



Hard Clam Habitat Suitability Model and Potential Restoration Site Selection



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SCCF Marine Laboratory



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Executive Summary

The hard clam (*Mercenaria campechiensis* and *Mercenaria mercenaria*) has been harvested by man from the Charlotte Harbor Estuary (CHE) since at least 300 – 500 AD (Thompson et al. 2016). Since the mid-twentieth century, over-harvesting, water quality changes, habitat loss and ecosystem disturbance has drastically reduced the abundance of hard clams in Southwest Florida. Hard clam aquaculture is now practiced in the CHE and farmers are often faced with an inability to market their clams due to red tide, fishery closures and other natural events. Most of the events which prevent farmers from selling their clams do not physically affect the health of the clams. This project will identify and evaluate areas within the CHE which may be used as clam restoration areas – using non-marketable clams relocated to suitable habitat.

A GIS-based hard clam habitat suitability map was produced using available environmental data from the Charlotte Harbor Water Atlas, the Lee County water quality database and the SCCF water quality database. Parameters used for the development of the GIS-based habitat suitability map included salinity, dissolved oxygen, temperature, chlorophyll *a*, seagrass cover, and depth. Optimal, acceptable, marginal and unsuitable values of these parameters were set using findings from previous studies. Interpolated GIS layers for each parameter were developed and scores assigned to each pixel in each layer based on mean or maximum values. Higher scores corresponded to more suitable habitat. The final interpolated suitability map identified the best habitat in the CHE as well as the unsuitable habitat.

After development of the hard clam suitability map, clam farmers and biologists in the clam restoration working group picked 20 sites within suitable habitat for further evaluation. From these sites, 10 were chosen for more in-depth surveys based upon proximity to existing clam leases and predicted habitat suitability from the GIS results. Two sites were in Gasparilla Sound close to existing clam farm leases, one site was in Pine Island Sound within four miles of a lease and one site was in Charlotte Harbor near clam farm leases there. The field work at these sites was used to collect sediment samples, survey for adult and juvenile clams and compare relative water flow between sites. *Mercenaria campechiensis* were found in low concentration at three of the 4 sites proposed for restoration. The sites were ranked based upon the presence (or absence) of clams, sediment characteristics and relative food flux and four candidate sites were recommended for potential restoration.

Introduction

The southern hard clam (*Mercenaria campechiensis*) and the northern hard clam (*Mercenaria mercenaria*) are both found in the Gulf of Mexico. The southern species is indigenous while the northern species is likely a product of aquaculture introduction. When abundant, hard clams have an important role in estuaries as benthic filter feeders. The feeding activity of hard clams reduces phytoplankton and turbidity and transfers nutrients from the water column to the sediment (Petersen et al. 2019). Hard clams benefit seagrass by increasing water clarity (Carroll et al. 2008) and are a food source for estuarine predators (Eversole 1987). Hard clams are becoming less abundant in most areas of the Gulf of Mexico (Arnold et al. 2009) and resource managers are investigating techniques to effectively restore natural populations along the Florida coast.

The State of Florida has established hard clam farming leases in several coastal areas. The Charlotte Harbor (CH) Estuary is a home for clam farm leases in Pine Island (PIS) and Gasparilla (GS) Sounds. Farmers can experience market failures or see their entire stock affected by red tide blooms or other natural events which make their clams unmarketable. During these instances, the farmed clams are still viable and could be used to help regional restoration efforts by relocating them to suitable areas for their long-term survival and natural propagation.

A Charlotte Harbor estuary clam restoration study group was formed to address the potential of using unmarketable hard clams for restoration efforts. The study group consists of clam farmers and scientists from Florida Department of Environmental Protection (FDEP), Florida Fish and Wildlife Commission (FWC), and Sanibel Captiva Conservation Foundation (SCCF).

By examining the findings of previous studies, the environmental characteristics needed for successful hard clam growth and survival were identified. Analysis of existing environmental data for the Charlotte Harbor estuary using ArcGIS tools provided comparisons of current conditions to desired optimal conditions. A GIS-based model was then developed which identifies areas that should provide the best habitat for hard clams.

The goal of this project was to identify and rank 10 potential clam restoration sites within the Charlotte Harbor Estuary which provide optimum habitat suitability with minimal logistical challenges. Project objectives included:

1. Creation of a habitat requirement matrix which identifies important water quality and environmental factors and suitable value ranges for those factors.

2. Using the factors identified in the habitat requirement matrix to develop a GIS-based hard clam suitability map of the Charlotte Harbor Estuary that identifies sites with optimal suitability for hard clams. These sites could be targeted for restoration efforts including obtaining permits, funding for restoration, and relocation of clams to these areas.
3. Provide the GIS habitat suitability map to the project working group to allow them to further narrow the (20) suitable areas down to those they see as most feasible for actual restoration work.
4. Rank the (20) potential site locations based on logistical and preferred environmental factors.
5. Use field surveys to characterize the 10 highest ranked potential restoration sites by collecting additional field data including sediment characterization, relative flow/food flux estimates, and existing clam density.
6. Rank the 10 potential sites based upon field survey results.

Methods

Much of the work in this study followed a similar effort by Arnold et al. (2000). In that study, GIS was used to help identify suitable sites to be designated for clam farm leases within Charlotte Harbor, Pine Island Sound, and Indian River Lagoon. Many of the factors used in that evaluation were also used in this project but were chosen based upon different goals (restoration verses farming).

For the GIS analysis, water quality data was obtained from the CHNEP water quality atlas, the Lee County Environmental Laboratory database and the SCCF water quality database for the period 2010 through 2020. Stations located in Charlotte Harbor, Pine Island Sound, and the Caloosahatchee Estuary were included in the analysis (Figure 1). The data were checked to remove duplicates and other errors.

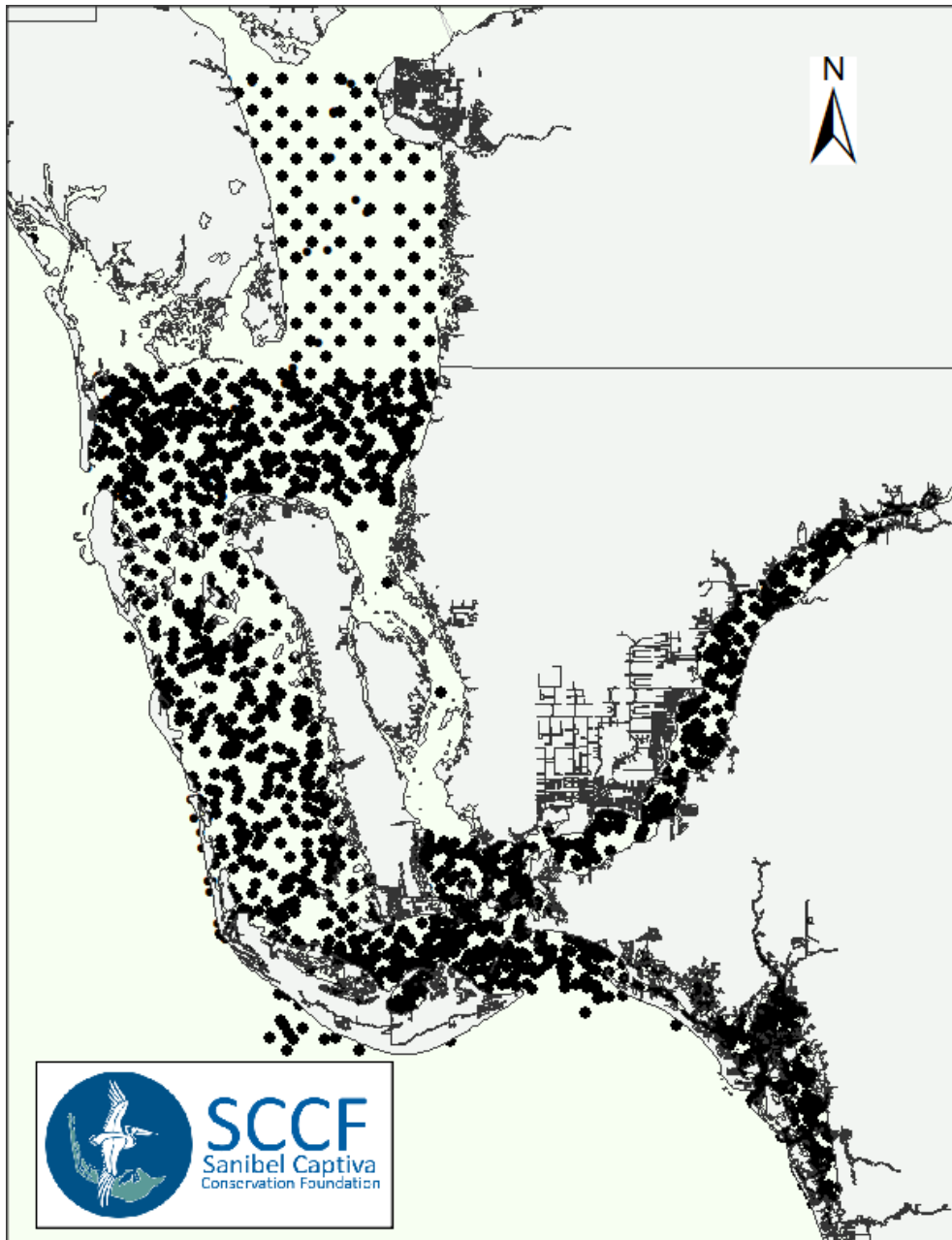


Figure 1. Water quality data sites (black dots) used to develop interpolated maps of water quality parameters for this study.

A literature review was conducted to determine which environmental variables had the greatest influence on the suitability of habitat for hard clam survival. A matrix was developed of important factors and parameter values reported to be suitable or unsuitable for clam health. The values of the most important parameters were extracted from the water quality databases. The data used was error checked and manipulated to upload into ArcGIS 10.

Using results of the previous studies (Arnold et al. 2000, Judge et al. 1993, Baker et al. 2005, Grizzle 1989, Peterson et al. 1984, Murphy 1985, Mann 2005, Hadley 2007, Weber 2010, Powers 2009, Carmichael et al. 2012), parameter values were chosen to classify habitat as optimal, acceptable, marginal, or unsuitable (Table1).

Table 1. Factors used in GIS habitat suitability map development.

Factor	Optimal	Acceptable	Marginal	Unsuitable	Exposure Duration	Notes
Salinity psu	>25	20-25	12.5 - 20	<12.5 or >45	3-6 days of unsuitable	
Seagrass coverage	0%	<10%	10-25% seagrass with sandy mud to shelly mud substrate	No seagrass with anoxic, unconsolidated mud or abundant seagrass		Greater food availability with seagrass present but state and federal permitting concerns
Flow or food flux	Flowrates from 0.2 - 0.6 cm/sec for densities of 4-450 clams/m ²					Greater flow increases food delivery.
Substrate	Shelly soft bottoms	Sandy to Muddy Sand	Sandy Mud	Unconsolidated muddy bottoms - Anoxic		
Chlorophyll a ug/l	Seston flux is best indicator of growth = optimum seston flux = 90-130 mg/cm ² -sec POM anything greater or less than optimum may reduce growth					Chlorophyll a is measure of phytoplankton (food).
Harvesting area	No harvesting permitted	Conditional harvesting permitted	Harvesting permitted			Areas where harvesting is permitted may increase poaching of restored clams
Depth meters	4-8	6-18	0-3, 18-30	>30		
Dissolved oxygen mg/l	>5	4.2-5.0	2-4.2	<1		
Temperature °C	22.5-30	12.5-30	30-31	>32	Can survive 32°C for 15 days w/o mortality at 25ppt	

These values were then entered into ArcGIS®10.5 and the inverse distant weighing method of interpolation was used to make maps of the Charlotte Harbor Estuary for each factor (parameter). Optimal, acceptable, marginal and unsuitable value ranges were taken from the factor matrix and used to indicate (by color) classes of habitat for each important factor in the GIS maps.

