Opuntia corallicola (Cactaceae): Population Monitoring on Swan Key, Biscayne National Park

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SUMMARY

In November 2001, a colony of the semaphore pricklypear cactus, *Opuntia corallicola*, endemic to the Florida Keys, was discovered on Swan Key in Biscayne National Park. Previous to this discovery only nine plants of reproductive age were known to exist in the wild on Little Torch Key at The Nature Conservancy's Torchwood Hammock Preserve, 145 km to the south. Since 2002, monitoring of the Swan Key population continues in order to determine basic aspects of the species' life history, to monitor for the presence of the introduced moth *Cactoblastis cactorum*, and to monitor for poaching. Between October 2004 and October 2005, 655 plants were tagged and monitored at two sites on Swan Key of which 490 (67.68%) were adults and 234 (32.32%) were juveniles. No evidence of *C. cactorum* or poaching was observed. Overall, the *O. corallicola* population on Swan Key appears relatively stable. Mortality was relatively low (9%) but was higher than mortality recorded (2%) during the previous year. Hurricane activity may explain this higher mortality. Growth and pad production was greatest between April and July. The number of vegetative pads decreased during the late summer (Jul – Oct) months, which coincided with hurricane season. In addition to mortality, high winds associated with hurricanes caused a high number of vegetative pads to fall off of *O. corallicola* plants. No differences between growth periods for adults and juveniles were detected, however, growth for propagules was highest during the rainy season (April to October) suggesting a longer growth period than adults. Flower production occurred throughout the year with a noticeable peak from January through April and was at its lowest during the rainy season (April to October).

Cover Photo of Semaphore pricklypear (*Opuntia corallicola*) taken by Rick Cruz, professional photographer.

INTRODUCTION

Semaphore pricklypear (*Opuntia corallicola* (Small) Werderm., Cactaceae) is an erect, trunk-forming cactus endemic to the Florida Keys (see photo on cover page). The species was discovered by John Kunkel Small on Big Pine Key in 1919 (Small 1930). By the 1960s, it was extirpated from Big Pine Key by road building and poaching (Gann et al. 2002; Bradley & Gann 1999). However, in the 1960s a second population was discovered on Little Torch Key, an island immediately west of Big Pine Key (Bradley & Gann 1999; Gann et al. 2002). Small (1930) also reported the species from Key Largo in the upper Florida Keys; however no specimens have been located. By early 2001, the population on Little Torch Key had only nine adult plants (Gann et al. 2002). *O. corallicola* is currently listed as endangered by Florida Department of Agriculture and Consumer Services (FDACS), critically imperiled by Florida Natural Areas Inventory (FNAI) and The Institute for Regional Conservation (IRC), and is currently under review for listing by the U.S. Fish and Wildlife Service (USFWS).

In November 2001, Keith Bradley and Steven Woodmansee of IRC found a colony of *O. corallicola* on Swan Key, an island in southern Miami-Dade County in Biscayne National Park (Figure 1; Bradley & Woodmansee 2002; Gann et al. 2002). From 2002-2003, a survey the of all other islands containing suitable habitat in Biscayne National Park and on Palo Alto Key in the adjacent John Pennekamp Coral Reef State Park was undertaken to attempt to find additional colonies. None were found (Bradley and Koop 2003).

Opuntia corallicola populations are threatened by poaching and an exotic moth, *Cactoblastis cactorum* Berg (Lepidoptera: Pyralidae) discovered in the Florida Keys in 1989 (Habeck & Bennett 1990). This pest infested two of the remaining wild *O. corallicola* at the Torchwood Hammock Preserve, killing one of them (Stiling & Moon 2001). In a survey of the Swan Key population in January 2002, Robert Pemberton of the U.S. Department of Agriculture found no evidence of *C. cactorum*, although the survey may not have been conducted at the optimal time of year. Even if the moth has not yet reached the island, the likelihood is high that it will based on the rapid spread of the species in the Caribbean and Florida (Mahr 2001).

The reproductive biology of semaphore pricklypear has been studied by Negron-Ortiz (1998). Negron-Ortiz found that fruit set in the species is rare. Seeds are viable but no propagule recruitment has been found under natural conditions. Negron-Ortiz (1998) proposed that the species has been unable to reproduce sexually either because of meiotic problems resulting from polyploidy, or because the existing plants are incompatible. No propagules were observed in the Swan Key population from 2002 to 2003 (Bradley and Koop 2003), however, the population appears to be stable due to occasional vegetative establishment of fallen pads.

Monitoring of the Swan Key population was initiated in 2002 to determine basic aspects of the species' life history, to monitor for the presence of the introduced moth *C. cactorum*, and to monitor for poaching (Bradley and Koop 2003). Between August 2002 and June 2003, 586 plants were tagged and monitored on Swan Key. No evidence of *C. cactorum* or poaching was observed.

Frequent monitoring of the Swan Key population is desirable. Frequent site visits allow for monitoring of *C. cactorum* and poaching. In addition, a monitoring program which tracks the status, growth, and reproductive phenology of individual plants allows researchers to determine whether the newly discovered population is increasing, decreasing, or stable, and contributes to the knowledge of the life history of the species. The goals of this study were to (1) continue to monitor the *O. corallicola* population on Swan Key in order to observe the health of the colony and (2) to watch for poaching and *C. cactorum*.

METHODS

Opuntia corallicola was monitored quarterly on Swan Key in October 2004 and 2005 in January, April, July, and October. It only occurs near the center of the island where it grows approximately 0 to 10 meters from the edge of the hammock, which is embedded in tidal swamp dominated by red mangrove (*Rhizophora mangle*) (Figure 2). Conditions are probably too shady beyond the hammock edge to support optimal plant growth. Plants most likely do not grow in the sunny edge outside of the hammock because of periodic tidal flooding. We defined two subpopulations of *O. corallicola* on the island, one along the north edge and one along the south (Figure 2). Although no quantitative measurements were made on habitat differences between both sites, there appears to be more sunlight in the south (especially during the winter) and less litter and soil.

