KEYS RESTORATION FUND

APPENDIX B: PAST KEYS SEAGRASS RESTORATION PROJECTS - REVIEW AND COST ANALYSES REPORT

Final Report

May 15, 2015

Prepared for

U.S. ARMY CORPS OF ENGINEERS
Regulatory Division - Jacksonville District
P.O. Box 4970
Jacksonville, FL 32232-0019

Prepared by

COASTAL RESOURCES GROUP, INC.
Sponsor of:
Keys Restoration Fund In-Lieu Fee Mitigation Program (KRF)
11449 Calhoun Ct.
Venice, FL 34293

EXECUTIVE SUMMARY

The purpose of this review is to evaluate past methods and associated costs for multiple seagrass restoration projects located in the Florida Keys and provide recommendations for cost-effective, reliable procedures to accelerate recovery of damaged seagrasses in the area. Information presented and evaluated will be used to determine what costs should be assessed and at what price advanced credits (AC) should be sold to ensure "full cost recovery" of seagrass restoration within the Keys Restoration Fund (KRF) In-Lieu Fee Program service areas.

Efforts to restore the seagrass species *Halodule wrightii* (shoal grass), *Syringodium filiforme* (manatee grass) and *Thalassia testudinum* (turtle grass) by removing fill from submerged lands or filling previously dredged areas, enhancing impounded lagoons, and restoring boat caused prop scars and grounding sites with blow holes has been underway in the Florida Keys and surrounding areas for over 30 years. The motivation to accomplish restoration of Keys seagrass habitats has included actions required by state and federal enforcement and/or legal actions (especially in the 1980s and 1990s), restoration for the sake of restoration (1990s), and the restoration of vessel impacts (late 1990s and 2000s). Many previous projects were opportunistic with methods suited to location and prior conditions. Current standard restoration methods used for vessel impacts depends on the severity of damage, the likelihood of natural recovery without intervention, and the selective use of various techniques for restoration as needed to stabilize damaged areas, and encourage recovery back to reference conditions. The actual cost of a particular technique has not previously been a primary guiding factor in choice of methods or locations and is often not documented in project reports making it difficult to adequately determine what "full cost recovery" is (generally pre-construction design, permitting, project construction and long term monitoring).

This review documents reports actual or theoretical expenditures found in reports (14 locations) or resulting from interviews with project managers (31 locations) at a total of 45 locations in the Florida Keys. On a per square foot restored basis, costs range from $0.53 to $50.30, with a mean 2013 cost of $22.33 ($972,694 per acre). This is in contrast to the lower base rates charged by the previous Keys Environmental Restoration Fund (KERF) program which ranged from $4.54 to $5.30 per square foot in 2013 costs.

The current Advanced Credit fee for seagrass impact mitigation was raised to $10.00 per sq foot of restoration as part of the new ILF Instrument prepared by KRF and applies to new permits issued after July 1, 2013. This credit fee was an estimated cost for seagrass restoration determined by the principals of KRF without any detailed data analyses and represented a step by KRF and the Corps of Engineers to bring the transferred program into compliance with the *2008 Final Compensatory Mitigation Rule for In-Lieu Fee Programs.*

Based upon this review of past project costs, two options were proposed to the Interagency Review Team in July 2014. The first option is to raise the per square foot base rate to an amount that would cover the required full cost accounting for a mixture of possible seagrass restoration options proposed by KRF and approved by the Army Corps of Engineers, the IRT, and the submerged land managers in the Keys where restoration activities are proposed.

The second option is to leave the current base rate at $10.00 and adjust the types of projects and methods used for offsetting permitted seagrass losses to only those costing less than or equal to that amount. This option would have included a renewed focus on topographic restoration of historic submerged lands subjected to dredging and filling in the past and addressing vessel impacts with bird stakes only, or perhaps emphasizing improved channel and boating restricted zone marking and boater education. Monitoring and reporting of seagrass recovery using specific methods applied to various types of sites would be essential for all options proposed.

After extensive review of these options the Army Corps of Engineers approve revising the per square foot rate to $25 ($1,089,000 per acre = per credit) by letter dated May 13, 2015.

INTRODUCTION

Seagrass habitat loss caused by dredging and filling, physical damage from motor vessels, and water quality declines (Lewis et al. 1985, Johansson and Lewis 1992) can have numerous adverse effects on seagrass systems and have become a widespread problem in Florida seagrass meadows (Sargent et al. 1995; Kenworthy et al. 2002; Whitfield et al. 2002). Dredging and filling permanently impact viable seagrass meadows while vessel damage including propeller scarring and hull groundings damage seagrass meadows by disrupting the seagrass rhizome matrix, through the excavation of sediments, and by destruction of the reservoir of available plant nutrients. The result of this kind of damage is often nutrient-depleted, unvegetated prop scars and blowholes that require some level of intervention to facilitate recovery. In some cases, vessel injuries may be more than a meter deep, several meters wide, and hundreds of meters long.

Of the three seagrass species found in the Keys, *Thalassia testudinum* (turtle grass) is the climax species and recovery of the slow-growing species can take decades in large blowholes (Whitfield et al. 2002; Kenworthy et al. 2002). The exposure from vessel injury is compounded by boat wakes, currents, wind turbulence, and severe storms (Whitfield et al. 2002). In addition, dredging and filling and the impoundment of former mangrove and seagrass lagoons associated with road construction and shoreline development in the Keys have destroyed hundreds of acres of seagrass (Lewis et al. 1994). The resulting habitat loss and fragmentation can negatively impact fauna that utilize seagrass beds (Bell et al. 2001; Uhrin and Holmquist 2003), thereby compounding the damage to seagrass ecosystems from all causes.

Locations such as the Florida Keys are particularly susceptible to propeller scarring and grounding events because many seagrasses in the region occur at depths of < 2m, and boating activities are quite intensive due to the high population density and the large number of tourists. As a consequence, vessel damage in many parts of the Keys is now a major source of habitat destruction. In 1995 it was estimated that 30,000 acres of seagrass beds in the Florida Keys National Marine Sanctuary (FKNMS) were moderately to severely scarred by boat propellers (Sargent et al. 1995). Recent estimates suggest that 300 to more than 650 boat groundings occur in the FKNMS on an annual basis, and up to 80% of these take place in seagrass beds (Kirsch et al. 2005, SFNRC 2008, Farrer 2010). In addition to physical impacts to seagrass, other impacts including the disturbance of fish and wildlife, especially birds by noise and human activity in shallow near shore habitats is a growing concern. As Florida's population increases, boat-related damage to seagrass beds will undoubtedly become worse.

In response to wide-spread vessel impacts and historical losses of seagrasses due to dredging and filling, water quality issues, and impounded lagoons, resource agencies have made numerous attempts to minimize current seagrass damage through regulation of dredging and filling and through management actions such as increased channel marking, establishing motorboat caution and exclusion zones, enforcement, and implementing public education programs. Even with these efforts, propeller scarring and vessel groundings still occur at an alarming rate and as a result resource agencies generally express great interest in having reliable options for enhancing recovery rates of extensively damaged areas under their management that can be implemented in a timely fashion and at a reasonable cost. It is our objective in this report to review past seagrass restoration projects to evaluate the alternatives and associated costs, with

some assumptions, and provide recommendations to achieve collective restoration goals. This information will help our in-lieu fee program determine the most cost effective approaches to restoration and determine an appropriate credit fee schedule to implement these projects. In addition, knowledge gained from this review will provide all resource managers a new perspective for full cost recovery of seagrass restoration projects.

METHODS

To adequately evaluate information on historical seagrass restoration efforts, including cost estimates in the Florida Keys and adjacent similar efforts in Biscayne Bay and Everglades National Park, we reviewed all available information and selected fourteen seagrass projects that were completed or ongoing between 1983 and 2013.

We note that the actual successful restoration of a prop scar or grounding site back to reference conditions of mostly turtle grass with similar cover to adjacent reference conditions, has been rarely documented in the Keys. Usual success criteria are 50% coverage by any seagrass species within three years (Hobbs 2007). Sufficient monitoring time needed to document recovery back to reference conditions in a predominantly turtle grass bed has only been reported, to our knowledge, at Craig Key by Lewis et al. (1994) and was observed at a second site in the Lignumvitae Key Submerged Lands Managed Area (LV) (Site #8 in Table 2) in October 2013. The LV site monitoring reportedly achieved full restoration of turtle grass approximately fourteen (14) years after restoration efforts began. This is the same interval for recovery back to apparent reference conditions reported by Lewis et al. (1994). The factor of "time lag" associated with full restoration of predominately turtle grass meadows is one of several critical factors when determining full cost recovery.

When looking at costs of restoration, we reviewed the discussion in King (1991) where he quotes Marylee Guinon as stating that "discrepancies between reported and true restoration costs…due to hidden costs and inaccurate cost data, are the rule rather than the exception and can be astoundingly large." We also note that King and Bohlen (1994) reviewed the data available at that time and although they report data for 578 projects, 494 of these were only agricultural conversion to previous wetlands through minor drainage modifications such as crushing and blocking drainage tiles at a typical 1993 cost of $1,000 per acre restored. No pre-construction or post-construction costs were assumed for these simple projects, so we did not use them in our calculations of typical wetland restoration costs nor the percentage of total costs for various categories. Using the remaining 84 projects, we averaged the pre-construction, construction and post-construction percentages of the total cost of a project type and calculated a mean value of 71.6% of the total costs were construction related, and 28.4% were related to pre-construction and post-construction activities such as planning, permitting, surveying, monitoring and reporting (we refer to these as "other project costs").

The importance of this is that we find some of the projects we looked at had good construction cost accounting, but little or no pre-construction and post-construction costs. Often agency personnel do monitoring and reporting and do not keep track of their time and costs, or use direct salary costs without accounting for benefits or overhead. Similarly, Spurgeon (1998) reports on costs of seagrass restoration as ranging from $22,230 to $1,689,480 per hectare ($9,000 - $684,000 per acre) in 1997 costs, but also states that these costs do not include any pre- or post-construction costs. Even without those, this range of costs converted to 2013 costs would result in cost estimates of $1.31 - $99.33 per sq ft.

If other costs were 33.3% of the project costs, and construction was 66.7% of the costs, then you could estimate other costs when they were not available as 50% of construction costs (33.3/66.7). Similarly for the data set in King and Bohlen (1994) the ratio is 28.4/71.6 or 39.7%. We therefore will use 40% of the construction costs where available to estimate other costs to determine the most likely total cost of a project where "other project costs" are not provided.

