

Buck Island Reef National Monument Lobster Population Study

Final Summary Report

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## Introduction

The Florida Fish and Wildlife Conservation Commission (FWC) was contracted by Buck Island Reef National Monument (BUI) to conduct a baseline study of an important fisheries species, the Caribbean spiny lobster (*Panulirus argus*) inside and adjacent to BUI. Field research took place between April of 2004 and April 2007 and included five separate expeditions by FWC biologists to BUI. There were several research objectives/directives during the course of the study. 1) Compare lobster populations inside and outside the protected area of BUI in order to evaluate its effectiveness as a reserve and also to determine if select features (the haystacks) were lobster habitat. 2) Examine population breeding metrics to determine reproductive activity in and around BUI. 3) Measure postlarval lobster abundance and identify suitable juvenile settlement habitat adjacent to BUI to understand the ontogeny of the population. 4) Visually inspect spiny lobsters for the virus PAV1 to determine whether the virus, found in the Florida spiny lobster population, is also present in St. Croix. 5) Finally, we were asked to recommend a protocol for monitoring the lobster population in and adjacent to BUI through time.

## Objective 1: Adult Lobster Population Comparisons

### Methods

#### *Site Selection*

The lobster population census at BUI was stratified by habitat type. A 200 x 200 m grid was overlaid on 10 x 10 m resolution benthic habitat maps of the area surrounding BUI. Information gathered during an initial habitat survey in 2003 was also applied to identify habitats of interest. Sites were selected randomly by grid within each habitat type for each sampling period 2004-2007 (Figure 1). To be able to compare the lobster population inside and outside BUI, a paired design was used. An equal number of sites in each habitat type were surveyed within BUI (protected area) and outside of the park (exploited reference area). Sites within the protected area were selected in April 2004, and reference sites outside of the protected area were selected during the next expedition in June 2004. Paired sampling inside and outside of BUI was continued in the spring for the next three years (Table 1).

#### *Habitat Strata*

Potential areas of suitable lobster habitat were identified on NOAA habitat maps as described above and during the 2004 expeditions; divers assessed potential habitat types and study sites. Five habitats comprising high quality lobster shelters were selected inside BUI (Fig 1 closed circles). These habitats were easily discernable, accessible for monitoring, and lobsters were relatively abundant. Habitats selected for long-term monitoring include: 1) Deep Reef – spur-and-groove reef north of Buck Island (depths between 10-31m), 2) Linear Reef – outside the southeast lagoon (5-13m in depth), 3) Back Reef – rubble areas on either side of the linear reef to the north and west of Buck

Island, 4) Patch Reefs –isolated patch reefs surrounded by sand halos and sea grass. 5) Western Ledges – high relief ledges along the northwest border of BUIS. The Western Ledges had no equivalent habitat type outside BUIS. For direct comparison, four equivalent habitats were selected for lobster monitoring in the exploited fishery area outside of BUIS (Fig 1 open circles). Equal sampling effort was attempted between habitat strata and inside and outside of BUIS. In addition to the four paired habitats, censuses were conducted in the unique lobster habitat outside of BUIS; nearshore patch reefs. These patches are located behind the linear reef fringing the north coast of St. Croix, south of BUIS.

Colonized pavement and the haystacks were two habitats assessed during April of 2004. Colonized pavement areas north of Buck Island were surveyed by towed divers and were eliminated because there was insufficient structure to support lobster. The haystacks, reefs formed by monotypic populations of elkhorn coral, were laboriously searched by divers and sampled with traps but no *P. argus* were observed with either method. These two habitats are not appropriate for long term surveys and were not revisited.

### *Census Methods*

Divers counted and captured lobsters during 60 minute timed searches. Each survey was performed by two teams of divers, each pair searched for lobsters for 30 minutes. Time was kept with underwater stopwatches which were stopped while lobsters were captured and started again when the search resumed. Lobster abundance was calculated as the total number of lobsters observed in 60 minutes of search time or catch per unit effort (CPUE). When patch reef surveys did not last a full 60 minutes, surveys on patches that were less than 30m apart were combined. When this was necessary, total search times and lobster totals were summed. The timed survey sampling method allowed for a standardized sampling effort between sites that were dissimilar in habitat complexity.

At time of capture, sex and den depth were noted. All captured lobsters were brought to the boat for determination of size and molt condition. If a lobster eluded capture, an estimated size was recorded and sex was determined when possible. Reproductive status of females was also recorded (e.g. presence or absence and condition of spermatophores, ovaries, and eggs). Lobsters were returned alive into the site from which they were captured.

During 2004, each lobster was numbered and fitted with a unique color coded antenna tag. Individual antenna tags on released lobsters became part of a mark recapture investigation performed at that time. Several sites were revisited days, weeks, or months later and with the tags, researchers were able to identify lobsters that were previously captured. Overall, recaptures were rare and always at the site of initial capture, and since antenna tags were only retained until the animal's next molt, had the capacity to provide only a small amount of information. Evaluation of the approach at the end of 2004 led to the decision to no longer tag lobsters. Sampling efforts 2005-2007 forwent multiple visits

to individual sites in favor of increasing the total number of sites sampled during each expedition (Table 1).

Because of the low numbers of spiny lobsters observed at each site and each year, all years and all sites within each stratum have been pooled in order to make the comparisons presented in the results.

## Results

### *Lobster Size*

Lobster size inside and outside of the reserve differed by habitat and distance from shore. Lobsters sampled close to the shore of St. Croix, were primarily juveniles and increased in size as sites were farther from shore (Table 2, Figure 2A-F). The mean size of a lobster on nearshore patch reefs, the habitat closest to the shore of St. Croix, was only 51 mm CL (Table 2, Figure 2F). Back reef and base of linear reef outside of BUIS were also dominated by juvenile lobsters; mean sizes 54mm CL and 61mm CL respectively. Lobsters on mid-channel patch reefs (both inside and outside of BUIS) varied widely in size (Table 2, Fig 2C). Deep reef habitat outside of BUIS was the only area with a mean lobster size (93 mm CL) above the legal minimum. Adult lobsters populate the remaining habitats, all within the BUIS boundary. Lobsters on deep reef BUIS and western ledges BUIS were on average, the largest (106 mm CL). These habitats were also the furthest from the shore of St. Croix. Results of a linear regression analysis of lobster size also indicate a significant positive trend in lobster size as distance from St. Croix increases ( $r^2=0.601$ ,  $SE=0.454$ ,  $p<0.001$ ).

The ontogenetic progression from nearshore to offshore, limits the pair-wise habitat comparisons that can be made between BUIS and the adjacent reference area. Only the deep reef, western ledges, and mid-channel patch reef habitats were used in pair-wise comparisons, because the BUIS and outside reference sites were adult lobster habitat.

### *Pair-wise Comparisons*

Lobsters inside BUIS were larger than those in the adjacent reference areas (Fig 2). Males and females both showed a positive reserve effect on size (males:  $F_{4,331} = 22.20$ ,  $p<0.001$ ; females:  $F_{4,315} = 22.20$ ,  $p<0.001$ ). Males on the deep reef inside BUIS, including western ledges, were significantly larger than those on the deep reef outside of the reserve (Fig 2A, 2B). Males on mid-channel patch reefs did not differ significantly in mean size between inside and outside the reserve, but size distributions were different (Fig 2C). Mid-channel patches inside BUIS have more large lobsters than those mid-channel patches outside BUIS. Females on mid channel patch reefs outside BUIS were significantly smaller than female lobsters found on deep reef or western ledges both inside and outside of BUIS (Fig 2 A, B, C).

Though back reef sites were omitted from pair-wise comparisons, large adult lobsters of both sexes were abundant in this habitat inside BUIS. Back reef sites were within the Marine Garden, an area wherein lobsters have been historically protected. This protection and/or high quality habitat may contribute to their notable size in this location.

### *Lobster Abundance*

Lobster abundance was measured by “catch per unit effort” (CPUE) weighted by search time (lobsters per hour search). Abundance is only depicted for those habitats where the expectation of differences related to fishing pressure would be the most likely cause of differences plus the Inside BUIS back reef (Marine Garden). The dramatic size-structure differences observed between back reef and linear reef habitats are as likely related to ontogenetic changes as fishing pressure. CPUEs were the most variable on mid-channel patch reefs, where sampling times fluctuated considerably. Significant differences in lobster abundance were not indicated with statistics until overall CPUE increased nearly 5 fold (from 0.95 to 4.6 lobsters per hour search). However, over twice as many lobsters were found at sites inside BUIS than at paired reference sites (Table 2). Non parametric statistics (Mann-Whitney U) were used to compare the CPUE of legal size ( $\geq 89\text{mm CL}$ ) lobsters to that of sublegal ( $< 89\text{mm CL}$ ) lobsters since CPUEs of legal and sublegals violated the assumption of homogeneity of variances. There were significantly more legal size lobsters on deep reef habitat inside BUIS than outside ( $p < 0.001$ ) (Figure 3). There were also more legal lobster on mid-channel patches inside BUIS than those just outside, though this relationship was not as strong ( $p = 0.032$ ).

