallow and deep sites in 2007 and 2008 (Figure 1 a,b). The Upper Keys sites have always had lower recruitment rates at both shallow and deep sites compared to the Lower Keys sites, but they were more similar across these regions in 2007 and 2008. The deep sites in the Lower Keys have had the highest historic recruitment rates ($10\text{-}20 \text{ m}^{-2} \text{ yr}^{-1}$), but the estimates for 2007 were nearly all below $5 \text{ m}^{-2} \text{ yr}^{-1}$. The depressed rates in 2007 were probably the result of the ambiguity of the origins of many of the small corals observed due to the lack of data from 2006, and potential hurricane impacts in 2005. In 2008 recruitment rates had increased marginally at two FPZ shallow sites (South Carysfort and Eastern Sambo) but had increased substantially at the Western Sambo Shallow and Pelican Deep sites. Recruitment rates at the remaining sites in 2008 were similar to 2007 rates. Thus, coral recruitment rates have been depressed at all sites, irrespective of protection status, since 2005, with the Lower Keys sites showing the greatest reductions compared to earlier trends in the study.

The trends in mean overall coral recruitment rates at each site were assessed by regression over time at each depth (Figure 2). Clearly the low r^2 values at all sites and depths demonstrate that there have not been any changes in recruitment rates over time and no distinction between the FPZ and Reference sites.

Recruitment was dominated at all sites and depths in 2007 and 2008 by *Siderastrea* spp., *Agaricia* spp. and *Porites* spp., continuing the trends seen since 2000 (Tables 1, 2;

Figures 3-6). *Siderastrea siderea* was the numerically dominant recruit at the Lower Keys deep sites. However, the levels of recruitment in 2007 and 2008 were considerably reduced at both the shallow and deep sites, especially in the Lower Keys (Figure 3 a,b). *Montastraea cavernosa* also showed a reduction in recruitment in the Lower Keys in 2007 and 2008 (Figure 4 a,b). *M. cavernosa* has continued to recruit at higher rates at the deep sites and was absent from the shallow sites at South Carysfort and Maitland; only one colony was observed at the shallow Western Sambo site in 2007 and 2008. *Porites astreoides* showed increased rates of recruitment at the Lower Keys shallow FPZ sites compared to the shallow Reference sites, but this pattern was not evident at the respective deep sites (Figure 5). Generally, recruitment by *P. astreoides* declined at all deep sites in 2007 and 2008. Similarly, recruitment by *Agaricia* spp. has increased at some shallow sites (Maitland, Western Sambo, South Carysfort), but declined uniformly at all deep sites in the Lower Keys (Figure 6 a,b). No *Montastraea* “*annularis*” recruits were observed in 2007 or 2008. There is still no evidence that the protective status of the FPZ sites (South Carysfort, Eastern Sambo and Western Sambo) has enhanced recruitment rates over time for the most consistently recruiting species.

Juvenile coral mortality

An assessment of juvenile coral mortality in the permanent quadrats in 2007 had to evaluate the changes from the census data and photographs obtained in 2005. Our census system relies on annual surveys to determine the loss of a coral. Thus, the observation of a coral missing in 2007 compared to the 2005 data raises the ambiguity of when the coral disappeared. We normalized the changes observed over a two-year period to estimate an “annual” rate by dividing by 2. The rates are underestimates because we cannot know how many new colonies were established in 2006 but did not survive until 2007. The mortality rates estimated in 2008 were determined using either the data collected in 2007 or interpreted from the 2005 quadrat data, if no 2007 data were available

The overall “annual” mortality rates of all juvenile corals in the quadrats (in aggregate by quadrat, not distinguishing between species) in 2007 and 2008 were very similar to historical rates, falling in the range of 25-35% per year (Figure 7 a,b). The only clear difference was that the mortality rates in both the shallow and deep sites at South Carysfort were higher (32-39%) compared to the rates at the Maitland sites (20-21%) in 2007. This distinction between the Upper Keys shallow sites was not evident in 2008, with mortality rates at about 25%, which were lower than the rates in the Lower Keys (~35%). The mortality rates in the Lower Keys sites were quite similar across sites within depths in 2007 and 2008. The lowest rates (~20%) were observed at both Western Sambo shallow and deep sites in 2008. The patterns of overall juvenile coral mortality have remained remarkably stable across sites and depths since 2000, ranging between 20-35%. The high rates observed in 1999 were directly related to the impacts of Hurricanes Mitch and Georges. The impacts of the record hurricane season in 2005 could not be assessed as no data were collected in 2006. The impact of Hurricane Dennis in 2007 appears to have been very limited.

There were no significant trends over time in juvenile coral mortality (Figure 8 a-f). The shallow and deep Maitland Reference sites and the shallow Western Sambo FPZ site appear to have slightly declining mortality rates from 1999 to 2008. This decline was caused by the very high mortality rates observed in 1999 due to the impacts of Hurricanes Georges and Mitch in Fall 1998, immediately after we initiated this study. It is also quite evident that the patterns of juvenile coral mortality in the FPZ and Reference sites have remained very similar over this ten-year period.

The analyses of species-specific patterns of mortality indicate that juvenile coral mortality rate of *Agaricia agaricites* has varied significantly at all sites and depths and was generally high (over 60%). The shallow sites in the Lower Keys, with the exception of Western Sambo, have experienced high rates of mortality, with the complete loss of this species from the Middle Sambo shallow site in 2008 (Figure 9 a,b). The deep sites in the Lower Keys were more similar, with *A. agaricites* mortality rates generally less than 40%. *Montastraea cavernosa* also showed highly variable mortality rates (0-60%) at all of the sites (Figure 10 a,b). *Porites astreoides* had fairly consistent mortality rates (20-40%) at all sites and depth (Figure 11 a,b), with only Western Sambo shallow showing a very low rate in 2008 (~10%) as well. *Siderastrea siderea* has had very similar mortality rates at the shallow sites compared to the deep sites, generally less than 40%, since the beginning of the study (Figure 12 a,b).

It is quite clear that the FPZ sites did not exhibit lower mortality rates compared to the adjacent unprotected reference sites.

Coral assemblage structure: video transects

We successfully collected 10 random video transects at each depth at South Carysfort, Maitland, Pelican Shoal, Eastern Sambo, Middle Sambo and Western Sambo in 2007. In 2008 we again collected 10 random video transects at each site and each depth, except at Middle Sambo Deep where only 5 transects were sampled. Automated frame capture has been completed for both depths at each of the six study sites. Fifty stop-action frames have been captured from each of the 10 transects per site, for a total of 6,000 frames. These frames have been written to CD-ROM. Ten random dots have been overlaid on each frame for point-count analysis to estimate percent cover of all taxa at each depth for each site.

Analysis of the 2007 and 2008 video data indicates that overall coral cover has continued to decline or remain at low levels at several shallow and deep sites (Figures 13 a, b). In the Upper Keys, coral cover remained at around 2-3% at the South Carysfort and Maitland shallow sites. At the deep sites in the Upper Keys, cover at South Carysfort remained at about 2%, while cover at Maitland declined slightly since the last measurements in 2004. It is clear that the FPZ sites are indistinguishable from the Reference sites in terms of coral cover.

At the shallow Lower Keys sites, coral cover dropped significantly at Western Sambo, Middle Sambo and Pelican Shoal from 2007 to 2008 to only 1-2%. Eastern

Sambo declined slightly from 2007 to about 3%. Western Sambo Shallow has shown the most severe loss of coral since 1998, compared to the other shallow sites (Figure 13 a). The deep sites in the Lower Keys have remained at similar levels (4-5%) since 2004, while coral cover at the deep Upper Keys sites has remained between 2 and 3% since 1998 (Figure 13 b). All of the Lower Keys deep and shallow sites have shown a fairly steady decline in coral cover, to between 6 and 1%, since 2000 (Figure 13 a).

The most abundant corals at most sites and depths were colonies of the *Montastraea* 'annularis' species complex, and the decline of these corals accounts for the precipitous loss of coral cover, especially in the Lower Keys (Figure 14 a, b).

Gorgonian cover at the shallow Upper Keys sites declined from 2007 to 2008 to less than 2% cover. At the Lower Keys shallow sites cover did not change between 2007 and 2008, with only Pelican Shoal showing a small increase in cover to 2% (Figure 15 a). Gorgonian cover at the deep Upper Keys sites remained at 1 to 2% in 2007 and 2008. The gorgonian cover at the deep Lower Keys sites is generally higher than cover in the Upper Keys. Cover increased at Western Sambo Deep from 3 to 4% in 2008 but remained the same or declined slightly at the other three sites to 2-3% (Figure 15 b).

Sponge cover remained at low levels (~2%) at the Upper Keys shallow sites in 2007 and 2008. At the Lower Keys shallow sites sponge cover increased slightly from 2007 to 2008 at Eastern Sambo and Pelican Shoal (from 1 to 2%) and remained at less than 2% at the other two sites. Sponge cover at the deep sites remained 4-5 % from 2007 to 2008, except at the Maitland sites where it was about 8%, and at Western Sambo deep where it declined from 3 to 2% (Figure 16 a, b).

Reef macroalgal biomass and diversity

We conducted a pilot study of macroalgal biomass and diversity at all our study sites in 2007 and increased our sampling effort in 2008. At each site randomly selected permanent quadrats were sub-sampled for macroalgae. A 25 cm x 25 cm area within the permanent quadrat was sampled by removing all macroalgae that could be manipulated by hand into a mesh bag within 5 min. Our sample sizes varied at each site according to the time available to the survey divers and are listed in Tables 3 and 4.

The macroalgae were rinsed thoroughly in large volumes of fresh water to remove loose sediment and salt. The algae in each quadrat were sorted into the lowest taxonomic categories possible and then dried to a constant weight at 45 °C for several days. Total algal biomass in each quadrat was determined from the sum of the constituent algal taxa.

In 2007 total macroalgal biomass varied between sites within depths (Figure 17 a, b). The highest biomass levels were found at Pelican Shoal at both the shallow and deep sites and the lowest quantities were observed at Western Sambo shallow and deep sites. In 2008 we again observed very distinct differences in total algal biomass across sites within depths (Figure 17 a, b). In addition, the biomass more than doubled from 2007 to 2008 at 6 of our 12 sampling locations, at both shallow and deep sites. In particular, the increases

in total algal biomass were very pronounced at Western Sambo Shallow, both the South Carysfort Shallow and Deep sites, Eastern Sambo Deep and Pelican Shoal Deep. Only the shallow Reference sites remained at similar levels in 2007 and 2008. There were differences in sample sizes at particular sites in 2007 vs. 2008, but this may not account for the apparent increases in macroalgal biomass in 2008. For example, the number of samples at Eastern Sambo Deep was the same in both years ($n=6$), but the large error estimated in 2008 resulted because two of the six samples were two orders of magnitude larger than the other four samples. This reflects the heterogeneous distribution of macroalgae at a particular site. This level of variance was also observed at Pelican Shoal Deep, even though 4 fewer samples were collected in 2008 versus 2007 (7 vs 11). Given the limitations of the sampling effort it is clear that there was consistently more macroalgal biomass within the shallow FPZ sites in 2008, but the distinction between the deep FPZ and Reference sites was not evident in 2008.

An assessment of the relative abundance of the dominant algae at each site was made by pooling dry-weight biomass estimates for three categories: *Halimeda* spp., *Dictyota* spp. and all other algal species. The first two genera were consistently present at all sites and depths. *Halimeda* spp. contributed more than 50% of the total dry weight at all sites, shallow and deep, compared to *Dictyota* spp. and an aggregated category of “Other” algae (Figure 18). A comparison between the 2007 and 2008 data sets clearly shows a very large increase in *Halimeda* spp. biomass at the deep sites in 2008, except at the Western Sambo Deep site. *Halimeda* spp. biomass increased only at the Eastern Sambo and Western Sambo Shallow sites. Changes in *Dictyota* spp. biomass from 2007 to 2008 were evident with significant increases observed at the Upper Keys shallow sites and the South Carysfort and Eastern Sambo Deep sites (Figure 19). “Other” macroalgae increased significantly from 2007 to 2008 at both depths at South Carysfort and dropped substantially at the Pelican Shoal Shallow and Deep sites (Figure 20). The differences in “Other” macroalgae at the South Carysfort sites were the result of changes in species abundance and the occurrence of many new species in 2008, such as *Udotea* spp. The decline in “Other” biomass at Pelican Shallow may be due to the absence of species such as *Styopodium zonale* and *Bryothamnion triquetrum*; at Pelican Deep *Amphiroa* spp. and *Jania* sp. declined sharply in 2008 (Tables 3 and 4).

The initial phase of this long-term project included extensive studies of benthic algae and herbivory in 1998 and 1999, by our then-co-PI Margaret Miller. One of our goals in this current phase of this study was to evaluate how similar or different benthic macroalgal assemblage structure was in 2007 and 2008, compared to the previous work in 1998 and 1999. A publication by Miller et al (2002) described the general patterns of benthic macroalgal biomass and assemblage structure. Their sampling protocol used slightly smaller quadrats (40 cm x 40 cm) compared to ours. For comparison to our results we scaled up their mean estimates of algal biomass in their Figure 2 and standardized them to 0.25 m² for comparison to our results.

There are some interesting differences and similarities between these data sets (Figure 21). At the shallow sites in 2007 macroalgal biomass levels were consistently lower than the 1998 levels, but only 2 sites (South Carysfort, Western Sambo) were lower than the

1999 levels. In 2008 macroalgae had increased beyond the 1999 levels, except at Middle Sambo, and Western Sambo was much higher than the 1998 level. At the deep sites the 2007 levels of macroalgal biomass at South Carysfort and Western Sambo were lower than those recorded in 1998 and 1999. Macroalgal biomass at Middle Sambo was lower than only the 1998 levels. However, Eastern Sambo and Maitland had higher levels than in 1998 and 1999. Pelican Shoal Deep had the highest biomass in 2007 and it was higher than the macroalgal biomass levels recorded in 1998 and 1999. It is very clear that in 2008 macroalgae at all the deep sites had increased above the 1998 and 1999 levels, except at Western Sambo. A qualitative comparison of algal assemblage composition in 2007 to the 1998 and 1999 data (Miller et al., 2002) indicates that *Dictyota* spp. and other fleshy algae have declined in abundance and *Halimeda* spp. has increased at nearly all sites and depths. In 2008 *Dictyota* spp., *Halimeda* spp., and other algae have increased as described above. Miller et al (2002) did not report sampling sizes and this limits our conclusions about the comparisons. It does seem evident that macroalgal abundance can vary substantially between years within a site, as observed in both assessments. Also, there is no evidence that the patterns of macroalgal abundance show any relationship to the status of reef protection.

Submarine Irradiance in the Lower Keys

Light is a critical element for the growth of macroalgae, scleractinian corals and gorgonians. Light can be rapidly attenuated by suspended particles in the water column and increasing depth. We have been aware of variability in water clarity at our sites over the past 9 years, especially at the deep Lower Keys sites. On several occasions at the deep sites in the Lower Keys, a shift in prevailing hydrographic factors over the course of several days allowed clear offshore Florida Current “blue water” to displace more turbid “Hawk Channel water,” which increased visibility from ~5 to ~20 m. At our deep sites in the Upper Keys and in the Lower Keys we frequently observed internal waves of turbid cool water moving upslope over the course of an hour, as described by Leichter et al. (1996), and visibility dropped to <4 m.