The following factor (parameter) values were used:

- Salinity – used lowest 25% data at each site.
- Temperature – maximum temperature value at each sampling site.
- Dissolved oxygen – minimum DO at each site.
- Chlorophyll *a* – mean value at each site.
- Seagrass cover – 2014 FWC layer. Continuous and patchy classifications.
- Shellfish harvest areas – from FDACS boundary files.
- Depth – bathymetry data from NOAA.
- Currents – no data available – field surveys needed.
- Hard clam lease areas – layer from FDACS.
- Substrate – no data available – field surveys needed.
- In addition to the main factors shown in the table, we would also consider:
 - Distance from existing clam leases.
 - Existing clam density – field surveys needed.

Draft clam habitat suitability maps were developed using a scoring procedure and color coding on the GIS map layers. The composite suitability maps were then used to identify sites for exploratory field surveys of actual conditions in areas which are both suitable and accessible.

- Green is optimal, light green acceptable, yellow marginal and red unsuitable.
- Scores for each suitability class:
 - Optimal = 3
 - Acceptable = 2
 - Marginal = 1
 - Unsuitable = 0
- Unsuitable areas for DO, temperature and salinity were mapped and shown in red for final composite map. These are areas not to be considered for clam relocation.

- For each of the factors considered, every pixel in the interpolated GIS raster was given an underlying score of 0 to 3 (unsuitable to optimal).
- ArcGIS tools were used to add scores for each pixel and come up with an overall score. Pixels with highest scores are predicted to be best habitat for hard clam relocation. Lowest scores are to be avoided.
- A suitability map was made from composite scores for each pixel. Green is most suitable and red is unsuitable.

After the initial habitat suitability maps were produced, the hard clam restoration study group met to provide additional thoughts related to where the best potential clam relocation and restoration sites might be found. It was decided to prioritize sites that were in 4 – 8 feet depth of water and which were reasonably close (within 10 miles) of existing clam leases. The meeting participants were invited to provide specific site locations to SCCF that they would like to have further information on based upon the suitability maps and based upon their knowledge of hard clam habitat in the study area. The clam study group provided 20 sites for consideration for further field surveys. SCCF staff then rank-prioritized those 20 sites based upon habitat suitability model information, depth (4 – 8 foot preferred) and distance from existing hard clam leases. Ten (10) sites were chosen to study further from the 20 selections. It was also decided that the existing clam density at proposed restoration sites would serve as an additional factor in determining site suitability. For the purposes of this study, *Mercenaria spp.* density above 10 m⁻² is considered a healthy natural abundance (Mann and Roegner 1991). Should density greater than 10 m⁻² be encountered, restoration would not be recommended for that site. If *Mercenaria spp.* is present but in densities lower than 10 m⁻², the site would be considered for restoration.

Field surveys were conducted in December 2020 through January 2021. During the surveys, 3 samples of bottom substrate were collected at each of the ten sites using a 38mm diameter corer inserted to 25-centimeter depth (Figure 2). Each sample was placed in labeled bags and taken to the SCCF Marine Laboratory for sieving to determine percent sand (>63µm) and mud (<63µm). Approximately 100 grams of homogenized wet sample was dried in an oven at 60°C to constant weight. The dried sample was then sieved through a 63µm sieve and the portion captured on the sieve was again dried to constant weight at 60°C. The percent sand was determined as the captured portion of the dried sample while percent silt was the remaining portion.

Additionally, a 160 mm corer was used to collect 5 samples from the bottom substrate at each site to identify the presence of juvenile *Mercenaria* spp. clams (Figure 3). Each sample was sieved on site through a 1mm mesh strainer (Figure 4) and the quantity and size of *Mercenaria* spp. was recorded.

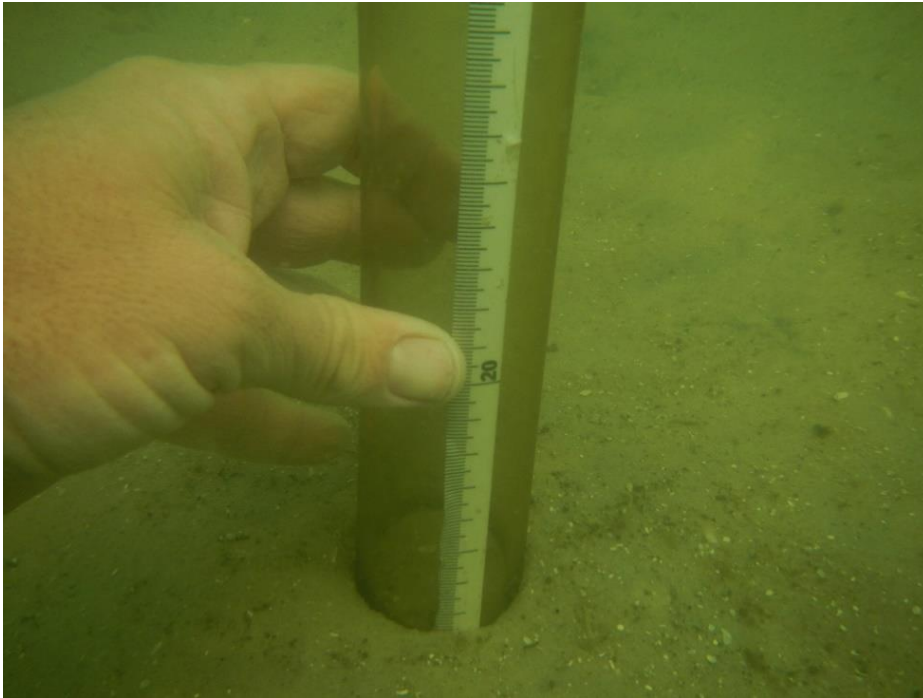


Figure 2. Collecting a substrate sample from a study site.



Figure 3. Collecting core sample to sieve for juvenile hard clams.

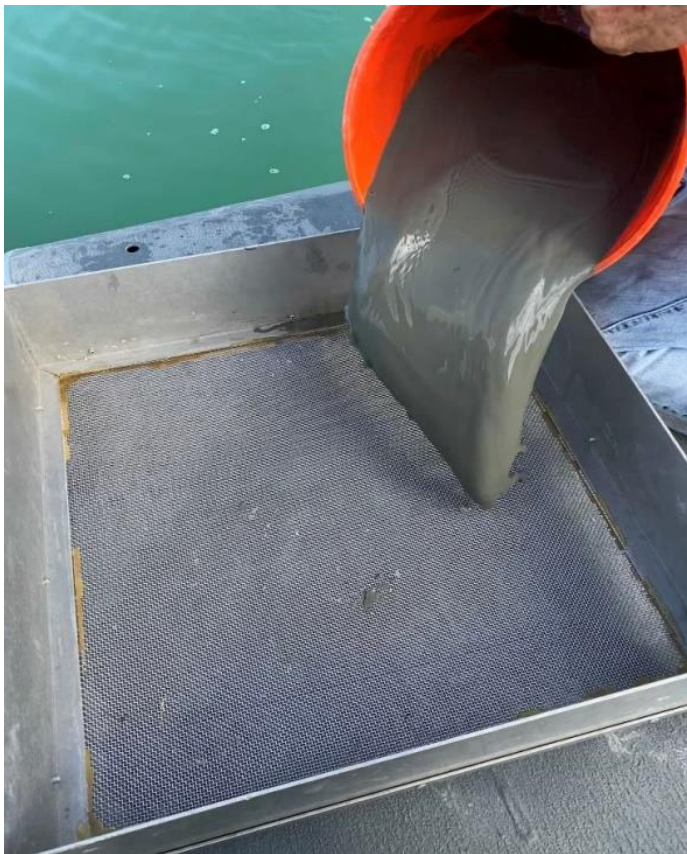


Figure 4. Pouring juvenile clam core sample through sieve for counting hard clams present.

To estimate the density of existing adult *Mercenaria* at each study site, a 0.24 m wide clam rake was used to find clams in 5 haphazardly placed 1 m² quadrats (Figure 5). The number and size of all hard clams found within each quadrat sampling area was recorded.

Procedures previously used by researchers were followed to compare spatial and temporal differences of flow rates in complex estuarine flow regimes (Jokiel and Morrissey 1993). Three “plaster-of-paris” clod cards were deployed at each site for 1 to 3 days (Figure 6). Computation of the dissolution rates of these cards (percent dissolved per day) allows comparison of relative flow rates (water movement) between the 10 study sites. After deployment, each clod card was dried at 60°C to constant weight. The dried clod card was then cooled and weighed to determine the percent dissolved weight over the deployment period.

A subjective description of the shell content present in the 5 juvenile clam cores was recorded on the logsheet. This description was then used to provide a score for the “shelliness” of the substrate.

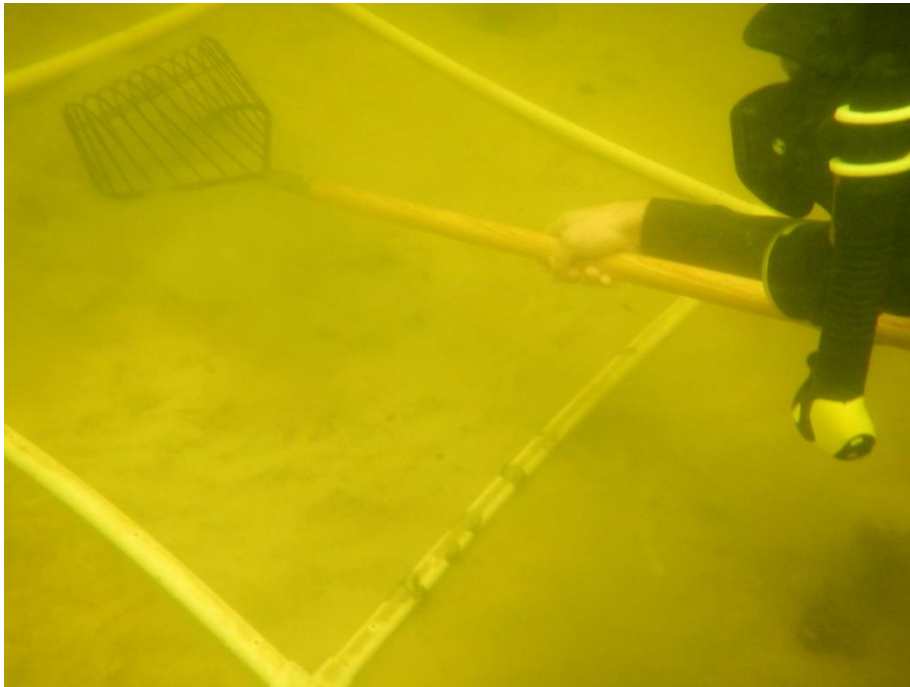


Figure 5. Using clam rake inside a 1 square meter quadrat for enumeration of adult clams present at each site.