In other cases, documents were reviewed that provided information regarding methods for seagrass restoration however, were lacking in details of restoration success and/or costs needed for this review or had unrealistic costs. For example, the data of King and Bohlen (1994) was updated by King (1998) and the cost of "aquatic bed" restoration was given as $45,000 per acre equivalent to $65,315 per acre in 2013 costs or $1.50/sq ft. As noted in the following sections, these do not appear to be realistic cost estimates for genuinely successful projects.

After reviewing all available reports, fourteen specific documents and/or projects presented information we felt supported our efforts in determining the most cost-effective seagrass restoration methods and/or provided useful project cost details. An additional thirty-one projects were lumped together in terms of costs and an average figure provided. This information is found in seagrass restoration summary documents, management plans and reports from Biscayne National Park, Everglades National Park, Florida Keys National Marine Sanctuary and NOAA, and other sources including reports from the prior Keys Environmental Restoration Fund and personal communications with Florida Keys seagrass restoration experts.

RESULTS

Summary Document Review

Kruczynski and Fletcher (2012) is considered one of the most up-to-date summary documents about South Florida marine resources and their management. Chapter 5 (pages 247-294) is the chapter on seagrass habitats, and includes discussion regarding human impacts to seagrasses and restoration of damaged sites. Notably, however, the largest seagrass restoration project in the Florida Keys, the Keys Bridges Replacement Project (134 acres of successful mitigation or natural recovery) (Lewis 1987, Lewis et al. 1994) is not mentioned nor referenced.

Another significant seagrass restoration project in South Florida, the Miami Seaport Facility seagrass mitigation project (238 acres of attempted seagrass restoration) (Lewis 1987) is mentioned in a summary document (Milano 2012), and the lack of success described. Milano (2012) also briefly describes fifteen completed seagrass restoration sites in Biscayne Bay, stating that [M]onitoring for long-term success is conducted at all sites…" however we have been unable to find any data on these projects. Milano (2012) describes six "lessons learned" important when determining the best methods to use at a seagrass restoration site which include:

1. Water quality, including turbidity, and physical site conditions (e.g., current substrate type, depth, wave energy), have been found to be important factors determining the success of seagrass restoration efforts.
2. Seagrass planting is generally more successful when restoration is conducted at sites where a seagrass community previously existed, provided that conditions have improved to allow seagrass recruitment and survival.
3. Specific restoration methodologies have been developed for various types of seagrass restoration. Restoration efforts are underway to restore damage caused by propeller scars and boat groundings, as well as the filling of previously dredged areas in Biscayne Bay.
4. Seagrasses have been documented to naturally recruit into stabilized restored bay bottom.
5. Herbivory has been observed to occur in newly transplanted restoration areas. Evaluations are underway to develop recommendations for the transplanting of restored sites to maximize success.
6. Enhanced navigational signage, boating education programs, and motor boat exclusion zones are effective management tools to protect and conserve seagrass communities.

Biscayne National Park (BNP)

The Biscayne National Park (BNP) Draft General Management Plan (National Park Service 2011) based upon Milano (2012) suggests at least 15 completed seagrass restoration projects had been completed and monitored. No references to seagrass restoration in BNP were found in the document, nor were citations to reports about seagrass restoration in the literature cited in the document. Seagrass damage was noted to occur in BNP with the emphasis upon better channel marking and closed internal combustion engine zones (i.e., pole and troll zones) to control future damage.

Bourque (2012), describing her dissertation work in BNP, states that "…over fifty sites…" [seagrass restoration sites] have been restored in BNP since 2003 (p. 5). However, no specific sites are described as to methods or results although general patterns of recovery are discussed in some detail and recommendations made as to future methods of restoration. Specifically, topographic restoration is endorsed, but the routine use of bird stakes and transplanting of shoal grass are recommended with caution based upon the limited time frame data discussed in the document.

Importantly, given our interest in cost-effective seagrass restoration and protection, none of the above documents cite real costs for these projects, nor make recommendations to maximize success at a minimum cost.

Everglades National Park (ENP)

Essentially all of the submerged lands in Everglades National Park (ENP) are within Monroe County, and thus any activity within ENP related to seagrass management and restoration has direct bearing on the Keys and the question of success of various methods of seagrass restoration and their cost. ENP has been actively studying seagrass management and has released several work products. As a result of the development of several alternatives in its ongoing work to complete the ENP General Management Plan (NPS 2013), ENP funded a study of propeller scarring of seagrasses in Florida Bay (NPS 2008) and an aerial survey study of boater use in the waters of the park (Ault et al. 2008).

Recently ENP circulated a draft seagrass habitat restoration management plan (Atkins 2013) that includes detailed recommendations but no new information relative to seagrass restoration methods and no information on restoration costs. It largely refers to Fonseca et al (1998) and NOAA and FDEP (2004) for recommended methodologies. It does recommend adoption of a number of management alternatives including extensive pole and troll zones (PTZs) covering about 33% of Florida Bay or about 132,000 acres where internal combustion engines would be prohibited, more law enforcement, and better signage including more channel markers. Finally, for large vessel grounding sites it recommends a relatively new concept a "Rapid Damage Control Plan" ["Pre-settlement Emergency Restoration" in NOAA and FDEP (2004), p. 79]. Goals of this new approach are to put obvious disturbed surficial sediments and disturbed plant materials back into the damaged area along with additional fill as needed to achieve rapid topographic restoration and some placement of restoration plant materials before months or years pass waiting for a detailed restoration plan to be designed, permitted and funded. The implementation of such "emergency" plans are designed to prevent the damaged area from increasing in size through erosion thus increasing long-term costs to restore a site.

Florida Keys National Marine Sanctuary (FKNMS)

NOAA and FDEP (2004), in the Final Programmatic Environmental Impact Statement for Seagrass Restoration in the Florida Keys National Marine Sanctuary (FKNMS) list restoration alternatives for seagrass habitats impacted by vessels, typical site conditions for that alternative, and the desired result as shown in Table 1.

While no specific costs are associated with these individual approaches, the report does include a detailed design and cost estimate for a hypothetical grounding site restoration (Appendix A, p. 66) which is updated on page 90 to be equivalent to $2,426,000 per hectare (2004 costs) without including assessment or follow-up monitoring costs. Using this figure updated to 2013, the amount is $3,007,123 per ha or $27.94 per sq ft ($1,216,920 per acre).

Table 1. Seagrass Restoration Alternative Matrix/Comparison (NOAA and FDEP 2004).

ALTERNATIVE	SITE CONDITION	RESULT
1. No Action: Leaving the injury untouched.	Chosen for injuries where there is a relatively small likelihood of secondary injury before natural recovery occurs, or where any restoration is considered too difficult to undertake due to high-energy conditions.	• Natural recovery occurs on a longer time scale relative to restoration activities. OR • Further deterioration of the seagrass bed occurs due to ineffective natural recovery.
2. Seagrass Transplants: Planting seagrass (*S. filiforme* and *H. wrightii*) taken from donor sites in injured areas including berms, blowholes and/or propscars.	Often selected at low to moderate energy sites, where the probability of transplant loss due to high water velocity is lowest.	• Stabilization of sediments decreases injury recovery time. • Planting faster growing opportunistic species like *H. wrightii* or *S. filiforme* serves as a temporary substitute for the climax species, *T. testudinum.*
3. Bird Stakes: Insertion of stakes upon which birds roost, dropping their feces on and thus fertilizing seagrass beds. Inserted into berms, blowholes and/or propscars.	Used on seagrass beds in water depths of 1.5 meters or less (mean high water).	• Bird feces reach the seagrass floor for as long as the stakes are in place. • Colonization of seagrasses into disturbed sediments is facilitated and/or seagrass transplants grow at a faster rate than natural recovery. • Fertilizer is released regularly over an area of approximately 3 square meters below the stake
4. Fertilizer Spikes: Insertion of chemical fertilizer spikes that release fertilizer into the sediments of replanted seagrass beds over a period of 3-4 months. Inserted into berms, blowholes and/or propscars.	Used on replanted seagrass beds when water depths are greater than 1.5 meters or when bird stakes are inappropriate due to hazards to navigation or risk of vandalism.	• Colonization of seagrasses into disturbed sediments is facilitated and/or seagrass transplants grow at a faster rate. • A concentrated dose of nutrients is delivered in a small area that directly benefits individual planting units.
5. Sediment Fill: Filling of blowholes or wide propeller scars with sediment similar to that of the surrounding area.	Used for injuries greater than 20 cm deep.	• The seafloor is rapidly returned to its original grade. • The substrate is stabilized quickly after an incident to prevent further deterioration from erosion and to prepare the area for colonization by neighboring or transplanted seagrasses.
6. Sediment Tubes: Placement of biodegradable sediment-filled fabric mesh tubes inside the trench of a propscar or blowhole.	Often used in narrow excavations (such as propscars) deeper than 20 cm or to cap fill placed in larger blowholes in high-energy environments.	• Erosion rates are reduced. • Conditions are made more suitable for natural re-colonization of the injured area by neighboring seagrasses and growth of transplants is fostered.

Requests were made to the FKNMS for available reports on previous or ongoing seagrass restoration projects. A total of 46 incidents have been noted by them during the period 2001-2007, and available restoration plans were provided, though many did not list the potential or actual costs of restoration. Monitoring reports were also provided, but in most cases the costs for many of these projects were not mentioned in the monitoring reports. For 18 of the 46 incidents, it was noted that the site "recovered naturally." We were able to extract costs for five incidents

(*Heidi Baby*, *Julia Reanne*, *Lucky One*, *Kristal* and *True Justice*). The updated 2013 costs per square foot were $16.03 for *Heidi Baby*, $35.18 *Julia Reanne*, $50.30 for *Lucky One*, $46.03 for *Kristal* and $6.83 for *True Justice* (Table 2). As with the range of costs from KERF (2013) data discussed below, the lower costs were associated with minimal or no fill placement, just seagrass transplanting and bird stakes, while the higher costs are associated with more fill placement plus transplanting and stakes.

The most recent seagrass restoration work (fill, transplanting and bird stakes) was carried out by FKNMS and a contractor in February 2014 at the January 2011 Upper Keys grounding site of the vessel *Sari III* (NOAA and FDEP 2013). Contracted costs to restore 242 square feet of the impact site were $8,200 or about $34/ft2 (S. Werndli, FKNMS, personal communication), and these costs include only on site restoration costs with no pre-construction or post-construction costs. In addition, information provided by the FKNMS reveal that due to the time lag (3+ years) in addressing the physical damage at the *Sari III* impact site, erosion resulted in a doubling of the area of impact from about 122 ft2 to 242 ft. We will include this information in our Table 2 when a Time Zero report is made available.