### Discussion

Though trends are evident in lobster size and abundance across habitat strata, a priority of this study was to compare lobsters inside BUIS to those in areas open to fishing. This comparison is only relevant for a two of the four habitats sampled, since distance from the shore of St. Croix was detected as a confounding factor. Selecting areas outside of BUIS that were comparable to lobster habitat inside the park, called for sampling sites near shore in what has now been identified as predominantly juvenile habitat. Back reef and base of linear reef sites inside BUIS are adult lobster habitat, but the equivalent reference areas outside BUIS were predominantly populated by lobsters smaller than 60 mm CL. Thus, comparisons between lobster populations inside the reserve and outside were only made between deep reefs and mid-channel patch reefs. Comparing lobsters in these two habitat types was also valuable, since they were in different parts of the reserve. Deep reef sites inside BUIS were located within the reserve north and northwest of Buck Island and the deep reef reference area was distant from the edge of the reserve. In contrast, mid-channel patches were adjacent to the park boundary either inside or outside.

Overall, lobsters found outside of the reserve at the deep reef and patch reef sites were smaller than those inside the reserve. We conclude that these differences were most likely due to a fishery effect outside the reserve. The higher abundance of larger lobsters inside the reserve likely indicates that lobsters experience substantial refuge from the

fishery. It is also likely that outside of the reserve, fishers select out the largest animals. If a primary benefit of refuge from the fishery allows lobsters to reach a larger size, then it makes sense that deep reef lobsters are larger than those on mid-channel patch reefs. Deep reef lobsters far from the boundaries are less likely to leave the reserve when foraging than lobsters in habitat along the edge.

Habitat quality may also affect size and abundance patterns. Lobsters in the back reef (“Marine Garden”) and base of linear reef habitats inside BUIS were as large as and more abundant than those on the deep reef, which may suggest that the habitat is of exceptional quality. Overall, we conclude that BUIS has a positive effect on spiny lobster abundance and size. Future monitoring should concentrate on making further comparisons between the reserve and the fishery both along the edge (Patch Reefs) and farther from the edge (Deep Reefs), especially to determine if the trends in size and abundance change over time.

## **Objective 2: Examining Breeding Metrics**

### *Methods*

In addition to size, reproductive status was recorded for each female spiny lobster. Three types of reproductive information were gathered from each female lobster; presence/absence of external eggs and their color if present, presence/absence of an external spermatophore, and ripeness of ovaries. The color of the eggs roughly indicates the stage of the embryos, orange eggs were more recently laid, and brown eggs were closer to hatching. A spermatophore is a sperm packet deposited by the male onto the underside of the female’s carapace. Spermatophores can either be fresh (recently deposited), eroded (already used to fertilize eggs) or layered (fresh over eroded). Lastly, the ovaries were examined for ripeness, which would indicate if a female was ready to lay a clutch of eggs.

### *Results*

The breeding metrics used were a relative percent of total female lobsters in each habitat that displayed each reproductive indicator (eggs, spermatophore, ovaries). It is important to recognize that these metrics are not mutually exclusive; for instance, a female with eggs and a spermatophore would be counted in both “percent females with eggs”, and “percent females with a spermatophore”. No lobster reproductive activity was observed on nearshore patch reefs and very few reproductive females were observed in the other nearshore habitats outside of BUIS. The percentage of females reproductive was also positively related to distance from St. Croix’s shore. Over 60% of females at western ledges and deep reef inside BUIS had eggs and 91% of the females at deep reef sites inside BUIS had evidence of spermatophores (Table 3). On back reef and base of linear reef sites inside BUIS, over 50% of the females had a spermatophore, and over 40% had eggs.

Pair-wise comparisons of reproductive activity inside and outside BUIS indicate reproductive activity is higher inside BUIS. At deep reef sites inside BUIS, 62% of

females sampled had eggs and 91% had spermatophores. Reproductive activity was lower for females at deep reef sites outside BUIS; only 26% had eggs, and 53% had a spermatophore (Table 3). Mid-channel patch reefs were not areas of high reproductive activity. However, females with eggs were three times more common, and those with spermatophores and/or ripe ovaries were twice as common on patch reefs inside the reserve as on patch reefs outside the reserve (Table 3).

## *Discussion*

Breeding metrics give important information about a population, however, the breeding information reported above are data based on 100 females in sampled in each habitat (from five sample periods combined). The sampling regime was not specifically geared toward understanding breeding dynamics and reproductive information and data were too sparse to analyze with statistics.

Adult spiny lobsters reproduce in reef habitat, the male deposits a spermatophore onto the carapace of the female relatively close to the time a female has laid or is about to lay a clutch of eggs. As the eggs approach hatching, female lobsters in Florida typically move to deep water at the edge of the reef to release their larvae. Detected trends in reproductive activity at BUIS include highest percent of females with eggs and/or spermatophores on deep reef sites and noticeably lower egg and spermatophore percentages on the back reef habitat inside. The back reef inside BUIS was the habitat where the most adult females were captured, yet only 40% had eggs. Thus, reproduction, at least within BUIS suggests that females may exhibit similar reproductive behavior. Since sampling was conducted early in the reproductive season (April and May) it is possible that the largest females had not yet moved from the back reef to the deep reef to release their eggs. Large lobsters in Dry Tortugas National Park experience the peak of breeding activity during June (Bertelsen and Cox 2001). Deep reef habitat both inside and outside of BUIS, along with back reef habitat inside, are areas of female reproductive activity. Conducting surveys during June may aid in better understanding the influence of the BUIS reserve on breeding metrics.

## **Objective 3: Postlarval and Juvenile Lobster Surveys**

### Postlarval Lobster Collectors

Twenty puerulus collectors were deployed in groups of five around Buck Island on April 15, 2004. Collectors were positioned in the northwest, northeast, southeast, and southwest shallows out of the way of boaters and with their anchoring systems in the sand or uncolonized pavement (Fig. 4). These collectors were sampled by FWC staff on April 26, 2004 and sampled by BUIS staff thereafter for one year year. Collector maintenance (specifically the replacement of hogshair filter material after 3 months) was conducted by BUIS staff. Each month (with the exception of January of 2005) all collectors were pulled, postlarval lobsters were counted, and their stage was recorded

(clear puerulus, semi-pigmented puerulus, pigmented puerulus, or juvenile). Data were compiled by BUIS and submitted to FWC for analysis.

## Results

### *Abundance of Postlarvae*

Average monthly catches per collector were  $33 \pm 4$  (NW),  $32 \pm 4$  (NE) and  $13 \pm 2$  (SE) and  $10 \pm 2$  (SW) (Figure 5). There were significant differences in total catch between sites (ANOVA  $F_{3,183} = 14.349$   $p < 0.001$ ). There were also differences in collector catches of each of the lobster postlarval stages. We found significantly more postlarval lobsters on the northern sets of collectors than the southern sets (Hochberg Post Hoc analysis  $\alpha = 0.05$ ).

### *Seasonal Patterns*

Determining seasonal patterns with only one year of data proved difficult since collector catches from April through September 2004 were constant and high, with all collectors catching lobster. During October catches on all sets of collectors dropped dramatically and continued to decrease in the winter (Figure 6). We cannot discern whether the drop in postlarval lobster catch was a natural seasonal pattern, or related to change in the effectiveness of the collectors.

### *Juvenile habitat*

Juvenile lobsters ( $< 50$  mm CL) were consistently observed at sites near the shore of St. Croix in high numbers (Table 2). Many of these sites also contained substantial numbers of lobsters less than 35 mm CL. These sites were generally similar in appearance to the patch reef located in Teague Bay and depicted in Figure 7. Of the 10 lobsters captured there during a survey in June 2004, 7 were less than 50 mm CL and 5 were  $\leq 35$  mm CL (Table 4). However, when the patch was surveyed again the following spring only two individuals were found and only one was a small juvenile (24 mm CL). Juveniles were most common at nearshore patch reef habitats where 72% of all lobsters encountered were  $\leq 50$  mm CL (Table 2). Even farther offshore on mid channel patch reefs, 63% of all lobsters observed were  $\leq 50$  mm CL. Nearly half of the spiny lobsters on sites at the base of the nearshore linear reef and back reef nearshore habitats were smaller than 50 mm CL. Small juveniles (less than 35 mm CL) were found in all nearshore habitats but were most abundant on nearshore patches (30%  $\leq 35$  mm CL), mid-channel patches (21%  $\leq 35$  mm CL), and back reef areas (21%  $\leq 35$  mm CL).