Figure 6. Clod cards used to estimate relative flow rate between sites. Images show three cards ready to deploy and manual deployment by divers to base of float and block.

The field studies provided the information needed to rank the 10 potential restoration sites relative to one another. The factors included adult clam density, juvenile clam density, seagrass coverage, bottom substrate percent silt, estimated relative food flux (relative flow rate x mean chlorophyll *a*), and presence of shell in the substrate. Each factor was scored on a 0-3 scale (0 being worst, 3 being best). Scores for the mean number of adult clams present was multiplied by 3 giving this factor the most weight amongst those studied. Two other factors were also weighed differently during scoring. The juvenile clam density score was multiplied by 2 to give it more weight in the overall score. The score for “shelliness” was multiplied by 0.5 due to the subjective nature of this measure. The total score of each site was computed and the sites were ranked to predict which would be most suitable for restoration. Sites with highest total scores were recommended as potential restoration sites. The scoring regime used for each factor is shown in Table 2.

Table 2. Factor values and associated scores for site suitability ranking in this study.

Factor	Optimal Score (3)	Acceptable (2)	Marginal (1)	Unsuitable (0)
Mean Number Adult Clams/m ²	1-5	5-10	0	>10
Mean Number Juvenile Clams/m ²	>100	10-100	0-10	0
Mean % Silt	<10%	10-15	15-20	>20%
Seagrass Cover %	0	1-10	10-25	>25%
Shelly Substrate Presence	Very Shelly	Shelly	Some Shells	Not Shelly
Relative Food Flux This Score Doubled	>9	6-9	3-6	0-3

Results

GIS-Based Habitat Suitability Maps

Using the methods explained above, the following hard clam habitat suitability GIS layers were developed (Figures 7-15). An ArcGIS map package is included with this report.

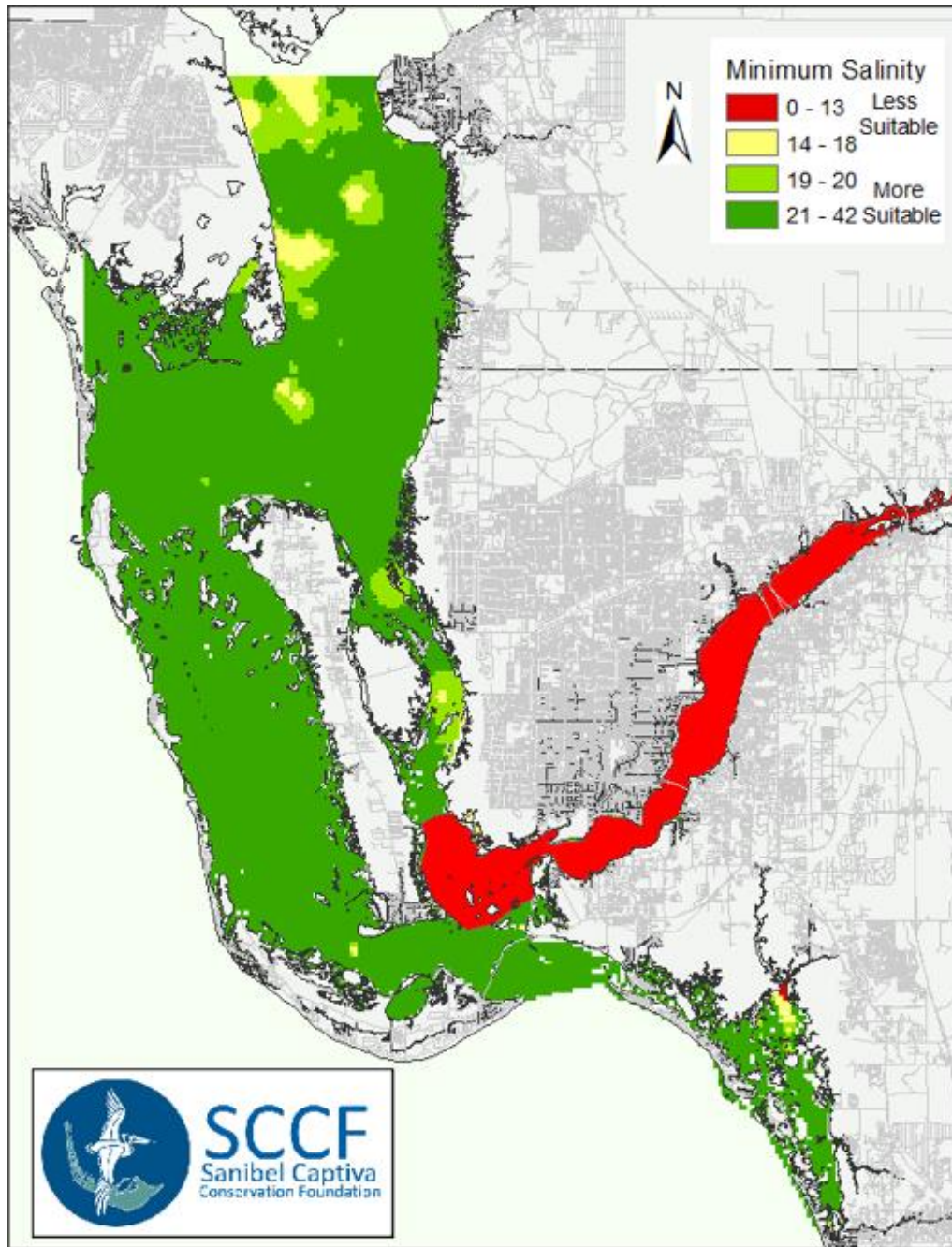


Figure 7. Layer showing areas with unsuitable (red) to optimal (dark green) salinity regimes based upon lowest 25th percentile of salinity data for stations used within the study.

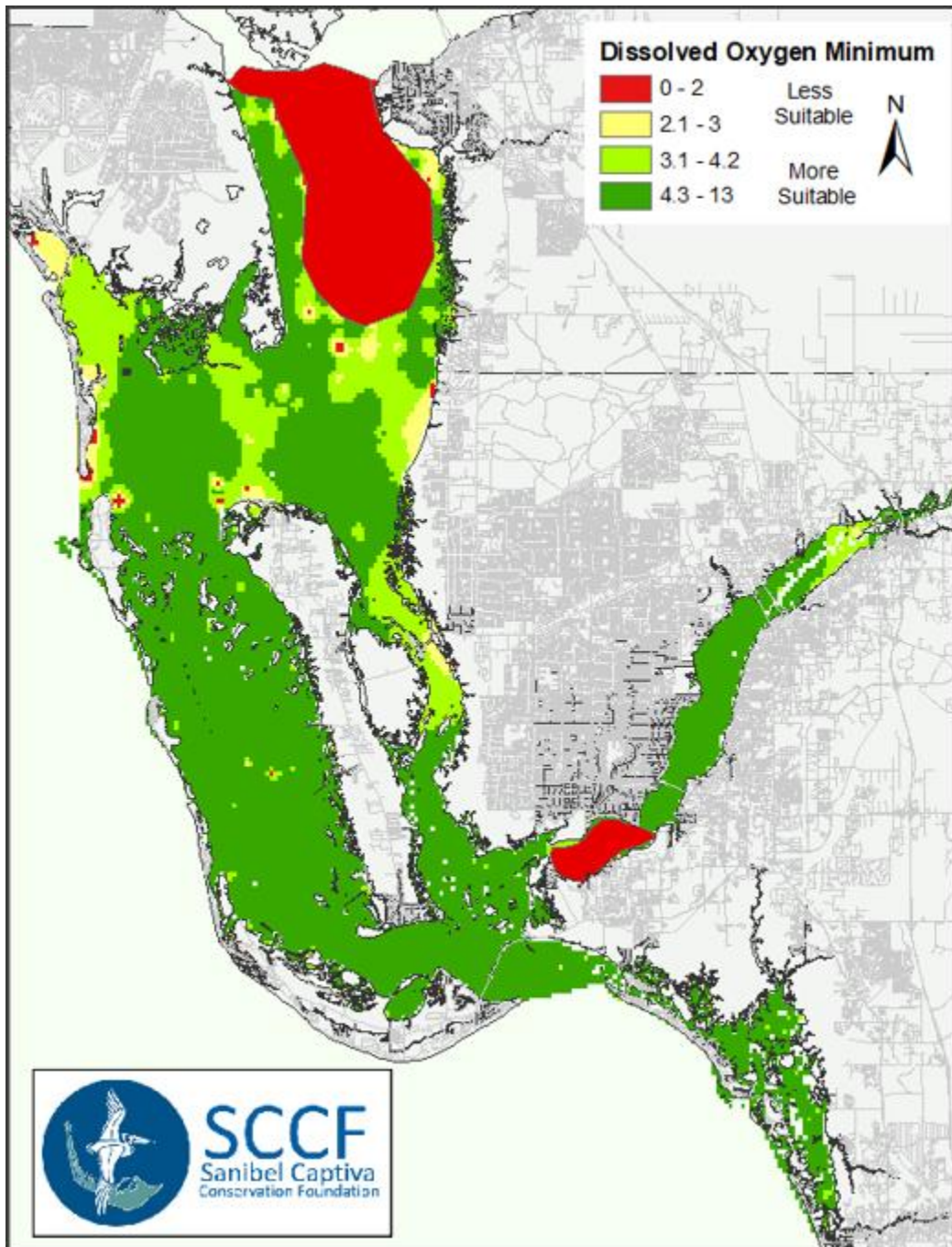


Figure 8. Layer showing areas with unsuitable (red) to optimal (dark green) dissolved oxygen based upon dissolved oxygen minimum data for stations used within the study