We initiated a pilot project in 2007 to assess temporal and spatial trends in submarine irradiance at our four Lower Keys deep sites. We deployed inexpensive Hobo Pendant light and temperature data loggers on mounting brackets about 50 cm above the substrate at 16 ± 1 m depth at each site on our first dive at a site. We also deployed one on the superstructure of our vessel. A comparison of incoming irradiance to levels measured at depth estimated light attenuation by both wave scatter and suspended particles in the water column. The data loggers recorded a temperature and light reading every 10 minutes for about 20 days. The units were recovered by Sanctuary divers and returned to us for data download. We deployed the data loggers again in July 2008 but they have not been retrieved to date (September, 2009).

Each day in 2007 and 2008, when we visited either a shallow or deep site, we recorded a horizontal Secchi reading to estimate light attenuation in the surface waters. We could not use vertical Secchi measurements because the bottom was usually visible, even at the deep sites. We obtained 5-7 readings per reef site over 2-4 days. In this

assessment, the close physical location of the deep sites directly downslope from the shallow sites by 100-200m allows us to assume that the shallow and deep sites are exposed to the same surface waters and we pooled these data within sites.

We processed the data logger light-level data by removing nighttime measurements. We report mean light levels at Pelican Shoal, Eastern Sambo, Middle Sambo and Western Sambo over a 16-day period from July 21 to August 6 2007 (Figure 22). Light was detected at ~7 AM and declined to zero by ~7 PM. In general, light at depth was attenuated to between 5-8% of surface irradiance at solar noon on different days. Attenuation was greater during sunrise and sunset, due to the lower angles of incidence. There were consistent differences between the sites, with Eastern Sambo experiencing higher levels of irradiance compared to the other three sites (Figure 22). There also appears to have been a pattern of declining water clarity from 7/22/07 to 7/28/2007 and then increasing clarity after that time point. It is clear that each site experienced significant changes in submarine irradiance over time, but there was high variation between sites during a given day.

To emphasize the inter-site differences we have replotted the light data as a relative percent (+ or -) compared to Western Sambo (Figure 24). The persistent high water clarity at Eastern Sambo was evident on every day except for two dates. Middle Sambo and Pelican Shoal frequently experienced very reduced submarine illumination over several days, compared to Western Sambo, which was used to demonstrate the magnitude of differences that occurred between the sites

The Secchi data showed a large difference in water clarity between 2007 and 2008 (Figure 24). There were no substantive differences among the sites in 2007, but in 2008 Pelican Shoal appeared to have reduced water clarity relative to the other sites. Each site had periods when Secchi readings exceeded 30 m and other times when it was reduced to 12-13 m. Pelican Shoal had a lower mean because it had fewer days of greater water clarity than the other sites. Our data were sufficient to demonstrate that we are able to measure site-to-site differences with simple technology over extended time spans. Only limited light-attenuation data exist for the Florida Keys apart from the SeaKeys data stations that report surface PAR and attenuation at 2 m and 4 m. The WQPP program measures Secchi depth once per month at several sites near ours.

Conclusions

This report summarizes the broad patterns and trends observed over the life of the study from 1998 to 2008. The underlying hypotheses that we set out to test, in regard to the efficacy of management control of the FPZs, concerned the potential for trophic cascades to be re-established in the FPZs potentially benefitting resident coral populations. The opportunity for coral reef fish populations, especially grazing herbivorous fishes, to recover in the FPZs could allow for the control of reef macroalgae that translates into reduced competitive interactions between reef algae and corals. There is evidence that some herbivorous fishes (*Scarus* spp.) have not changed significantly in

FPZs (Bohnsack et al. 2009), but it is clear from our study that there has been a sustained loss of coral cover in both FPZ and Reference sites and at both depths. These changes appear to be driven primarily by large-scale forcing by bleaching and disease over the past 10 years, as noted in related studies (CREMP, 2007). Reef algae do not appear to have been reduced over time in either the FPZ and Reference sites; they have exhibited very high inter-annual variation that complicates interpretation of the changes observed.

The patterns of coral recruitment and juvenile coral mortality are indistinguishable between the FPZ and Reference sites. Relatively high rates of recruitment have occurred for some species, but the rates for all species appear to have diminished on both shallow and deep reefs significantly in the past 4-5 years. In contrast, juvenile coral mortality appears to have been relatively constant throughout the study. With average annual mortality rates ranging from 30-40%, there would appear to be a limit on population growth, given the recent decline in recruitment rates. The loss of coral cover over time represents the loss of reproductive adults and reduced reproductive capacity, as fecundity declines with size in corals and as a consequence of stress. Thus, the depleted coral populations in the Keys appear to have set the stage for recruitment limitation for some species. For example, the *Montastraea* “*annularis*” species complex has lost cover substantially at all sites over the past ten years (Figure 14, a,b). We recorded only 18 recruits at all sites and depths during the study, and none survived. This pattern of coral population collapse has been demonstrated clearly in Jamaica (Hughes and Tanner, 2000).

It is clear that we have documented significant changes within the FPZ and the Reference sites. The protection status of the FPZs has not had a substantive effect on their resident coral populations. Our initial hypotheses in regard to the impacts of restored grazer populations in facilitating coral growth remain unsupported. With so much reef substrate unoccupied by coral and other sessile invertebrates, ongoing stress to older corals, and reduced recruitment rates, it may well be another decade before the impact of grazers on benthic macroalgae will be evident. The recovery of *Diadema antillarum* populations in Jamaica and other locations in the Caribbean, appears to be effective in promoting high recruitment and juvenile survival rates (Carpenter and Edmunds, 2006). Our observations are that *D. antillarum* populations at our sites have remained very low.

Management actions at local scales have clear and positive effects on populations of fish and other taxa that are the targets of exploitation. The impacts of local management actions on corals, however, will remain elusive given the global challenges that coral reef ecosystems are currently facing. Coral populations are threatened by rising temperature, declining ocean pH, diseases and other factors that act at regional to global scales. These factors, individually and synergistically, work against successful sexual and asexual reproduction in corals and are not subject to management control, except at the highest levels of societal organization, and over decadal time scales at minimum. Our results suggest that restoring coral populations within FPZs will require local management actions in tandem with concerted efforts to address climate change and other overarching environmental problems.

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2. Applications

a. *Publications, presentation and workshops*

A presentation on coral recruitment, juvenile mortality was made at the Benthic Ecology meeting in 2007. Two papers were presented at the 11th International Coral Reef Symposium in 2008. We plan to proceed with the preparation of a comprehensive paper, based on our original research plan for this project, covering the period from 1998 to 2008. The paper will focus on broad patterns of coral cover, species diversity and how species-specific patterns relate to patterns of recruitment and juvenile coral mortality. The paper will examine the effectiveness of the FPZs in enhancing the health of the benthic communities, particularly the stability of the coral populations. We intend to complete this paper after our 2008 data have been subjected to statistical analyses. A summary report will be submitted to an upcoming FKMNS review paper.

b. *Applications to management or research*

We hope that the forthcoming summary paper will be valuable in helping define future management objectives and especially highlight the temporal patterns of change in reef communities that may not fit well with management plans and funding cycles. The present assessment of the lack of a strong beneficial effect of the FPZs on coral populations will require consideration of new approaches to enhance the recruitment growth and survival of corals in the FPZs.

c. *Data and/or information products*

The permanent quadrat data are located in custom Excel spreadsheets, along with quadrat images, and are burned on to CDs and DVDs in Dr. Smith's lab at the Bermuda Aquarium Museum and Zoo. The data sets will be forwarded to the Florida Marine Resource Institute (FMRI) for inclusion in the metadata database. The captured frames and resulting data from the video transects will be archived on CD-ROM at the Florida Institute of Technology. As in previous years, the data will also be registered in the FMRI metadata database.

d. *Partnerships established*

In terms of human resource development, the project supported two graduate students, Lauren Toth (DISL, U. South Alabama) and Erin Looney (U. Georgia) in 2007. Ms. Toth was responsible for all video transect data analyses. Ms. Looney collected permitted samples of coral tissue at our study sites to develop assays for *Serratia marcescens* on corals and their susceptibility to disease infections. A third graduate student, Bill Tyminski (Univ. North Carolina Greensboro) provided dive support. An undergraduate student, Victoria Ryan (GSU) provided dive support. A professional diver, James Nimz, was loaned to the project *gratis* by the Georgia Aquarium in Atlanta, Georgia. In 2008 two GSU undergraduates participated as a research diver, Joshua Johnson, and surface support, Sarah Layton. A Master's student, Isa Porto from the *Universidad Nacional de Colombia*, also participated as a research diver. The Georgia Aquarium provided two divers, James Nimz and Mauritius Bell. Ms. Looney and Ms. Toth provided critical and experienced dive support again.

Figure 1 a,b. Patterns of overall recruitment (mean, SE) of all scleractinian coral species in permanent quadrats at the shallow and deep FPZ and Reference sites from 1998 to 2008. Sites labels are: SC, South Carysfort; MO, Molasses Reef; ES, Eastern Sambo; WS, Western Sambo; MA, Maitland; PK, Pickles; MS, Middle Sambo; PEL, Pelican Shoal. No data were collected at MO and PK from 1999-2001 or MO and PK Deep from 1999-2002 or MA Shallow and Deep in 2005.

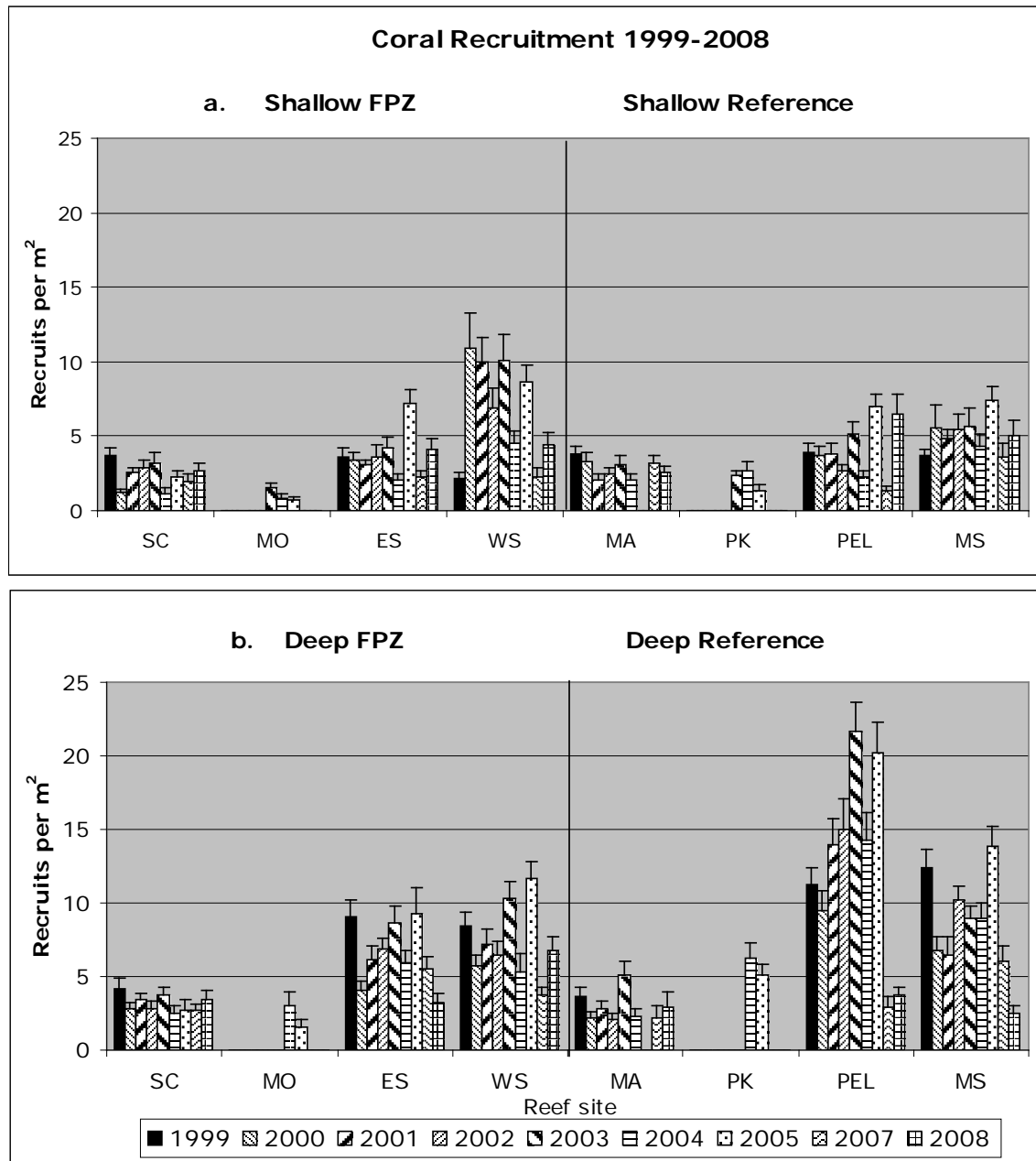


Figure 2. Trends over time in overall coral recruitment from 1999 to 2008. Sites labels are: SC, South Carysfort; MO, Molasses Reef; ES, Eastern Sambo; WS, Western Sambo; MA, Maitland; PK, Pickles; MS, Middle Sambo; PEL, Pelican Shoal.

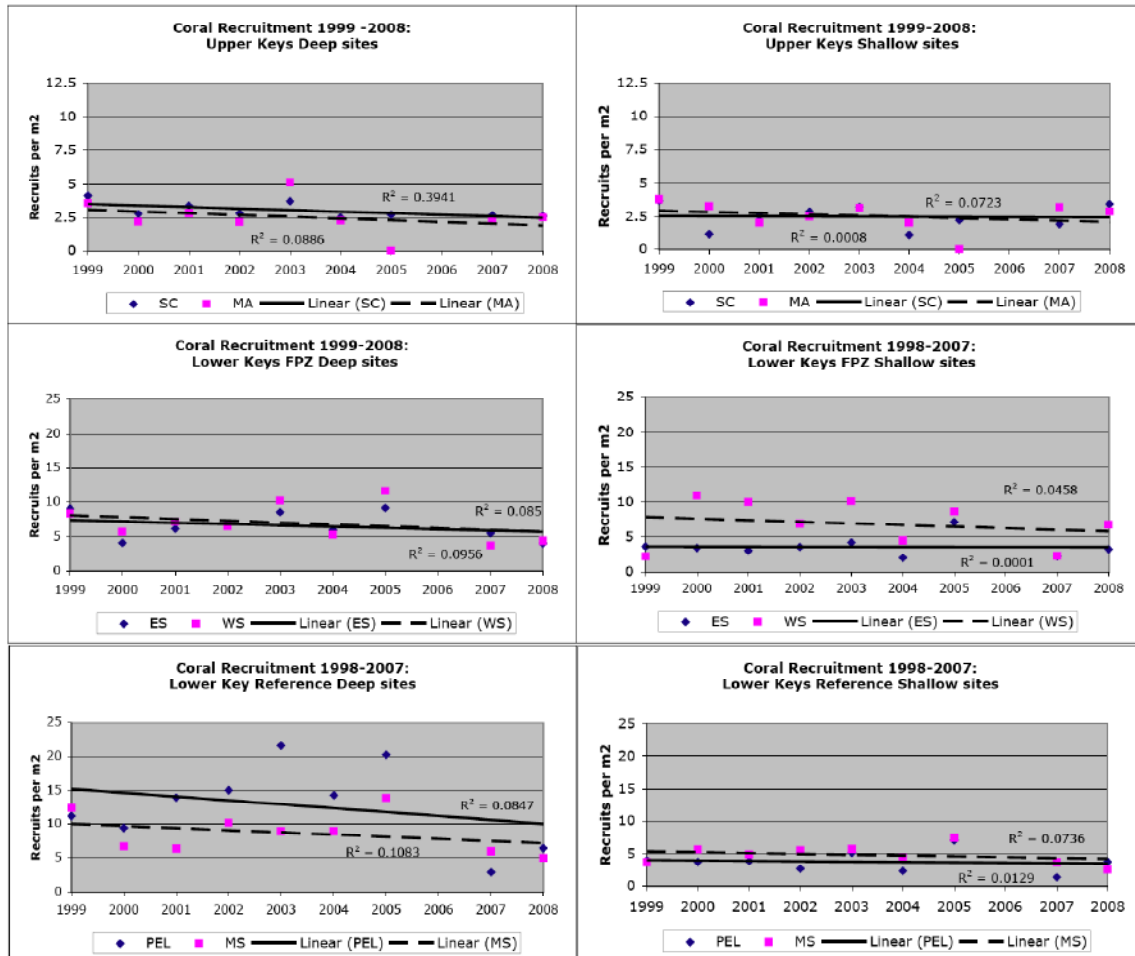


Figure 3 a, b. Patterns of recruitment of *Siderastrea siderea* (mean, SE) within permanent quadrats at the shallow and deep FPZ and Reference sites from 1998 to 2008. Sites are: SC, South Carysfort; MO, Molasses Reef; ES, Eastern Sambo; WS, Western Sambo; MA, Maitland; PK, Pickles; MS, Middle Sambo; PEL, Pelican Shoal. No data were collected at MO and PK Shallow from 1999-2001 or MO and PK Deep from 1999-2002 or MA Shallow and Deep in 2005.