Lignumvitae Key Submerged Lands Managed Area

Addendum A was provided by Janice Duquesnel of the Florida Park Service and lists 31 individual projects within LV of which one project (#29) reports complete costs. Duquesnel (personal communication 2013) estimates that the average cost for topographic restoration with .25" pea rock fill mixed with lime rock screenings and no use of sediment tubes has averaged $22-$25 per square foot ($958,320 - $1,089,000 per acre). It is our understanding that this estimate does not include "other project costs".

Keys Environmental Restoration Fund

KERF (2013) and Hobbs et al. (2006) provide descriptions and costs for 59 projects completed by the various iterations of the "Keys Restoration Fund" from 1982 to 2013, many but not all were funded by mitigation fees. Eleven of these included some seagrass restoration, and six were for seagrass restoration projects only. The total seagrass area restored for the eleven projects was 6.82 acres. For the six Fund projects addressing seagrass restoration only, the updated 2013 costs per square foot ranged from $0.53 (LV stake array) to $44.99 (Peterson Bank trench fill project) or $23,087 to $1,959,764 per acre. This range over two magnitudes (for vessel impacted sites) reflects the use of different techniques to restore seagrass and the varying depths of restoration sites, where in general, the deeper the site, the more fill needs to be placed to bring the bottom elevations up to grade to support either planted or naturally recruiting seagrass (topographic restoration). The least expensive project (LV stake array) only placed bird stakes over prop dredged and scarred seagrass and blocked additional damage from boats leaving a channel (Kruer 2001) The most expensive project placed fill in an approximately 5 foot deep grounding site in 2013 (Site # 11 in Table 2) and is still being monitored (KERF 2013). Thus for the latter site, all costs are not yet accounted for.

For the Egret Island project, for example, two phases are described. The first involved no seagrass restoration and the cost listed is $255,254 (2012). The second includes 0.5 acre

of seagrass restoration with a listed 2012 cost of $125,058. These total $380,312 or $385,883 in 2013 costs. This is in contrast to the total project costs in 2004 of $409.455 listed in the Time Zero report (p 11). This is equivalent to $504,952 in 2013 costs. The discrepancy is due to the lack of inclusion of other incurred costs by Monroe County including removal of the bridge and partial removal of the land side approach where the seagrass restoration took place.

The cost issue is further complicated by the fact that removal of the bridge was an essential part of the seagrass restoration project as access to the landside fill underneath would not be possible without it, and bridge removal itself did not result in any restoration of habitat. So how do you accurately assign costs associated with the bridge removal and partial removal of the land side approach fill to the total cost of the seagrass portion of the restoration project as listed by KERF? Unfortunately the numbers in the Time Zero report and the 2006 summary report and the 2013 table do not match up.

We think it would be safe to use half the total bridge removal cost and all the land side fill removal costs adding both the amount KERF spent and the amount Monroe County spent. We are still trying figure out what those costs actually were. Adding half of the bridge removal costs would add $60,428 to the seagrass restoration costs. Monroe County's fill removal costs are unclear from the record. No monitoring or reporting costs were included in any of these estimates.

In any case we think it is safe to say that the previous estimate of $5.85 per sq foot of seagrass restored would likely double with these additions. Thus this becomes in at about $11.70 per square foot, which is near but slightly over our current $10 per square foot recommended advanced credit charge for seagrass impacts.

Additional Seagrass Restoration Resources

The Florida Department of Transportation Houseboat Row Seagrass Mitigation project (FDOT and Stantec 2013) was examined for methods and 2013 costs. Phil Frank, Ph.D., of Terramar Environmental Services, Inc., provided costs for the construction of the project and the transplanting of seagrass. Total construction and seagrass transplanting costs were $1,136,000 for 2.6 acres of seagrass restoration. These costs do not include design, permitting, monitoring or reporting (P. Frank, personal communication). Using the data from King and Bohlen (1994), as previously discussed, we calculated that pre-construction and post-construction costs for a wide variety of wetland restoration projects typically amount to 40% of the construction costs alone. We discussed using a figure around 33% with Dr. Frank and he agreed that was likely a fair estimate. We have therefore taken 40% of the construction and planting costs and added it to the construction costs alone to give the best estimate of the total cost of all items related to this project. This total is $1,590,400 in 2012 costs. Updated to 2013 costs this is $1,614,471. Divided by 2.6 acres of resulting seagrass restored, this produces a per acre cost of $620,950, and per square foot cost of $14.26.

Comparably, Fonseca et al. (2002) quantifies cost estimates for a federal court case regarding seagrass damage and estimated costs for restoration at $940,000 per ha. Updated to 2013 costs, this figure is $566,475/ac or $13.00/sq ft.

Based on long-term knowledge of Keys habitat restoration projects KRF attempted to list and document all Keys seagrass restoration projects (other than attempted restoration of vessel impacts) and these are summarized in Addenda B, C, and D as either topographic, hydrologic, or transplanting projects, respectively. Few of these projects have costs associated with them due to the lack of historic information. Although only rough estimates are possible for some of the larger hydrological projects, this summary suggests that since the early 1980s approximately 56 acres of Keys seagrass habitat have been recovered through topographic restoration of submerged lands, 110 acres through hydrological enhancements, and 48 acres via transplanting seagrasses.

Table 2. Summary of fourteen seagrass restoration projects and approximate full restoration costs.

SITE	YEAR COMPLETED	METHODS	2013 TOTAL COST	2013 COST PER FT^2	REFERENCES
1. House Boat Row	*2012*	*Fill and Transplant*	*$1,614,471**	*$14.26*	*FDOT and Stantec 2013, Phil Frank (pers. comm).*
2. Heidi Baby	*2005*	*Fill, Stakes and Transplant*	*$89,704***	*$16.03*	*NOAA 2009*
3 Julia Reanne	*2006*	*Fill, Stakes and Transplant*	*$73,933***	*$35.18*	*NOAA 2007A*
4. Lucky One	*2006*	*Fill, Stakes and Transplant*	*$27,513***	*$50.30*	*NOAA and FDEP 2006, 2007*
5. Kristal	*2008*	*Sediment tubes, Stakes and Transplant*	*$41,312***	*$46.03*	*NOAA 2007B, Bailey 2011*
6. True Justice	*2002*	*Stakes and Transplant*	*$46,092***	*$6.83*	*Anderson and Farrer 2011, NOAA and FDEP 2002*
7. Egret Island Phase 2	*2004*	*Road Removal Only*	*$254,422*	*$11.70*	*Hobbs et al.2006, KERF 2013*
8. Lignumvitae Phase 1 Scar Repair	*1999*	*Fill and stakes followed by sediment tubes and planting in part (2002?)*	*$59,061.66*	*$21.40*	*Kruer 2001, McNeese et al. 2006, Hobbs et al. 2006, KERF 2013, Hall (pers. comm)*
9. Lignumvitae Phase I Stake Array	*1999*	*Stakes only*	*$9,818*	*$0.53*	*Kruer 2001, Hobbs et al. 2006, KERF 2013*
10. Lignumvitae Phase 2 (2 projects)	*2005*	*Fill, Stakes and Planting*	*$124,241*	*$14.26*	*Hobbs et al. 2006, KERF 2013*
11. Lignumvitae Phase 3	*2013*	*Fill only*	*$215.947****	*$44.99*	*Hobbs et al. 2006, KERF 2013, Hobbs 2013*
12. Middle Torch	*1983*	*Fill Removal*	*$11,430*	*$10.15*	*Hobbs et al. 2006,*

Key Circulation Cut					*KERF 2013*
13. Hypothetical FKNMS PEIS Seagrass	*2004*	*Fill, Stakes and Transplant*	*$28,741*	*$27.94*	*NOAA and FDEP 2004*
14. Potential Restoration for Federal Court Settlement	*1996*	*Planting only*	*$566,475*	*$13.00*	*Fonseca et al. 2002*
Mean of all Per Square Foot Estimates				**$22.33**	

***** *"Other Costs" estimated as 40% of construction costs*
*** Cost estimates included site restoration and compensatory mitigation offsite*
**** Cost does not include monitoring or reporting and additional work on site (placement of sediment tubes and planting) are not included in this cost*
***** Cost does not include any monitoring or reporting*

DISCUSSION AND RECOMMENDATIONS

These results indicate that while there are many methods that can be used for seagrass restoration in South Florida, they can range in cost from about $0.50 per square foot to as much as $50.00 per square foot with an average for the fourteen projects with some associated specific cost estimates we were able to find (Table 2) of $22.33 in 2013 costs. This is equivalent to $972,695 per acre. This is very close to the estimated average costs of $22-$25 per square foot provided by Janice Duquesnel (personal communication) for the 31 projects in LV (Addendum A).

Previous base costs assessed by the prior Keys ILF Mitigation Program and the Corps of Engineers to mitigate for federally permitted impacts to seagrass meadows ranged from $3.25 per sq ft in 1999 to $5.22 in 2011 (McNeese 1999a, b, Hobbs 2009, 2011). These are equivalent to $4.54-$5.30 in 2013 costs.

When KRF principals were preparing the Final Instrument (KRF 2013) to guide implementation of the new KRF in-lieu fee program they realized that the proposed cost of mitigation credits for seagrass impacts was likely too low based upon their professional backgrounds and their history of involvement with seagrass restoration in the Keys dating back to the early 1980s. Without time to do a complete analyses of records on seagrass restoration costs, they suggested, based on requirements for full cost accounting, that the mitigation fee should be raised to $10 per square foot of impact as an interim measure. That has taken place, but has generated very little in terms of funding to date. Funds in place for seagrass restoration from the old KERF transfer funds are substantial, but were collected over the last decade at rates much lower than that which would provide "full cost recovery" for design, permitting, constructing, monitoring and reporting on seagrass restoration projects of the type currently

preferred by seagrass managers in the Keys. Recent projects typically include topographic restoration at large grounding sites and/or filling of prop scars using 0.25" limerock mixed with screenings, with stakes and transplants estimated at $22 - $25 per square foot without many of the "other project costs" required by the 2008 Final Rule included.

In order to fulfill all requirements of the 2008 Final Rule and adequately sustain the in-lieu fee program, it was our recommendation that one of two options be considered. The first option was to increase the cost of credits sold to a rate that will sufficiently fund the current preferred type of topographic restoration of large vessel grounding sites. The cost per mitigation credit could be as much as $25 - $50 per square foot. The second option was to adjust the type of preferred seagrass habitat restoration to include projects that can be accomplished for around $10 per square foot. The latter option could include building on work already in progress by the Florida Park Service and the FKNMS assisting with or expanding on work with channel and boat restricted area markers, boating education programs and more work with bird stakes to speed up natural recovery of scarred areas. Topographic restoration of seagrass habitat could result from working with land managers to restore dredged and filled areas in shallow water priority areas where there is likely to be recovery of historic seagrasses. Regardless of what type(s) of seagrass habitat restoration is ultimately pursued by KRF, the funds that were being currently collected did not support the preferred methods and costs, and could not be expected to be spent in a manner to fully offset permitted seagrass losses on even a 1:1 basis.