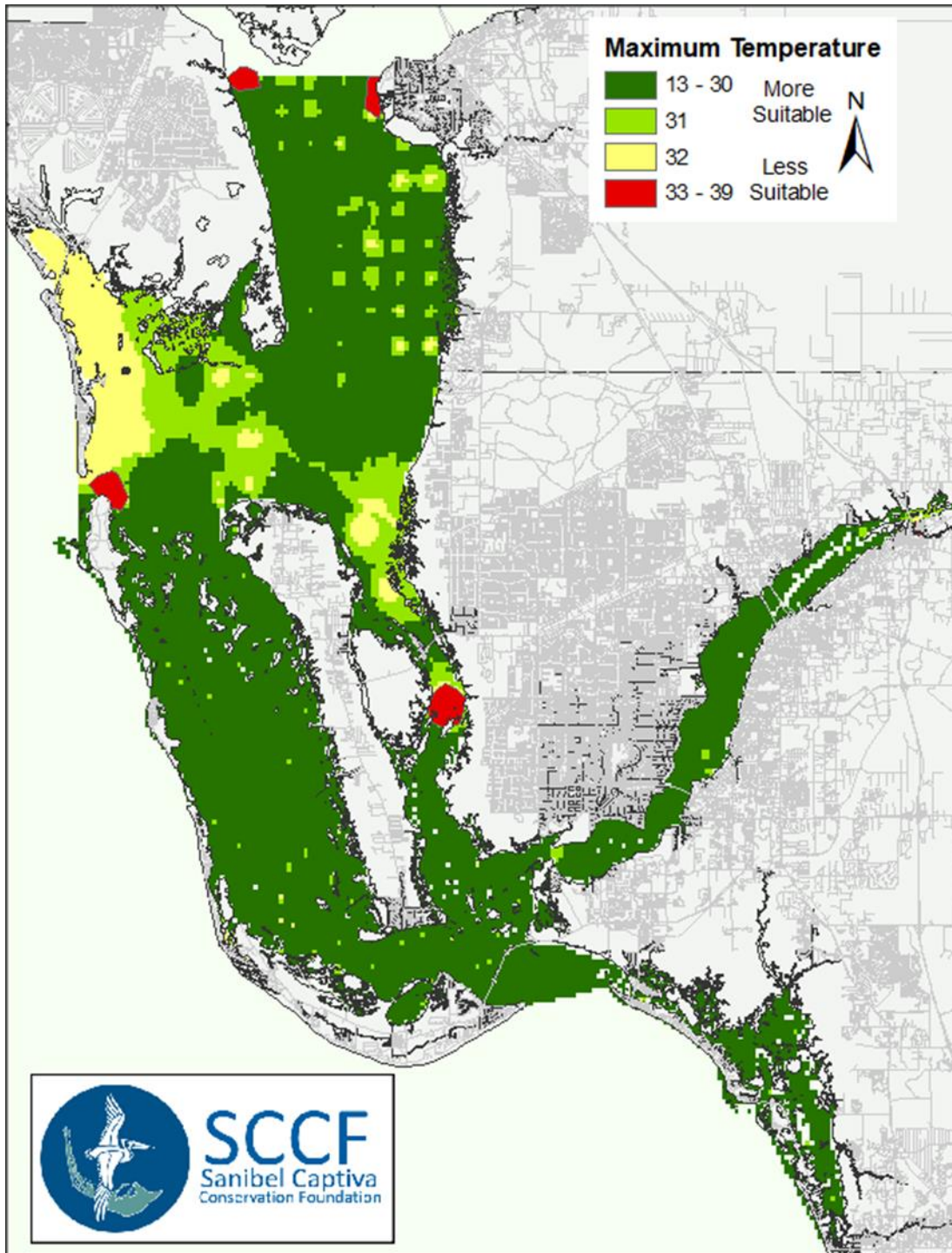


Figure 9. Layer showing areas with unsuitable (red) to optimal (dark green) temperature data based upon maximum temperature values for stations used within the study.

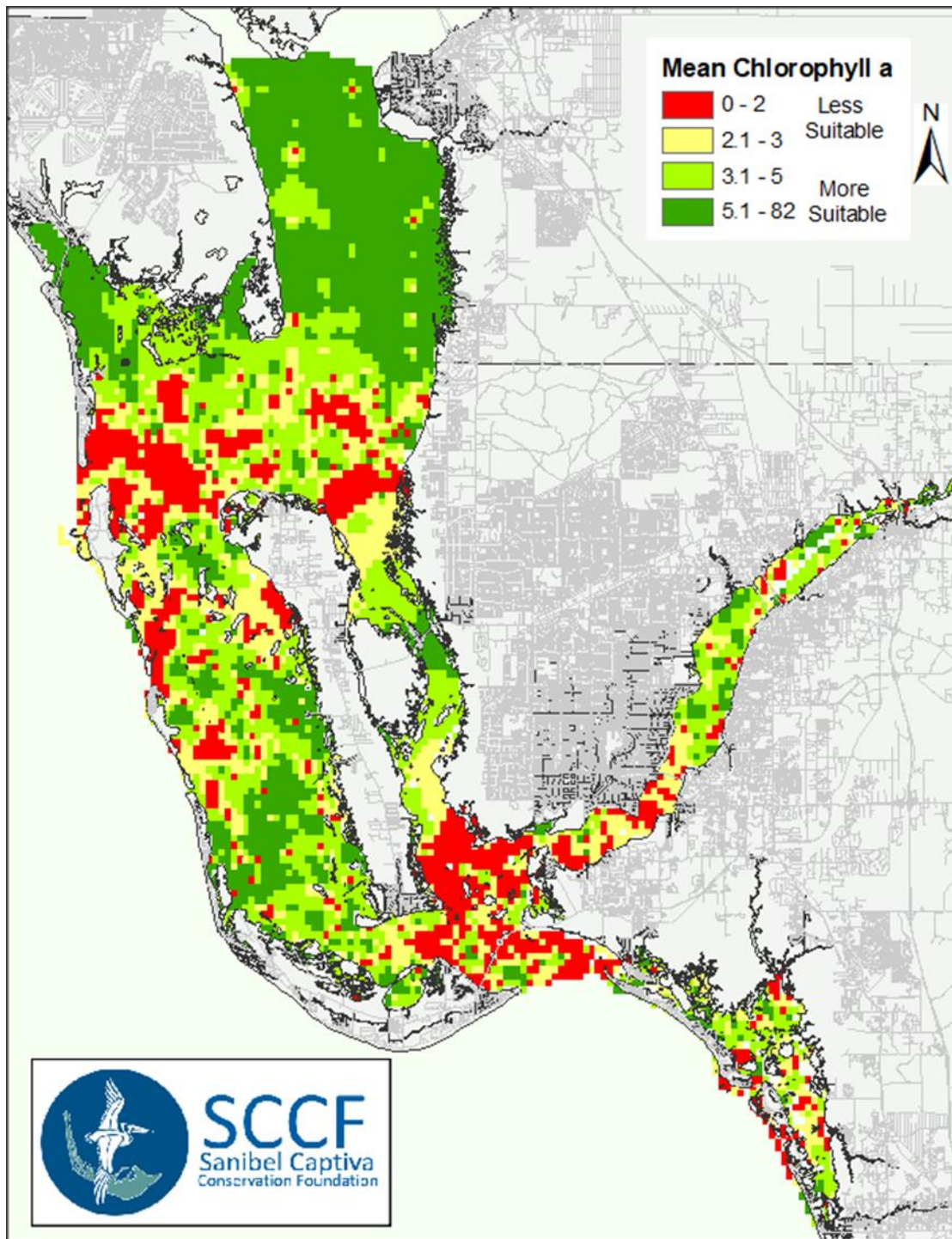


Figure 10. Layer showing areas with unsuitable (red) to optimal (dark green) chlorophyll *a* ($\mu\text{g/L}$) data based upon mean chlorophyll *a* for stations used within the study.

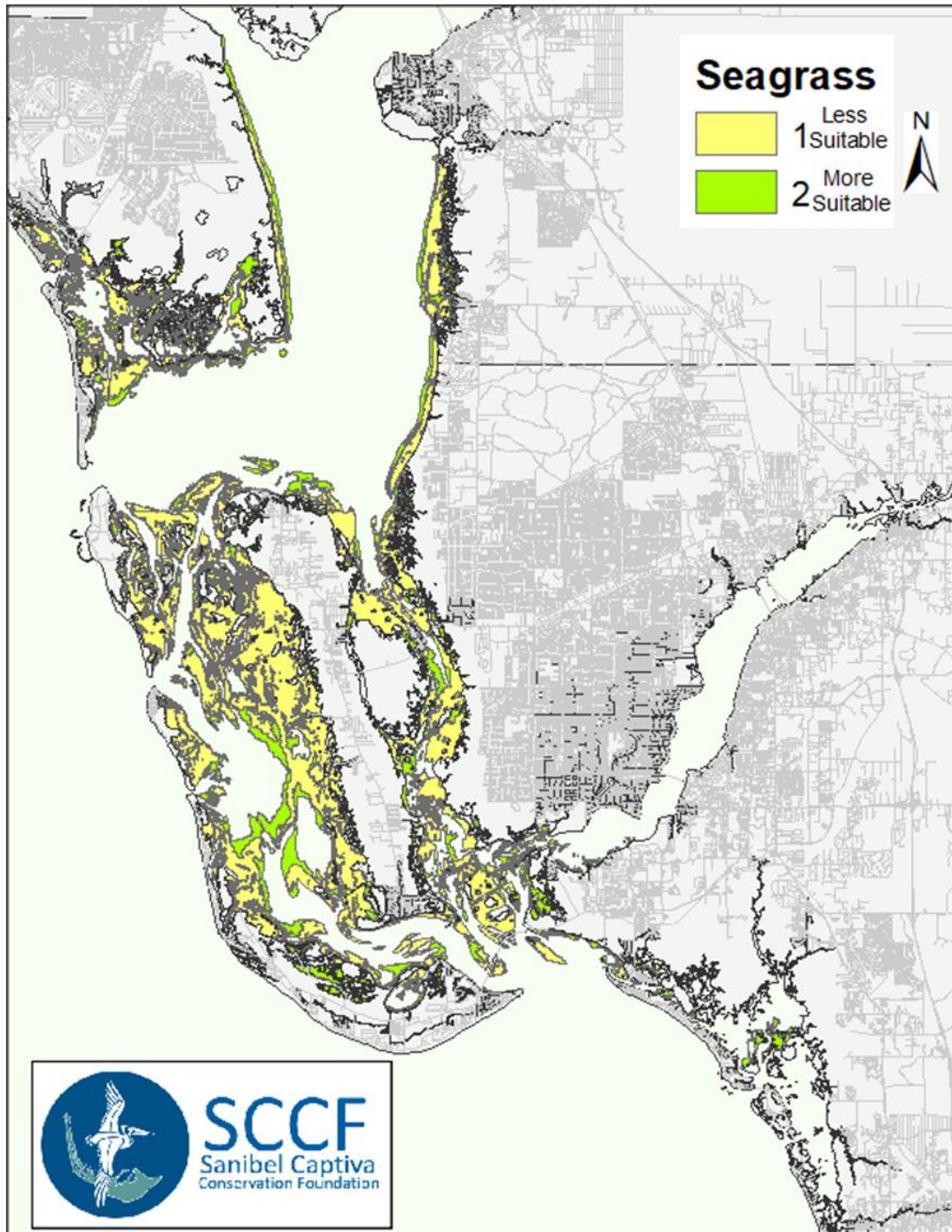


Figure 11. Layer showing less suitable (yellow) to more suitable (light green) areas based upon seagrass coverage. Seagrass has been found to be desirable for clam habitat but restoration efforts in dense seagrass beds may have adverse environmental impacts, so areas with sparse seagrass (light green) were rated as more suitable than areas with dense seagrass (yellow). Areas with shelly sand substrate and no seagrass are easiest to permit and thus restore (not shown). Areas with no seagrass but anoxic, easily suspended sediments would be least desirable (not shown).