## Discussion

Postlarvae are apparently quite abundant in the St. Croix region of the Caribbean. At least during the spring and summer, collector catches were quite high, averaging greater than 30 per collector at the two locations along the northern shore of Buck Island (Figure 5). Collector catches in the Florida Keys during the same time were considerably

lower, especially when examined on a month per month basis. Studies in the Florida Keys indicate that juvenile lobsters settle in patches of macroalgae dominated by the red alga, *Laurencia* spp. and are abundant in the shallow structure rich hardbottom of Florida Bay. This high quality juvenile habitat is plentiful in most nearshore areas especially Bayside along the entire chain of islands. In contrast, we observed no equivalent juvenile habitat in the Buck Island region of St. Croix, including Teague Bay. Small juvenile lobsters ( $\leq 35$  mm CL) were often observed on reefs within Teague Bay; though these patch reefs were heavily covered with macroalgae, the habitat was likely sub-optimal for juvenile lobster and we think it likely that predation risk for these juveniles is high. Although speculative and based solely on the Teague Bay region of St. Croix, it is possible that poor juvenile habitat and associated post settlement mortality of small juveniles may be a substantial factor that controls and limits the overall abundance of *Panulirus argus* in St. Croix. Broader based surveys for juvenile may be a worthwhile venture to explore this issue.

#### **Objective 4:PAV1**

##### *Introduction*

During 1998, a virus that infects *Panulirus argus* was discovered in Florida (Shields and Behringer, 2004). This irido-like virus, PAV1, is a lethal pathogen, so far only known to infect *P. argus*. From 6% to 8% of the juvenile spiny lobsters in the Florida Keys have been observed infected by this virus during annual surveys conducted by the FWC and our partners (FWC, unpublished data). Juvenile lobsters are more susceptible to infection than adults (Butler, et al 2008). The prevalence of this disease in Florida led us to decide to examine the lobsters captured during this study for the prevalence of the PAV1 virus.

##### *Methods*

Every captured spiny lobster was examined visually for evidence of late-stage infection by the PAV1 virus. The virus attacks the blood, ultimately turning the normally clear blood a chalky white (Figure 8). The technique is simply to pull back on the tail and examine the area between the carapace and the tail for blood that has become chalky. We followed up on suspect lobsters with a confirming histological examination of the blood.

##### *Results*

Two lobsters, a 24 mm CL female and a 66 mm CL female, were identified visually as being infected. Both were observed and captured at nearshore patch reefs, one inside Teague Bay and one to the east of Teague Bay, during June of 2004. Both observations of infection were confirmed histologically by Dr. Jeff Shields, the original describer of the virus.

##### *Discussion*

These observations mark the third location where the PAV1 virus is known to occur. The others are Florida, as previously mentioned, and Mexico (Huchin-Mian et al, 2008). Although the significance of this disease to either the St. Croix spiny lobster population or to Buck Island Reef National Monument management cannot be determined from our localized sampling, one recommendation is to consider an island wide survey of juvenile lobsters to estimate the frequency of infection and compare that to infection rates observed elsewhere. Recent advances in detection using PCR (Montgomery-Fullerton et al. 2007) could be one approach used to improve understanding of the PAV1 virus in St. Croix.

## **Objective 5: Protocol Recommendations**

### *Introduction*

The Buck Island region of St. Croix presented a challenging location for conducting spiny lobster surveys whose purpose is to detect change over time. In general, abundance was low; so meeting the disparate needs of striving to understand trends and differences in both abundance and life history based population characteristics, such as changes in size structure and reproductive capacity was difficult. We selected the timed-roving-search method in order to maximize the chance to detect differences in size structure and other life history characteristics between the protected waters of BUIS and the adjacent fished areas while still being able to use CPUE as a mechanism for evaluating abundance shifts.

### *Challenges regarding surveying lobsters when abundance is low*

We have used two basic methods to estimate the abundance of lobsters in Florida. The first method is a timed roving search and the second method is an area transect. The roving search generates a “catch per unit effort” or CPUE. The unit of effort is based on the amount of time devoted to a search and has been typically one hour performed by four divers searching in teams of two divers for 30 minutes. A strength of this method is that in places where lobsters are relatively uncommon, we will generally find at least a few lobsters and know that they are present. Another strength is where lobsters are abundant, this method provides a large number of individuals where when other measurements such as size or reproductive status are taken, significant differences across various regions are easily confirmed. A weakness is that a single sample can consume a great amount of time because handling time is not included in search time. Even when no lobsters are found, a sample requires 30 minutes of time for four divers. This reduces the number of replicate samples that can be collected. Another weakness is that CPUE cannot be used to estimate abundance (i.e.; the number of lobsters per hectare).

Our area searches have typically consisted of 10 by 50 meter transects performed by two divers. The search time required averages less than 10 minutes. With two rotating teams of divers, we can complete 4-5 samples per hour when sites are within 500 meters of each other. A strength of this method is that it is possible to collect many more

samples than the timed roving surveys. This increases the statistical power to detect differences in abundance. In addition, because the samples are area based, actual abundance or density estimates are possible. A possible but un-testable strength is that divers' searches are constrained to highly definable spaces that can be rigorously randomized (for a statistical design) whereas roving searches may be influenced by an experienced diver's previous knowledge or individual skill. A weakness is that lobsters are not typically collected and therefore ancillary information such as size and reproductive status is not determined as well (e.g.; size is estimated into size bins) as the roving survey.

We have conducted both roving and transect surveys simultaneously in the Western Sambo region of the Florida Keys to investigate the sensitivity and power of the two methods (both sets of surveys required roughly the same amount of time and manpower) followed by a series of extensive computer simulations to estimate the power of the two methods on lower and higher densities of lobster than observed in the Western Sambo Ecological Reserve (Rod Bertelsen, unpublished; for questions contact Rod at [rod.bertelsen@myfwc.com](mailto:rod.bertelsen@myfwc.com)). The following is a synopsis of those findings. For one hour timed surveys we conducted 3 replicate surveys at 12 sites (36 total surveys). These surveys were divided into 2 habitat strata (forereef and backreef). The mean number of lobsters per survey was 60. Given the variance in the data we collected, we determined that a difference of 65 lobsters was required to detect a significant difference across any two sets of replicates.

We also performed 20 replicate surveys using the transect approach at the same 12 sites (240 total surveys). The mean number of lobsters per survey was 4.4 lobsters. Given the variance of the data we collected, we determined that a difference of 3 lobsters was required to detect a significant difference across any two sets of replicates. In conclusion, at the densities of lobsters that occur in the Western Sambo region and given the amount of time and effort we have to devote surveys, the transect method has a far better chance to detect significant differences in abundance than the timed searches. For transects, the minimum difference (3 lobsters) required to declare a significant change in abundance was 30% lower than the mean number of lobsters per transect (4.4 lobsters). For timed surveys, the minimum difference (65 lobsters) required to declare a significant change in CPUE was nearly 10% higher than the mean number of lobsters per timed survey (60 lobsters).

The CPUE of lobster found in St Croix during our surveys was approximately one order of magnitude smaller (~ 5 lobsters) than the CPUE found in Western Sambo. As a consequence, detecting differences at these low numbers requires a very large number of surveys. Only when pooling all the surveys conducted across all years thereby boosting the number of surveys to approximately 25 per habitat, could differences spanning nearly an order of magnitude (1.5 lobsters vs. 8 lobsters) be detected. Within a single year of surveys, no significant differences in CPUE were found.

Unfortunately, changing survey methods from timed searches to transects will not improve the power of detection of change in St. Croix. I worked with simulated data

designed to mimic early surveys we conducted on the Tortugas Banks. The Tortugas Banks is a remote hard bottom region located more than 100 km west of Western Sambo. We found lobster CPUE's there roughly equal to those in St Croix. In 2001, a large portion of Tortugas Bank was scheduled to become a new ecological reserve. The goal in the simulations was to estimate the number of surveys required to detect a hypothetical doubling of lobster CPUE inside the new reserve. The analysis suggested that more than 100 time surveys per stratum would be required to detect a doubling. Unfortunately, at these low densities and unlike at higher densities, the transect method did not outperform timed surveys. More than 400 transect surveys would have been required to detect a doubling of lobster densities.