All plants which had been tagged in Bradley and Koop's (2003) study were located quarterly (October 2004 and January, April, July, and October 2005) in both subpopulations. At each census, we measured height of the main trunk and counted the number of vegetative pads and flowers. Plants with pads were identified as adults and those without as juveniles. Status of each plant was noted as alive or dead. Plants and pads were examined carefully for *C. cactorum.*

In addition, we surveyed propagule plots around the bases of adults on both sides of the populations quarterly. 10 plots were established during Bradley and Koop's study in 2003; 6 at the north site and 4 in the south. Due to the nature of the limestone substrate, we did not use stakes to mark plot corners. Instead plots were demarcated using flagging tape that was tied to surrounding vegetation; thus the plots were irregularly shaped (approx. 1 – 5 m^2). Plot shape corresponded to the cover of the adult plant, encompassing the area in which flowers and pads would fall. Within these plots, all plants were censused and tagged. If a plant was too small to be tagged, then its distance and compass bearing to the base of the adult was measured.

A paired t-test was conducted to determine whether there was any significant difference between sampling periods. An Analysis of Variance (ANOVA) was conducted to determine whether there were any significant differences between sites. Plant growth was calculated by subtracting the height of a plant from the previous month's height.

RESULTS

During the course of this study, 655 plants were monitored of which 594 were alive during the last sampling period of October 2005 and 61 had died during the course of this study; 490 (67.68%) were adults and 234 (32.32%) were juveniles. Of these plants, 418 (57.73%) were located on the north side of the island, while the remainder (306; 42.27%) were located on the south side. No poaching or predation by *Cactoblastis cactorum* was observed, however, a scale insect was observed on 3 plants. This scale insect has not yet been identified; however, it may be the native scale *Diaspis echinocati* (Diaspididae) which is generally not harmful to healthy plants.

Descriptive statistics for both populations (north and south) are given in Table 1. Mean height did not vary greatly within sites between sampling periods. However, when looking at differences between sites, results indicate that the north site has a significantly higher mean height every month (ANOVA: Oct 04: $p=0.032$; Jan 05: $p=0.006$; Apr 05: $p<0.001$; Jul 05: $p=0.012$) except for the month of October 2005 ($p=0.372$) than the south site.

Overall, plants showed little growth during the 12 month study period (Figure 3). When plants grew it was relatively obvious because the tip of the main stem was slightly paler and had several small leafy bracts at the tip. Mean growth of plants between censuses ranged between -0.7023 cm and 1.1547 cm. Mean growth of plants decreased significantly at the north site from January to April 2005 (T-test: $t=2.005$, $p=.046$) and increased significantly at the south site from April to July 2005 ($t=-3.075$, $p=0.002$). No other differences in plant growth were detected (all other variables $p>0.05$). Mean growth was significantly higher at the south site between January to April (ANOVA: $p=0.033$) than the north site (all other $p>0.05$).

Descriptive statistics for both life stages (adult and juvenile) are given in Table 2. Adults had significantly higher heights than juveniles (ANOVA: all $p<0.001$). The overall pattern of growth that was seen for all plants combined was also evident when growth was analyzed for adults and juveniles separately (Figure 4). Juveniles had significant growth between April and July 2005 (T-test: $t=-5.001$, $p<0.001$, all other $p>0.05$). Juvenile and adult growth periods were not significantly different from each other (ANOVA: all $p>0.05$).

The number of vegetative pads *O. corallicola* plants have is potentially an important indicator of plant reproductive status and a measure of plant fitness because flowers are borne on pads and not on the main stem. Descriptive statistics for vegetative pads in both populations (north and south) are given in Table 1. No significant differences between north and south sites were detected (ANOVA: all $p>0.05$).

Although most plants did not exhibit a change in the number of pads, approximately 30% of the population experienced either an increase or a decrease. Between April and July 2005, plants experienced a significant increase in the number of vegetative pads at both sites (Figure 5; T-test: North site, $t=-3.272$, $p=0.001$; South site, $t=-3.998$, $p<0.001$). However, plants experienced a significant decrease in the number of vegetative pads between July and October 2005 (North site: $t=1.989$, $p=0.049$; South site: $t=2.553$, $p=0.12$).

O. corallicola produces flowers at the end of small reproductive pads that are borne on larger vegetative pads. Once the flowers fall off, additional flowering pads sometimes develop on the remaining flowering pads. Then once again, flowering pads may develop on the new ones, resulting in clusters of flowering pads all attached to the vegetative pad at one point. As many as 20 flowering pads can occur on these clusters. Higher orders of flowering pads (i.e., primary, secondary and tertiary) are progressively smaller than the previous ones. Many of the higher order flowering pads never develop flowers, probably because they are too small (Bradley and Koop, personal observation). Eventually flowering pads fall to the ground where some die and some root in the soil and establish new plants.

Reproductive adults refers to those adults that are either currently reproducing or have reproduced in the past. Only 7.5% (37/490 adults) are considered reproductive with 24 located in the north site and 13 at the south site (Table 3). This study showed that although plants may flower for most of the year, there is a noticeable seasonality in flower production (Figure 6). Both the frequency of reproductive adults flowering (Figure 6) and the mean number of flowers per reproductive adult was lowest in July 2005 and highest the spring of 2005 (Figure 7). Mean number of flowers significantly increased at both sites from Oct 04 to Jan 05 (T-test: North, $t=-2.685$, $p=0.013$; South, $t=-2.203$, $p=0.050$) and from Jul 05 to Oct 05 at the south site ($t=-2.345$, $p=0.039$). A significant decrease was detected at both sites from Apr to Jul 2005 (North: $t=2.956$, $p=0.008$; South: $t=3.086$, $p=0.010$). No significant differences were detected between sites (ANOVA, all $p>0.05$) except in October when the south site had significantly higher mean number of flowers than the north site ($p=0.035$).

Propagule plots were monitored quarterly in order to better understand propagule recruitment. Except for January 2005 (ANOVA, $p=0.013$), abundance of propagules were similar between the north and south sites (Figure 8; all $p>0.05$). From January to April 2005 (T-test: North: $t=2.074$, $p=0.044$; South: $t=2.582$, $p=0.020$), there was a significant increase in number of propagule in the propagule plots but this number decreased significantly from Jul to October 2005 (North: $t=2.164$, $p=0.034$; South: $t=2.095$, $p=0.044$). No differences were detected between other sampling periods (all $p>0.05$).

Propagules in these propagule plots had a higher mean height at the north site for all periods (Figure 9; ANOVA: Jan 2005: $p=0.010$; Jul 2005: $p=0.008$; Oct 2005: $p=0.021$) except during Apr 2005 ($p=0.54$). The north site had significant positive growth among the propagules between Apr and Jul 2005 (T-test: $t=-5.007$, $p<0.001$) and Jul and Oct 2005 ($t=-2.630$, $p=0.012$). The south site also had significant growth between Jul and October 2005 ($t=-2.440$, $p=.028$).