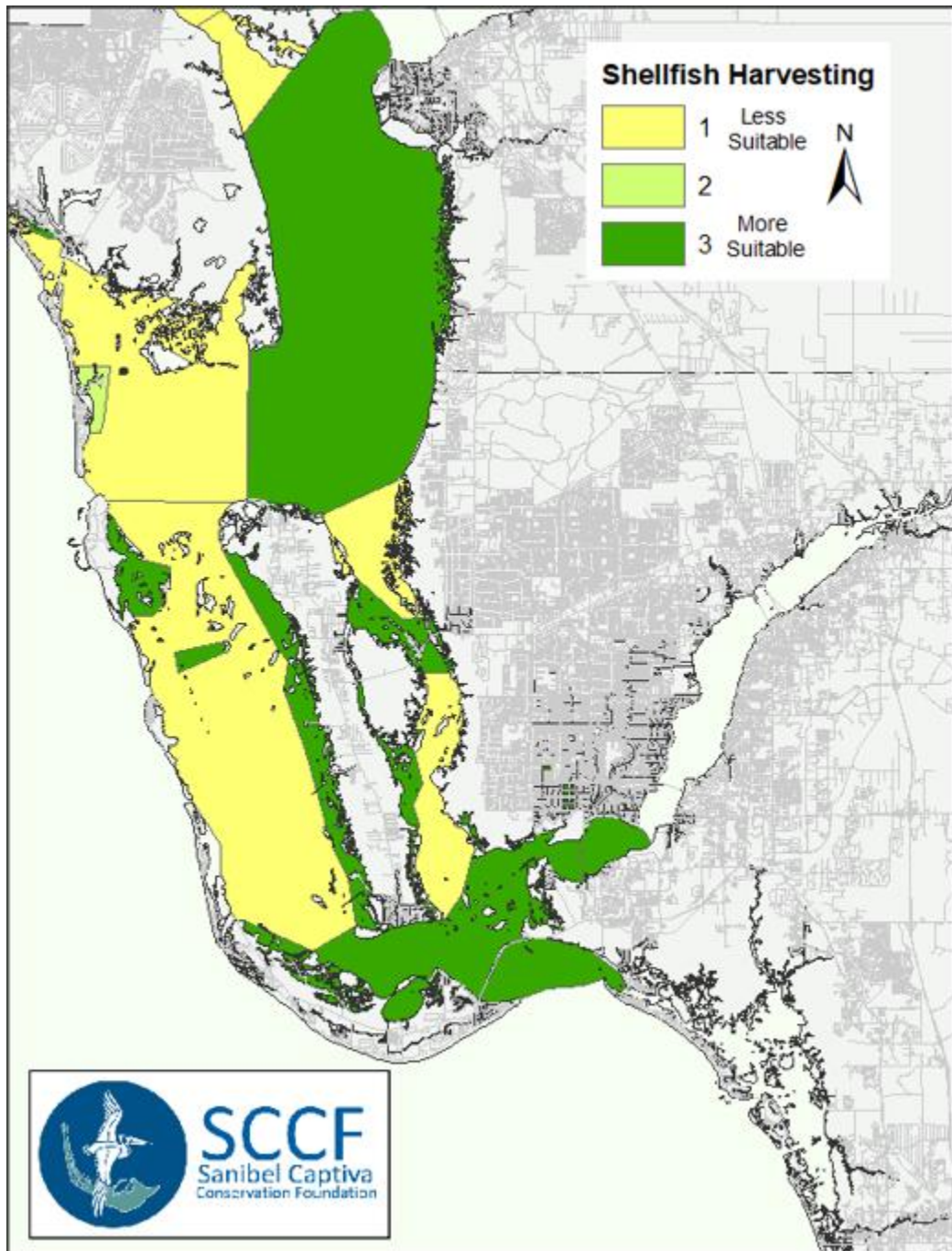


Figure 12. Layer showing less suitable (yellow) to optimal (dark green) areas based upon shellfish harvest regulatory status. It was determined the most suitable areas would be those closed to shellfish harvest, while conditionally open areas would be acceptable, and areas open to shellfish harvest less suitable.

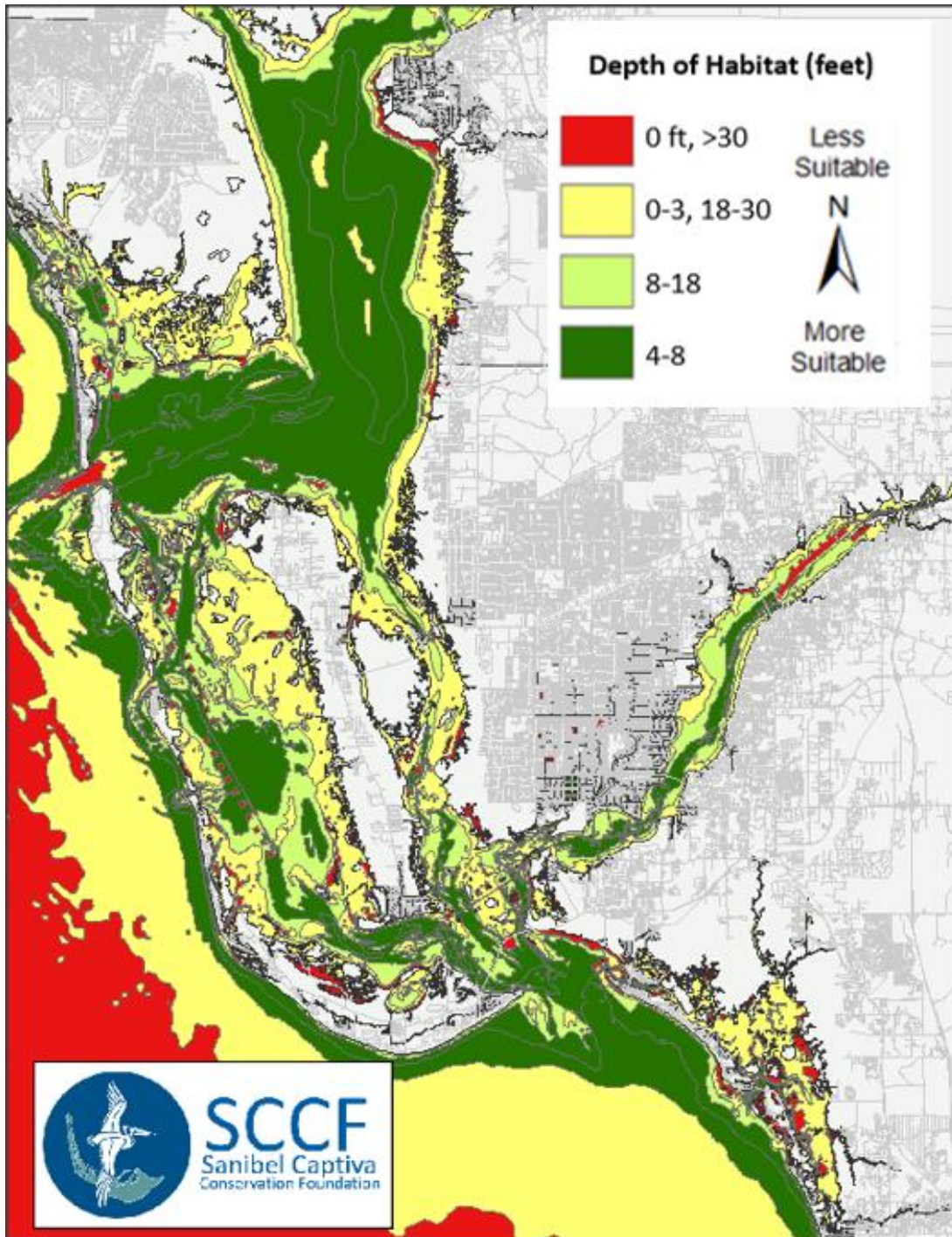


Figure 13. Layer showing areas with unsuitable (red) to optimal (dark green) depth based upon NOAA bathymetry data.

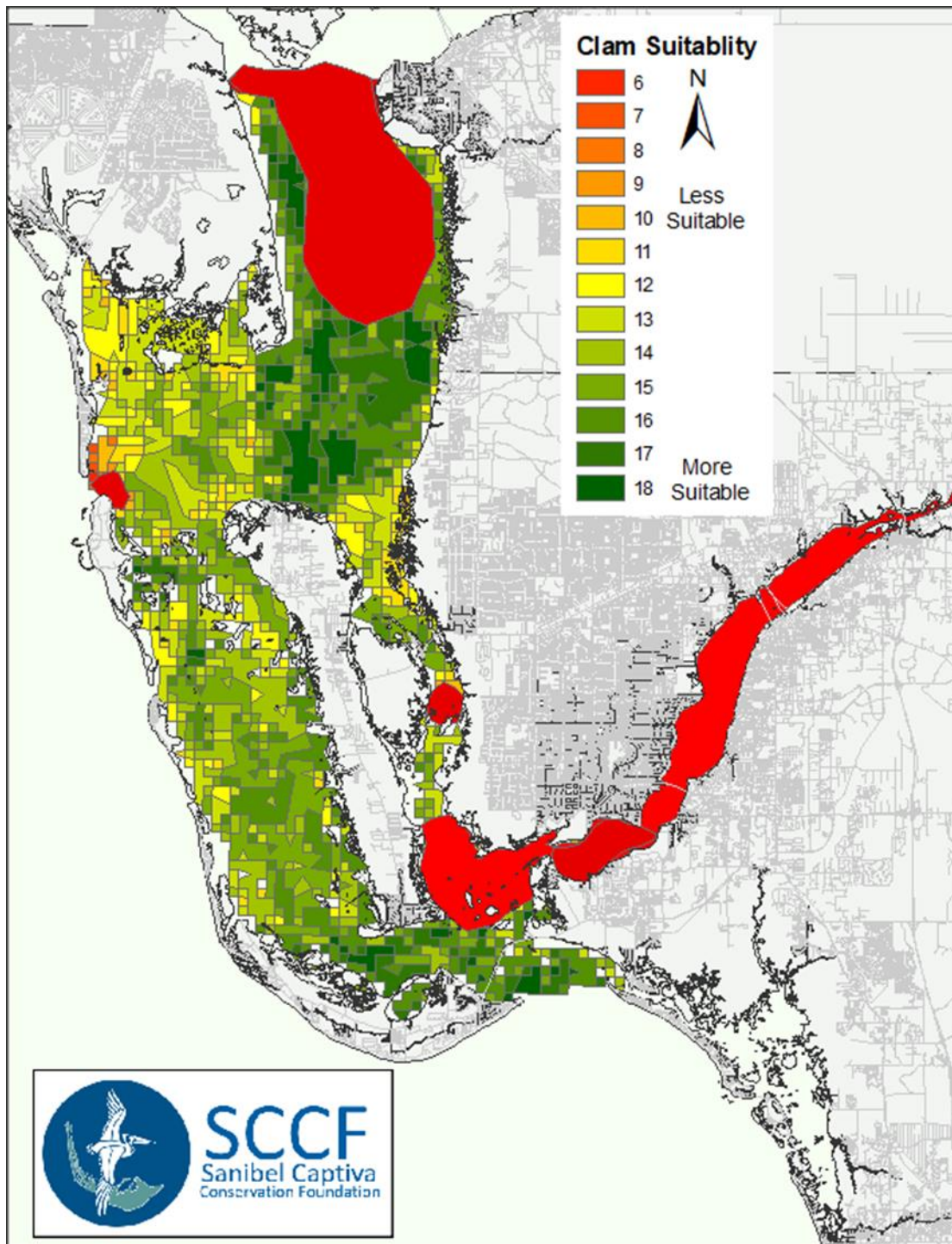


Figure 14. Layer showing combined suitability factors with aggregated suitability scores for each pixel. The dark green areas indicate predicted most suitable habitat while the red areas predict unsuitable habitat. This map will be used to survey potential clam restoration sites located within habitat predicted to be suitable.