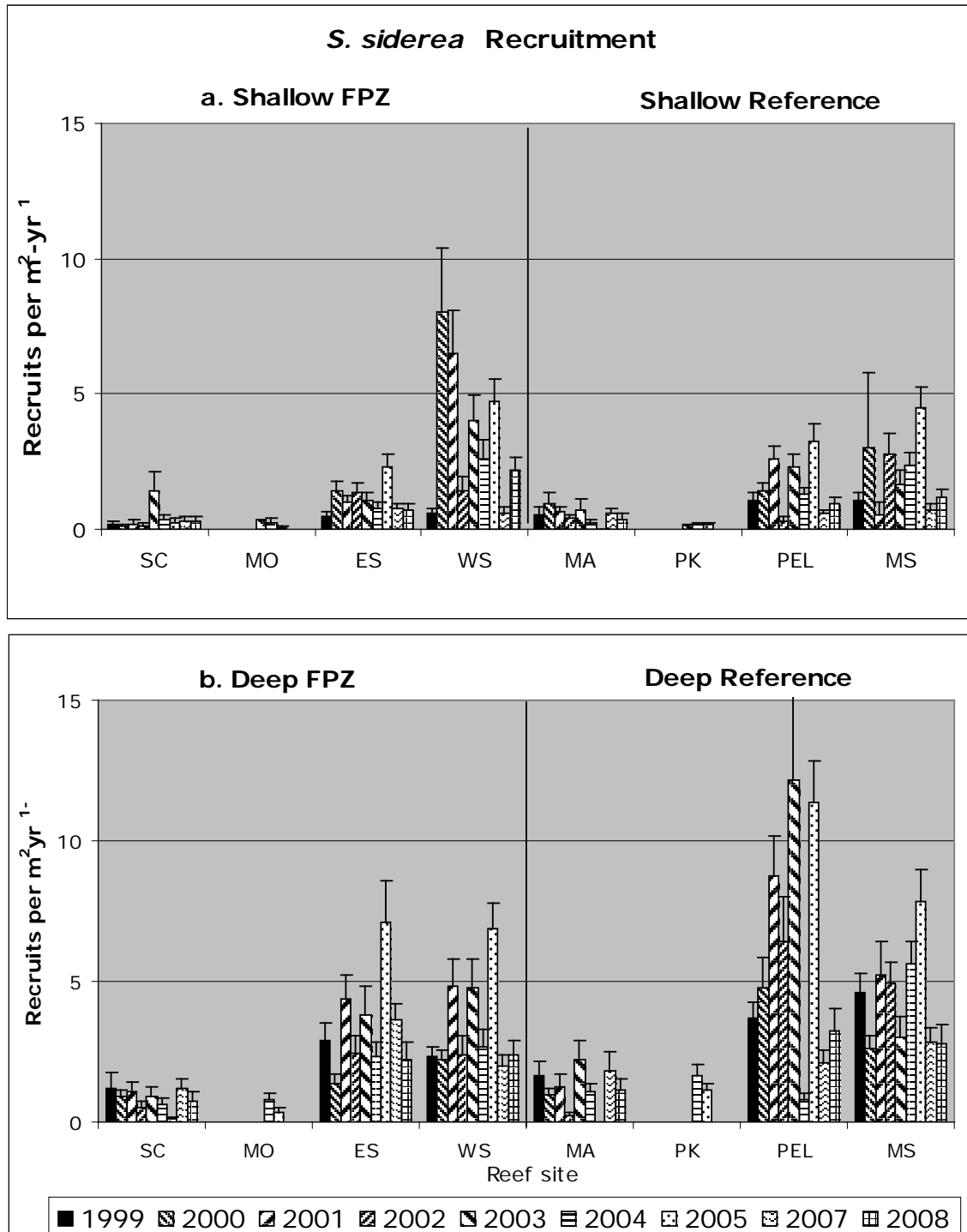


Figure 4 a, b. Patterns of recruitment of *Montastraea cavernosa* (mean, SE) within permanent quadrats at the shallow and deep FPZ and Reference sites from 1998 to 2008. Sites labels are: SC, South Carysfort; MO, Molasses Reef; ES, Eastern Sambo; WS, Western Sambo; MA, Maitland; PK, Pickles; MS, Middle Sambo; PEL, Pelican Shoal. No data were collected at MO and PK from 1999-2001 or MO and PK Deep from 1999-2002 or MA Shallow and Deep in 2005.

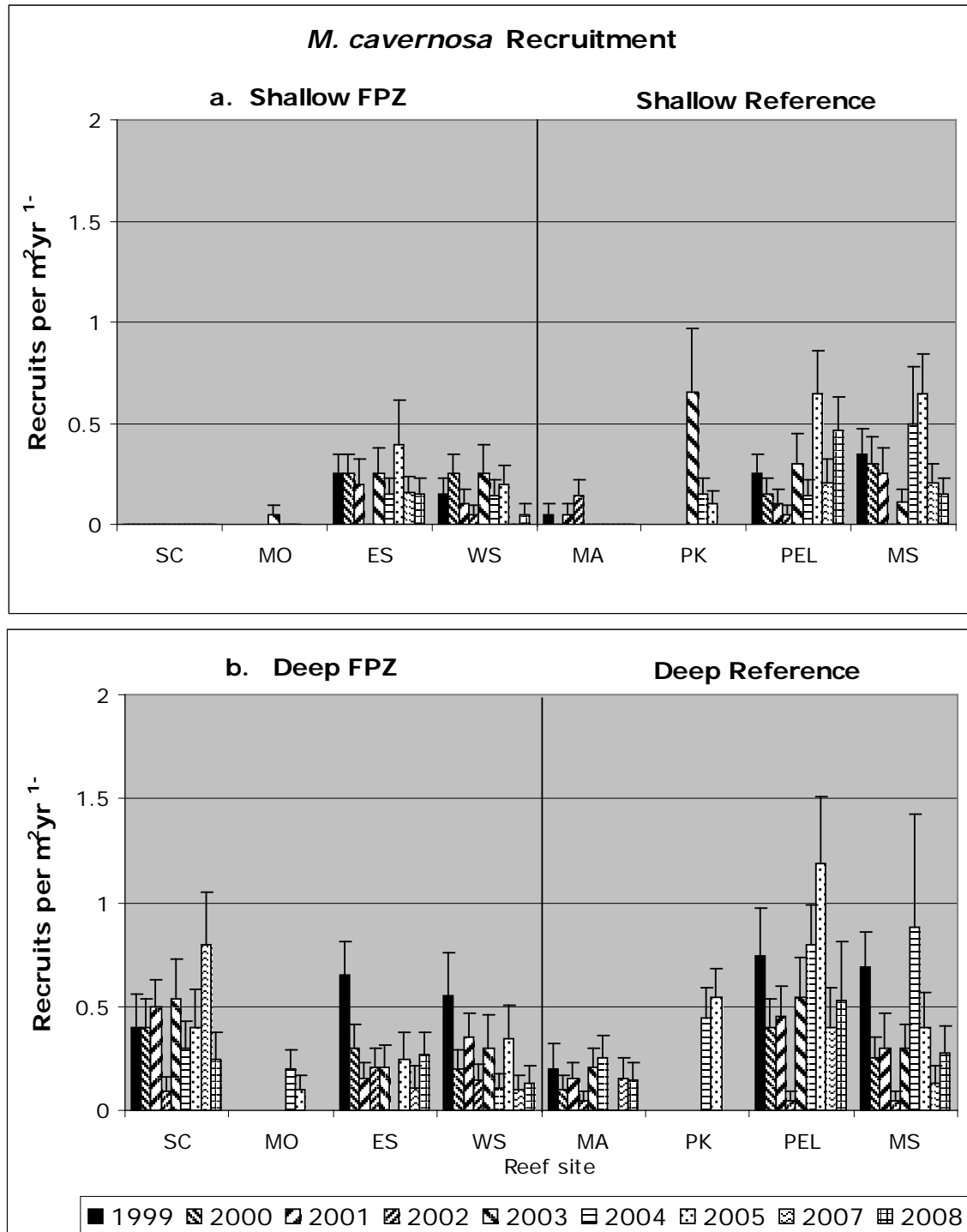


Figure 5 a, b. Patterns of recruitment of *Porite astreoides* (mean, SE) within permanent quadrats at the shallow and deep FPZ and Reference sites from 1998 to 2008. Sites are: SC, South Carysfort; MO, Molasses Reef; ES, Eastern Sambo; WS, Western Sambo; MA, Maitland; PK, Pickles; MS, Middle Sambo; PEL, Pelican Shoal. No data were collected at MO and PK from 1999-2001 or MO and PK Deep from 1999-2002 or MA Shallow and Deep in 2005.

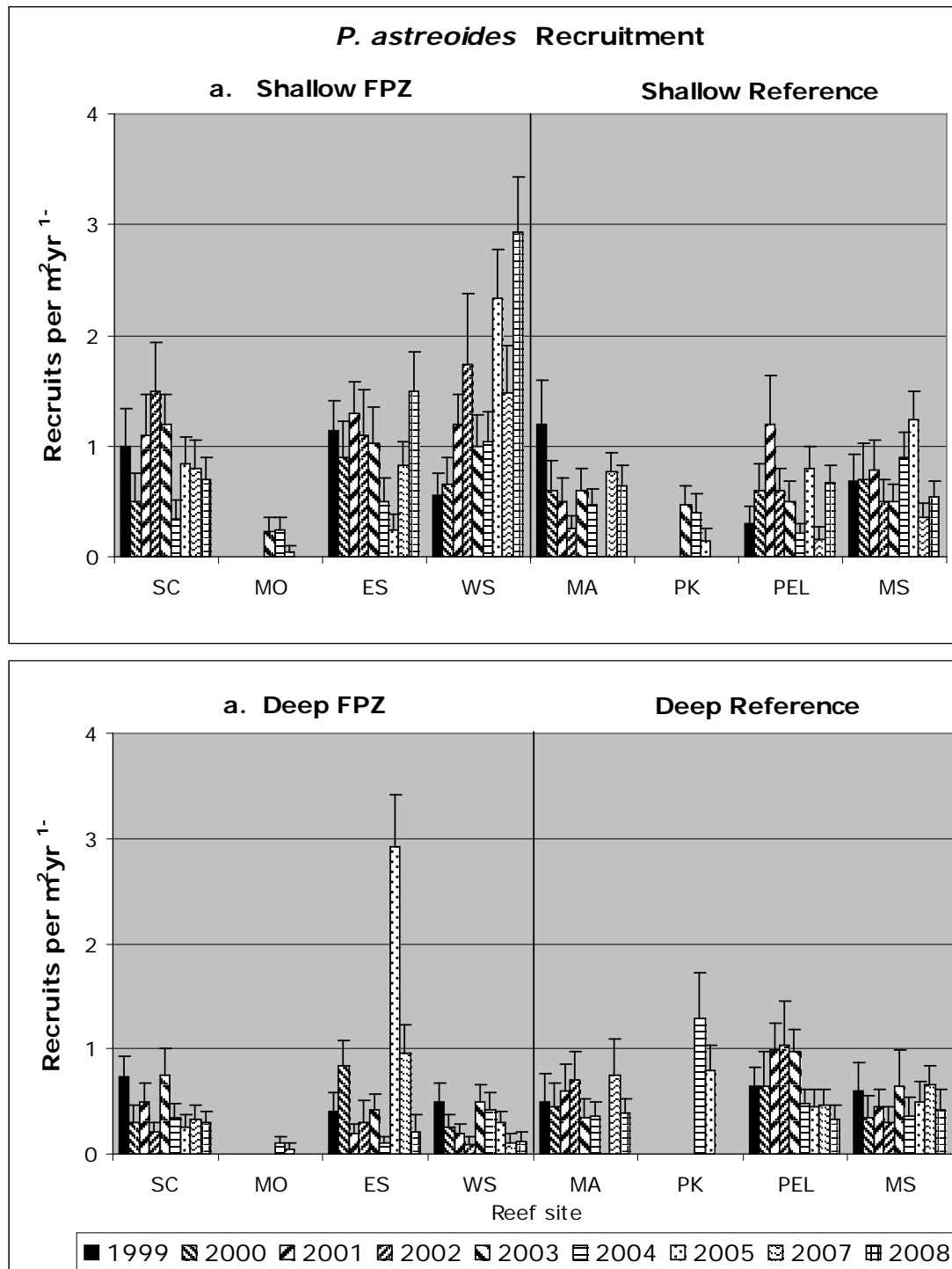


Figure 6 a, b. Patterns of recruitment of *Agaricia* spp. (mean, SE) within permanent quadrats at the shallow and deep FPZ and Reference sites from 1998 to 2008. Sites are: SC, South Carysfort; MO, Molasses Reef; ES, Eastern Sambo; WS, Western Sambo; MA, Maitland; PK, Pickles; MS, Middle Sambo; PEL, Pelican Shoal. No data were collected at MO and PK from 1999-2001 or MO and PK Deep from 1999-2002 or MA Shallow and Deep in 2005.