### *Protocol Recommendations*

Based upon the results of the surveys in St. Croix and the modeling, we recommend that future survey efforts primarily focus on direct comparisons of two of the habitat types; the deep reef/western ledges inside BUIS and the mid-channel patch reefs adjacent to the BUIS boundary. For the deep reef comparisons, we recommend a continuation of roving timed surveys as they will have the highest probability of capturing enough lobsters to have an adequate sample size for comparison of size structure, sex ratio, and reproductive characteristics. Because of the wide variability in size of the patch reefs along the BUIS boundary and the resultant high likelihood of wide variability in search times for roving timed surveys, we recommend taking an area based approach. However, rather than using a transect approach as described above, our recommendation is to search entire patch reefs and ultimately equal area inside and outside BUIS. This can be accomplished by using orthorectified MrSID (multiresolution seamless image database) files of the patch reefs and load them into ArcGIS and calculating the area of each. The area of each patch reef can then be calculated by digitizing the perimeter. Although this approach will be time intensive prior to the first sampling, it will permit the rapid selection of sites for long-term surveys and easier than establishing belt transects in this habitat type. Finally, we recommend continued sampling of the back reef inside BUIS due to the somewhat higher number of lobsters observed there and the wide size range of lobsters observed there. In all strata, inside vs. outside comparisons will be difficult within each year. A possible approach could be to examine the trends over time within each stratum and then compare the trends to test for the performance of BUIS relative to the fished area.

### **Literature Cited**

Bertelsen, R.D. and C. Cox. 2001. Sanctuary Roles in population and reproductive dynamics of Caribbean spiny lobster. In: Spatial Processes and Management of Marine Populations. Alaska Sea Grant College Program, AK-SG-01-02. p 591-605.

Butler, M.J., Behringer, D.C., and J.D. Shields. 2008. Transmission of *Panulirus argus* virus1 (PaV1) and its effect on the survival of juvenile Caribbean spiny lobster. Diseases of Aquatic Organisms 79:173-182.

Huchin-Mian, J.P., Rodríguez-Canul, R., Arias-Bañuelos, E., Simá-Álvarez, R., Pérez-Vega, J.A., Briones-Fourzán, P., and E. Lozano-Álvarez. 2008. Presence of *Panulirus argus* Virus 1 (PaV1) in juvenile spiny lobsters *Panulirus argus* from the Caribbean coast of Mexico. *Diseases of Aquatic Organisms* 79:153–156. d

Montgomery-Fullerton, M.M., Cooper, R.A., Kauffman, K.M., Shields, J.D., and R.E. Ratzlaff. 2007. Detection of *Panulirus argus* Virus 1 in Caribbean spiny lobsters. *Diseases of Aquatic Organisms* 76:16.

Shields, J.D. and D.C. Behringer. 2004. A new pathogenic virus in the Caribbean spiny lobster *Panulirus argus* from the Florida Keys. *Diseases of Aquatic Organisms* 59: 109-118.

**Table 1: Summary of FWC sampling effort.**

| <b>Sampling Period</b> | <b>Start</b>   | <b>End</b>     | <b># Sites</b> |
|------------------------|----------------|----------------|----------------|
| April 2004             | April 13, 2004 | April 27, 2004 | 35             |
| June 2004              | June 9, 2004   | June 19, 2004  | 44             |
| April 2005             | April 19, 2005 | May 30, 2005   | 59             |
| April 2006             | April 24, 2006 | May 4, 2006    | 62             |
| April 2007             | April 24, 2007 | May 4, 2007    | 70             |

**Table 2:** Summary of sampling effort and lobster metrics by habitat type. Total N = the number of *P. argus* observed at each habitat type across all surveys in all years; BUIS = Buck Island Reef National Monument; Out = Outside of BUIS. The black arrow indicates the progression of sampling habitats away from the shoreline of St. Croix.

|                                                                                                      | Habitat                     | # surveys | Total N | Mean size (mm CL) | Size Range (mm CL) | # Lobs CL ≤ 50 (mm CL) | # Lobs CL ≤ 35 (mm CL) | Sex Ratio M:F |
|------------------------------------------------------------------------------------------------------|-----------------------------|-----------|---------|-------------------|--------------------|------------------------|------------------------|---------------|
| <b>Offshore</b><br> | Deep Reef BUIS              | 27        | 102     | 106 ± 1           | 60 - 135           | 0                      | 0                      | 1 : 1         |
|                                                                                                      | Western Ledges BUIS         | 25        | 118     | 106 ± 2           | 59 - 161           | 0                      | 0                      | 1 : 1         |
|                                                                                                      | Back Reef BUIS              | 27        | 209     | 101 ± 2           | 34 - 168           | 7                      | 4                      | 1 : 1         |
|                                                                                                      | Base of Linear Reef BUIS    | 22        | 80      | 88 ± 3            | 32 - 154           | 8                      | 1                      | 1 : 1         |
|                                                                                                      | Mid-Channel Patch Reef BUIS | 53        | 138     | 91 ± 3            | 28 - 166           | 18                     | 6                      | 2 : 1         |
|                                                                                                      | Deep Reef Out               | 20        | 37      | 93 ± 5            | 44 - 148           | 4                      | 0                      | 1 : 1         |
|                                                                                                      | Mid-Channel Patch Reef Out  | 41        | 72      | 73 ± 4            | 23 - 131           | 45                     | 15                     | 1 : 2         |
|                                                                                                      | Base of Linear Reef Out     | 18        | 150     | 61 ± 2            | 15 - 137           | 66                     | 20                     | 1 : 1         |
|                                                                                                      | Back Reef Out               | 19        | 162     | 54 ± 2            | 15 - 116           | 76                     | 34                     | 1 : 1         |
| <b>Nearshore</b>                                                                                     | Nearshore Patches Out       | 23        | 107     | 51 ± 2            | 20 - 91            | 77                     | 32                     | 1 : 2         |

**Table 3: Female reproductive metrics from all sampling periods 2004-2007.**

Values reflect all females sampled during four years of sampling. % with eggs reflects number of females with either orange or brown eggs. % with spermatophore reflects the number of females with either an eroded or a fresh spermatophore. Reproductive categories are not mutually exclusive, for example, a female with eggs and an eroded spermatophore was included in both columns. BUIS = Buck Island Reef National Monument; Out = Outside of BUIS. The black arrow indicates the progression of sampling habitats away from the shoreline of St. Croix.

|                                                                                                      | Habitat                     | Total Females | % with eggs | % with ripe ovaries | % with spermatophore |
|------------------------------------------------------------------------------------------------------|-----------------------------|---------------|-------------|---------------------|----------------------|
| <b>Offshore</b><br> | Deep Reef BUIS              | 58            | 62.07%      | 34.48%              | 91.38%               |
|                                                                                                      | Western Ledges BUIS         | 54            | 62.96%      | 35.19%              | 79.63%               |
|                                                                                                      | Back Reef BUIS              | 96            | 43.75%      | 20.83%              | 58.33%               |
|                                                                                                      | Base of Linear Reef BUIS    | 37            | 43.24%      | 29.73%              | 59.46%               |
|                                                                                                      | Mid-Channel Patch Reef BUIS | 37            | 27.03%      | 13.51%              | 35.14%               |
| <b>Nearshore</b>                                                                                     | Deep Reef Out               | 15            | 26.67%      | 40.00%              | 53.33%               |
|                                                                                                      | Mid-Channel Patch Reef Out  | 23            | 8.70%       | 8.70%               | 13.04%               |

**Table 4: Juvenile lobster found on Teague Bay Nearshore Patch Reef**

| Sample Period | CL | sex     |
|---------------|----|---------|
| June 2004     | 24 | female  |
|               | 25 | unknown |
|               | 25 | unknown |
|               | 28 | male    |
|               | 35 | female  |
|               | 38 | female  |
|               | 42 | male    |
|               | 53 | male    |
|               | 59 | male    |
|               | 77 | female  |
| April 2005    | 24 | female  |
|               | 64 | female  |

## FIGURE LEGENDS

Figure 1. Map of all lobster census sites (2004-2007) by habitat strata both inside and outside BUIS.

Figure 2. Lobster size distribution histograms with total abundance on the x axis, and size in millimeters carapace length on the y axis. Distribution for male and female lobsters are shown for each habitat type inside (BUIS) and outside (OUT) the protected area.