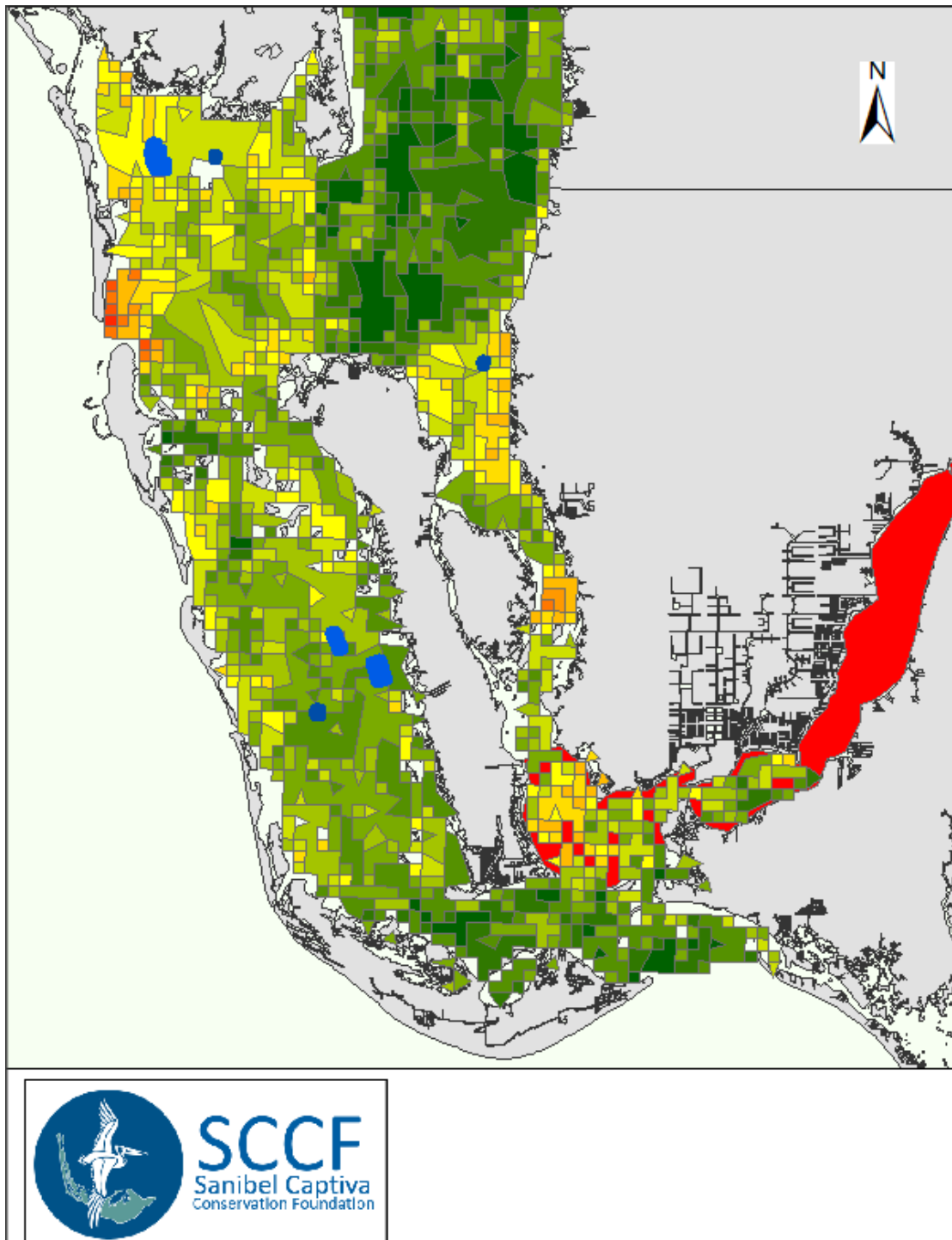


Figure 15. Layer showing existing clam farm leases in blue on background of habitat suitability map.

Identification of Potential Clam Restoration Sites

The composite suitability map (Figure 14) was distributed to the hard clam advisory working-group along with solicitation for identification of locations within the suitable areas for in-field site surveys. Twenty potential restoration sites were then identified (Figure 16) for possible further study. Ten sites were selected for field surveys (Table 3, Figure 16) from the 20 potential sites based upon proximity to existing leases, depth of water between 4 – 8 feet, and confirmation of location within suitable habitat per suitability map (Figure 14).

Table 3. Potential clam restoration sites ranked by priority showing distance to nearest clam farm lease.

Site_ID	SiteDescrp	Lat	Long	Priority	Miles To Lease	Location
CR11	Pine Island Sound West McKeever Keys	26.51422985870	-82.12506125710	1	4	Pine Island Sound
CR13	Pine Island Sound North Chino Isalnd West McKeever	26.51465703390	-82.13393090260	1	4	Pine Island Sound
CR16	Pine Island Sound NE Buck Key Near Bar	26.52673100600	-82.16817702250	1	4	Pine Island Sound
CR14	Pine Island Sound West Demere Key Near Clam Leases	26.59334017870	-82.15758863240	1	1	Pine Island Sound
CR17	North Sandfly Key	26.78959671370	-82.24588205720	1	1	Gaspirilla Sound
CR19	Grouper Hole off Boca Grande	26.79385540200	-82.26451181090	1	2	Gaspirilla Sound
CR18	South of Placida	26.81429562470	-82.25313409460	1	2	Gaspirilla Sound
CR09	Pine Island Sound SW of York Island	26.48399951960	-82.10842993270	2	9	Pine Island Sound
CR12	CH N of Bokellia S of Jug Creek Point Shoal	26.70623211270	-82.13270706030	2	8	Charlotte Harbor
CR15	CH at Southern Mouth Turtle Bay	26.77915158590	-82.16569241180	2	6	Charlotte Harbor
CR08	Pine Island Sound Just NW Shallow Cut	26.46022176310	-82.08680925130	3	10	San Carlos Bay
CR05	Woodring Point	26.46920394590	-82.06171444750	3	11	San Carlos Bay
CR06	Pine Island San Carlos at Mouth of Tarpon Bay	26.47154870900	-82.06634561710	3	11	San Carlos Bay
CR07	CH NW Burnt Store Marine	26.78127993980	-82.06717123490	3	11	Charlotte Harbor
CR02	SanCarlosBay Near Oyster Restore Site	26.48352521050	-82.03193602140	4	13	San Carlos Bay
CR04	SW of Picnic Island	26.48735713280	-82.05429313520	4	12	San Carlos Bay
CR01	South of Fisherman Key San Carlos Bay	26.48793771150	-82.02881556050	4	13	San Carlos Bay
CR03	SW of Big Island	26.49328630720	-82.03306339870	5	13	San Carlos Bay
CR10	CH NE of Bokellia	26.73970422110	-82.12093268850	5	8	Charlotte Harbor

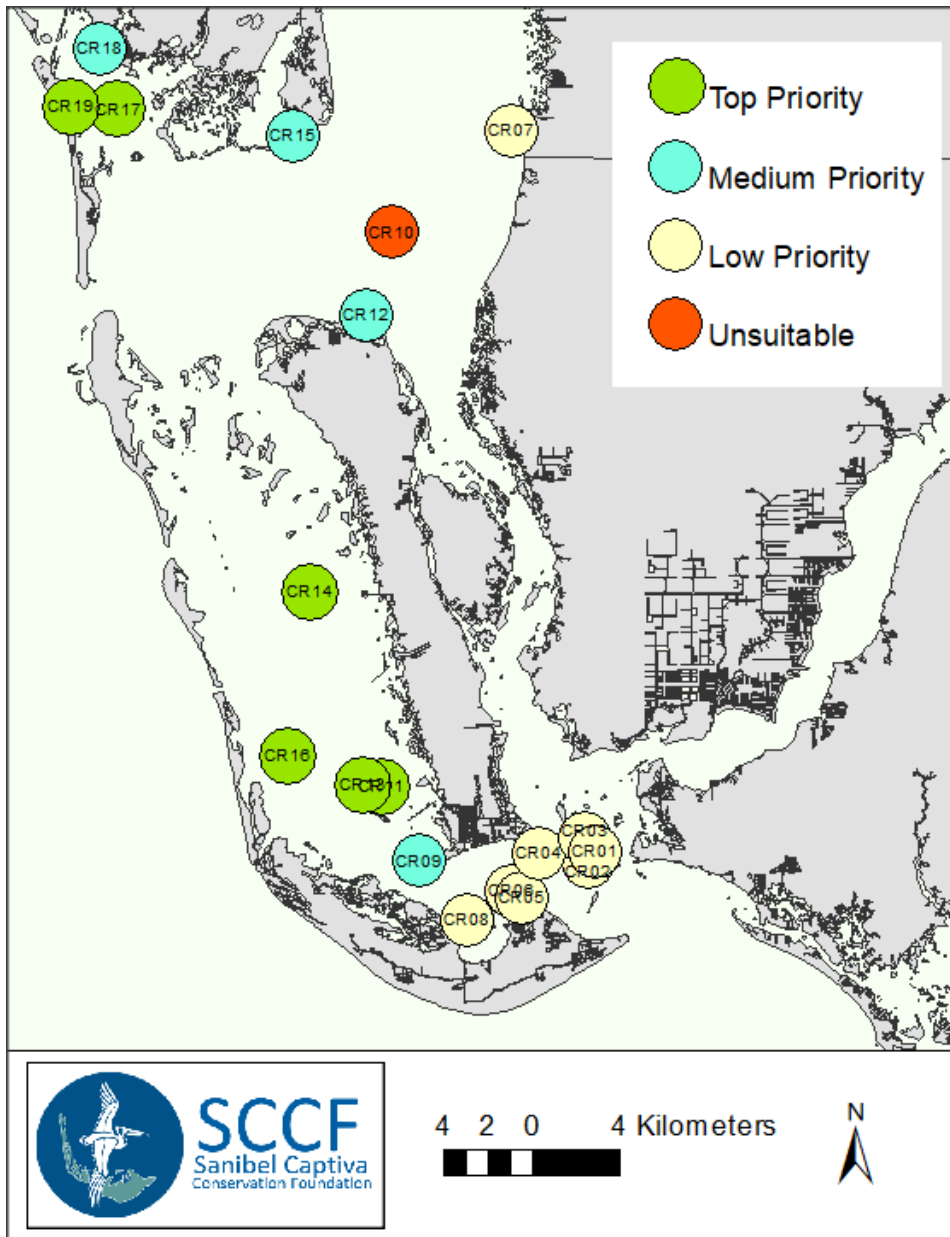


Figure 16. Sites chosen by the working group for further study. The six sites shown in green and the 4 sites in blue were ultimately determined to be most suitable for further field study for this project.