DISCUSSION

Although north and south sites are similar in plant growth, number of flowers, number of vegetative pads, and number of propagules, they differ in that the north site has a higher number of plants and a higher mean height than the south site. However, the higher number of plants at the north site may be a reflection of our sampling area rather than density.

Overall, the *O. corallicola* population on Swan Key appears relatively stable. Mortality of tagged plants was relatively low (9%) during the course of this monitoring but was higher than mortality recorded (2%) between Aug 2002 and Jun 2003 (Bradley and Koop's 2003). Propagule plots also showed a significant increase in number of propagules over time (Figure 8). In August and October of 2005, south Florida was hit by hurricanes Katrina (Category 1) and Wilma (Category 2), respectively. Swan Key was directly in the path of both hurricanes, which may explain why mortality was higher this year (Figure 10).

Although plant growth and vegetative pad production occurs throughout the year, growth and pad production appears to be greatest between April through July for adults and juveniles. However, during our first year of monitoring, Bradley and Koop (2003) found growth to be highest during the late winter to early spring. Further monitoring of the population is needed in order to determine any long term growth trends. The number of vegetative pads decreased during the late summer (Jul – Oct) months, which coincides with hurricane season. In addition to mortality, high winds associated with hurricanes can cause a high number of vegetative pads to fall off of *O. corallicola* plants (Grahl and Bradley personal observation).

We found no differences between growth periods for adults and juveniles, however, growth for propagules was highest during the rainy season (April to October) suggesting a longer growth period than adults. In 2003, Bradley and Koop detected a significant growth period in the late summer months for juveniles but not for adults. This data suggests that juveniles and propagules may have a longer growth period than adults, but this needs to be tested with more replication.

Flower production occurred throughout the year with a noticeable peak from January through April and was at its lowest during the rainy season (April to October). Bradley and Koop's (2003) data also showed the same trends in flower production (Figure 11). This was also reflected in the propagule plots with the highest number of rooted propagules from January through April and the lowest at the end of the rainy season (July to October). This data agrees with our observations of flowering pads falling to the ground where some die and some root in the soil and establish new plants.

Additional goals of this study were to monitor the population for evidence of poaching or predation by the invasive exotic moth, *C. cactorum*. We did not see evidence of either one of these. The only other extant population of *O. corallicola* is located on Little Torch Key and is currently threatened by *C. cactorum*. Although we did not detect the moth on Swan Key, it may colonize the island in the future given its ability to successfully spread. Continued monitoring is needed to detect the invasion. Park managers of Biscayne National Park should also develop contingency plans prior to the establishment of *C. cactorum* so that managers can respond quickly to this threat.

ACKNOWLEDGEMENTS

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Table 1. Descriptive statistics for *Opuntia corallicola* north and south populations (see Figure 2) on Swan Key in Biscayne National Park.

Site	Date	Mean Height	N	SD	Mean # Pads	N	SD
North	Oct-04	35.9747	265	30.6533	2.8691	191	3.5716
North	Jan-05	33.4377	297	29.9182	2.6010	193	3.2710
North	Apr-05	35.2372	253	31.4582	3.0000	164	3.4976
North	Jul-05	32.3484	287	30.8134	3.0852	176	3.6471
North	Oct-05	31.2045	313	29.3550	3.1916	167	3.6700
South	Oct-04	30.1222	180	24.2675	2.7368	133	3.8176
South	Jan-05	26.5728	213	23.6414	2.3448	145	2.9472
South	Apr-05	25.4793	217	23.8755	2.3767	146	3.0651
South	Jul-05	25.9327	223	24.7879	2.7297	148	3.5024
South	Oct-05	28.8293	205	29.8878	2.9603	126	2.8493

Table 2. Descriptive statistics for both life stages (adult and juvenile) of *Opuntia corallicola* on Swan Key in Biscayne National Park.

Life Stage	Date	Mean Height	N	SD
Adult	Oct-04	41.4923	323	28.9390
Adult	Jan-05	40.6113	337	28.5395
Adult	Apr-05	41.4091	308	29.4688
Adult	Jul-05	40.3963	323	29.9732
Adult	Oct-05	45.2500	292	30.9420
Juvenile	Oct-04	12.7320	122	10.8470
Juvenile	Jan-05	11.0116	173	9.4795
Juvenile	Apr-05	10.4321	162	9.7043
Juvenile	Jul-05	10.7968	187	10.3882
Juvenile	Oct-05	10.9027	226	10.0845

Table 3. Descriptive statistics for reproductive adults of *Opuntia corallicola* on Swan Key in Biscayne National Park.

Site	Date	Mean # Flowers	N	SD
North	Oct-04	0.2500	24	0.6079
North	Jan-05	1.1250	24	1.6235
North	Apr-05	1.9130	23	2.8109
North	Jul-05	0.0000	20	0.0000
North	Oct-05	0.3750	24	0.9237
South	Oct-04	0.0238	13	0.5991
South	Jan-05	2.4167	12	3.4761
South	Apr-05	1.9231	13	2.1001
South	Jul-05	0.1667	12	0.3893
South	Oct-05	1.3846	13	1.8947

Figure 1. Location of study site, Swan Key, in Biscayne National Park, FL.