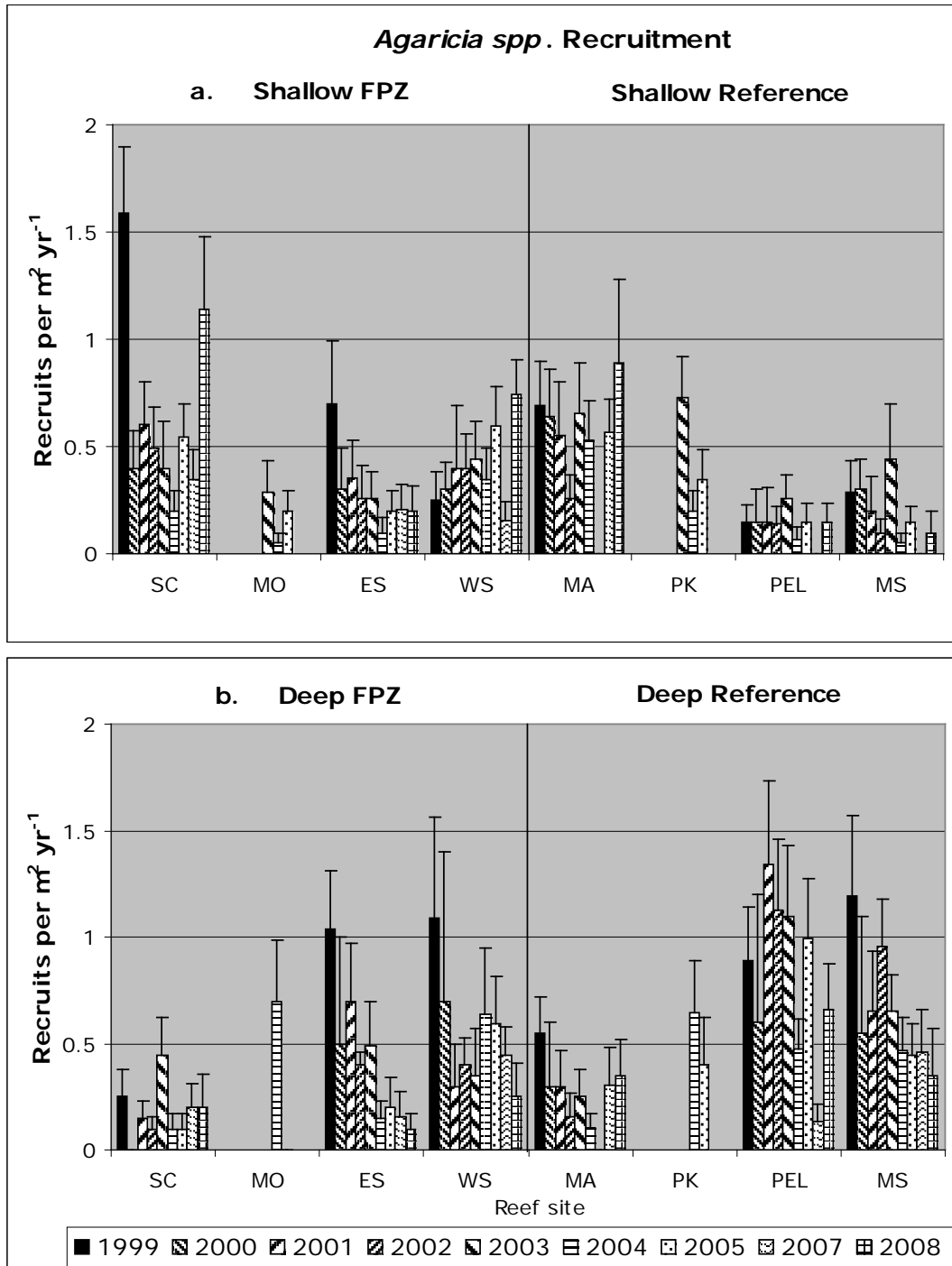


Figure 7 a, b. Patterns of overall mortality of all juvenile scleractinian corals (<5 cm diameter) within permanent quadrats at the shallow and deep FPZ and Reference sites from 1998 to 2008. Sites are: SC, South Carysfort; MO, Molasses Reef; ES, Eastern Sambo; WS, Western Sambo; MA, Maitland; PI, Pickles; MS, Middle Sambo; PEL, Pelican Shoal. No data were collected at MO and PK from 1999-2001 or MO and PK Deep from 1999-2002 or MA Shallow and Deep in 2005.

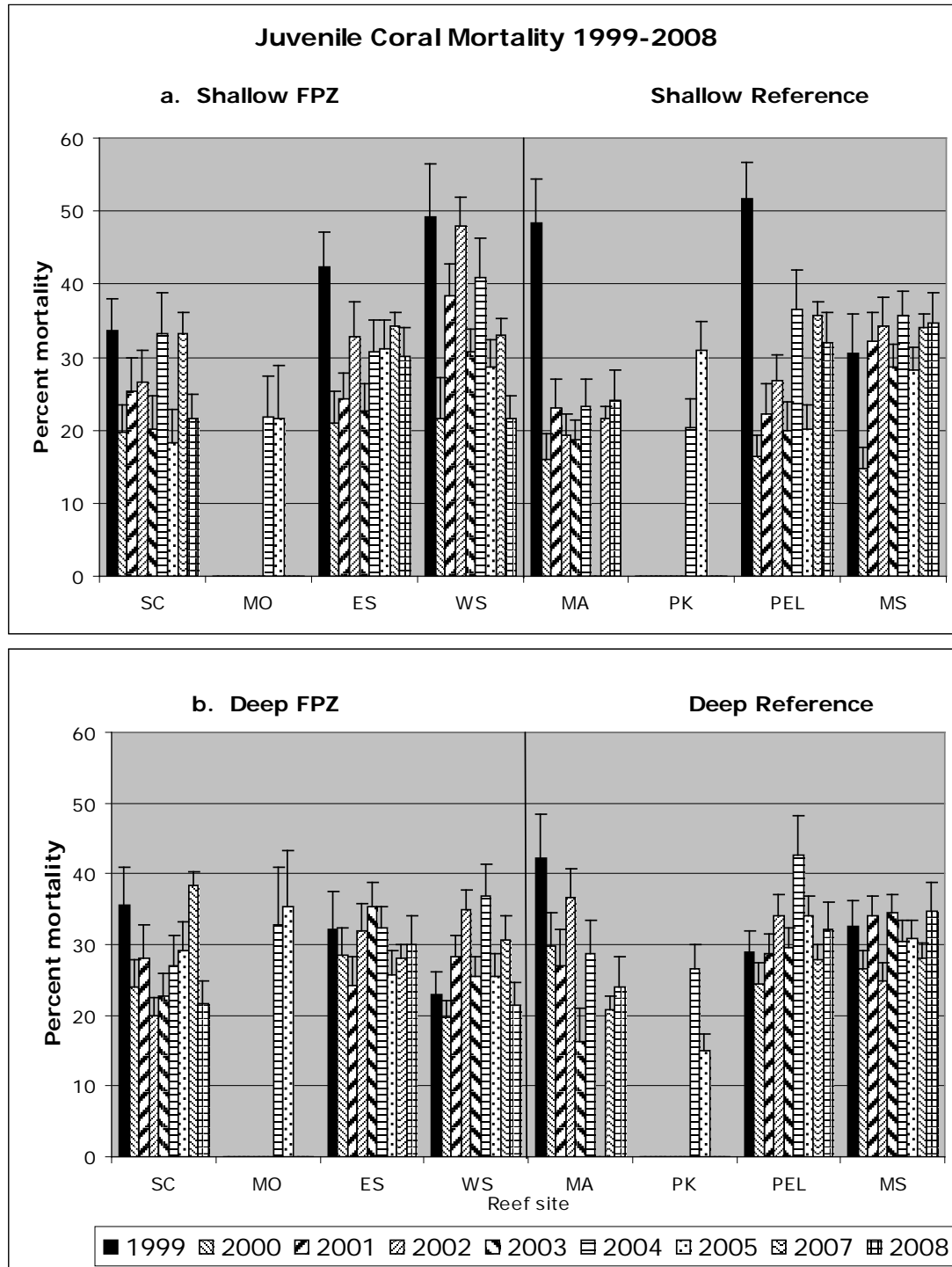


Figure 8. Trends over time in overall juvenile coral percent mortality from 1999 to 2008. Sites labels are: SC, South Carysfort; MO, Molasses Reef; ES, Eastern Sambo; WS, Western Sambo; MA, Maitland; PK, Pickles; MS, Middle Sambo; PEL, Pelican Shoal.

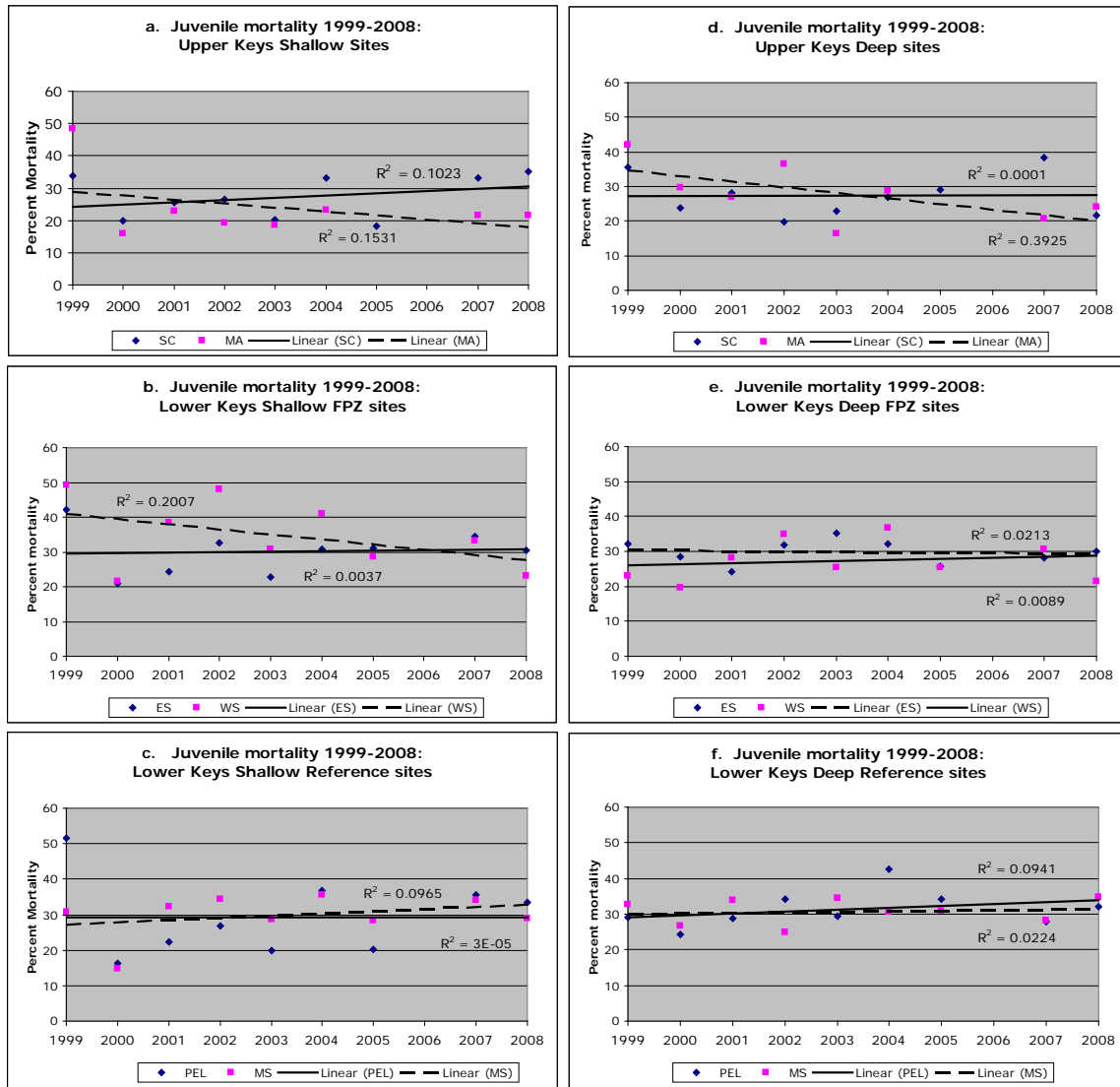


Figure 9 a, b. Patterns in juvenile coral mortality for *Agaricia agaricites* (mean, SE) within permanent quadrats at the shallow and deep FPZ and Reference sites from 1998 to 2008. Sites are: SC, South Carysfort; MO, Molasses Reef; ES, Eastern Sambo; WS, Western Sambo; MA, Maitland; PK, Pickles; MS, Middle Sambo; PEL, Pelican Shoal. No data were collected at MO and PK from 1999-2001 or MO and PK Deep from 1999-2002 or MA Shallow and Deep in 2005.

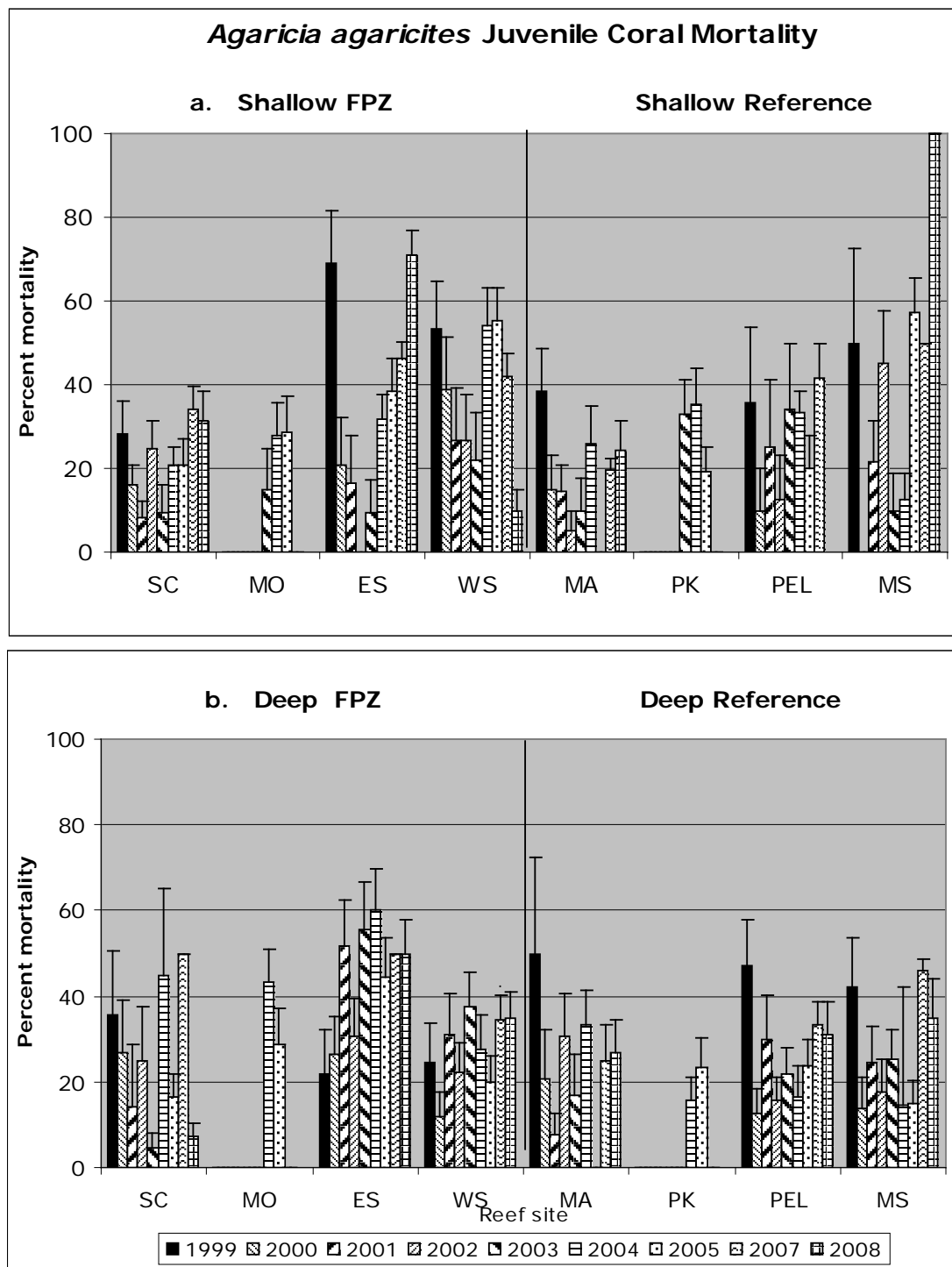


Figure 10 a, b. Patterns in juvenile coral mortality for *Montastraea cavernosa* (mean, SE) within permanent quadrats at the shallow and deep FPZ and Reference sites from 1998 to 2008. Sites are: SC, South Carysfort; MO, Molasses Reef; ES, Eastern Sambo; WS, Western Sambo; MA, Maitland; PK, Pickles; MS, Middle Sambo; PEL, Pelican Shoal. No data were collected at MO and PK from 1999-2001 or MO and PK Deep from 1999-2002 or MA Shallow and Deep in 2005.