Field Surveys

Analysis of clod card dissolution rates found significant differences existed between sites (ANOVA, $p < 0.01$). Sites 12 (CH-Jug Creek Point Shoal) and 15 (CH-Turtle Bay) had significantly greater dissolution rates while sites 17, 13, 11 and 18 had significantly lower rates compared to the mean (0.131 percent per day) (Figure 17).

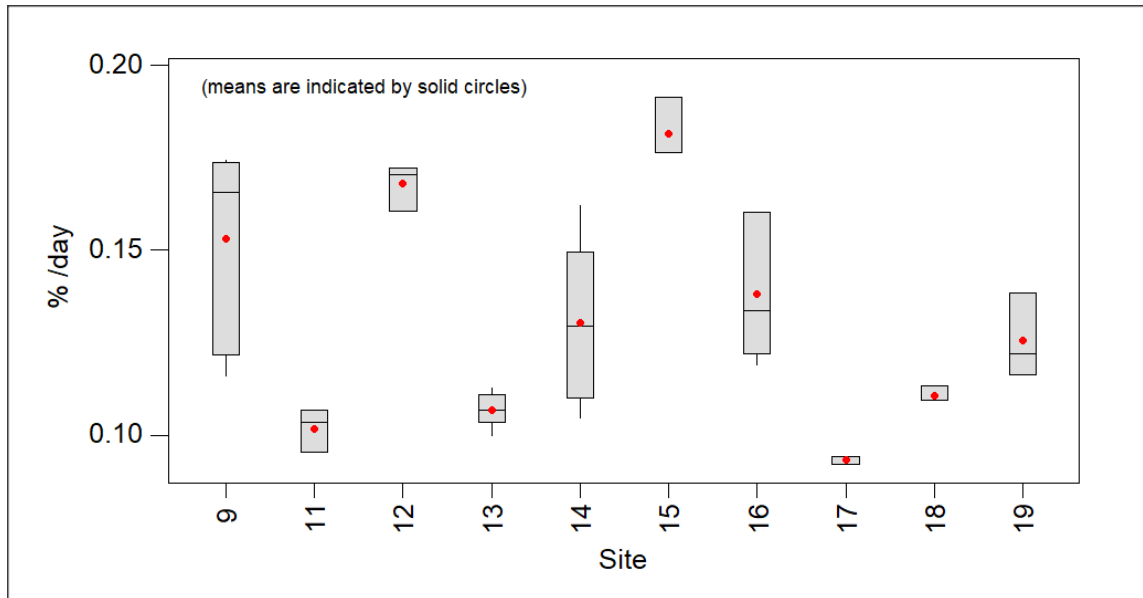


Figure 17. Clod card dissolution rates (%/day) compared between sites. Site 15 was significantly greater than other sites. Sites 11, 17 and 13 had lower relative dissolution.

Significant differences were found for % silt of sediment samples between sites (Figure 18). Site 09 near York Island had a greater proportion of silt than the other sites (ANOVA, $p < 0.01$). Most sites had similarly high proportions of sand (Table 4). Sites 17 (GS-north of Sandfly Key) and 11 (PIS-west of MacKeever Keys) had slightly greater presence of silt but were not significantly different than other 7 sites.

Surveys for adult hard clams found three sites (11-PIS west of MacKeever, 17-GS north of Sandfly Key, 19-GS south of Grouper Hole) had an existing population of *Mercenaria campechiensis* (Table 4). The density at site 11 near MacKeever Keys in Pine Island Sound was greatest at 3 clams m^{-2} . Two other two sites had a density of 1 clam m^{-2} . No *Mercenaria mercenaria* were found. The mean size at site 11 was 73 mm while sites 17 and 19 had 55mm mean clam sizes.

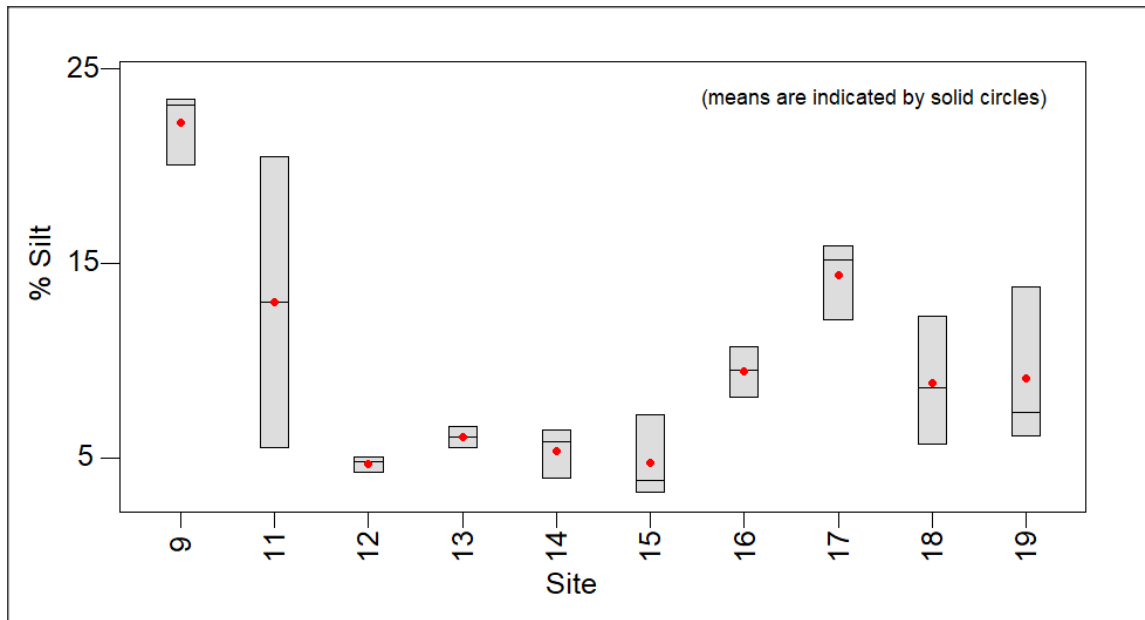


Figure 18. Comparison of bottom sediment composition by site. Site 9 had significantly greater silt than other sites.

Juvenile clams were found at two sites (11-PIS west of MacKeever, 14-PIS north of existing clam leases Demere Key) (Table 4). Site 11 had 125 clams m⁻², while site 14 had 10 clams m⁻². All clams were morphologically identified as *Mercenaria campechiensis*. The mean size of the clams at site 11 was 13mm while mean size at site 14 was 5mm.

Most sites had little or no seagrass present (Table 4). Sites 13 (PIS-north of Chino Island) and 18 (GS-south of Placida) had less than 10 percent cover while sites 14 (PIS-west of Demere Key) and 16 (PIS-northeast of Buck Key) had 10-25 percent cover. All sites except 9 (York Island) and 14 (Demere Key) were characterized as being shelly.

Table 4. Results of field surveys at 10 potential restoration sites.

Site	Survey Date	Mean Adult Clams/m ²	Mean Juvenile Clams/m ²	Mean Adult Size mm	Mean Juvenile Size mm	Mean % Silt	Mean % Sand	Seagrass Cover	Shelly Substrate	Clod Card Dissoluton (%/day)	Relative Flow	Mean Chlorophyll a ug/l	Relative Food Flux
CR09	1/6/2021	0	0	*	*	22.3	77.7	0.0	No	0.15	1.7	15	25.5
CR11	1/6/2021	3	125	73.2	13	13.0	87.0	0.0	Yes	0.10	1.1	6	6.8
CR12	1/12/2021	0	0	*	*	4.7	95.3	0.0	Yes	0.17	1.9	5	9.3
CR13	1/6/2021	0	0	*	*	6.1	94.0	<10%	Yes	0.11	1.2	5	5.9
CR14	1/7/2021	0	10	*	5	5.4	94.6	10-25%	No	0.13	1.4	4	5.8
CR15	1/12/2021	0	0	*	*	4.7	95.3	0.0	Yes	0.18	2.0	5	10.1
CR16	1/7/2021	0	0	*	*	9.4	90.6	10-25%	Yes	0.14	1.5	6	9.2
CR17	1/11/2021	1.2	0	55.14	*	14.4	85.6	0.0	Yes	0.09	1.0	6	6.2
CR18	1/11/2021	0	0	*	*	8.9	91.1	<10%	Yes	0.11	1.2	6	7.4
CR19	1/11/2021	1.2	0	55.08	*	9.1	90.9	0.0	Yes	0.13	1.4	6	8.4

A unitless relative food flux was calculated using a standardized clod card dispersion rate multiplied by the mean chlorophyll *a* value for that site taken from the GIS analysis (Table 4). The highest relative food flux was estimated to be 25 at site 9 (York Island) while the lowest was 5.8 at site 14 (Demere Key). The median food flux was 7.9 with sites 14 (PIS-Demere Key), 13 (PIS-Chino), 17 (GS-Sandfly Key), 11 (PIS-MacKeever Key) and 18 (GS-Placida) being less than the median and sites 19 (GS-Grouper Hole), 16 (PIS-Buck Key), 12 (CH-Jug Creek Shoal), 15 (CH-Turtle Bay) and 9 (PIS-York Island) having values greater than the median.

The final scores of the ten potential sites are provided with comparative site rank (Table 5). The 3 sites with adult clams present were ranked as best potential sites. The sites with the next highest scores were ranked accordingly (Table 5).

Table 5. Scores for factors considered in this evaluation along with potential restoration site rank.

Site	Mean Adult Clams/m ²	Score	Mean Juvenile Clams/m ²	Score	Mean % Silt	Score	Seagrass Cover	Score	Shelly Substrate	Score	Relative Food Flux	Score	Total Score	Rank
CRI1	3.0	9	125	6	13.0	2	0.0	3	Very	1.5	6.8	2.0	23.5	1.0
CRI9	1.2	9	0	0	9.1	3	0.0	3	Shelly	1.0	8.4	2.0	18.0	2.0
CRI7	1.2	9	0	0	14.4	2	0.0	3	Shelly	1.0	6.2	2.0	17.0	3.0
CRI5	0.0	3	0	0	4.7	3	0.0	3	Shelly	1.0	10.1	3.0	13.0	4.0
CRI2	0.0	3	0	0	4.7	3	0.0	3	Some	0.5	9.3	3.0	12.5	5.0
CRI4	0.0	3	10	4	5.4	3	10-25%	1	Some	0.5	5.8	1.0	12.5	5.0
CRI8	0.0	3	0	0	8.9	3	<10%	2	Shelly	1.0	7.4	2.0	11.0	7.0
CRI3	0.0	3	0	0	6.1	3	<10%	2	Very	1.5	5.9	1.0	10.5	8.0
CRI6	0.0	3	0	0	9.4	3	10-25%	1	Some	0.5	9.2	3.0	10.5	9.0
CR09	0.0	3	0	0	22.3	0	0.0	3	Some	0.5	25.5	3.0	9.5	10.0

Discussion and Conclusions

Sites 19 and 17 in Gasparilla Sound and site 11 near MacKeever Key in Pine Island Sound had the native hard clam *Mercenaria campechiensis* present. The presence of adult clams indicates that the environmental conditions at those sites are acceptable for long-term survival. It is hypothesized that these three sites have the greatest potential for clam restoration success. However, the density of adult clams at these sites was below the literature reports of healthy natural clam densities of 10 m⁻² or above. Clam spawning success is density dependent (Arnold et al. 2002). Restoration may increase the densities at those sites and make the clam populations more viable. On the other hand, an environmental factor such as food availability may be limiting

the population density. The food flux at sites 11 and 17 was lower than the median food flux (7.9) found for all sites in the study, while site 19 was near the median. These three sites also had little or no seagrass in the surveyed areas, and shelly, non-silty substrate. In addition, these three top ranked sites were 1-4 miles from existing clam leases, minimizing transport distances if restoration clams were sourced from the leases.