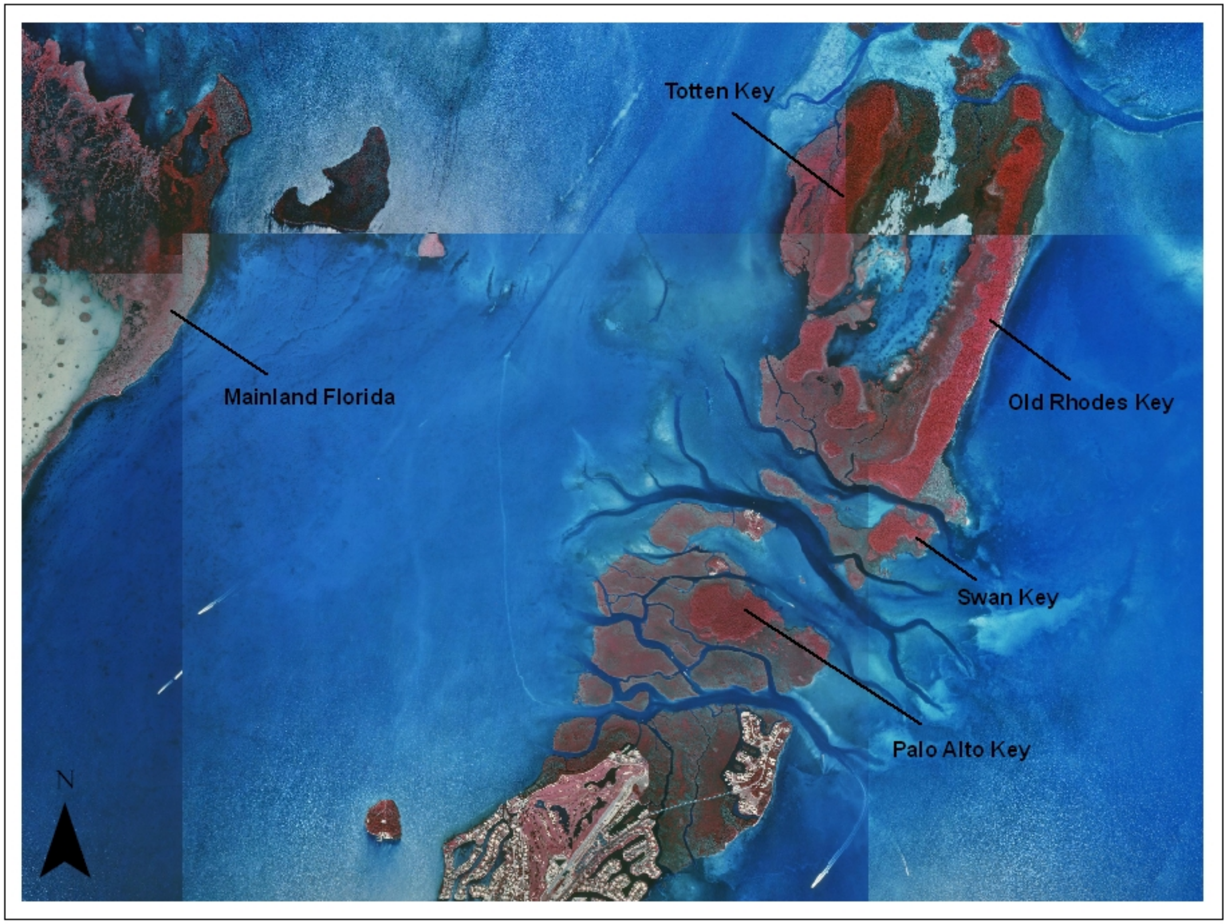


Figure 2. General distribution (yellow line) of *Opuntia corallicola* on Swan Key.