Based upon our recommendations and review by the IRT, the Corps of Engineers approved raising the per square foot rate for mitigation credits to $25 ($1,089,000 per acre = per credit) by letter dated May 13, 2015.

REFERENCES AND LITERATURE CITED

Anderson, LA, and A Farrer. 2011. *True Justice* – Seagrass restoration monitoring report – monitoring events 2004-2011 – Florida Keys National Marine Sanctuary, Monroe County, Florida. 26 pp.

Andorfer, J and C Dawes. 2002. Production of rhizome meristems by the tropical seagrass *Thalassia testudinum*: The basis for slow recovery into propeller scars. J. Coast. Res. 37:130-142.

Atkins. 2013. Florida Bay Everglades National Park – Draft seagrass habitat restoration management plan. National Park Service. 163 pp.

Ault, JS, SG Smith, D McClellan, N Zurcher, A McCrea, NR Vaughan , and JA Bohnsack. 2008. Final Report: Aerial survey of boater use in Everglades National Park marine waters: Florida Bay and Ten Thousand Islands. University of Miami, Miami, Florida. 93 pp + appends.

Bailey, H. 2011. *Kristal* seagrass restoration monitoring report baseline monitoring event Florida Keys National Marine Sanctuary, Monroe County, FL. 19 pp.

Bell SS, RA Brooks, BD Robbins, MF Fonseca, and MO Hall. 2001. Faunal response to fragmentation in seagrass habitats: implications for seagrass conservation. Biological Conservation 100:115-123.

Bourque, A. 2012. Ecosystem structure in disturbed and restored subtropical seagrass meadows. Florida International University Electronic Theses and Dissertations. Paper 792. 195 pp.

Bourque, AS and JW Fourqurean. 2014. Effects of common seagrass restoration methods on ecosystem structure in subtropical seagrass meadows. Mar. Env. Res.

Burke, JS, WJ Kenworthy, TS Viehman, VL McDonough, and B Degan. 2012. Biodiversity and Ecosystem function of Shallow Bank Systems within Florida Keys National Marine Sanctuary (FKNMS. Marine Sanctuaries Conservation Series ONMS-12-03. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries, Silver Spring, MD. 45 pp.

Derrenbacker, JA and RR Lewis. 1983. Seagrass habitat restoration, Lake Surprise, Florida Keys. Pp. 132 - 154 in Proceedings of the Ninth Annual Conference on Wetlands Restoration and Creation. Hillsborough Community College, Tampa, Florida.

Duquesnel, JA, and HT Smith. 2007. One-year preliminary analysis of seagrass restoration in Lignumvitae Key Submerged Land Management Area, Florida, USA. Natural Area News. 11(2):1-2 + 4.

Durako, MJ and M Moffler. 1984. Qualitative assessment of five artificial growth media on growth and survival of *Thalassia testudinum* (Hydrocharitaceae) seedlings. In: F.J. Webb Jr.

(Editor), Proceedings of the Eleventh Annual Conference on Wetlands Restoration and Creation. Hillsborough Community College, Tampa, FL, pp. 73-92.

Durako, MJ, MO Hall, F Sargent and S Peck. 1992. Propeller scars in seagrass beds: an assessment and experimental study of recolonization in Weedon Island State Preserve, Florida. Pages 42-53 in F.J. Webb, Jr. (Ed.), Proceedings of the 19th Annual Conference on Wetlands Restoration and Creation, Hillsborough Community College, Tampa, Florida. 227 p.

Engeman, RM, JA Duquesnel, EM Cowan, HT Smith, SA Shwiff and M Karlin. 2008. Assessing boat damage to seagrass bed habitat in a Florida Park from a bioeconomics perspective. J. Coast. Res. 24(2):527-532.

Erftemeijer, PLA and RR Lewis. 2006. Dredging impacts on seagrass meadows. Marine Pollution Bulletin. 52:1553 - 1572.

Farrer, AA. 2010. *N-Control* Seagrass Restoration Monitoring Report, Monitoring Events 2003-2008. Florida Keys National Marine Sanctuary, Monroe County, Florida. Marine Sanctuaries Conservation Series ONMS-10-06. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries, Silver Spring, MD. 32 pp.

Florida Department of Natural Resources. 1990. Lignumvitae Key Aquatic Preserve Management Plan, FDNR, Div. of State Lands, Bur. of Submerged Lands and Preserves, 156 pp.

Florida Department of Transportation and Stantec. 2013. US-1/SR5 two lane safety project – Houseboat Row seagrass mitigation – Monroe County, Florida. Year One Monitoring Report. 7 pages + figs and attach.

Folit, R and J Morris. 1992. Seagrass beds, boats, and buoys: A study in protecting seagrass beds from motorboat propeller damage. New College, Sarasota, Florida. 45 pp + appends.

Fonseca, MS. 1994. A guide to planting seagrasses in the Gulf of Mexico. Texas A&M University Sea Grant College Program. TAMU-SG-94-601. 27pp.

Fonseca, MS and JS Fisher. 1986. A comparison of canopy friction and sediment movement between four species of seagrasses with reference to their ecology and restoration. Marine Ecology Progress Series 29:15-22.

Fonseca, MS, WJ Kenworthy, FX Courtney and MO Hall. 1994. Seagrass planting in the Southeastern United States: methods for accelerating habitat development. Rest. Ecol. 2(3): 198-212.

Fonseca, MS, WJ Kenworthy and FX Courtney. 1996. Development of planted seagrass beds in Tampa Bay, Florida, USA. I. Plant components. Mar. Ecol. Prog. Ser. 132:127-139.

Fonseca, MS, WJ Kenworthy, and GW Thayer, 1998. Guidelines for the Conservation and Restoration of Seagrasses in the United States and Adjacent Waters". NOAA's Coastal Ocean Program Decision Analysis Series No. 12. 222 pp.

Fonseca, MS, Julius, BE, and WJ Kenworthy. 2000. Integrating biology and economics in seagrass restoration: how much is enough and why? Ecological Engineering 15:227-237.

Fonseca, MS, WJ Kenworthy, BE Julius, S Shutler and S Fluke. 2002. Seagrasses. Pages 149-170 in MR Perrow and AJ Davy (Eds.), Handbook of Ecological Restoration, Volume 2, Restoration in Practice. Cambridge University Press, Cambridge, UK. 599 pp.

Fonseca, MS, PE Whitfield, WJ Kenworthy, DR Colby, and BE Julius. 2004. Use of two spatially explicit models to determine the effect of injury geometry on natural resource recovery. Aquatic Conservation: Marine and Freshwater Ecosystems 14:281-298

Fourqurean, JW, GVN Powell, WJ Kenworthy, and JC Zieman. 1995. The effects of long-term manipulation of nutrient supply on competition between the seagrasses *Thalassia testudinum* and *Halodule wrightii* in Florida Bay. Oikos 72:349-358.

Fourqurean, JW, MJ Durako, MO Hall and LN Hefty. 2001. Seagrass distribution in south Florida: a multi-agency coordinated monitoring program. In: Porter, J.W., Porter, K.G. (Editors), The Everglades, Florida Bay, and coral reefs of the Florida Keys: an ecosystem sourcebook. CRC Press, Boca Raton, FL, pp. 497-522.

Haddad, K. 1996. Florida measures boating's impacts to seagrass beds. Coastal Current, FL Coastal management Program, 4(3), pp 12-13.

Hall, MO, M Merello, WJ Kenworthy, D Berns, K Ferenc, J Kunselman, F Hall and J Hyniova. 2006. Developing techniques to enhance the recovery rates of propeller scars in turtlegrass (*Thalassia testudinum*) meadows. Final report to the USFWS. Florida Fish and Wildlife Research Institute, St. Petersburg, Florida. 53 p.

Hall, MO, WJ Kenworthy and M Merello. 2012. Experimental evaluation of techniques to restore severe boat damage in South Florida seagrass habitats. Final report. Florida Fish and Wildlife Conservation Commission. 72 pp.

Hammerstrom, KK, WJ Kenworthy, PE Whitfield, and MF Merello. 2003. The effect of excavation depth and filling on seagrass recovery in experimental injuries in the Florida Keys National Marine Sanctuary. Final Project Report submitted to NOAA's Damage Assessment Center and Office of National Marine Sanctuaries, 22pp.

Hammerstrom, KK, WJ Kenworthy, PE Whitfield, and MF Merello. 2007. Response and recovery dynamics of seagrasses *Thalassia testudinum* and *Syringodium filiforme* and macroalgae in experimental motor vessel disturbances. Marine Ecology Progress Series 345:83-92.

Herbert, DA and JW Fourqurean. 2008. Ecosystem structure and function still altered two decades after short-term fertilization of a seagrass meadow. Ecosystems 11:688-700.
Hobbs, JF. 2007. Work performance review for project mitigation. KERF. MOU report to the Corps of Engineers. iv + 32 p.

Hobbs, JF. 2009. Work performance review for project mitigation. KERF. MOU report to the Corps of Engineers. iv + 45 p.

Hobbs, JF. 2010. Work performance review for project mitigation. KERF. MOU report to the Corps of Engineers. iv + 51 p.

Hobbs, JF. 2011. Work performance review for project mitigation. KERF. MOU report to the Corps of Engineers. iv + 41 p.

Hobbs, JF. 2012. Work performance review for project mitigation. KERF. MOU report to the Corps of Engineers. iv + 97 p.

Hobbs, JF. 2013. Lignumvitae Key submerged lands restoration project – Phase III: Peterson Bank - Construction methods and time zero report. Prepared for the FDEP and LKSBS. 17 p.

Hobbs, JF, and J Duquesnel. 2005. Lignumvitae Key submerged lands restoration project: Construction methods and time zero report. Prepared for the USCOE and FDEP and LKSBS. 166 pp.

Hobbs, JF, and J Duquesnel. 2006. Lignumvitae Key submerged lands restoration project: Year One monitoring report. Prepared for the USCOE and FDEP and LKSBS. 18 pp.

Hobbs, JF, and J Duquesnel. 2007. Lignumvitae Key submerged lands restoration project: Year two monitoring report. Prepared for the USCOE and FDEP and LKSBS. 19 pp.

Hobbs, JF, and J Duquesnel. 2011. Lignumvitae Key submerged lands restoration project: Time zero construction methods and final summary report. Prepared for the USCOE and FDEP and LKSBS. 23 p.

Hobbs, JF, PL McNeese and C Kruer. 2006. Pieces of the real Florida Keys – Twenty –five years of habitat restoration, 1981-2006 – Keys Environmental Restoration Fund. Audubon of Florida. 191 pp.