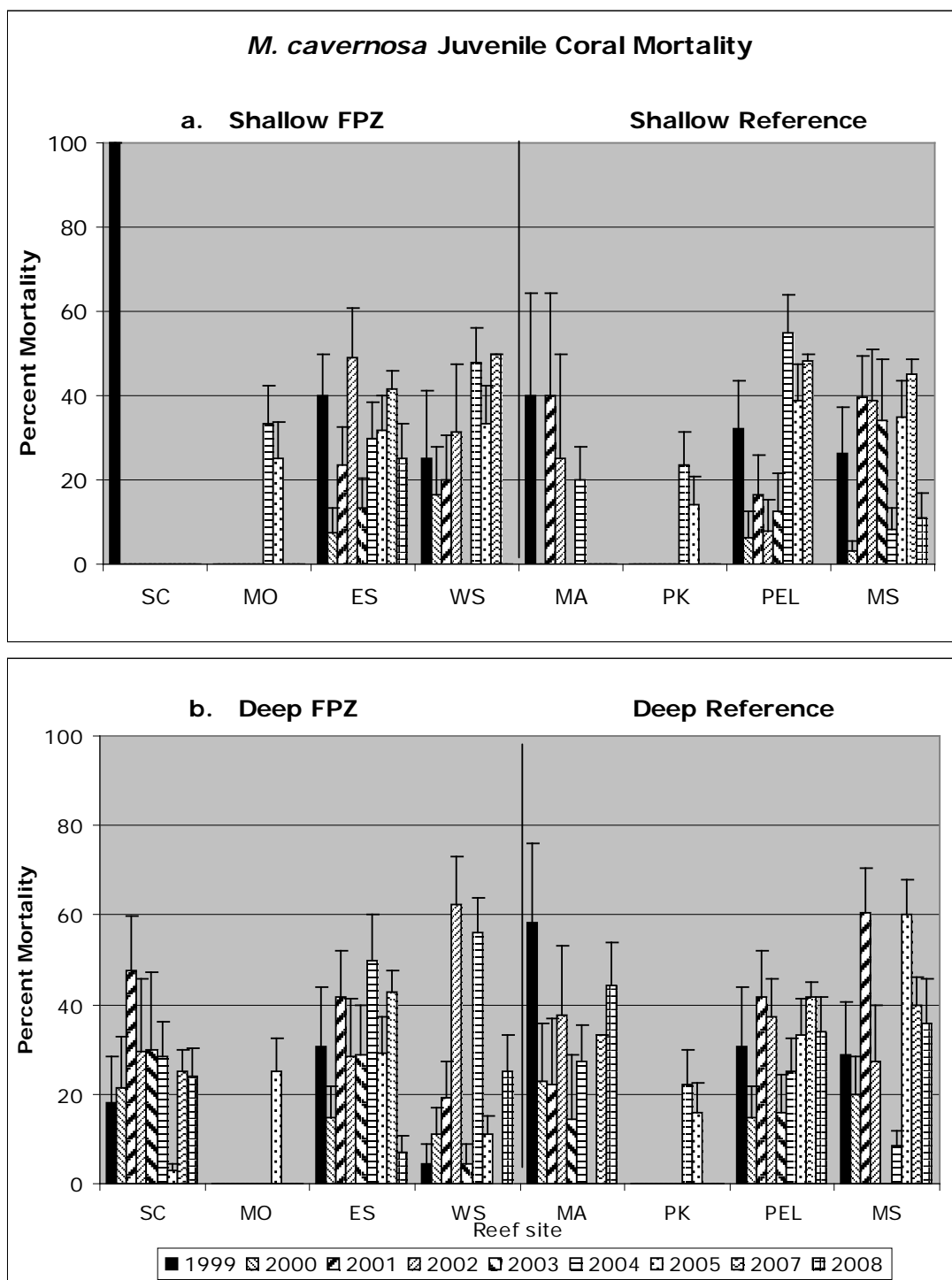


Figure 11 a, b. Patterns in juvenile coral mortality for *Porites astreoides* (mean, SE) within permanent quadrats at the shallow and deep FPZ and Reference sites from 1998 to 2008. Sites labels are: SC, South Carysfort; MO, Molasses Reef; ES, Eastern Sambo; WS, Western Sambo; MA, Maitland; PK, Pickles; MS, Middle Sambo; PEL, Pelican Shoal.

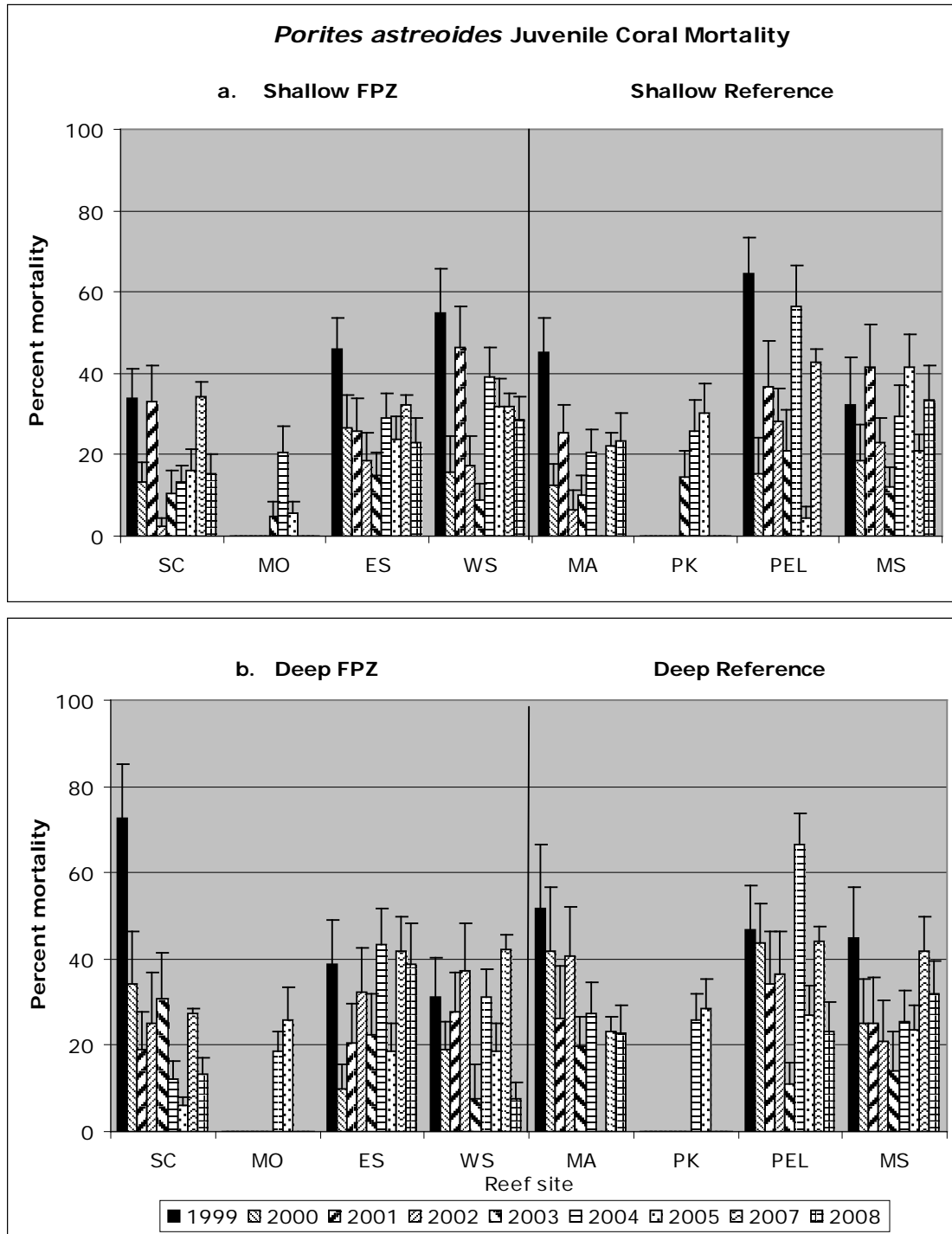


Figure 13 a, b. Mean percent scleractinian coral cover at the FPZ and reference sites from 1998 to 2007. Sites labels are: SC, South Carysfort; MO, Molasses Reef; ES, Eastern Sambo; WS, Western Sambo; MA, Maitland; PI, Pickles; MS, Middle Sambo; PEL, Pelican Shoal. MA was not sampled in 2005.

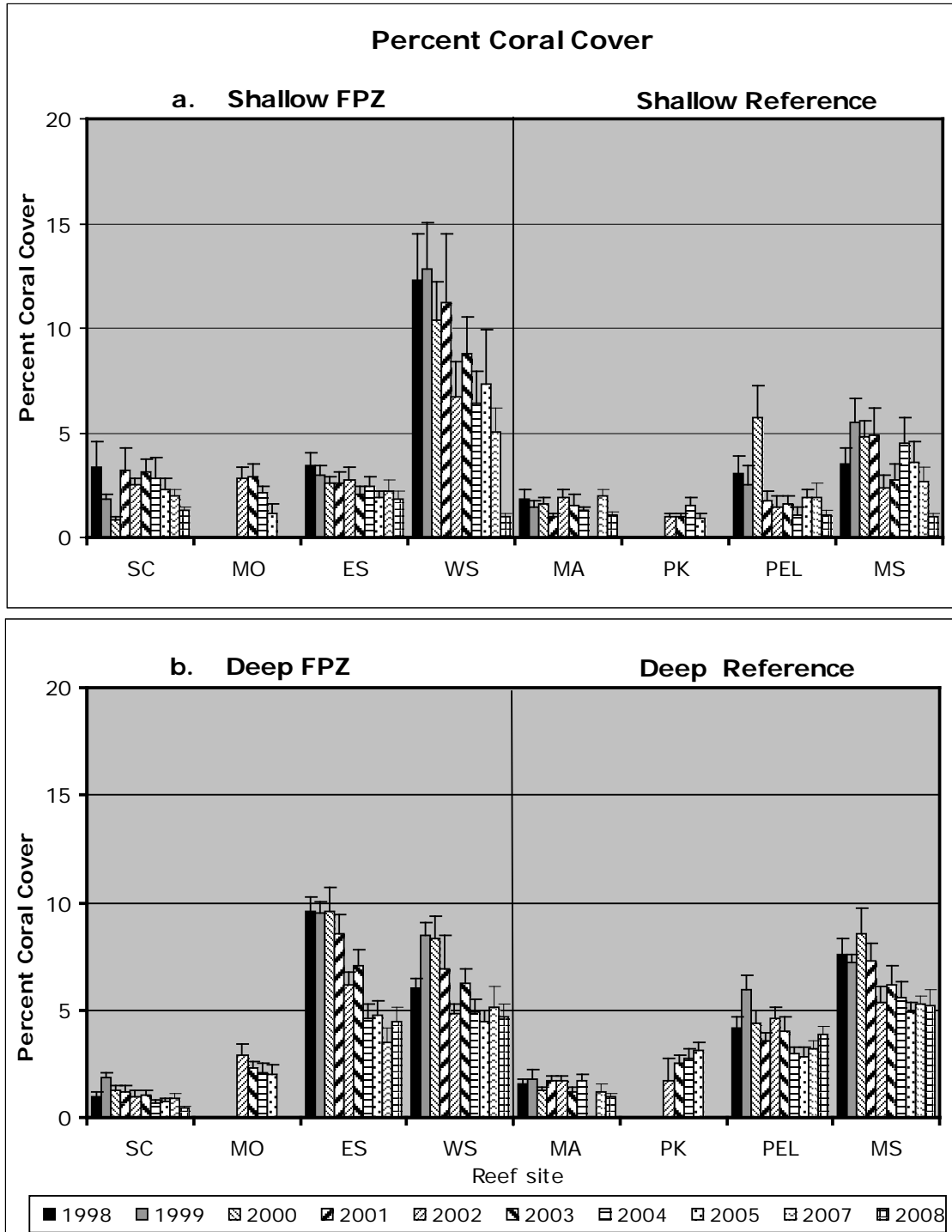


Figure 14 a, b. Changes in mean percent coral cover at the shallow and deep FPZ and reference sites from 1998 to 2008 for *Montastraea* “annularis. Sites labels are: SC, South Carysfort; MO, Molasses Reef; ES, Eastern Sambo; WS, Western Sambo; MA, Maitland; PI, Pickles; MS, Middle Sambo; PEL, Pelican Shoal. MA was not sampled in 2005. No data were collected in 2006.