Figure 3. Pairwise comparisons of the abundance of sublegal ( $<89\text{mm CL}$ ) and legal ( $\geq 89\text{mm CL}$ ) measured as the number of spiny lobsters per hour of search time.

Figure 4. Locations of postlarval lobster collectors around Buck Island. Each yellow ring represents a set of 5 collectors.

Figure 5. Mean catch per collector of each postlarval stage at four locations around Buck Island

Figure 6. Total collector catch of lobster by location through time. Open circles are individual collector catches per month at each location and lines indicate overall trends.

Figure 7. Photograph of juvenile habitat on nearshore patch reef in Teague Bay.

Figure 8. Photograph comparison of a healthy lobster (A) and one infected with the PAV1 virus (B). The blood of the healthy lobster is clear whereas, the blood of the infected lobster is chalky white.

**Figure 1**

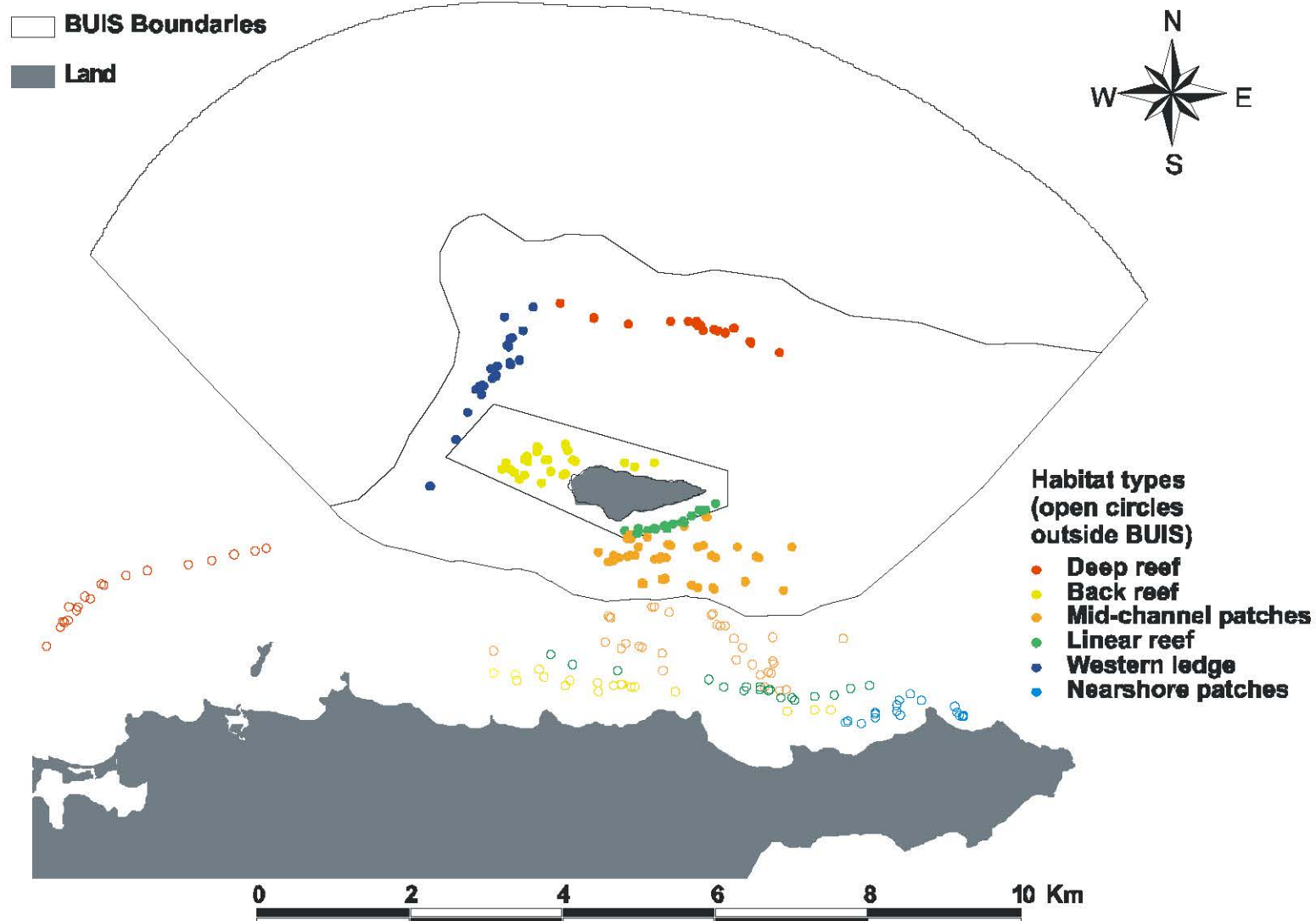
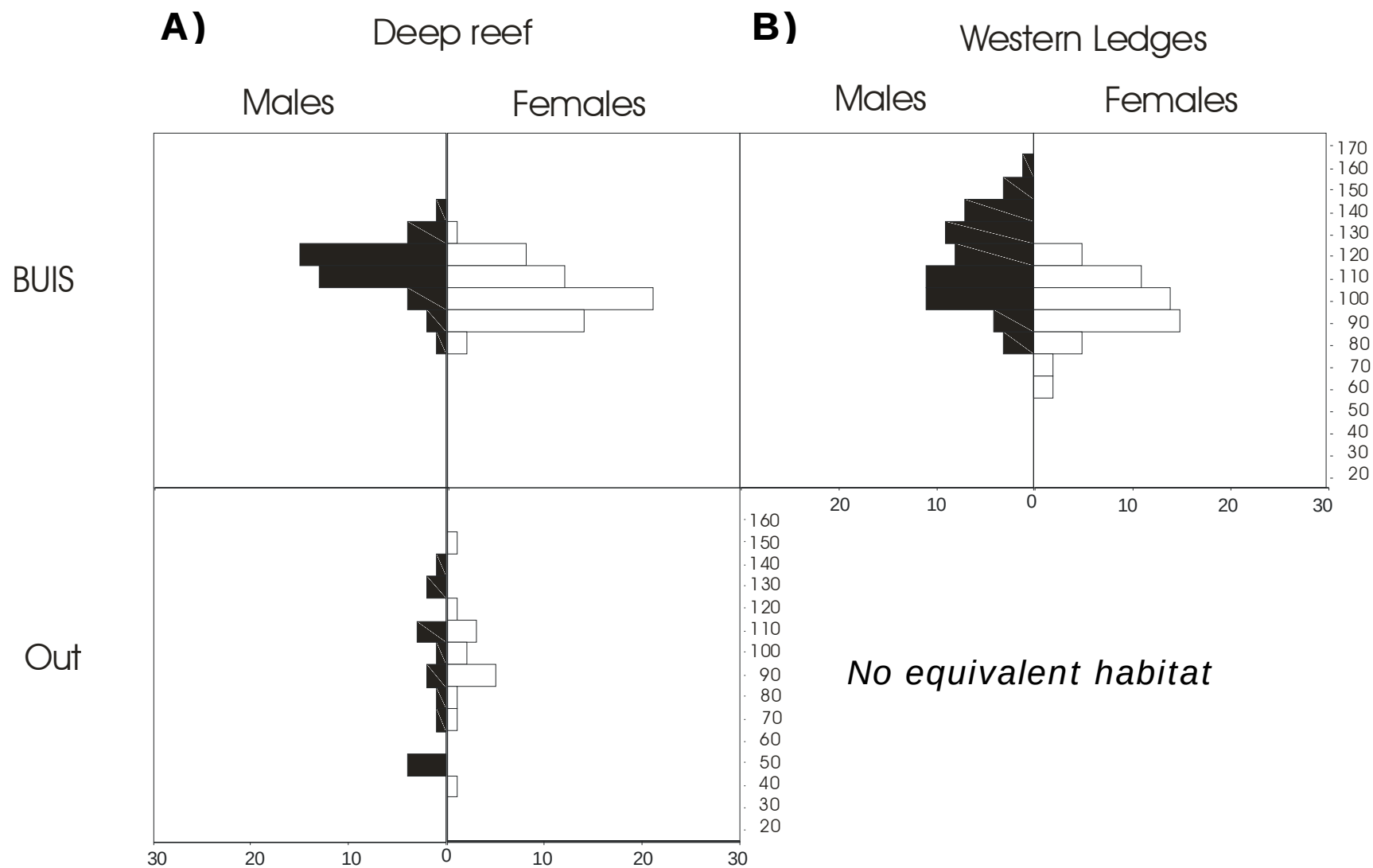
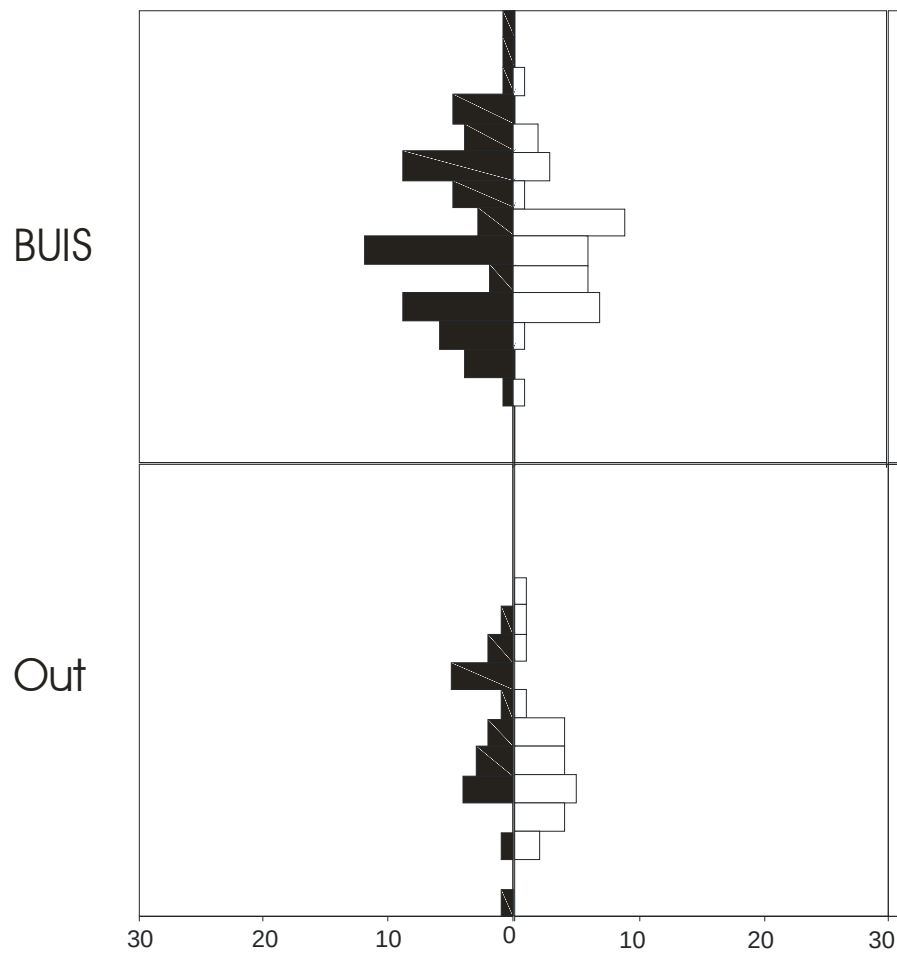