When the 4 priority sites were compared to the hard clam habitat suitability map produced during the initial phase of this project, the two Gasparilla Sound sites (17 and 19) fall within habitat predicted to be less than optimal. The underlying lower suitability score for the habitat in that area was affected by higher maximum temperatures, marginally shallow depths and an open shellfish harvesting designation. Field investigation of the Gasparilla Sound sites was prompted by local knowledge rather than by a high habitat suitability score. The presence of adult clams at two of the Gasparilla sites outweighs habitat suitability predictions. A suitable depth (4-8 feet) was found and the effects of open harvesting and higher maximum temperatures did not negate the other environmental factors which made these sites suitable in the final analysis. Although the habitat suitability analysis would have us shy away from these areas, in the end the on the ground analysis found a population of *Mercenaria campechiensis* present.

A 1962 paper (Woodburn) by the Florida Board of Marine Conservation Marine Laboratory describes the hard clam as being abundant in Gasparilla Sound mostly on the inside of Gasparilla Island in sticky mud with seagrass. The paper also describes Grouper Hole (near site 19) as being one of the most productive hard clam sites in Florida. Two of the three sites investigated for this study in Gasparilla sound had hard clams present. In the 1960's most of the interest in hard clams was directed toward extracting any clams that were present (Woodward 1962). This historical lack of science-based clam fishery management likely contributed to the modern day much-declined hard clam abundance.

Site 9 near York Island had the lowest ranked score and the substrate with the greatest percent silt. While surveying the site, the sediment was easily disturbed producing sustained clouds of dispersed sediments in the water column. Easily disturbed sediments have been shown to be detrimental to clam survival (Bricelj et al. 1984). Although the sediment was poor for potential clam restoration, food flux was greatest at this site with good flow and high chlorophyll concentrations. Additional exploration of the York Island area may yield potential sites near York Island which would be more favorable to restoration.

Site 15 (CH – mouth of Turtle Bay) ranked 4th overall and had the second greatest food flux value. It had no seagrass in the survey area and had sandy, shelly substrate. This area was suggested by current clam farmers as a potential relocation area. It is approximately 6 miles from current clam farm leases in Gasparilla Sound.

Clams harvested for market are classified by size. The adult clams found at the MacKeever Key site (11) would be classified as “chowder clams” and are the least marketable size due to toughness once they get older. Clams found at the two Gasparilla Sound sites (19 and 17) would be classified as “cherrystones” and are more marketable. The most marketable size is “little neck” which measure 25-40 mm.

The growth of *Mercenaria campechiensis* is reported to be logistic with a size asymptote of ± 80 mm being approached at about 7 or 8 years in Charlotte Harbor (Jones et al. 1990). The adult clams found at our sites ranged from a mean of 55 to 73mm with an estimated age range of 3-5 years (Jones et al. 1990). The maximum age of *M. campechiensis* in Charlotte Harbor is estimated to be 20-30 years. The clams found in our survey were not yet full-sized adults but were larger than optimal market size. The origin of hard clam populations at these three sites may be related to nearby clam farming operations or may be natural stock. None of the native clams that we found in this study had “notata” markings on the shell which are often found on aquaculture clams (Arnold et al. 2009).

Juvenile clams were found at Site 14 adjacent the PIS clam leases at Demere Key, yet no adult clams were discovered. The survey method may not have been fine enough to detect any low density of adult clams there or other environmental conditions such as predation or competition from nearby farming leases may interfere with survival. The relative food flux for site 14 was the lowest among the sites surveyed in this study. It was also the site closest to an existing clam lease (140 meters).

Two sites surveyed for potential restoration (14 and 16) had seagrass cover estimated to be above 10 percent. Although seagrass presence has been shown to improve food availability for hard clams (Judge et al. 1993), permitting agencies prefer restoration efforts take place in areas which have no seagrass. Site 14 is adjacent to existing clam farm leases in Pine Island Sound and site 16 NE of Buck Key in Pine Island Sound had relatively higher seagrass coverage compared to other potential sites. If either of these areas is of interest for potential restoration efforts, a wider sweeping survey would be needed to find suitable sized patches with little seagrass.

Based upon the information collected in our field surveys and through the GIS-based habitat suitability analysis, four sites are recommended for further consideration as initial clam restoration sites (Figure 19, Table 6). Three of the sites (sites 11, 19, and 17) have adult clams in low concentrations while the fourth (site 15) site has high relative food flux, no seagrass cover, and sandy-shelly substrate. Site 17 is located north of Sandfly Key in Gasparilla Sound. Site 19 is located near Grouper Hole in Gasparilla Sound. Site 11 is located west of MacKeever Keys in Pine Island Sound, and site 15 is in Charlotte Harbor just south of Turtle Bay. All sites are located in 6-8 feet of water, have salinity and oxygen regimes suitable for clam survival, and little or no seagrass. These sites also provide nearby choices for farmers working leases in Pine Island Sound, Gasparilla Sound or the Charlotte Harbor area. Although other sites surveyed during this study were ranked lower in the analysis, any of them except site 9 near York Island would potentially support a clam population.

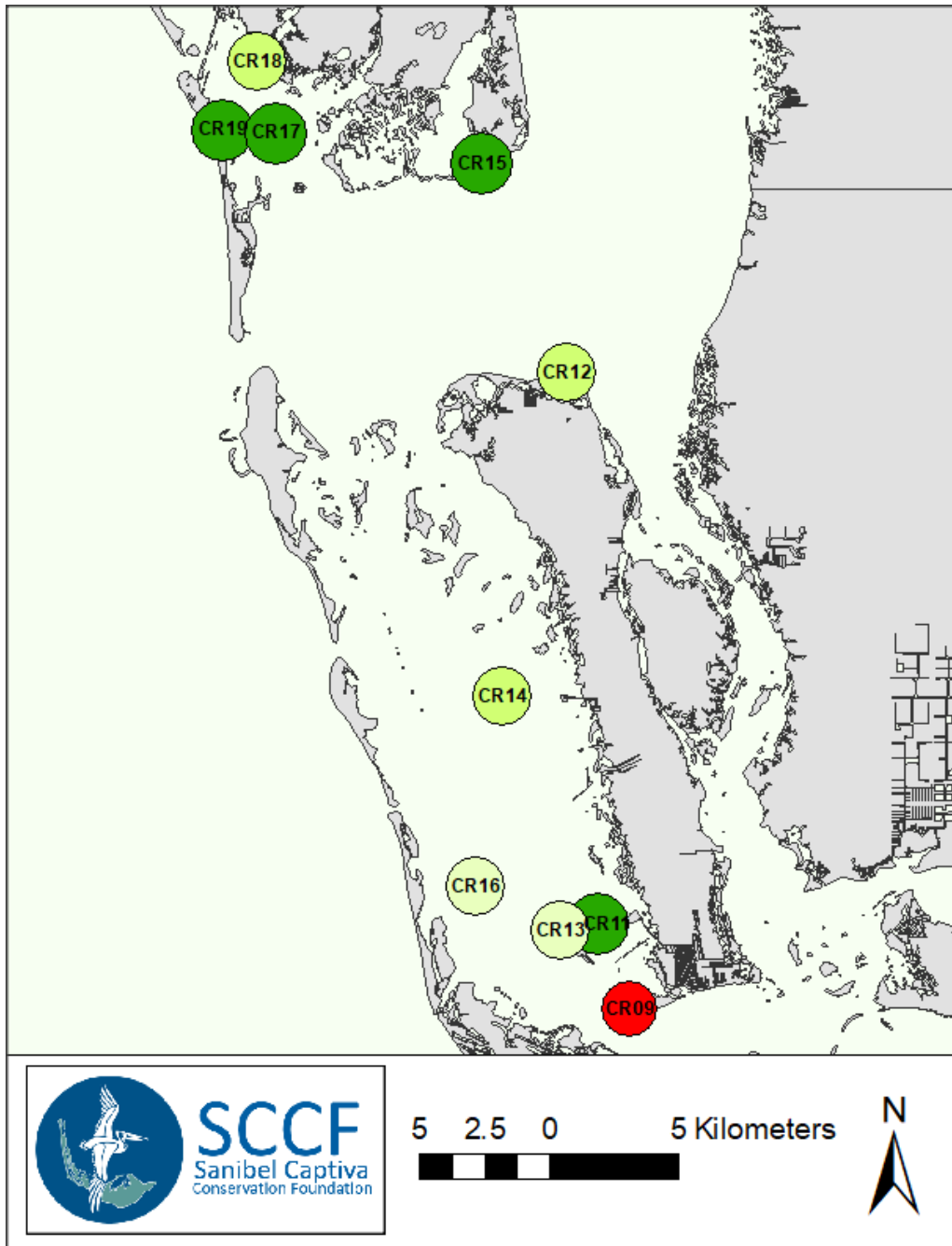


Figure 19. Location of sites recommended for hard clam restoration projects through the work in this project. Dark green are preferred sites. Medium green are next best ranked and light green are lower ranked of the ten sites surveyed in field. The site shown with red is not suitable due to unconsolidated sediments.

Table 6. Sites recommended by this project (by rank) for future clam restoration work.

Site_ID	SiteDescrp	Lat	Long	Rank	Waterbody
CR11	Pine Island Sound West McKeever Keys	26.51422985870	-82.12506125710	1	Pine Island Sound
CR19	Grouper Hole off Boca Grande	26.79385540200	-82.26451181090	2	Gaspirilla Sound
CR17	North Sandfly Key	26.78959671370	-82.24588205720	3	Gaspirilla Sound
CR15	CH at Southern Mouth Turtle Bay	26.77915158590	-82.16569241180	4	Charlotte Harbor
CR14	Pine Island Sound West Demere Key Near Clam Leases	26.59334017870	-82.15758863240	5	Pine Island Sound
CR12	CH N of Bokellia S of Jug Creek Point Shoal	26.70623211270	-82.13270706030	5	Charlotte Harbor
CR18	South of Placida	26.81429562470	-82.25313409460	7	Gaspirilla Sound
CR13	Pine Island Sound North Chino Isalnd West McKeever	26.51465703390	-82.13393090260	8	Pine Island Sound
CR16	Pine Island Sound NE Buck Key Near Bar	26.52673100600	-82.16817702250	9	Pine Island Sound
CR09	Pine Island Sound SW of York Island	26.48399951960	-82.10842993270	10	Pine Island Sound

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