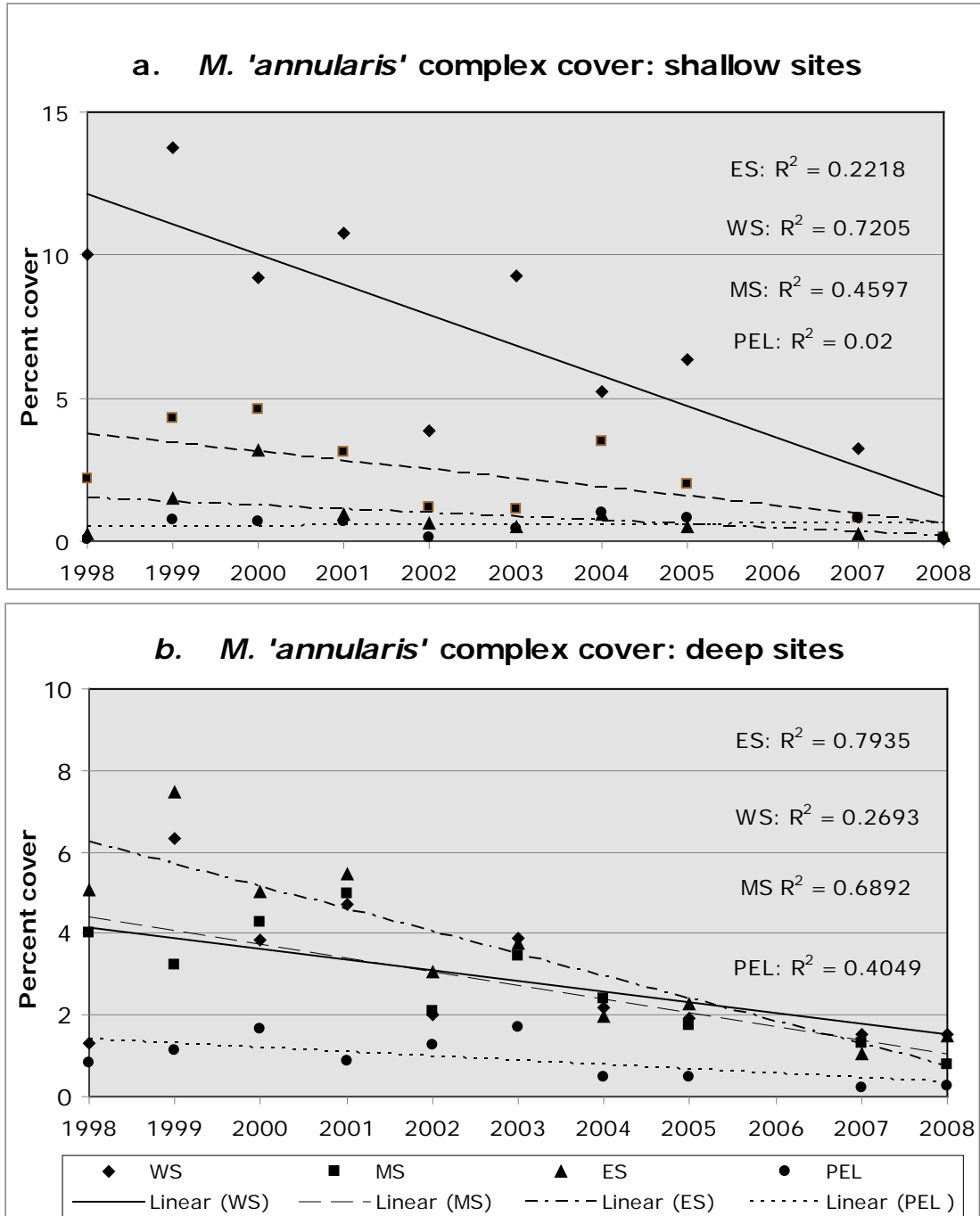


Figure 17 a, b. Total dry-weight macroalgal biomass at the FPZ and reference sites in 2007 and 2008. Sites labels are: SC, South Carysfort; ES, Eastern Sambo; WS, Western Sambo; MA, Maitland; MS, Middle Sambo; PEL, Pelican Shoal.

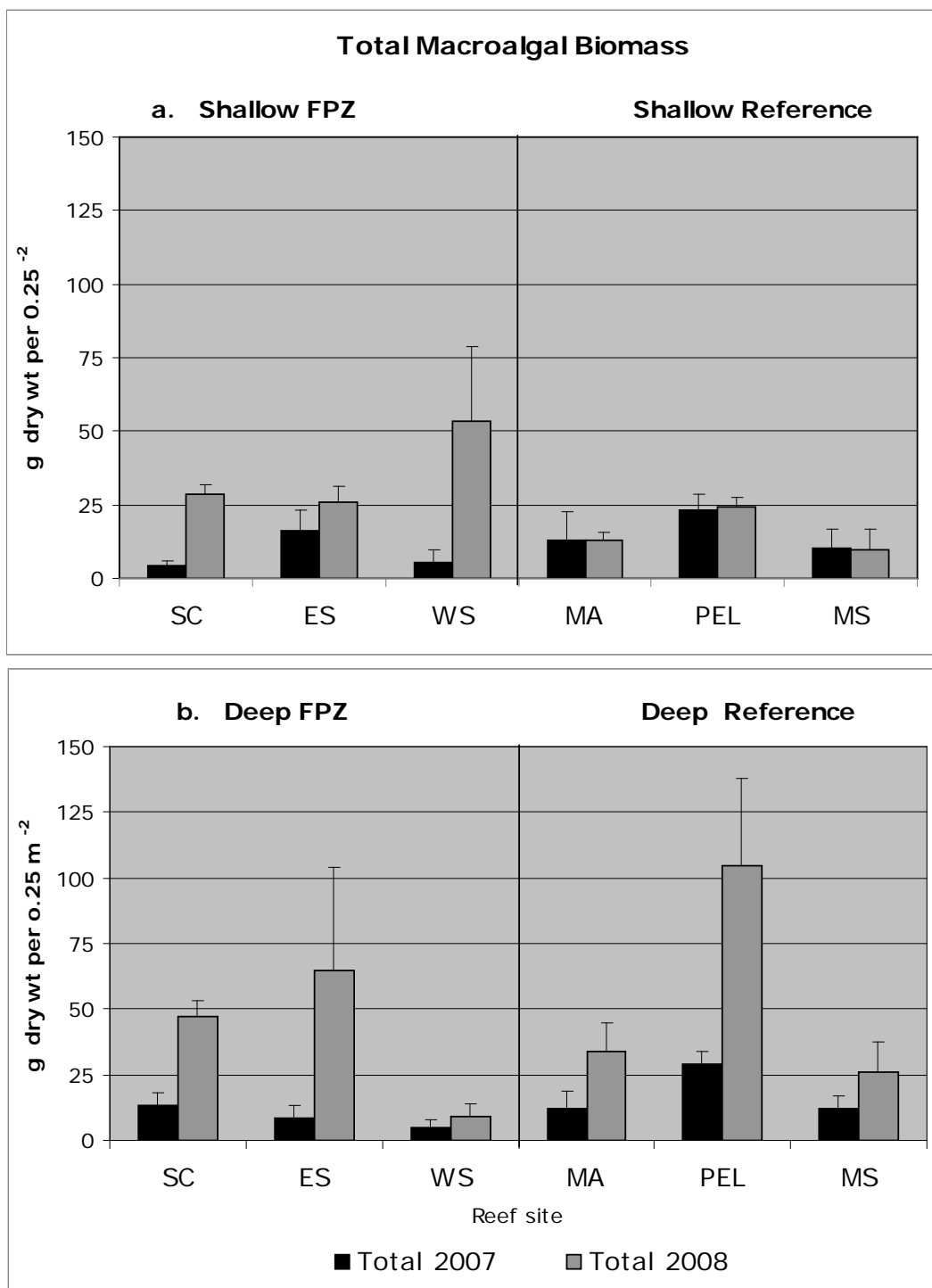


Figure 18. *Halimeda* spp. biomass at the FPZ and Reference sites in 2007 and 2008. Sites labels are: SC, South Carysfort; ES, Eastern Sambo; WS, Western Sambo; MA, Maitland; MS, Middle Sambo; PEL, Pelican Shoal. *Halimeda* spp. were primarily *H. goreau* and *H. tuna*, which varied by site (see Tables 3 and 4).

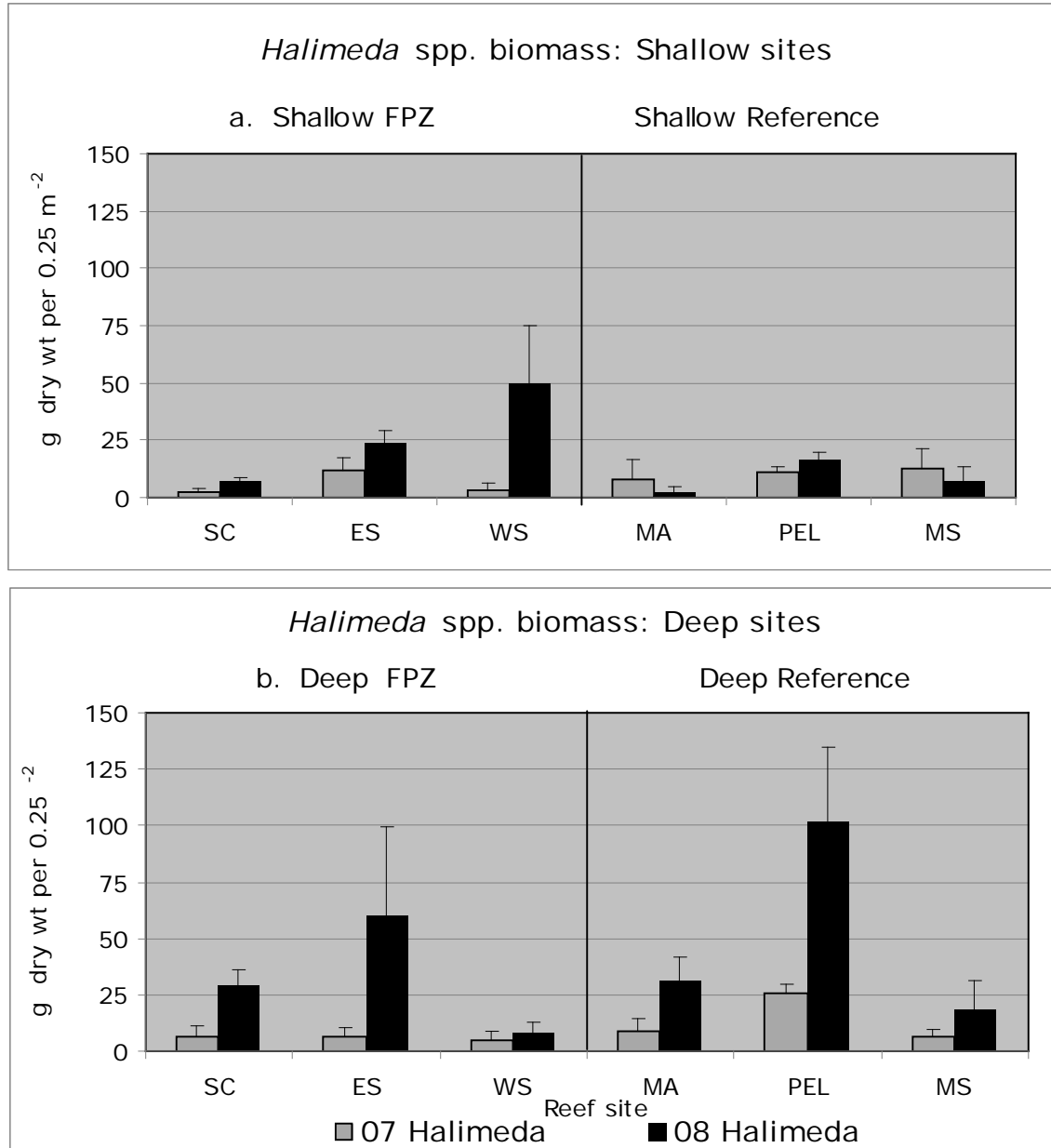


Figure 19. *Dictyota* spp. biomass at the FPZ and Reference sites in 2007 and 2008. Sites labels are: SC, South Carysfort; ES, Eastern Sambo; WS, Western Sambo; MA, Maitland; MS, Middle Sambo; PEL, Pelican Shoal. *Dictyota* spp. was primarily *D. menstrualis*.

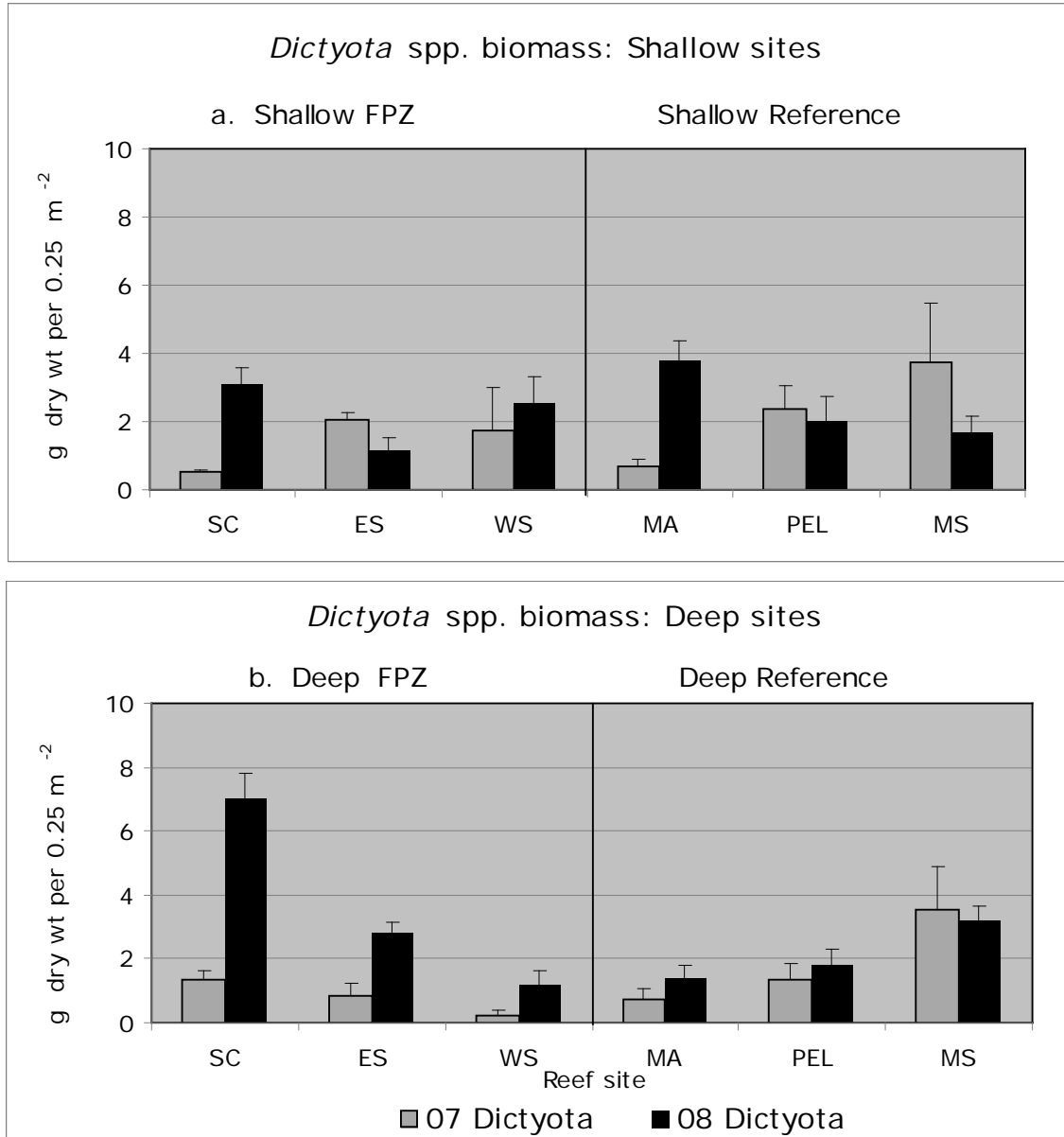


Figure 20. “Other” macroalgal biomass at the FPZ and Reference sites in 2007 and 2008. Sites labels are: SC, South Carysfort; ES, Eastern Sambo; WS, Western Sambo; MA, Maitland; MS, Middle Sambo; PEL, Pelican Shoal. Species found at each sites are listed in Tables 3 and 4.