**Figure 2**



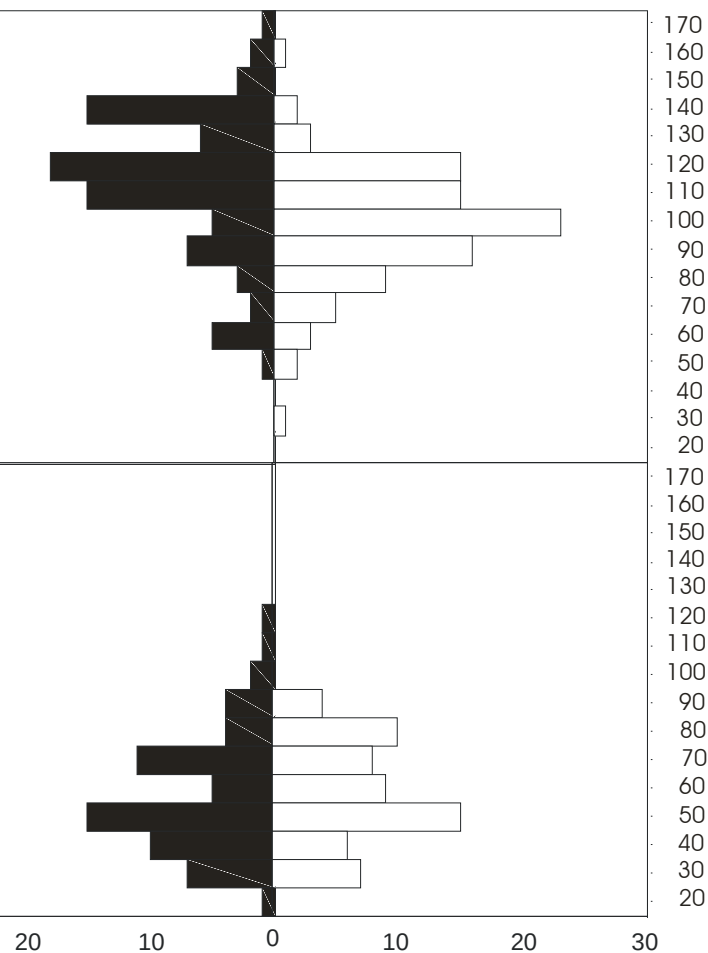
**C)** Mid-Channel Patch Reef

Males Females



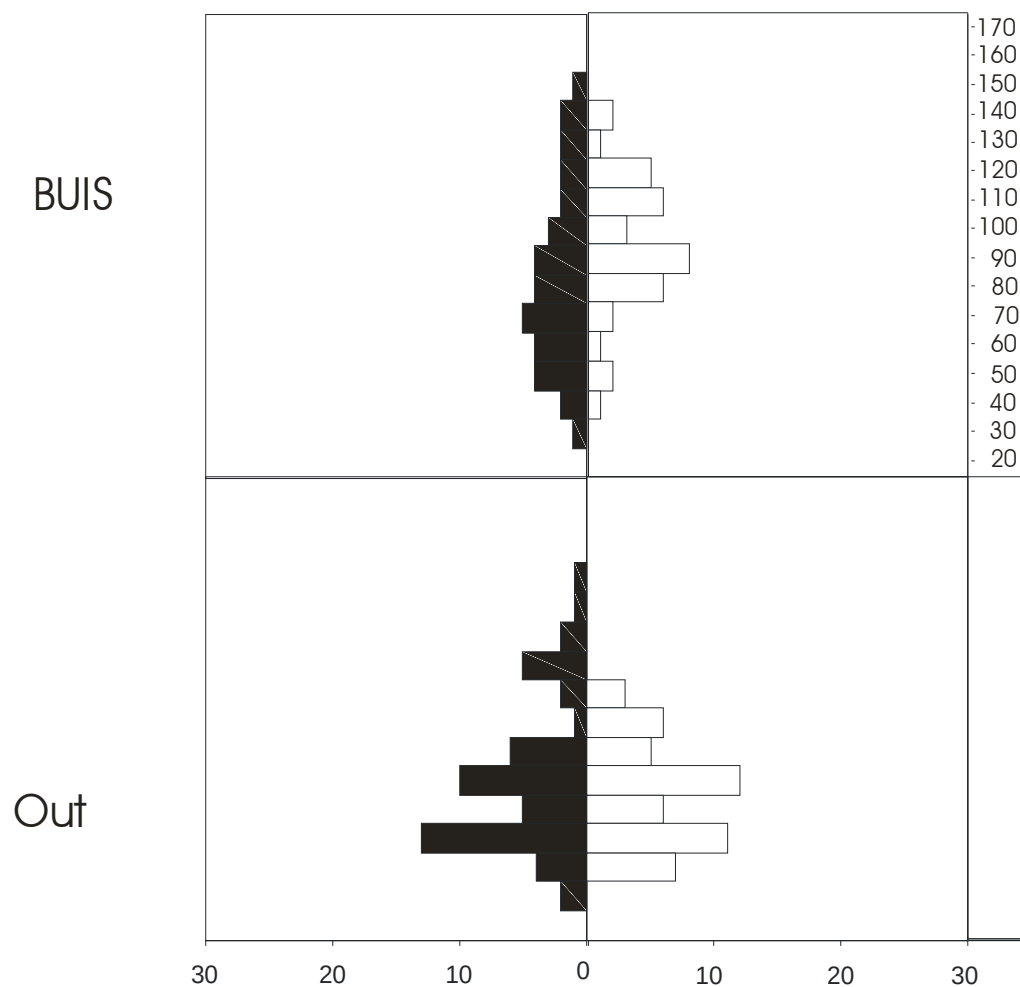
**D)** Back Reef

Males Females



**E)**

Base of Linear Reef  