Johansson, J0R and RR Lewis. 1992. Recent improvements of water quality and biological indicators in Hillsborough Bay, a highly impacted subdivision of Tampa Bay, Florida, USA International Conference on Marine Coastal Eutrophication, Bologna, Italy, March 1990. Pp. 1199 - 1215 in Science of the Total Environment, Supplement 1992. Elsevier Publishers, Amsterdam. 1310 pp.

Kenworthy WJ, GW Thayer, and M Fonseca. 1993. A pilot experimental study to determine the feasibility of restoring seagrass beds damaged by propeller dredging in the Florida Keys National Maine Sanctuary. A proposal submitted to the NOAA Restoration Center, NMFS, 11 pp.

Kenworthy WJ and AC Schwarzschild. 1995. Prop scar restoration pilot study. Progress report submitted to NOAA Sanctuaries and Reserve Division and NOAA Restoration Center, 16 pp + figures.

Kenworthy, WJ, MS Fonseca, PE Whitfield, K Hammerstrom, and AC Schwarzschild. 2000a. A comparison of two methods for enhancing the recovery of seagrasses into propellor scars: mechanical injection of a nutrient and growth hormone solution vs. defecation by roosting seabirds. Final Report. Center for Coastal Fisheries and Habitat Research, NCCOS, NOS, NOAA, Beaufort, N.C. 40 p.

Kenworthy, WJ, PE Whitfield, K Hammerstrom, MS Fonseca, A Uhrin and M Merello. 2000b. Ecological characterization of Red Bay Bank, Florida Keys National Marine Sanctuary and experimental evaluation of the effects of excavation depth on recovery of seagrasses and associated Bank-top communities injured by motor vessels. Progress Report # 1. Center for Coastal Fisheries and Habitat Research, NCCOS, NOS, NOAA, Beaufort, N.C. 17 p + figures.

Kenworthy, WJ. , M.S. Fonseca, P.E. Whitfield, K. Hammerstrom, 2002. Analysis of seagrass recovery in experimental excavations and propeller scar disturbance in the Florida Keys National Marine Sanctuary. J. Coast. Res. 37:75-85.

Kenworthy, WJ, AC Schwarzschild, MS Fonseca, P McNeese and C Kruer. 2003. A novel method for restoring tropical seagrass meadows based on our understanding of nutrient cycling, disturbance ecology and recovering dynamics. Estuarine Research Foundation Annual Meeting, September 2003, Seattle, Washington. Abstract.

Keys Environmental Restoration Fund (KERF). 2013. KERF Summary Document Tables - 2013 update. PDF file. 6 pp.

Keys Restoration Fund (KRF). 2013. In-Lieu Fee Mitigation Program, Final Instrument dated July 1, 2013. Coastal Resources Group, Riverview, FL. 56 pp.

King, DM. 1991. Costing out restoration. Restoration and Management Notes. 9(1):15-21.

King, DM. 1998. The dollar value of wetlands: trap set, bait taken, don't swallow. National Wetland Newsletter 20(4): 7-11.

King, D, and C Bohlen. 1994. Estimating the costs of restoration. National Wetland Newsletter 16(2): 3-5 + 8.

Kirsch, KD, KA Barry, MS Fonseca, PE Whitfield, SR Meehan, WJ Kenworthy, and BE Julius. 2005. The mini-312 program – an expedited damage assessment and restoration

process for seagrasses in the Florida Keys National Marine Sanctuary. Journal of Coastal Research 40:109-119.

Kruczynski, WL, and PJ Fletcher. Tropical connections – South Florida's marine environment. IAN Press. University of Maryland Center for Environmental Science. Cambridge, Maryland. 492 pp.

Kruer, CR. 1992. User impacts to shallow water resources of the Florida Keys. Proceedings of First Annual Coral Reef Coalition Conference, Key West, Florida, pp. 11-14.

Kruer, CR. 1994. Mapping assessment of vessel damage to shallow seagrasses in the Florida Keys. Final report to Florida Department of Natural Resources and University of South Florida Institute of Oceanography. F.I.O. Contract #47-10-123-L3, 26 pp.

Kruer, CR. 1994. Boating impacts to seagrass habitats in Florida. Pages 32-39 in RN Crawford, N Stolpe, and M Moore (Eds.), The Environmental Impacts of Boating; Proceedings of a Workshop held at Woods Hole Oceanographic Institution, December 1994. Woods Hole Oceanographic Institute, Massachusetts, WHOI-98-03. 202 pp.

Kruer, CR. 1995. Assessment of seagrass restoration options in the Florida Keys. Report to U.S. Dept. Justice, Environmental Defense Section, Washington, D.C., 17 pp.

Kruer, CR. 1998. Background information and recommendations for an outreach and education program to protect seagrass habitats from boating impacts in the Florida Keys National Marine Sanctuary. Report prepared for the Seagrass Summit, Key Largo, Florida, 12 pp. + photos.

Kruer, C. 2001. A report on two seagrass restoration projects in the Lignumvitae State Management Area, Monroe County, Florida - construction and time zero and year one monitoring data. Florida Keys Environmental Restoration Trust Fund, Tavernier. FL. 8 p + tables + figures + appends.

Kruer, CR, RR Lewis, JW Kenworthy and PL McNeese. 1996. Restoration of prop-scarred seagrass flats at Lignumvitae Key State Botanical Site, Florida Keys. Proposal in response to Florida Department of Environmental Protection Solicitation Number 9603C entitled Request for Proposals for the Marine Resources Grants Program. 9 pp.

Kruer, CR, R Lewis, P McNeese, and J Kenworthy. 1996. Restoration of prop scarred seagrass flats at Lignumvitae Key Botanical State Park, Florida Keys. Report to Florida Department of Environmental Protection, Keys Restoration Trust Fund, Summerland Key, Florida, 10 pp.

Lewis, RR. 1983. Protection and management of seagrass meadows - is it working? Fla. Scientist 46(Suppl.):15 (Abstract).

Lewis, RR. 1987. The restoration and creation of seagrass meadows in the southeastern United States. Pages 153 - 173 in MJ Durako, RC Phillips, and RR Lewis (eds.), Proceedings of the

Symposium on Subtropical Seagrasses of the Southeastern United States. Fla. Dept. of Natural Resources Mar. Res. Pub. No.42. St. Petersburg, Florida. 209 pp.

Lewis, RR. 1990. Ch. 4, Laboratory culture methods. Pp. 37 – 41 in RC Phillips and CP McRoy (eds.), Seagrass Research Methods. UNESCO, Paris. 210 pp.

Lewis, RR. 1993. Boating impacts to seagrass flats and development impacts to shorelines in the Florida Keys Marine Sanctuary. Summary of a presentation, Proceedings of the Second Annual Coral Reef Coalition Conference, May 13 – 15, 1993. Islamorada, Florida.

Lewis, RR and RC Phillips. 1980. Occurrence of seeds and seedlings of *Thalassia testudinum* Banks ex Konig in the Florida Keys, U.S.A. Aq. Botany 9(4):377 – 380.

Lewis, RR and RC Phillips. 1981. Experimental seagrass mitigation in the Florida Keys. Pp. 155 – 173 in DP Cole (ed.), Proceedings of the Seventh Annual Conference on Restoration and Creation of Wetlands. Hillsborough Community College, Tampa, Florida. 294 pp.

Lewis, RR, MJ Durako, MD Moffler, and RC Phillips. 1985. Seagrass meadows of Tampa Bay. Pp. 210 – 246 in SF Treat, JL Simon, RR Lewis III and RL Whitman, Jr. (eds.), Proceedings, Tampa Bay Area Scientific Information Symposium.

Lewis, RR, C Kruer, S Treat, and S Morris. 1994. Wetland Mitigation Evaluation Report, Florida Keys Bridge Replacement. Florida Dept. of Transportation WPI No.6116901, SP No. 90000-1560. 88 pp. + appends.

Lewis, RR, P Clark, WK Fehring, HS Greening, R Johansson, and RT Paul. 1998. The rehabilitation of the Tampa Bay estuary, Florida, USA, an example of successful integrated coastal management. Marine Pollution Bulletin 37(8 – 12):468−473.

Lewis, RR and CR Kruer. 2006. Boating impacts to seagrass meadows and seagrass residents. Pp. 241 – 247 in Program and Presentations of the Boating and Waterways Management in Florida meeting, Cocoa Beach, Florida, November 1 – 3, 2006.

Lewis, RR, MJ Marshall, SA Bloom, AB Hodgson, and LF Flynn. 2006. Evaluation of the success of seagrass mitigation at Port Manatee, Tampa Bay, Florida. Pp. 19 – 40 in SF Treat and RR Lewis III (Eds.), Seagrass Restoration: Success, Failure and the Cost of Both. Proceedings of the Conference. Mote Marine Laboratory, March, 2003. Lewis Environmental Services, Inc., Tampa, Florida. 175 pp.

Lignumvitae Key State Botanical Site. 1997. Baseline Monitoring Report – Demonstration Seagrass Restoration Project. Rep. prep. For the Florida Park Service, Florida Dept. of Env. Prot. 11 pp + appendices.

Mathews TR, Lazar AC, and Hunt JH. 1991. Aerial observations of boating impacts to shallow water seagrass beds in the Florida Keys. Report to FDEP Office of Marine Programs and Planning. 7 pp + Appendix.

McNeese, PL. 1999a. Report on MOU meeting dated September 7, 1999. 4 p.

McNeese, PL. 1999b. Cost of restoration. Memo dated November 29, 1999. Florida Keys Environmental Trust Fund. 6 p.

McNeese, PL. 2001. Indian Key Channel demonstration seagrass restoration project - final evaluation and recommendations. Florida Keys Environmental Restoration Trust Fund, Tavernier, FL. 39 pp + appends.

McNeese, PL. 2003. Lignumvitae Key submerged lands restoration plan. Project Report submitted to FDEP, Florida Park Service, Lignumvitae Key Submerged Land Managed Area, 93 pp.

McNeese, PL. 2005. Lignumvitae Key Submerged Land Management Area (LKMA) - implementation of LKMA restoration plan. Project Report submitted to FDEP Florida Coastal Management Program, NOAA Coastal Zone Management Grant #CZ514, Lignumvitae Key Submerged Land Managed Area, iii + 26 pp + appendices.

McNeese, PL. 2006. Vessel Grounding Management at Lignumvitae Key Botanical State Park. PowerPoint presentation. 18 images.