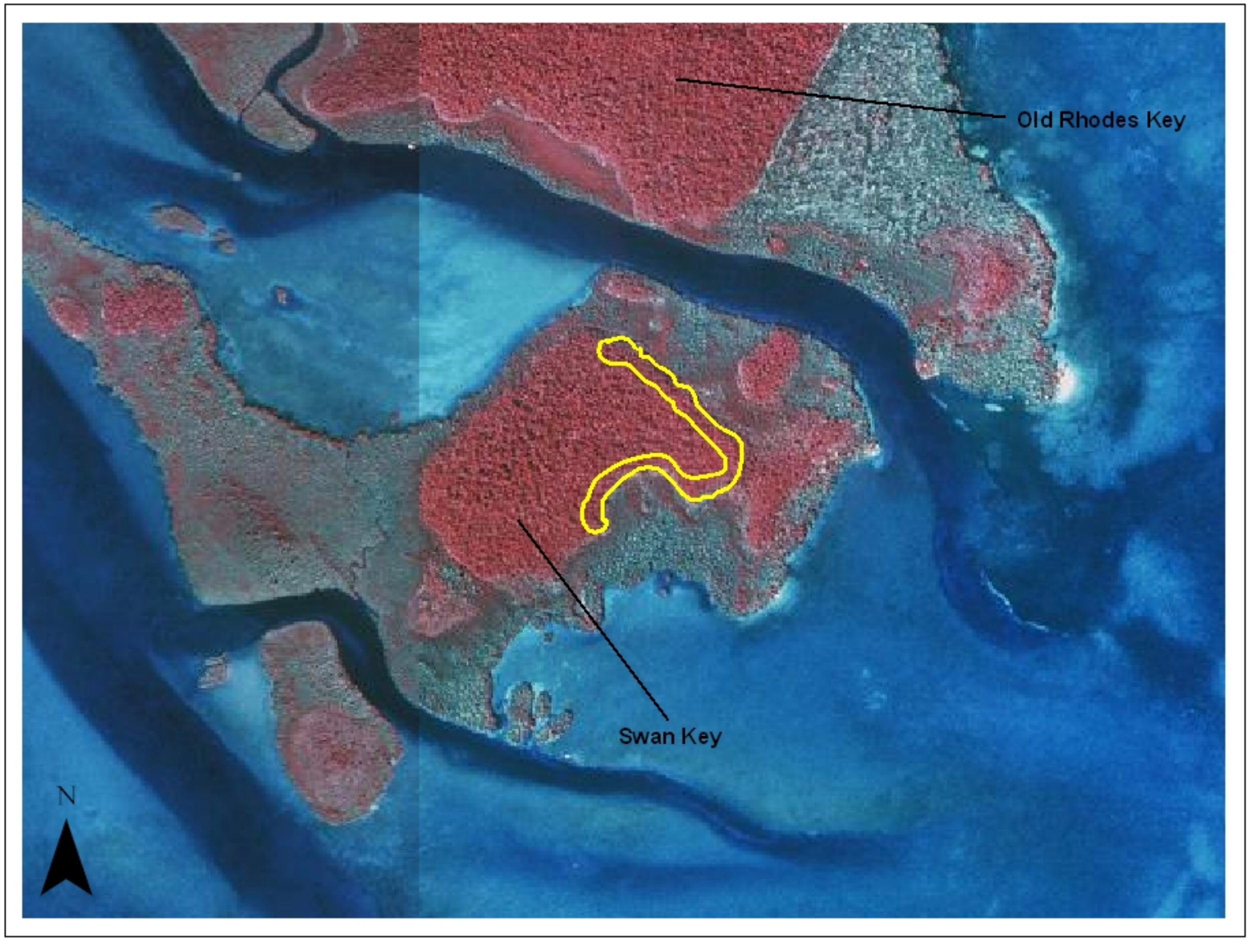
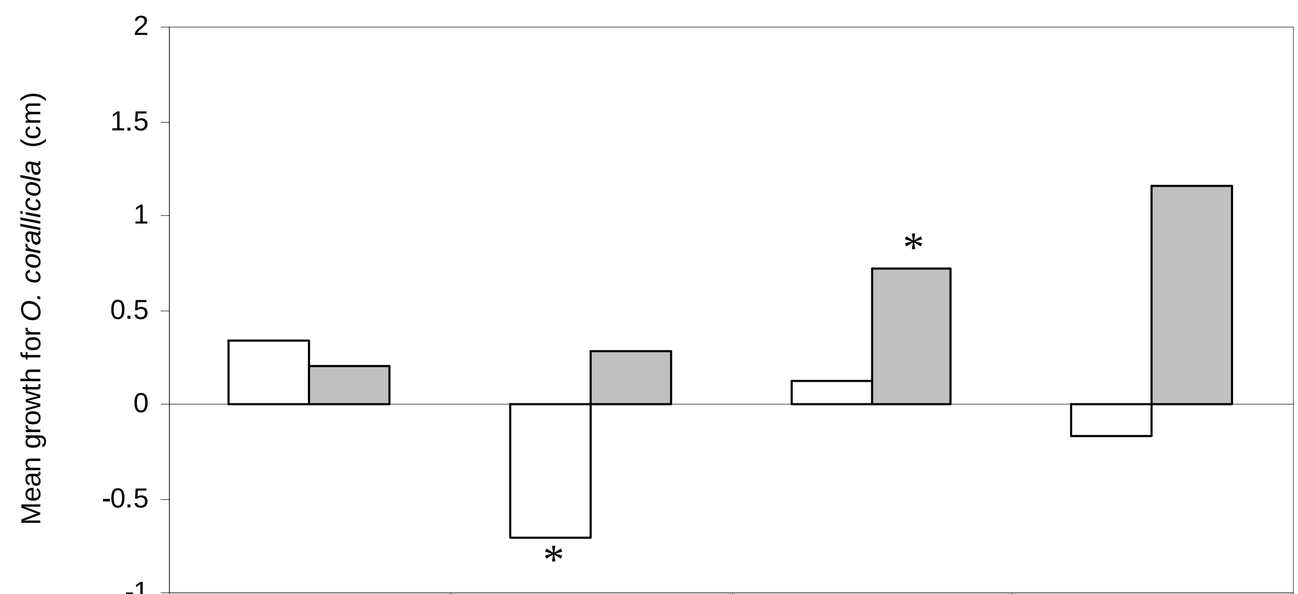
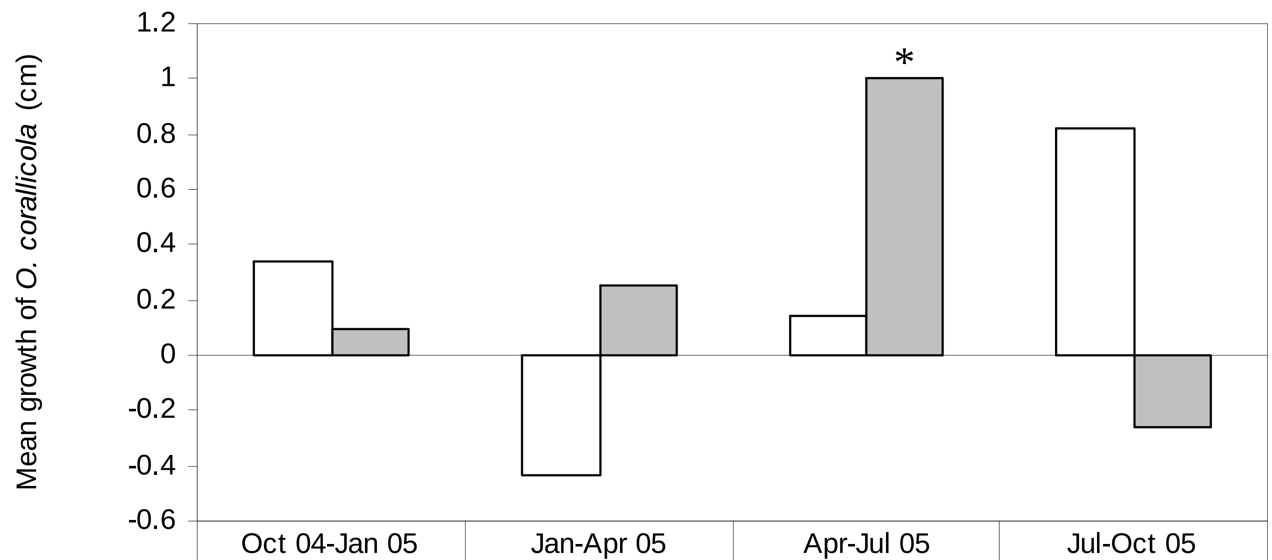


Figure 3. Mean growth (cm) of *Opuntia corallicola* between October 2004 and October 2005 at two sites (see figure 2) on Swan Key in Biscayne National Park. * = Significant ($p<0.05$) increase or decrease in height between census periods. There were no significant differences between sites except between January to April (ANOVA: $p=0.033$).



	Oct 04-Jan 05	Jan-Apr 05	Apr-Jul 05	Jul-Oct 05
north	0.3349	-0.7023	0.1226	-0.1673
south	0.2047	0.285	0.7157	1.1547

Figure 4. Mean growth (cm) of *Opuntia corallicola* between October 2004 and October 2005 on Swan Key in Biscayne National Park for adults and juveniles. * = Significant ($p<0.05$) increase or decrease in height between census periods. There were no significant differences between sites.



	Oct 04-Jan 05	Jan-Apr 05	Apr-Jul 05	Jul-Oct 05
Adult	0.341	-0.4345	0.1408	0.8217
Juvenile	0.096	0.2542	1	-0.2586

Figure 5. Mean increase or decrease in the number of vegetative pads of *Opuntia corallicola* between October 2004 and October 2005 at two sites (see figure 2) on Swan Key in Biscayne National Park. * = Significant (p<0.05) increase or decrease in number of pads between census periods. There were no significant differences between sites.