Male Female



**F)**

Nearshore Patch Reef

*No equivalent habitat*

Male Female

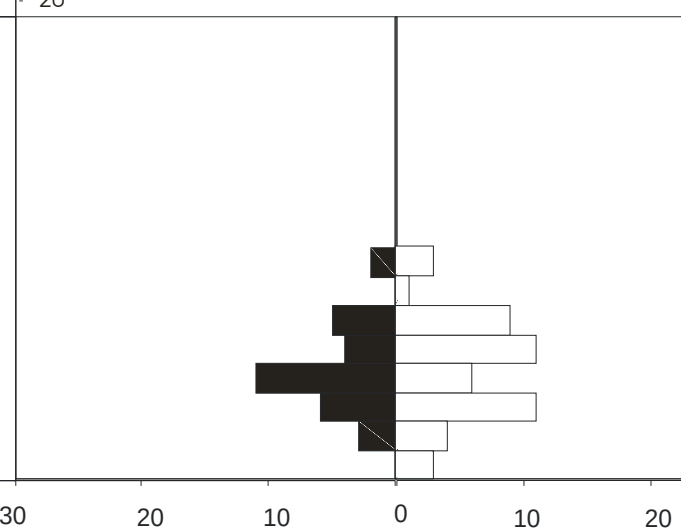


Figure 3

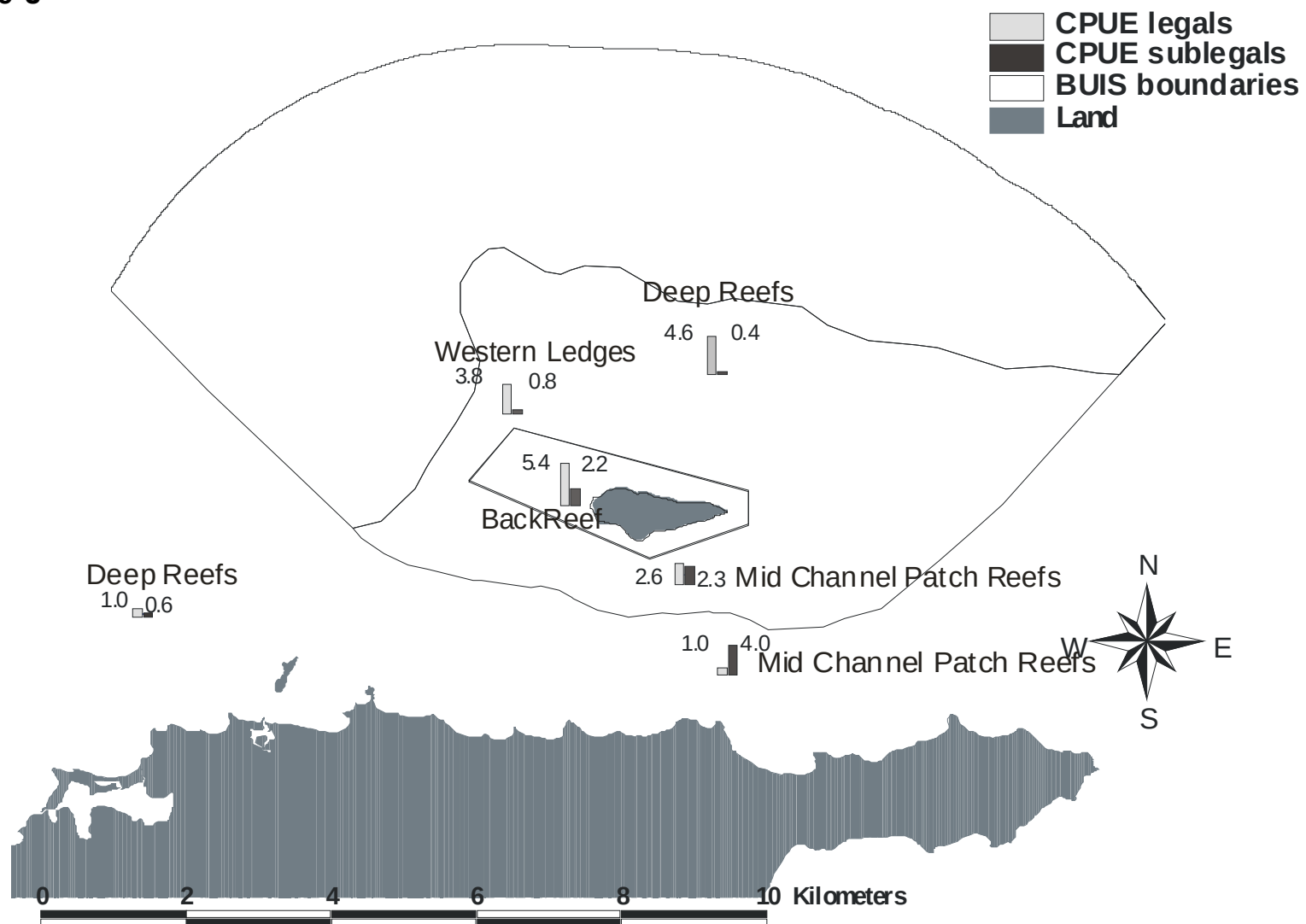


Figure 4