McNeese, PL, CR Kruer, WJ Kenworthy, AC Schwarzchild, P Wells, and J Hobbs. 2006. Topographic restoration of boat grounding damage at the Lignumvitae Submerged Land Management Area. Pages 131-146 in Treat, S.F. and Lewis, R.R. (eds.), Seagrass Restoration: Success, Failure and the Cost of Both. Proceedings of the Conference. Mote Marine Laboratory, March, 2003. Lewis Environmental Services, Inc., Tampa, Florida. 175 pp.

Milano, GR. 2012. Seagrass restoration in Biscayne Bay provides lessons for other locations. Pages 288-289 in WL Kruczynski and PJ Fletcher (Eds.). Tropical connections – South Florida's marine environment. IAN Press. University of Maryland Center for Environmental Science. Cambridge, Maryland. 492 p.

Montin, GJ, and RF Dennis III. 2006. A shallow water technique for the successful relocation and/or transplantation of large areas of shoalgrass (*Halodule wrightii*). Pages 41-48 in S.F. Treat and R.R. Lewis III (Eds.), Seagrass Restoration: Success, Failure and the Cost of Both. Proceedings of the Conference. Mote Marine Laboratory, March, 2003. Lewis Environmental Services, Inc., Tampa, Florida. 175 pp.

Mueller-Dombois, D.,and H Ellenberg. 1974. Aims and methods of vegetation ecology. John Wiley and Sons, New York, 547 pp.

National Park Service. 2008. Patterns of propeller scarred seagrass in Florida Bay: associations with physical and visitor use factors and implications for natural resource management. Resource Evaluation Report. South Florida Natural Resources Center (SFNRC) Technical Series 2008:1. South Florida Natural Resources Center, Everglades National Park, Homestead, Florida, USA, 27 pp.

National Park Service. 2011. Biscayne National Park draft general management plan/environmental impact statement. 360 pp.

National Park Service. 2013. Everglades National Park draft general management plan/east Everglades wilderness study/environmental impact statement. 614 pp.

NOAA and FDEP. 2002. *True Justice* restoration plan Florida Keys National Marine Sanctuary, Monroe County, FL. 17 pp.

NOAA and FDEP. 2004. Final Programmatic Environmental Impact Statement for Seagrass Restoration in the Florida Keys National Marine Sanctuary, 100 pp

NOAA and FDEP. 2007. *Kristal* restoration plan Florida Keys National Marine Sanctuary, Monroe County, FL. 23 pp.

NOAA and FKNMS. 2007. Close-out of *Julia Reanne* 312 case. 1 p.

NOAA and FKNMS. 2009. Close-out of *Heidi Baby* 312 case. 1 p.

NOAA and FDEP. 2006. *Lucky One* restoration plan Florida Keys National Marine Sanctuary, Monroe County, FL. 22 pp.

NOAA and FDEP. 2007. *Lucky One* restoration plan update Florida Keys National Marine Sanctuary, Monroe County, FL. 20 pp.

NOAA and FDEP. 2013. *Sari III* restoration plan, Florida Keys National Marine Sanctuary, Monroe County, FL. 19 pp.

Office of National Marine Sanctuaries. 2011. Florida Keys National Marine Sanctuary Condition Report 2011. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries, Silver Spring, MD. 105 pp.

Phillips, RC and RR Lewis. 1983. Influence of environmental gradients on variations in leaf widths and transplant success in North American seagrasses. J. Mar. Tech Soc. 17(2)59 - 68.

Powell, GVN, JW Fourqurean, WJ Kenworthy, and JC Zieman. 1991. Bird colonies cause seagrass enrichment in a subtropical estuary: observational and experimental evidence. Estuarine Coastal and Shelf Science: 32:567-579.

Sargent, FJ. 1996. Propeller Scar Monitoring Program for the Tampa Bay National Estuary Program". Contract No.T95-03-A2.

Sargent, FJ and MM Colby. 1998. Lignumvitae Key State Botanical Site propeller scar study. Florida Department of Environmental Protection, Florida Marine Research Institute, Coastal and Marine Resource Assessment. 13 pp.

Sargent, FJ, TJ Leary, DW Crewz and CR Kruer. 1995. Scarring of Florida's seagrasses: assessment and management options". Department of Environmental Protection Florida Marine Research Institute Technical Reports TR-1. Florida. 72pp.

Sargent, FJ and MM Colby. 1999. John Pennekamp Coral Reef State Park propeller scar study. Florida Department of Environmental Protection, Florida Marine Research Institute, Coastal and Marine Resource Assessment. 9 pp.

Seagrass Recovery, Inc. 2009. Knight's Key restoration project – Seagrass Grow. Year 1 Monitoring Event Report. 16 p.

Skinner, R and W Jaap. 1984. Effects of boat traffic and land development on Key Largo's coral reefs and adjacent marine environments. A report to the Fl Governor and Cabinet, 33 pp + attachments.

South Florida Natural Resources Center (SFNRC). 2008. Patterns of propeller scarred seagrass in Florida Bay: associations with physical and visitor use factors and implications for natural resource management. Resource Evaluation Report. SFNRC Technical Series 2008:1. South Florida Natural Resources Center, Everglades National Park, Homestead, Florida, USA, 27 pp.

Spurgeon, J. 1998. The socio-economic costs and benefits of coastal habitat rehabilitation and creation. Mar. Poll. Bull. 37(8-12):373-382.

Treat, SF and RR Lewis (eds.). 2006. Seagrass Restoration: Success, Failure and the Cost of Both. Proceedings of the conference, March 2003. Proceedings of the Conference. Mote Marine Laboratory, March, 2003. Lewis Environmental Services, Inc., Tampa, Florida. 175 pp.

Uhrin, AV, and JG Holmquist. 2003. Effects of propeller scarring on macrofaunal use of the seagrass *Thalassia testudinum*. Marine Ecology Progress Series 250:61-70.

Uhrin, AV and K Kirsch. 2008. Prioritizing seagrass restoration sites. ESRI ArcUser Summer 2008:24-29.

Uhrin, AV, MO Hall, MF Merello and MS Fonseca. 2009. Survival and expansion of mechanically transplanted seagrass sods. Rest. Ecol. 17(3):357-368.

Uhrin, AV, MS Fonseca, and WJ Kenworthy. 2009. Preliminary comparison of natural versus model-predicted recovery of vessel-generated seagrass injuries in Florida Keys National Marine Sanctuary. Marine Sanctuaries Conservation Series

NMSP-09-03. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries, Silver Spring, MD. 13 pp.

Uhrin, AV, WJ Kenworthy MS Fonseca. 2011. Understanding uncertainty in seagrass injury recovery: an information theoretic approach. Ecol. Appl. 21(4):1365-1379.

USACE and USEPA. 2008. Compensatory Mitigation for Losses of Aquatic Resources; Final Rule, April 10, 2008, 113 pp.

Whitfield, PE, WJ Kenworthy, KK Hammerstrom and MS Fonseca. 2002. The role of a hurricane in the expansion of disturbance initiated by motor vessels on seagrass banks. J. Coast. Res. 37:86-99.

Whitfield, PE, WJ Kenworthy,MJ Durako, KK Hammerstrom and MF Merello. 2004. Recruitment of *Thalassia testudinum* seedlings into physically disturbed seagrass beds. Marine Ecology Progress Series 267:121-131.

Wilderness Society, Florida Keys Audubon Society, and Lewis Environmental Services, Inc. "Is Uncontrolled Boating Damaging Thousands of Acres of Florida's Submerged Seagrass Meadows?" An Information Package. 36 pp.

Zieman, JC. 1976. The ecological effects of physical damage from motor boats on turtle grass beds in southern Florida. Aquatic Botany (2): 127-139.

Zieman, JC. 1982. The ecology of the seagrasses of South Florida: A community profile. US Department of the Interior, FWS/OBS-82/25.

ADDENDUMS

ADDENDUM A. TABLE OF SEAGRASS RESTORATION PROJECT DESCRIPTIONS WITHIN THE LIGNUMVITAE STATE PARK FROM JANICE DUQUESNEL

RESTORATION PROJECT	DATE COMP.	TIME ZERO MON.	YEAR 1 MON.	YEAR 2 MON.	YEAR 3 MON.	YEAR 4 MON.	YEAR 5 MON.	YEAR 6 MON.
1. Robbie's Flat Robbie's Flat is a shallow seagrass flat approximately 3/4 of an acre in size that was heavily scarred from prop damage. Restoration consisted of bird stake installation beginning 2m from the edge of the seagrass flat and then on 3m centers for a total of 291 stakes.	April 2005	May 2, 2005	May 1, 2006	May 4, 2007	April 18, 2008	August 20, 2009		
2. Princess Jullin The Princess Jullin grounding consisted of twin prop scars 938 feet in length ending in a deep blowhole, berm and vessel impression. Total impacted area was approxately 2 1/2 acres. Restoration consisted of topographic restoration, bird stake installation, and Halodule wrightii planting unit installation. Fifty-nine cubic yards of .25" native pea gravel mixed with native limerock screening were used to fill in the blowhole to the grade of the surrounding seagrass flat. Thirty bird stakes were installed 0.5m from the edge of the seagrass flat and then on 2m centers to cover this injury feature. One hundred and forty bird stakes were installed on 2m centers in an alternating pattern down the length of the twin scars. Fifty nine planting units of *H. wrightii* were installed over the blowhole, berm and vessel impression. Planting units were installed 0.5m and consisted of a minimum of four short shoots and two apical meristems per planting unit. No planting units were installed in the prop scars.	"	"	"	"	"	August 20, 2009		

RESTORATION PROJECT	DATE COMP.	TIME ZERO MON.	YEAR 1 MON.	YEAR 2 MON.	YEAR 3 MON.	YEAR 4 MON.	YEAR 5 MON.	YEAR 6 MON.
3. Curved Scar The Curved Scar originally was a twin prop scar but had suffered major erosion since the time of the vessel grounding becoming one wide injury approximately 1/3 acre in size. Sections of the scar that were colonizing with species of macroalgae were not included in the topographic restoration. A total of 198 cubic yards of .25" native pea gravel mixed with native limerock screening were installed to grade of the adjacent seagrass bed. Eighty-one bird stakes were installed along the length of the prop scar on 2m centers 0.5m from the edge of the seagrass flat. Where the prop scar increased in width, additional bird stakes were installed. One hundred and sixty shoal grass planting units were installed 0.5m from the bird stakes consisting of a minimum of four short shoots and two apical meristems per planting unit. However, less than 50% of these survived the required thirty-day time frame so additional planting units were installed. Mortality of the second planting was also high but natural recruitment has sporadically filled into the injury feature.	"	"	"	"	"	June 8, 2009		
4. Stake Array Because of the extensive damage to the seagrass flat between the Curved Scar and the Power Cat restoration sites, 132 bird stakes were installed in a stake array to provide a visual barrier to vessels and to promote the recovery of the seagrass flat. Bird stakes were installed on 3m centers in a rectangular grid. This array also includes an additional 15 bird stakes that were installed in a "T-array", which was placed over a single prop scar and is monitored as a separate unit. The total size of both sites is approximately 3/4 acre.	"	"	"	"	"	June 8, 2009	Removed bird stakes. Site will need to be re-addressed	