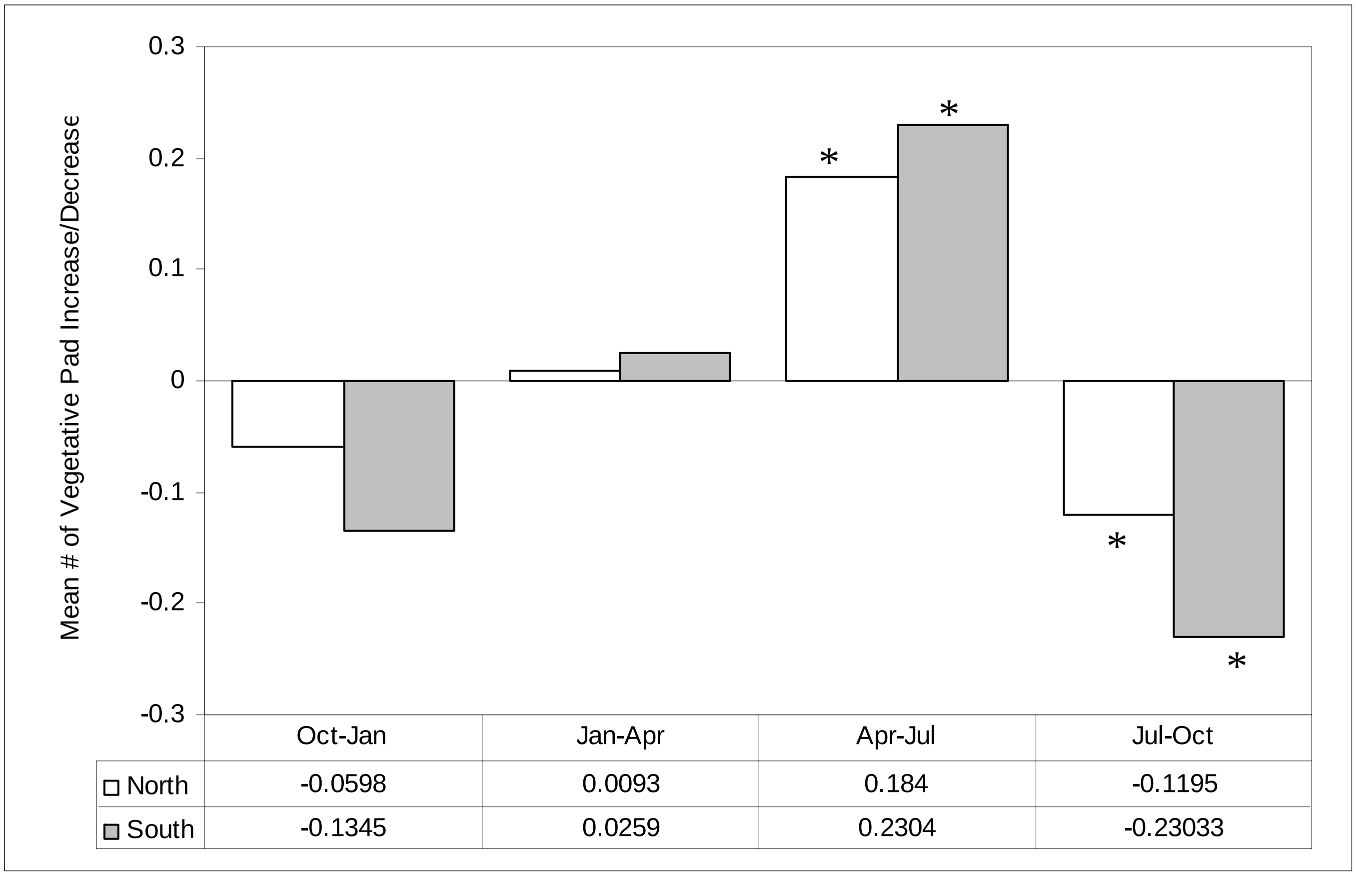
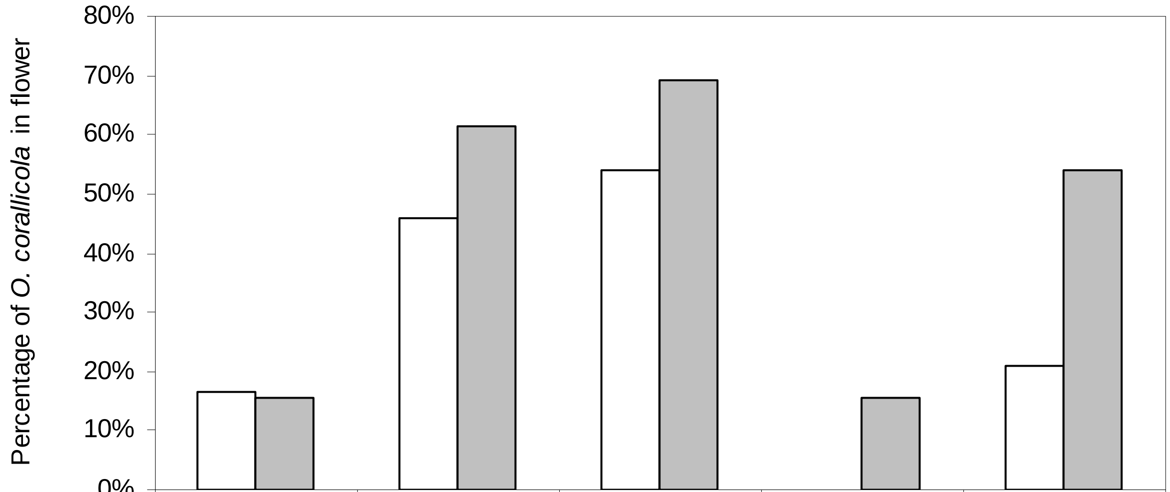
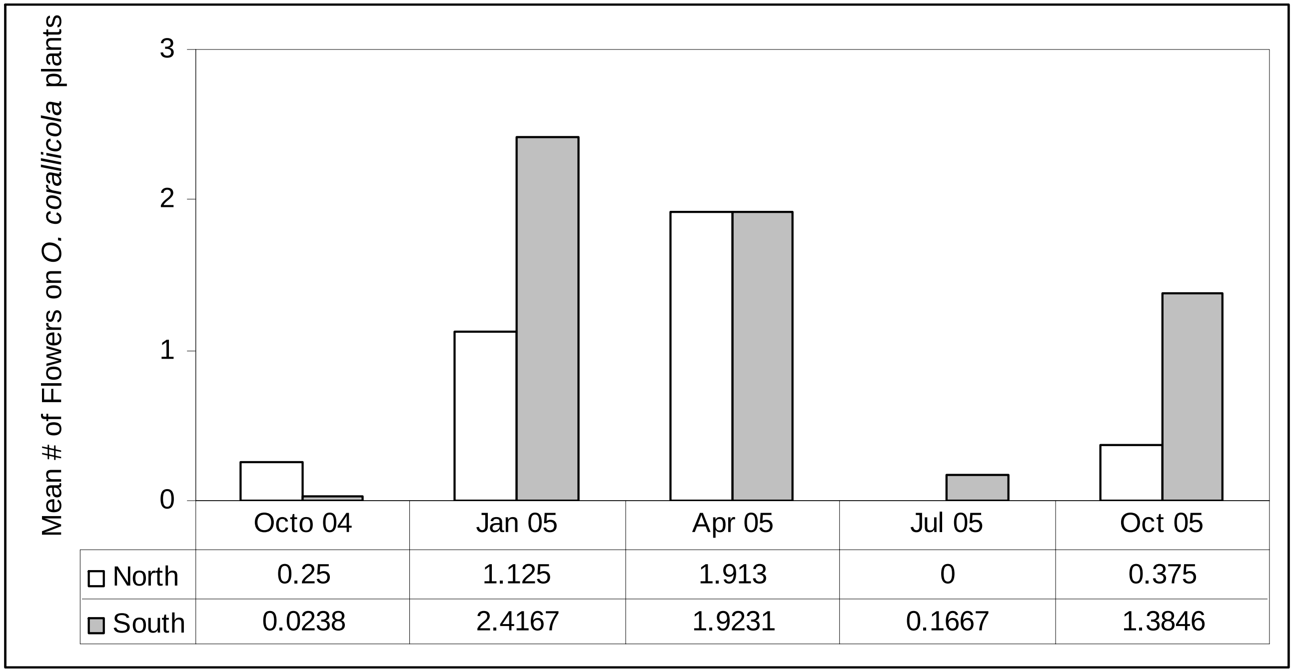