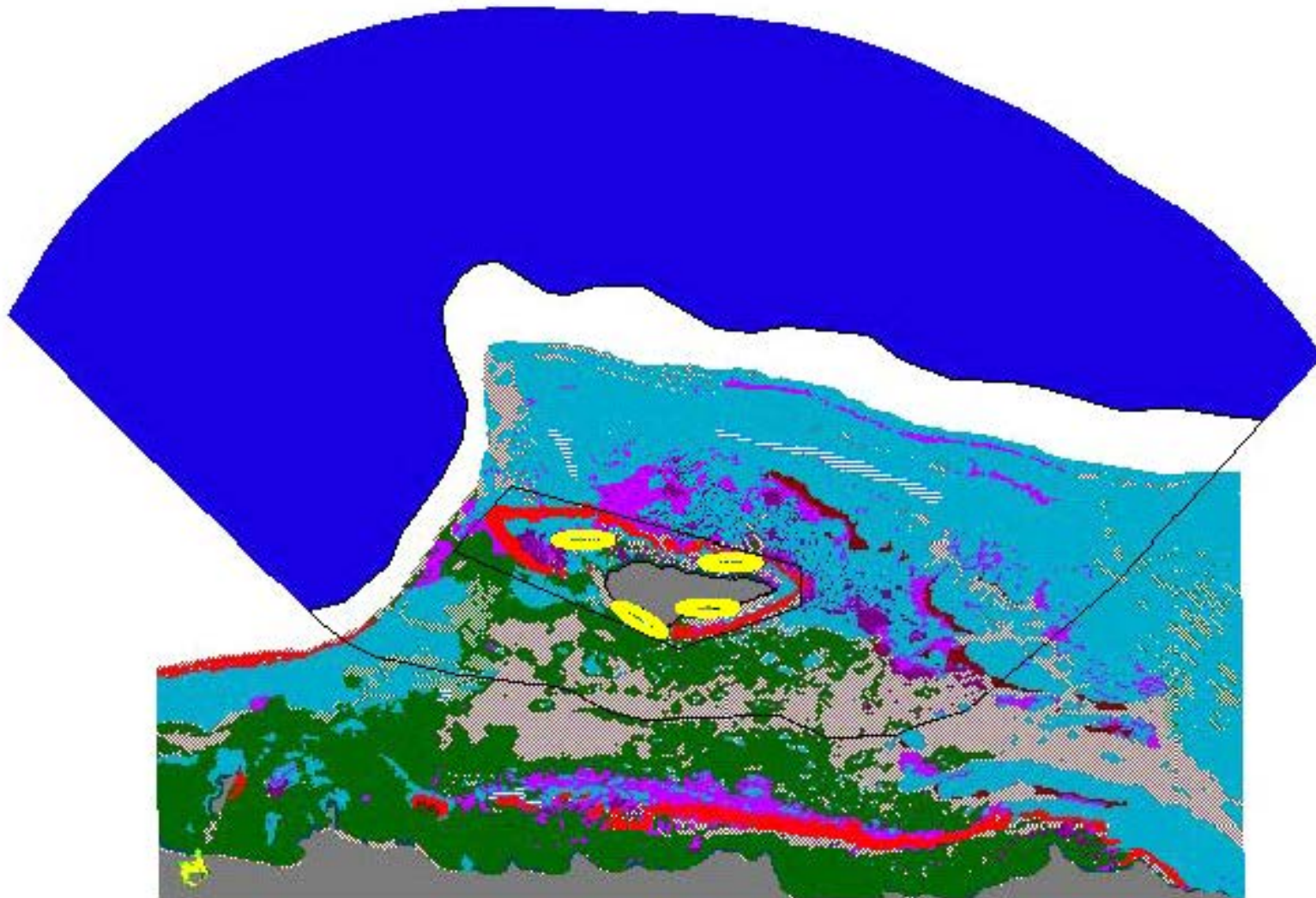


**Figure 5**

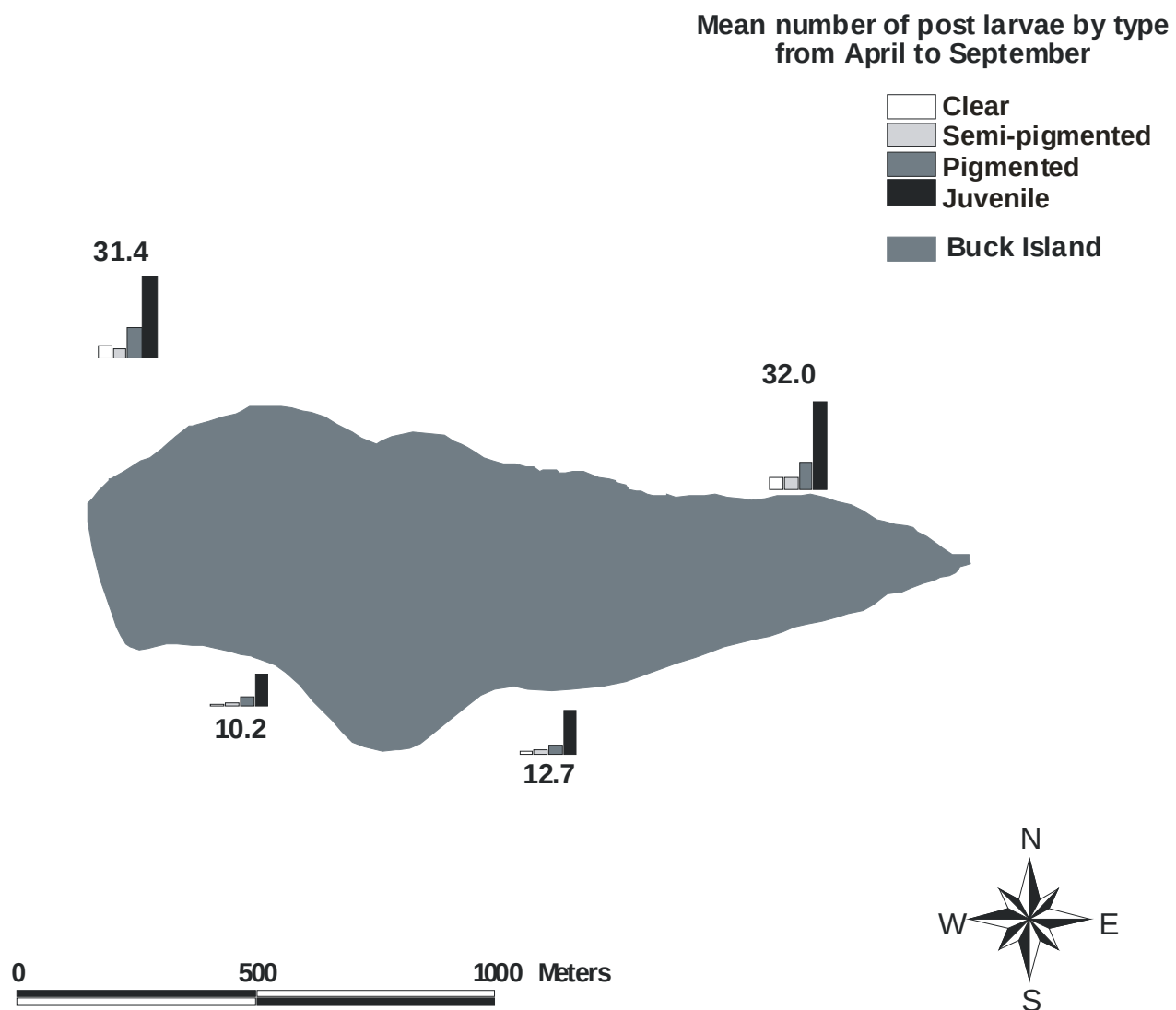


Figure 6

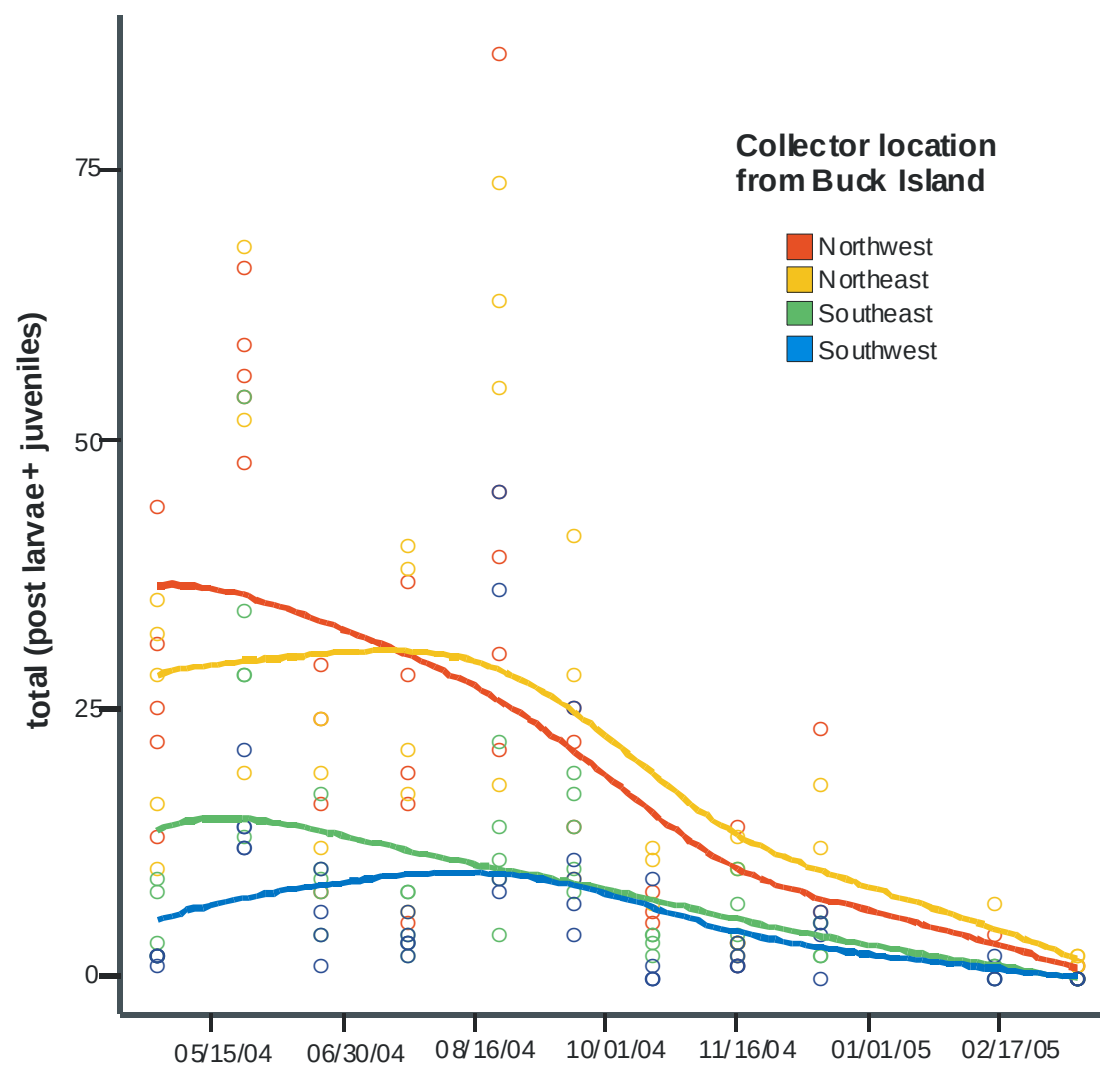


**Figure 7**



**Figure 8**

**A) Healthy**

**B) Infected**