RESTORATION PROJECT	DATE COMP.	TIME ZERO MON.	YEAR 1 MON.	YEAR 2 MON.	YEAR 3 MON.	YEAR 4 MON.	YEAR 5 MON.	YEAR 6 MON.
5. T-Array	"	"	"	"	"	June 8, 2009	Removed bird stakes. Site will need to be re-addressed	
6. Power Cat The Power Cat grounding consisted of twin prop scars ending in two blowholes which increased in size due to erosion and additional scarring. This site was approximately 1/4 acre in size. Topographic installation consisted of 48.5 cubic yards of 0.25" native pea gravel mixed with native limerock screening into the two blowholes. Seventeen bird stakes were installed on 2m centers, 2m from the vegetation that was between the filled holes, and 0.5m from the edge of the surrounding seagrass flat. Twenty-six bird stakes were installed on 2m centers in an alternating pattern the length of the twin scars.	"	"	"	"	"	August 20, 2009		
7. Indian Key Flat The Indian Key Flat grounding consisted of multiple scars, two blowholes and a vessel impression totaling 2,799.6ft² of damage. For this phase of the project 100 cubic yards of .25" native pea gravel mixed with native limerock screening was installed.	Sept. 2006	September 2006	September 28, 2007	September 26, 2008	August 17, 2009	August 23, 2010	Sept. 28, 2011	
8. Curry Site The Curry grounding consisted of a prop scar, two blowholes, and three berms This site of this site is approximately 1/8 acre and required 70 cubic yards of .25" native pea gravel mixed with native limerock screening.	"	"	September 24, 2007	"	August 20, 2009- achieved restoration goal by Year 2			

RESTORATION PROJECT	DATE COMP.	TIME ZERO MON.	YEAR 1 MON.	YEAR 2 MON.	YEAR 3 MON.	YEAR 4 MON.	YEAR 5 MON.	YEAR 6 MON.
9. Yerkes Site The Yerkes grounding consisted of twin scars, two blowholes and an exit scar covering approximately 1/2 acre. A total of 100 cubic yards of .25" native pea gravel mixed with native limerock screening was installed to bring the blowholes to the grade of the adjacent seagrass bed.	"	"	"	"	August 20, 2009	August 23, 2010		
10. Indian Key Flat Once the second phase of topographic restoration was completed, 124 bird stakes were installed on 2m centers. Recruitment of filamentous algae indicative of over nutrificiation was observed during the Year 1 monitoring so ninety-three bird stakes were removed. The remaining bird stakes were removed during the Year 2 monitoring. Observations during the Year 3 monitoring illustrated the elimination of this algae and an increase in macroalgae and seagrass into the restoration site.	See above	See above	See above	See above	See above	See above	See above	
11. Broughton Site The Broughton grounding consisted of multiple prop scars, scars from the vessel, a blowhole and several berms covering approximately 1/2 acre. Thirty-three cubic yards of 0.25” native pea gravel rock mixed with native limerock screening was installed to fill in the blowhole to the grade of the surrounding seagrass bed. Thirty bird stakes were installed on 2m centers in the blowhole and for approximately 60 feet of the prop scar. During the Year 1 monitoring, recruitment was observed over a majority of the prop scars so all of these bird stakes were removed and only six were left in the blowhole. The remaining bird stakes were removed in 2010.	Dec. 2006	Dec. 2006	January 11, 2008	January 30, 2009	March 18, 2010			

RESTORATION PROJECT	DATE COMP.	TIME ZERO MON.	YEAR 1 MON.	YEAR 2 MON.	YEAR 3 MON.	YEAR 4 MON.	YEAR 5 MON.	YEAR 6 MON.
12. Diorio Site The Diorio grounding consisted of twin prop scars 398 feet in length with varying topographic damage. This site is approximately 3/4 acre in size. Seventeen cubic yards of native 0.25" pea gravel mixed with native limerock screening was installed to fill the scar to the greade of the surrounding seagrass flat. Sixty-three bird stakes were installed on 2m centers in an alternating pattern down the length of the scars.	Dec. 2006	Dec. 2006	January 11, 2008	January 30, 2009	March 18, 2010			
13. Orphan Scar This site is a large and wide scarified area approximately 1 acre in size. Topographic restoration was not necessary but 150 bird stakes were installed on 2m centers in half of the injury feature. Additional bird stakes will be installed as current ones are removed in order to progress the restoration throughout the entire site. Recovery of this site is slow, but *Thalassia* recruitment is occurring on the edges and in portions of the interior.	Dec. 2006	Dec. 2006	January 11, 2008	January 30, 2009	March 18, 2010	April 15, 2011	April 27, 2012	
Curry Site (site 8 above) After completion of the topographic restoration, five bird stalks were installed in the filled blowhole on 2m centers.	See above	See above	See above	See above	See above			
Yerkes Site (site 9 above) After completion of the topographic installation, 101 bird stakes were installed throughout the site on 2m centers.	See above	See above	See above	See above	See above			

RESTORATION PROJECT	DATE COMP.	TIME ZERO MON.	YEAR 1 MON.	YEAR 2 MON.	YEAR 3 MON.	YEAR 4 MON.	YEAR 5 MON.	YEAR 6 MON.
14. Peterson Key Bank Site Peterson Key Bank is approximately 1 1/2 acres consisting of a long scar over 300 feet in length and ending in several large blowholes twenty-five feet in width. Depths along the scar vary but depths within the blowholes are one foot along the edges and five feet in the interior. One hundred cubic yards of .25" native pea gravel mixed with native limerock screening were installed during this phase of the project. No bird stakes were installed due to the proximity of this restoration site to the Orphan Scar site. Multiple funding sources will be required in order to complete restoration of this site.	Feb. 2007	February 19, 2007	April 18, 2008	April 24, 2008	April 29, 2010	April 15, 2011	April 27, 2012	
15. Indian Key Flat This phase of restoration consisted of the installation of 82 cubic yards of .25" native pea gravel mixed with native limerock screening to the grade of the adjacent seagrass bed.	July 2007	July 16, 2007	Aug. 4, 2008	August 17, 2009	August 23, 2010	September 28, 2011		
16. LV Channel -Site A LV Channel Site A was a large hole approximately 1/3 acre in size. 95 cubic yards of .25" native pea gravel mixed with native limerock screening was used to fill this site to the grade of the surrounding seagrass bed. 61 bird stakes were then installed in a grid pattern on 2m centers keeping 3m from the edge of the adjacent seagrass bed.	August 2007	August 9, 2007	August 4, 2008	August 17, 2009	August 23, 2010			
17. LV Channel - Site B LV Channel Site B is a long scar approximately 1/3 acre created by repetitive damage by vessels that were cutting the corner on the inside of the channel marker. Restoration consisted of the installation of 70 cubic yards of .25" native pea gravel mixed with native limerock screening. Fifty-eight bird stakes were then installed on 2m centers.	"	"	"	August 17, 2009	"	September 28, 2011	November 16, 2012	

RESTORATION PROJECT	DATE COMP.	TIME ZERO MON.	YEAR 1 MON.	YEAR 2 MON.	YEAR 3 MON.	YEAR 4 MON.	YEAR 5 MON.	YEAR 6 MON.
18. Peterson Key Bank Site This phase of restoration consisted of installing 87 cubic yards of .25" pea gravel mixed with native limerock screening to the grade of the surrounding seagrass flat.	"	"	"	August 20, 2009	"	August 2011	October 1, 2012	
19. Wheel Ditch East The Wheel Ditch is on the edge of the channel where repetitive scarring had completely scarified the seagrass flat. This phase of the project consisted of the installation of 62 bird stakes on 2m centers. The total site is approximately 1/2 acre.	Sept. 2007	September 28, 2007	"	August 17, 2009				
20. Peterson Key Bank Site This phase of the project consisted of the installation of 100 cubic yards of a 0.25" pea gravel mixed with native limerock screening.	April 2009	April 24, 2009	April 29, 2010	April 15, 2011	April 27, 2012			
21. Wheel Ditch west This site is located along the edge of the channel and has been subjected to propeller scarring from boats cutting across the seagrass flat as they exit the Wheel Ditch. One hundred bird stakes were installed on two meter centers in individual prop scars.	June 2009	June 8, 2009	June 4, 2010	July 21, 2011				
22. Wheel Ditch east This phase of the restoration consisted of the installation of 224 bird stakes in a grid pattern on 2m centers.	April 2009	April 24, 2009	April 29, 2010	April 15, 2011				
23. Teatable Key flat Tea Table Flat is a major injury feature consisting of a long, deep scar that is over 600 feet in length covering approximately 3 acres. This phase of restoration consisted of the installation of 90 cubic yards of 0.25" native pea gravel mixed with native limerock screening at the north end of the scar. Only two bird stakes were installed due to funding but these were removed during the Year 1 monitoring due to the amount of vegetative growth into the site.	June 2009	June 8, 2009	June 4, 2010	July 21, 2011				

RESTORATION PROJECT	DATE COMP.	TIME ZERO MON.	YEAR 1 MON.	YEAR 2 MON.	YEAR 3 MON.	YEAR 4 MON.	YEAR 5 MON.	YEAR 6 MON.
24. Peterson Key Bank Site This phase of topographic restoration consisted of the installation of 100 cubic yards of native limerock screening mixed with 0.25" pea gravel.	June 2010	June 4, 2010	July 21, 2011	October 1, 2012				
25. Teatable Flat This phase of the project consisted of the installation of 365.85 cubic yards of native limerock screening mixed with 0.25" pea gravel. Fifty-three bird stakes were installed on 3m centers	Sept. 2011	September 28, 2011	October 1, 2012					
26. Peterson Key Bank Site This phase of topographic restoration consisted of the installation of 108 cubic yards of native limerock screening mixed with 0.25" pea gravel.	October 2011	November 2011	November 16, 2012					
27. Peterson Key Bank This phase of restoration consisted of the installation of 100cubic yards of native limerock screening mixed with 0.25" pea gravel	August 2012	October 1, 2012						
28. Teatable Flat This phase of restoration consisted of installation of 260 cubic yards of native limerock screening mixed.	August 2012	October 1, 2012						
29. Peterson Key Bank This phase of restoration consisted of the installation of 826 cubic yards of native limerock screening mixed with 0.25" pea gravel	March 2013	March 2013						
30. Peterson Key Bank This phase of restoration consisted of the installation of 110 cubic yards of native limerock screening mixed with 0.25" pea gravel. To date 1,675 cubic yards installed	Apr-13	May-13						
31. Peterson Key Bank This phase of restoration consisted of the installation of 55 cubic yards of native limerock screening mixed with 0.25" pea gravel. To date, 1,730 cubic yards installed	Sept. 2013	Oct-13						