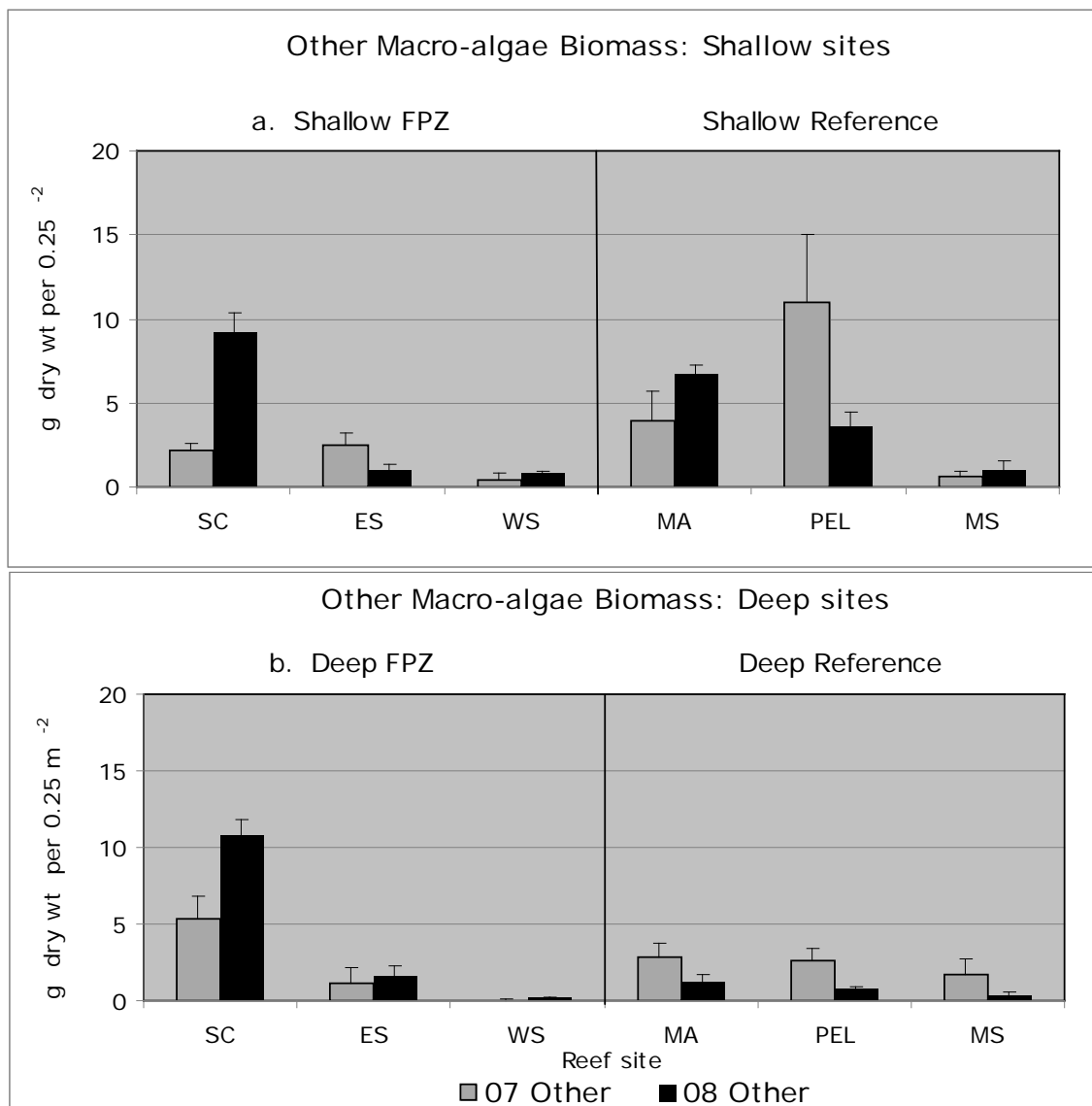


Figure 21. Comparison of mean total macroalgal biomass at the FPZ and Reference site in 2007 to the data extracted from Miller et al. 2002 for 1998 and 1999. Their data were collected from 0.16-m² quadrats and were normalized to our 0.25-m² quadrat sample size. Sites labels are: SC, South Carysfort; ES, Eastern Sambo; WS, Western Sambo; MA, Maitland; MS, Middle Sambo; PEL, Pelican Shoal.

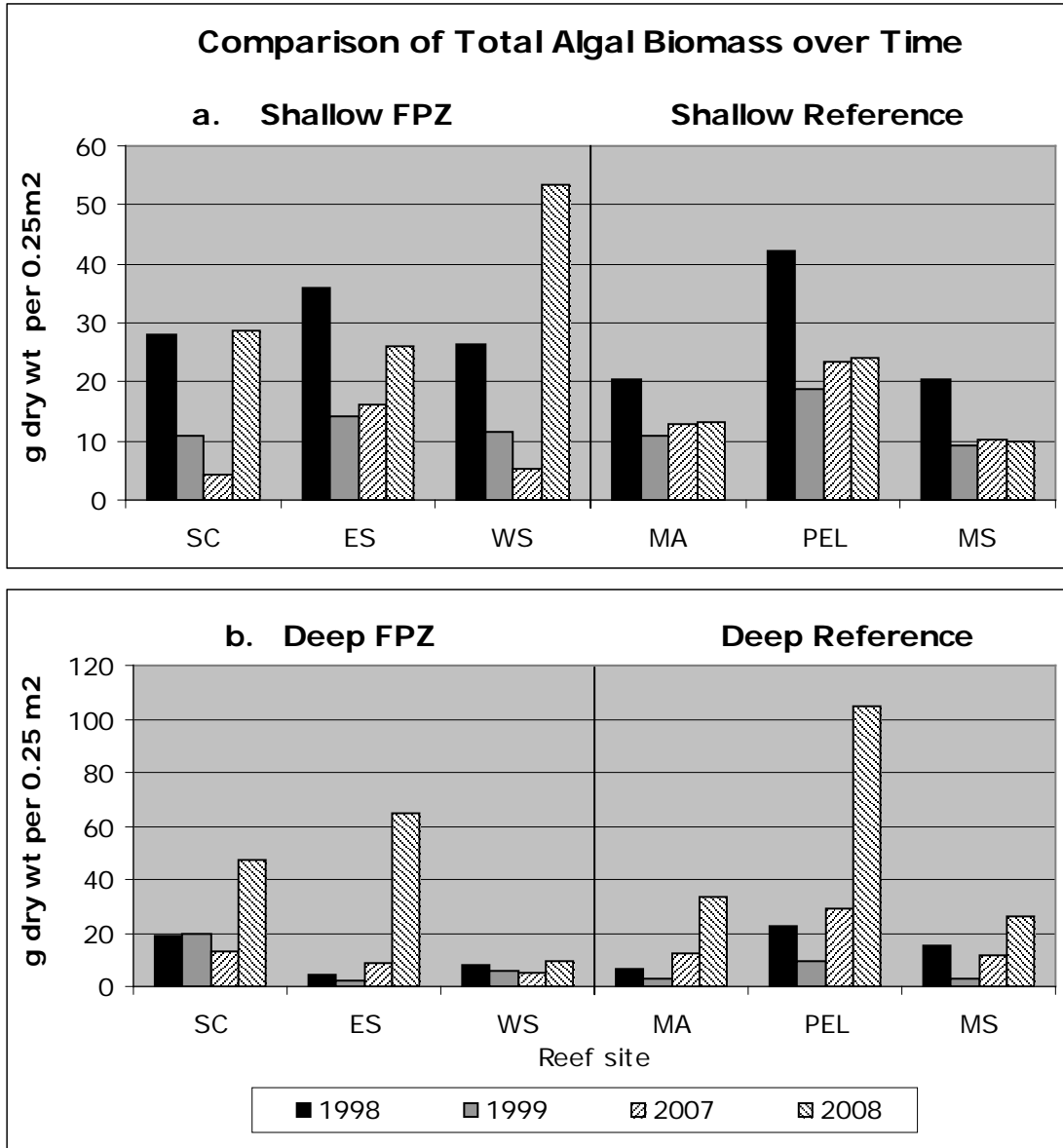


Figure 22. Trends in submarine irradiance at ~16 m depth at four study sites in the Lower Keys in 2007. Light measurements were made every 10 minutes with HOBO Pendant data loggers at each site. Daily means were calculated for irradiance measured from ~7 AM to ~7 PM. Measure light levels were 5-8% of surface irradiance. Sites labels are: ES, Eastern Sambo; WS, Western Sambo; MS, Middle Sambo; PEL, Pelican Shoal.

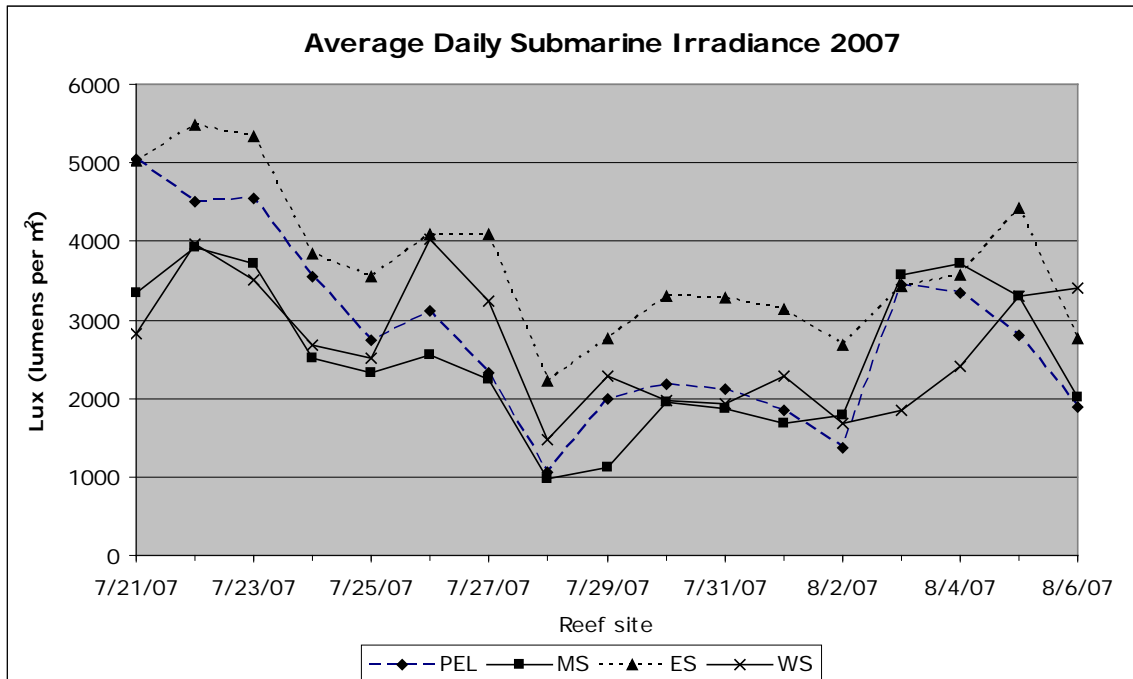


Figure 23. Trends in relative submarine irradiance at ~16 m depth at four study sites in the Lower Keys in 2007. Western Sambo site was selected as a “standard site” in order to more clearly show the magnitude of differences between the sites on a given date and over time. Light measurements were made every 10 minutes with HOBO Pendant data loggers at each site. Daily means were calculated for irradiance measured from ~7 AM to ~7 PM. Measure light levels were 5-8% of surface irradiance. Sites labels are: ES, Eastern Sambo; WS, Western Sambo; MS, Middle Sambo; PEL, Pelican Shoal.

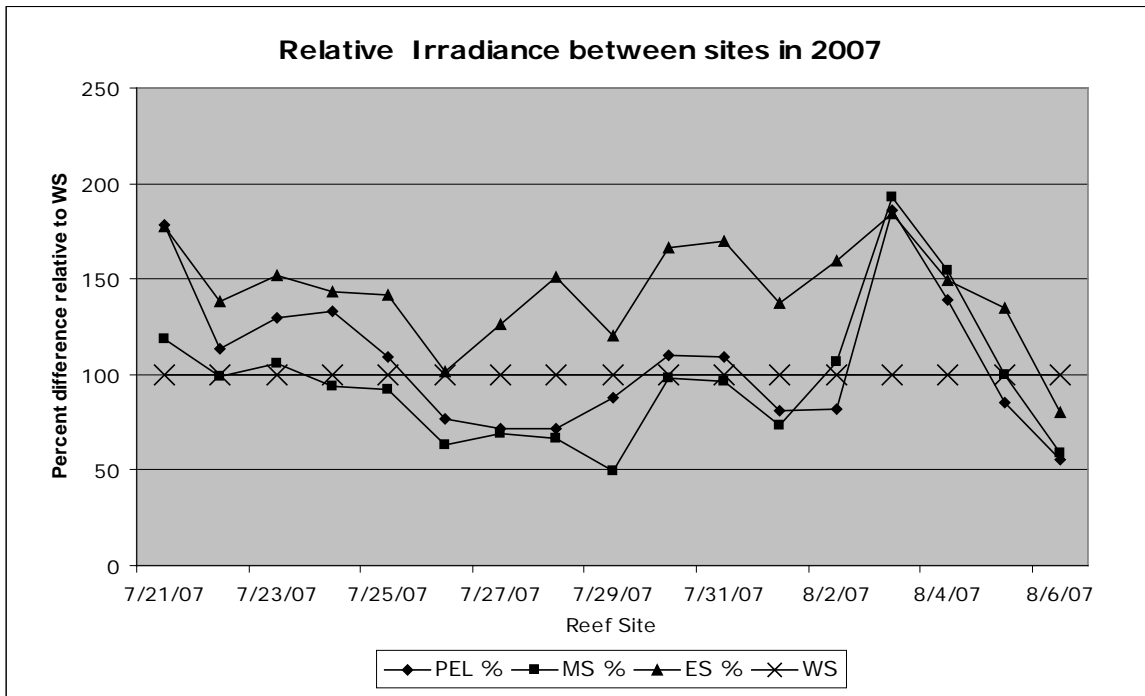


Figure 24. Mean horizontal Secchi measurements at four Lower keys sites in 2007 and 2008. Sites labels are: ES, Eastern Sambo; WS, Western Sambo; Middle Sambo; PEL, Pelican Shoal.

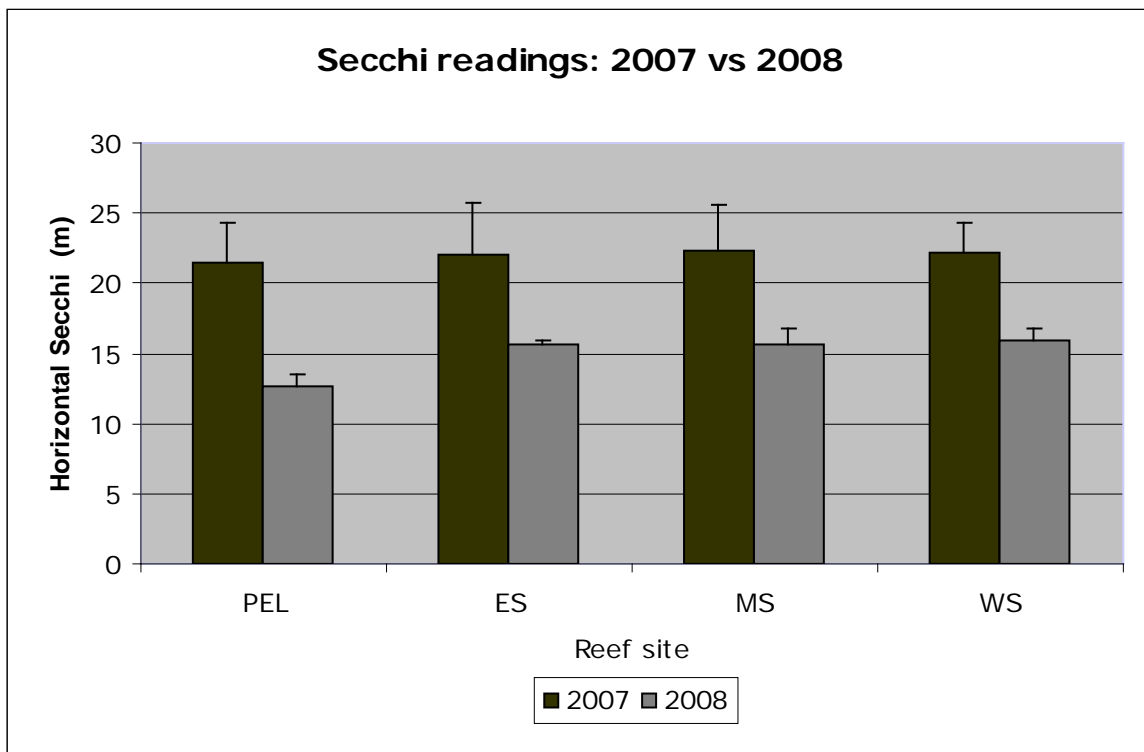


Table 1. Species-specific patterns of coral recruitment aggregated by site and depth from 2005 to 2007. REF refers to Reference sites and FPZ refers to Fully Protected Zones.