Figure 6. Proportion of reproductive adult *O. corallicola* plants (N=37) flowering at each census date. Flowers represent open flowers and premature flowers with noticeable petals. No plants were observed flowering on the north side in July.



	Oct 04	Jan 05	Apr 05	Jul 05	Oct 05
North	16.67%	45.83%	54.17%	0.00%	20.83%
South	15.38%	61.54%	69.23%	15.38%	53.85%

Figure 7. Mean number of flowers per reproductive adult *O. corallicola* plants at each census date. Flowers represent open flowers and premature flowers with noticeable petals. No plants were observed flowering on the north side in July.



	Octo 04	Jan 05	Apr 05	Jul 05	Oct 05
North	0.25	1.125	1.913	0	0.375
South	0.0238	2.4167	1.9231	0.1667	1.3846

Figure 8. Abundance of rooted propagule *O. corallicola* plants at 10 propagule plots between October 2004 and October 2005 at two sites (see figure 2) on Swan Key in Biscayne National Park.

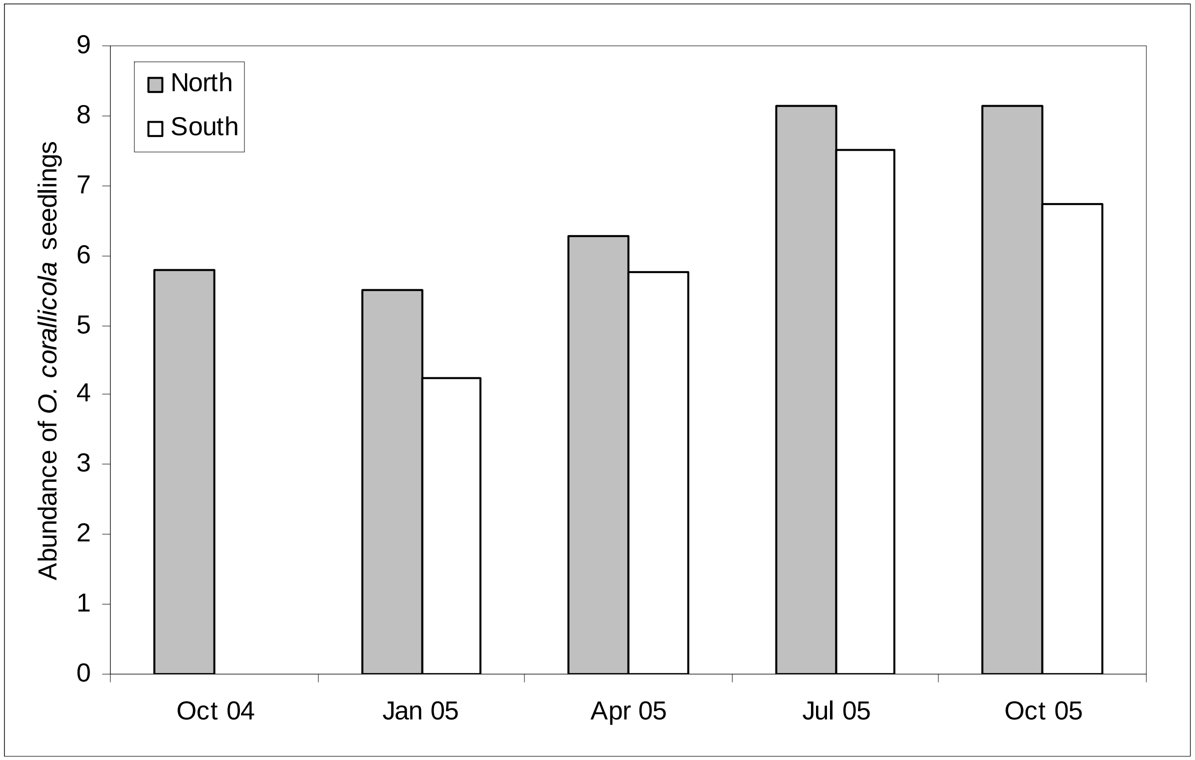


Figure 9. Mean height of propagule *O. corallicola* plants at 10 propagule plots between October 2004 and October 2005 at two sites (see figure 2) on Swan Key in Biscayne National Park.