ADDENDUM B. SUMMARY OF TOPOGRAPHIC SEAGRASS RESTORATION (1979 – 2013)

No.	Project Name	Island	Source	Reference	Year	Lat/Long	~ Seagrass Area Restored (min 0.1 ac)	Comments
1	Boog Powell Marina Fill Spit Removal	Stock Island	FDOT	a	~1982	24.57370 -81.72929	1.2	mitigation required for bridge replacement project, later planted
2	Carysfort Phase I	North Key Largo	FKRTF	b	2001	25.25425 -81.30910	0.1	in pools and depressions among restored mangroves
3	Carysfort Phase II and Madeira Village	North Key Largo	KERF	b	2004	25.25151 -81.31131	0.1	in pools and depressions among restored mangroves
4	Coco Plum Subdivision	Coco Plum	USACE	a	~1982	24.73253 -81.00276	7.6	Federal legal action forced partial subd. restoration
5	Coral Shores Estates	Little Torch Key	USACE	a	~1985	24.68783 -81.39954	6.2	canal subdivision restoration, patchy seagrass
6	Coupon Bight Fill Spit	Big Pine Key	FKEMTF	b	1984	24.64192 -81.35346	2.2	patchy SAV habitat, large area of enhancement.
7	Crocodile Lake Borrow Pit	North Key Largo	FKEMTF	b	1984	25.28427 -80.30769	1.2	fill removal around borrow pit in tidal system
8	Dispatch Slough	North Key Largo	FKRTF	b	1999	25.28637 -80.30082	0.1	patchy *Ruppia* occurs seasonally at 2 road removal sites
10	Dynamite Docks	North Key Largo	FKRTF	b	1994	25.27516 -80.29290	1.8	offshore fill spit removed and adjacent channel backfilled
11	Egret Island Phase II Seagrass	Key Largo	KERF	b	2004	25.11414 -80.41171	0.5	fill removed from shallow water
12	Hammer Point	Key Largo	USACE	a	~1982	25.02406 -80.51359	4.4	Federal legal action forced partial subd. restoration
13	Houseboat Row Seagrass Restoration	Key West	FDOT	c	2012	24.56129 -81.74869	2.6	dredged area backfilled to adjacent elevations
14	Key Haven Fill Spit Removal	Key Haven	USACE	a	~1985	24.58634 -81.74355	5.9	offshore fill removal, unclear as to full extent of removal
15	Key West Salt Ponds Sewer Road	Key West	FKRTF	b	2000	24.55563 -81.77274	0.2	includes seagrass enhancement via improved tidal circulation
16	Lake Surprise Causeway Removal	Key Largo	FDOT	d	2008	25.17878 -80.38010	4.6	~2600' long causeway removed to -2'
17	No Name Key Ferry Slip	No Name Key	FKEMTF	b	1983	24.69759 -81.31659	0.5	patchy and continuous seagrass
18	Refuge Headquarters Road	Big Pine Key	FKEMTF	b	1983	24.69068 -81.38294	0.1	shallow *Halodule*
19	Rock Harbor Spoil Site	Key Largo	FKEMTF	b	1983	25.08369 -81.44709	2.1	fill removal
20	Sexton Cove	Key Largo	USACE	a	~1984	25.16910 -80.38294	14.0	Federal legal action forced partial subd. restoration
21	Tower Road Removal	Big Pine Key	FKEMTF	b	1983	24.68932 -81.37993	0.1	shallow, patchy, seasonal *Halodule*
	Total Approximate Area (acres)						**55.5**	

Sources:

- FDOT = Florida Department of Transportation mitigation project
- USACE = U.S. Army Corps of Engineers enforcement action
- FKEMTF = aka Florida Keys Environmental Mitigation Trust Fund (FKEMTF, 1981 - 1990), the Florida Keys Environmental Restoration Trust Fund (FKRTF, 1991-2002), and the Keys Environmental Restoration Fund (KERF, 2002-2013)
- KERF = Keys Environmental Restoration Fund (2002-2013)

References:

- (a) Kruer, personal observation
- (b) Hobbs, J., P. McNeese, and C. Kruer. 2006. Pieces of the Real Florida Keys, Twenty-Five Years of
- Habitat Restoration, 1981-2006, Keys Environmental Restoration Fund. National Audubon Society, Miami, Florida, 191 pp.
- (c) Stantec. 2013. US-1/SR5 Two Lane Safety Project, Houseboat Row Seagrass Mitigation
- Monroe County, Florida, Year One Monitoring Report. 18 pp.
- (d) 3CTS. 2011. US 1 Two Lane Safety Project, Lake Surprise Causeway and Jewfish Creek Bridge Approaches
- Seagrass Mitigation, Monroe County, Florida, Second Annual Monitoring Report. 7 pp.

ADDENDUM C. SUMMARY OF HYDROLOGIC SEAGRASS RESTORATION SITES (1979 – 2013)

No.	Project Name	Island	Source	Year	Reference	Lat/Long	~ Seagrass Area Restored (min 0.1 ac)	Comments
1	Big Pine Slough Culverts	Big Pine Key	FKRTF	2001	a	24.69078 -81.38088	4.2	expanded seagrass in interior lagoon
2	Boca Chica Lagoon Culvert	Boca Chica	FKEMTF	1982	a	24.56156 -81.68150	2.0	1 set of culverts later filled by storms and channelized
3	Boca Chica Lagoon Culverts	Boca Chica	FDOT	2008	b	24.55786 -81.70643	10.0	3 sets of 4 barrel culverts later blown out and areas channelized by H. Wilma (2005)
4				to 2012		24.55983 -81.69738		Following H. Wilma the U.S. Navy/Boca Chica did additional hydrological improvements
5						24.56061 -81.68823		including culvert and debris removal and further mechanical channelization
6						24.56175 -81.68054		The acreage figure provided is likely conservative as of 12/2013
7	Crawl Key U.S. Highway 1 Culverts	Crawl Key	FDOT	~1990	c	24.73181 -81.02261	2.0	large area of seagrass enhancement north and south of US 1
8	Cudjoe Plantation Road Removal	Cudjoe Key	FKRTF	1991	a	24.68025 -81.47947	55.0	large scale increase in SAV in interior lagoon, difficult to estimate
10	Key West Salt Ponds Culverts	Key West	FKEMTF	1984	a	24.55406 -81.76743	1.0	culverts since removed and channels created
11	Middle Torch Key Circulation Cut	Middle Torch	FKRTF	1983	a	24.70013 -81.41220	1.0	includes seagrass enhancement through tidal flows
12	Stock Island U.S. Highway 1 Culvert	Stock Island	FDOT	~1990	c	24.57516 -81.73302	35.0	large scale enhancement of seagrass in a previously dead-end lagoon north of U.S. 1
13	Big Pine Slough Culverts	Big Pine Key	FKRTF	2001	a	24.69078 -81.38088	4.2	expanded seagrass in interior lagoon
14	Boca Chica Lagoon Culvert	Boca Chica	FKEMTF	1982	a	24.56156 -81.68150	2.0	1 set of culverts later filled by storms and channelized
15	Boca Chica Lagoon Culverts	Boca Chica	FDOT	2008	b	24.55786 -81.70643	10.0	3 sets of 4 barrel culverts later blown out and areas channelized by H. Wilma (2005)
16				to 2012		24.55983 -81.69738		Following H. Wilma the U.S. Navy/Boca Chica did additional hydrological improvements
	Total Approximate Area (acres)						**110.2**	

Sources:

- FDOT = Florida Department of Transportation mitigation project
- USACE = U.S. Army Corps of Engineers enforcement action
- FKEMTF = aka Florida Keys Environmental Mitigation Trust Fund (FKEMTF, 1981 - 1990), the Florida Keys Environmental Restoration Trust Fund (FKRTF, 1991-2002), and the Keys Environmental Restoration Fund (KERF, 2002-2013)
- KERF = Keys Environmental Restoration Fund (2002-2013)

References:

- (a) Kruer, personal observation
- (b) Hobbs, J., P. McNeese, and C. Kruer. 2006. Pieces of the Real Florida Keys, Twenty-Five Years of
- Habitat Restoration, 1981-2006, Keys Environmental Restoration Fund. National Audubon Society, Miami, Florida, 191 pp.
- (c) Stantec. 2013. US-1/SR5 Two Lane Safety Project, Houseboat Row Seagrass Mitigation
- Monroe County, Florida, Year One Monitoring Report. 18 pp.
- (d) 3CTS. 2011. US 1 Two Lane Safety Project, Lake Surprise Causeway and Jewfish Creek Bridge Approaches
- Seagrass Mitigation, Monroe County, Florida, Second Annual Monitoring Report. 7 pp.

ADDENDUM D. SUMMARY OF SEAGRASS TRANSPLANTING RESTORATION (1979 – 2013)

No.	Project Name	Island	Source	Year	Lat/Long	~ Seagrass Area Restored (min 0.1 ac)	Comments
1	Boog Powell Fill Spit	Stock Island	FDOT	1983, 1984	24.57370 -81.72929	1.20	Planted following fill removal
2	Channel No. 5		FDOT	1983		1.43	
3	Craig Key Seagrass Planting	Craig Key	FDOT	1979, 1983	24.83807 -81.75752	0.25	planted on 2 occasions
4	Harris Channel		FDOT	1983		0.24	
5	Indian Key Channel		FDOT	1983		1.25	
6	Kemp Channel		FDOT	1983		0.60	
7	Lake Surprise Seagrass Restoration	Key Largo	FDOT	1983	25.17898 -80.38078	14.00	required for water line placement
8	Long Key Channel, West		FDOT	1983		1.08	
10	Long Key Channel, East		FDOT	1983		0.51	
11	Niles Channel		FDOT	1983		0.44	
12	N. Harris Channel		FDOT	1983		0.47	
13	Park Channel		FDOT	1983		0.35	
14	Seven-Mile Bridge D		FDOT	1983		1.42	
15	Seven-Mile Bridge E		FDOT	1983		1.26	
16	Seven-Mile Bridge F		FDOT	1983		3.58	
	Total Approximate Area (acres)					**47.54**	

Source: Lewis, R.R., C.R. Kruer, S.F. Treat, and S.M. Morris. 1994. Wetland mitigation evaluation report - Florida Keys bridge replacement. Report to the Florida Department of Transportation, FL-ER-55-94, 88 pp., plus appendices.