Species	Upper Keys 2007					Lower Keys 2007												
	REF		FPZ		Total	REF		FPZ		REF		FPZ		Total				
	S. Carysfort	Shall	Deep	Maitland		Shall	Deep	Pelican	E. Sambo	Shall	Deep	M. Sambo	W. Sambo		Shall	Deep		
<i>Acropora cervicornis</i>	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Agaricia agaricites</i>	6	2		11	4	23	0	2	2	3	0	6	3	6	22			
<i>Agaricia fragilis</i>	0	0		0	0	0	0	0	2	0	0	1	0	2	5			
<i>Agaricia humilis</i>	1	1		0	0	2	0	0	0	0	0	0	0	1	1			
<i>Agaricia sp.</i>	0	0		0	0	0	0	0	0	0	0	0	0	0	0			
<i>Colpophyllia natans</i>	0	0		0	0	0	0	0	0	0	0	0	0	0	0			
<i>Dichocoenia stokesii</i>	1	1		0	1	3	1	0	1	1	0	1	0	0	4			
<i>Diploria strigosa</i>	0	0		0	0	0	0	0	1	0	0	0	0	0	1			
<i>Diploria labyrinthiformis</i>	0	0		0	0	0	0	0	0	0	0	0	0	0	0			
<i>Eusmilia fastigata</i>	0	1		0	0	1	0	0	0	0	0	3	0	1	4			
<i>Favia fragum</i>	0	1		0	0	1	0	0	0	1	0	0	0	0	1			
<i>Isophyllia spp.</i>	0	1		0	0	1	0	0	0	0	0	0	0	0	0			
<i>Leptoseris cucullata</i>	0	0		0	0	0	0	0	0	0	0	0	0	0	0			
<i>Madracis decactis</i>	0	0		0	0	0	0	0	1	1	0	1	0	1	4			
<i>Madracis mirabilis</i>	0	0		0	0	0	0	0	0	1	0	0	0	0	1			
<i>Manicina aureolata</i>	0	1		0	1	2	2	0	0	4	0	2	0	1	9			
<i>Meandrina meandrites</i>	0	1		0	0	1	0	0	0	0	0	0	0	0	0			
<i>Montastraea "annularis"</i>	0	0		0	0	0	0	0	0	0	0	0	0	0	0			
<i>Montastraea cavernosa</i>	0	12		0	2	14	4	6	3	2	4	2	0	2	23			
<i>Mycetophyllia spp.</i>	0	0		0	0	0	0	1	0	1	0	0	0	1	3			
<i>Porites astreoides</i>	16	5		15	10	46	3	7	16	18	9	10	29	2	94			
<i>Porites porites</i>	4	0		9	0	13	1	1	1	1	1	0	1	0	6			
<i>Scolymia spp.</i>	0	1		0	0	1	0	2	0	2	0	2	0	1	7			
<i>Siderastrea radians</i>	5	6		13	1	25	3	3	2	2	4	2	0	4	20			
<i>Siderastrea siderea</i>	6	18		11	24	59	11	32	15	69	14	43	12	40	236			
<i>Solenastrea bournei</i>	0	0		0	0	0	0	0	0	0	0	0	0	0	0			
<i>Stephanocoenia michelini</i>	0	3		5	2	10	2	4	1	5	0	17	1	13	43			
Unknown species	0	0		1	0	1	0	1	0	0	0	1	0	0	2			
Totals	39	54		65	45	203	27	59	45	111	32	91	46	75	486			
Number per m²	3.5	3.8		4.6	4.3	4.1	1.4	4.3	2.4	6.7	1.7	6.4	2.5	3.8	3.5			
Quadrats surveyed	18	23		23	17	81	31	22	30	27	31	23	30	32	226			

Table 2. Species-specific patterns of coral recruitment aggregated by site and depth from 2007 to 2008. REF refers to Reference sites and FPZ refers to Fully Protected Zones.

Species	Upper Keys 2008					Lower Keys 2008														
	REF		FPZ		Total	REF		FPZ		REF		FPZ		Total						
	S. Carysfort	Shall	Deep	Maitland		Shall	Deep	Pelican	Shall	Deep	East. Sambo	Shall	Deep		Midd. Sambo	Shall	Deep	West. Sambo	Shall	Deep
<i>Acropora cervicornis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Agaricia agaricites</i>	20	1	13	5	39	1	6	4	1	2	5	12	5	36						
<i>Agaricia fragilis</i>	0	0	2	1	3	0	1	0	1	0	0	1	2	5						
<i>Agaricia humilis</i>	2	3	3	1	9	2	1	0	0	0	0	1	0	4						
<i>Agaricia sp.</i>	1	0	0	0	1	0	2	0	0	0	0	0	0	2						
<i>Colpophyllia natans</i>	0	0	0	0	0	0	0	0	0	0	1	0	0	1						
<i>Dichocoenia stokesii</i>	4	0	0	0	4	4	1	2	1	0	0	2	0	10						
<i>Diploria strigosa</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0						
<i>Diploria labyrinthiformis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0						
<i>Eusmilia fastigata</i>	0	1	1	0	2	0	1	0	1	0	1	0	0	3						
<i>Favia fragum</i>	0	1	0	0	1	0	0	1	0	2	0	0	0	3						
<i>Isophyllia spp.</i>	0	0	0	0	0	1	0	0	0	0	0	0	0	1						
<i>Leptoseris cucullata</i>	2	0	0	0	2	0	0	0	0	0	0	0	0	0						
<i>Madracis decactis</i>	0	5	0	0	5	0	0	0	2	0	0	0	0	2						
<i>Madracis mirabilis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0						
<i>Manicinia aureolata</i>	0	1	0	1	2	2	0	0	2	0	1	4	3	12						
<i>Meandrina meandrites</i>	0	0	0	0	0	1	1	0	0	0	0	0	0	2						
<i>Montastraea "annularis"</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0						
<i>Montastraea cavernosa</i>	0	5	0	3	8	9	8	3	5	3	4	1	2	35						
<i>Mycetophyllia spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0						
<i>Porites astreoides</i>	14	6	13	8	41	13	5	30	4	11	6	59	2	130						
<i>Porites porites</i>	12	1	13	0	26	4	0	8	0	1	0	4	2	19						
<i>Scolymia spp.</i>	1	1	0	2	4	0	2	0	1	0	0	0	0	3						
<i>Siderastrea radians</i>	8	3	5	1	17	12	3	0	1	7	0	1	0	24						
<i>Siderastrea siderea</i>	6	15	7	23	51	19	49	14	42	24	40	44	38	270						
<i>Solenastrea bournei</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0						
<i>Stephanocoenia intersepta</i>	0	10	1	6	17	4	18	2	14	0	11	4	13	66						
Unknown species	0	0	0	0	0	1	1	1	2	1	3	2	4	15						
Totals	70	53	58	51	232	73	99	65	77	51	72	135	71	643						
Number per m ²	3.5	2.7	2.9	2.6	2.9	3.8	6.7	3.3	4.2	2.6	5.1	6.8	4.6	4.5						
Quadrats surveyed	32	32	32	32	128	31	24	32	30	32	23	32	25	229						

Table 3. Macroalgal species composition in 2007. Site names: SC = South Carysfort, ES = Eastern Sambo, WS = Western Sambo, MA = Maitland, PEL = Pelican Shoal, MS = Middle Sambo. Abundance categories: * = <1 g dry wt per 0.25 m², ** = 1-5 g dry wt per 0.25 m², *** = > 5 g dry wt per 0.25 m². FPZ= Fully Protected Zone, REF= Reference site.

Functional group	Reef Type Site	Shallow sites						Deep sites					
		FPZ SC	FPZ ES	FPZ WS	REF MA	REF PEL	REF MS	FPZ SC	FPZ ES	FPZ WS	REF MA	REF PEL	REF MS
Calcareous Green	<i>Halimeda goreau</i>	*	***	***	-	-	***	***	***	***	***	***	**
Calcareous Green	<i>Halimeda tuna</i>	**	***	-	***	***		*	-	-	*	-	**
Calcareous Green	<i>Halimeda lacrimosa</i>	-	-	-	-	-	-	-	-	-	**	-	-
Calcareous Green	<i>Avrainvillea</i> sp.	*	*	*	-	**	-	*	**	-	-	*	-
Calcareous Red	<i>Amphiroa</i> spp.	**	*	*	**	**	*	***	*	*	**	**	**
Calcareous Red	<i>Jania</i> spp.	-	*	-	*	-	-	**	**	-	**	**	*
Calcareous Red	<i>Galaxaura marginata</i>	**	**	-	**	-	-	**	-	-	**	-	-
Fleshy Brown	<i>Dictyota</i> spp.	*	**	**	*	**	**	**	**	*	**	**	**
Fleshy Brown	<i>Sargassum</i> sp.	*	-	-	*	**	-	*	-	-	*	-	-
Fleshy Brown	<i>Lobophora prolifera</i>	-	-	-	*	-	-	*	*	-	*	-	-
Fleshy Brown	<i>Styopodium zonale</i>	-	*	*	*	**	-	*	-	-	*	-	*
Fleshy Red	<i>Coelothrix irregularis</i>	*	*	-	*	*	*	*	*	-	*	-	-
Fleshy Red	<i>Gelidella acerosa</i>	*	*	-	*	-	-	*	-	-	*	-	-
Fleshy Red	<i>Botrycladia</i> sp.	-	-	-	-	-	-	*	-	-	*	-	-
Fleshy Red	<i>Bryothamnion triquetrum</i>	-	-	-	-	**	-	-	-	-	-	-	-
Number of species		9	10	5	10	8	4	13	7	3	13	5	6
Number of samples		3	6	4	4	6	5	8	6	2	7	11	5

Table 4. Macroalgal species composition in 2008. Site names: SC= South Carysfort, ES= Eastern Sambo, WS= Western Sambo, MA= Maitland, PEL= Pelican Shoal, MS= Middle Sambo. Abundance categories: * = <1 g dry wt per 0.25 m², ** = 1-5 g dry wt per 0.25 m², *** = > 5 g dry wt per 0.25 m². FPZ = Fully Protected Zone, REF = Reference site.

Functional group	Reef Type Site Species	Shallow sites						Deep sites					
		FPZ	FPZ	FPZ	REF	REF	REF	FPZ	FPZ	FPZ	REF	REF	REF
		SC	ES	WS	MA	PEL	MS	SC	ES	WS	MA	PEL	MS
Calcareous Green	<i>Halimeda goreau</i>	**	***	***	-	**	***	***	***	***	***	***	***
Calcareous Green	<i>Halimeda tuna</i>	**	**	**	**	***	-	**	-	-	**	-	-
Calcareous Green	<i>Halimeda opuntia</i>	*	*	**	-	**	-	**	-	-	-	-	-
Calcareous Green	<i>Halimeda lacrimosa</i>	-	-	-	-	-	-	*	-	-	*	-	-
Calcareous Green	<i>Udotea</i> spp.	*	*	*	*	**	*	*	*	*	*	*	*
Calcareous Green	<i>Avrainvillea</i> sp.	-	-	-	-	-	-	-	-	-	-	-	-
Calcareous Green	<i>Penicillus</i> sp.	-	-	-	-	-	-	*	-	-	-	-	-
Calcareous Red	<i>Amphiroa</i> spp.	**	*	*	**	*	*	**	-	-	*	*	*
Calcareous Red	<i>Jania</i> spp.	*	*	*	*	*	*	*	-	-	-	-	*
Calcareous Red	<i>Galaxaura marginata</i>	**	*	*	**	*	*	*	-	*	*	*	-
Calcareous Red	<i>Galaxaura obtusa?</i>	*	-	-	-	-	-	*	-	-	-	-	-
Fleshy Brown	<i>Dictyota</i> spp.	**	**	**	**	**	**	***	**	**	**	**	**
Fleshy Brown	<i>Sargassum</i> sp.	*	*	-	*	**	-	*	*	-	*	-	-
Fleshy Brown	<i>Lobophora prolifera</i>	*	-	*	*	-	-	**	*	*	*	*	-
Fleshy Brown	<i>Styopodium zonale</i>	*	-	-	*	-	*	-	-	-	-	-	-
Fleshy Brown	<i>Turbinaria turbinata</i>	-	-	-	*	-	-	-	-	-	-	-	-
Fleshy Red	<i>Coelothrix irregularis</i>	*	*	*	-	*	*	*	*	*	*	-	*
Fleshy Red	<i>Gelidella acerosa</i>	*	*	-	*	*	-	*	*	-	*	-	*
Fleshy Red	<i>Botrycladia</i> sp.	-	-	-	*	-	-	*	-	-	*	-	-
Fleshy Red	<i>Bostrychia</i> sp.	-	-	-	*	*	-	-	-	-	-	-	-
Fleshy Red	<i>Acanthophora spicifera</i>	-	-	-	-	*	-	-	-	-	-	-	-
Fleshy Red	<i>Cryptonemia</i> sp.	-	-	-	-	-	-	*	-	-	-	-	-
Fleshy Red	<i>Spyridea</i> sp.	-	-	-	-	*	-	-	-	-	*	-	-
Fleshy Red	<i>Chondus</i> sp.	*	-	-	-	-	-	*	*	*	*	*	*
Fleshy Red	<i>Laurencia</i> sp.	*	-	-	*	*	-	*	-	-	-	-	-
Fleshy Red	<i>Hypnea</i> sp.	*	-	*	*	*	*	*	*	-	-	-	-
Fleshy Green	<i>Cladophora</i> sp.	*	-	*	*	*	-	*	-	-	*	-	-
Fleshy Green	<i>Valonia</i> sp.	-	-	-	-	-	-	*	-	-	-	*	-
Fleshy Green	<i>Codium</i> sp.	-	-	-	-	-	-	*	-	-	-	-	-
Fleshy Green	<i>Caulerpa verticillata</i>	-	-	-	-	-	-	*	-	-	-	-	-
Number of species		18	11	12	16	17	9	24	9	7	15	8	8
Number of samples		7	7	6	7	6	10	10	6	6	7	7	4