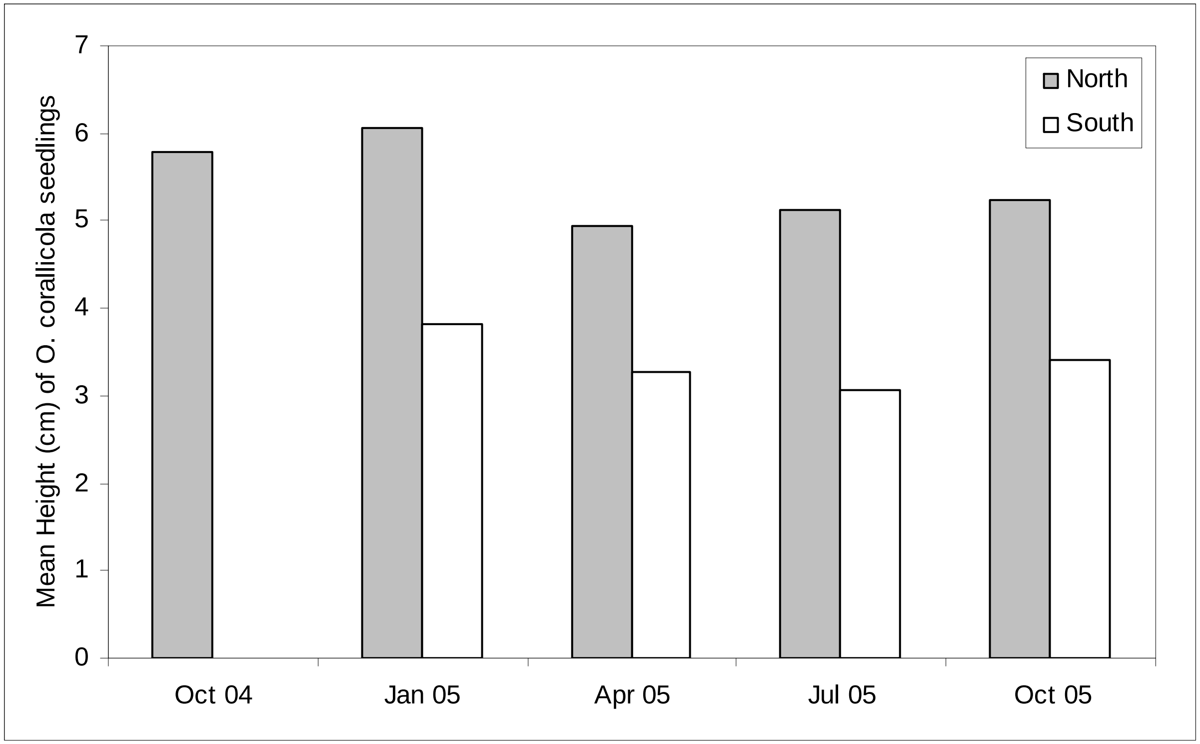


Figure 10. Mortality of *Opuntia corallicola* between October 2004 and October 2005 at two sites (see figure 2) on Swan Key in Biscayne National Park.

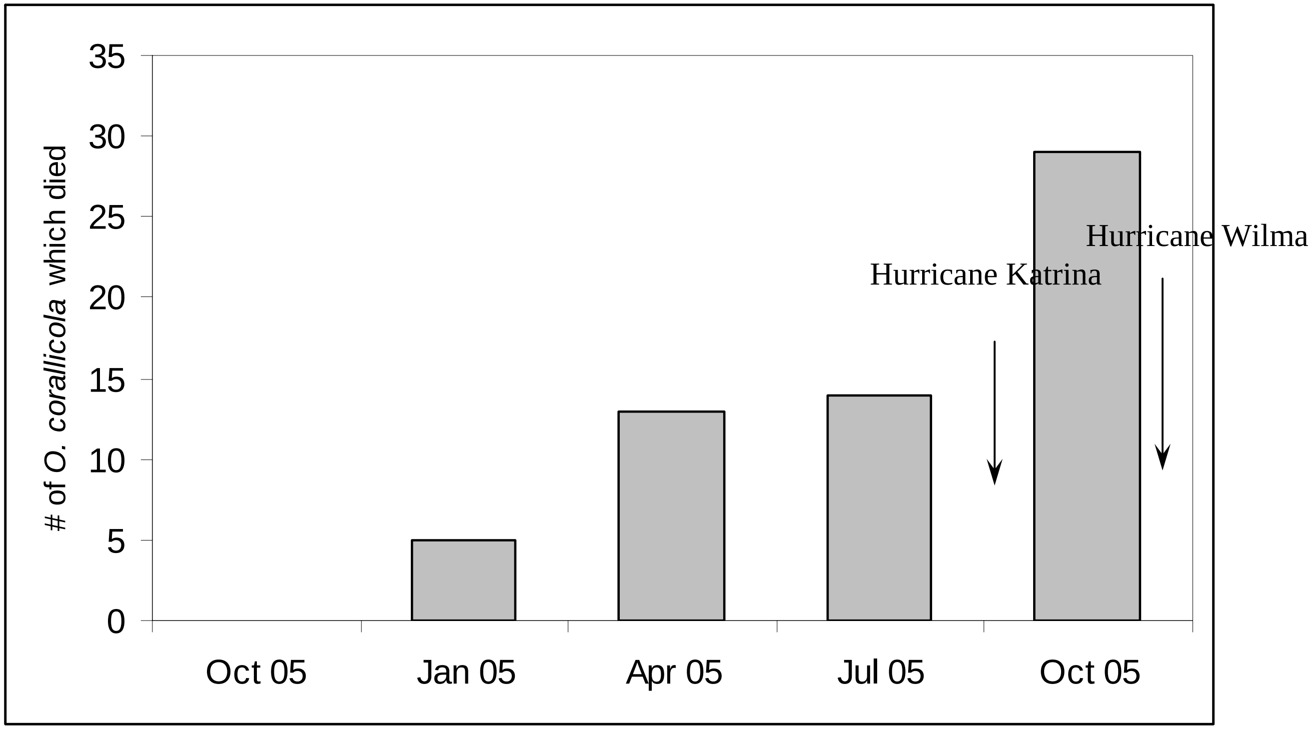


Figure 11. Mean number of flowers per reproductive adult *O. corallicola* plants at each census date from 200 to 2005. Flowers represent open flowers and premature flowers with noticeable petals. No plants were observed flowering on the north side in July and plants were not censused on the south side during Aug 02, Nov 02, and Feb 03.