South Florida / Caribbean Network

National Park Service
Inventory & Monitoring Division

Standard Operating Procedure SET05

Mangrove Elevation Monitoring—Version 1.00

Please cite this as:

Whelan, K.R.T. and M.C. Prats. 2016. Mangrove elevation monitoring—Version 1.00. South Florida / Caribbean Network Standard Operating Procedure NPS/SFCN/SOP—SET05. National Park Service, Miami, Florida.

Summary

The following standard operating procedure (SOP) outlines the process of using the rod-surface elevation table (RSET) to monitor mangrove soil surface elevation change in South Florida / Caribbean Network (SFCN) parks. The SOP was taken with very few modifications from the Southeast Coast Network SOP *Salt Marsh Elevation Monitoring* (Asper and Curtis 2013). That document outlined procedures adapted from the sampling method developed by Cahoon et al. (2002) and Folse and West (2004). The sampling methodology is also thoroughly explained on the Surface Elevation Table (SET) site hosted through the United States Geological Survey (USGS) website (Cahoon and Lynch 2003). These references give an excellent overview of how the sampling occurs, but note that the following standards are written for the collection of data as a part of the South Florida / Caribbean Network Vital Signs Monitoring Program.

Revision Log

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

Overview

The South Florida / Caribbean Network has implemented the use of the RSET technique developed by Cahoon et al. (2002). The RSET is the preferred version of the SET, and benchmarks will be established at specified locations in attached, herbaceous marsh and mangrove scrub/shrub ecosystems. The RSET method is a non-destructive process which precisely measures the sediment elevation over a long period of time relative to a fixed subsurface datum (Figure 1). Briefly, a series of 4-foot stainless steel rods are driven through the root zone, the organic matter, and any soft underlying materials until refusal is encountered from a driving force on the rod. Near the surface, a custom-made stainless steel receiver is attached to the rod which is stabilized by a 6-inch-diameter pipe that is cemented at the surface. This stainless steel receiver provides a constant horizontal reference plane as well as long-term repeatability, as the RSET arm remains fixed for each sampling period. Detailed installation procedures are written in the SFCN SOP *Mangrove Soil Surface Elevation Monitoring: Site Platform Construction and Installation* (Whelan and Prats 2016a).

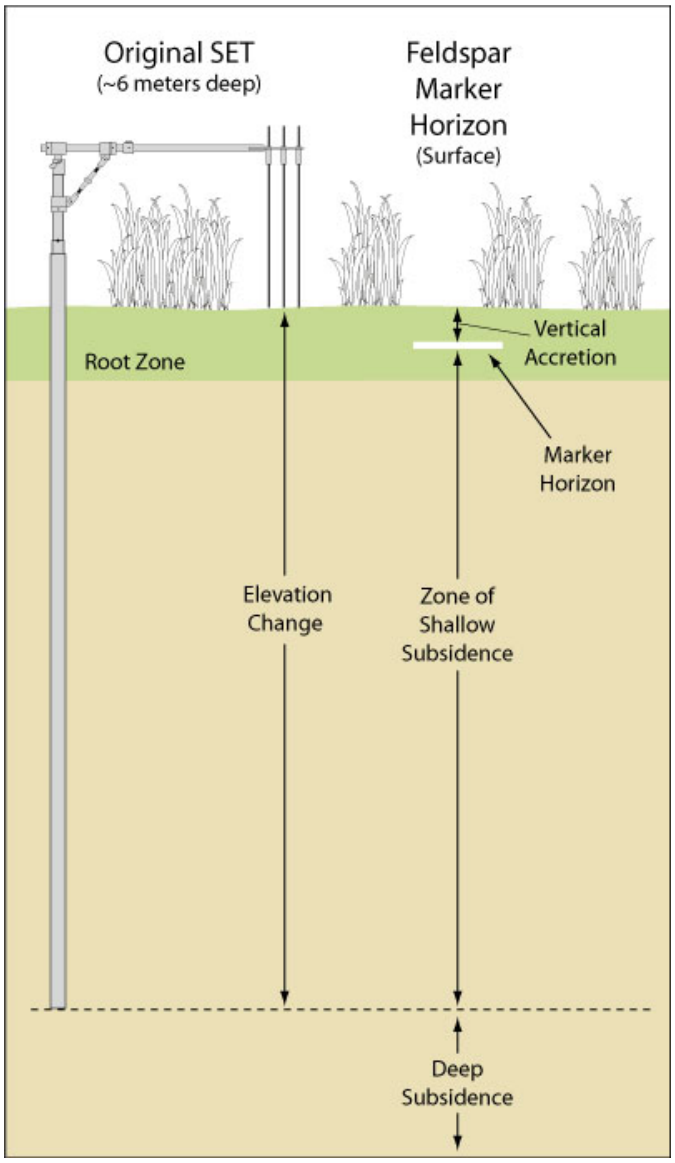

Figure 1. Conceptual diagram of SET monitoring station (Cahoon and Lynch 2003).

Data collection occurs by attaching a custom-made RSET arm (Figure 2) to the receiver, and lowering nine fiberglass pins through the RSET arm to the marsh surface. The height (measured in millimeters) that each pin extends above the arm is used to calculate vertical changes of the marsh surface over time. Using previously collected data, the rate of change can be calculated to provide status and trends with respect to changes occurring between the surface and the bottom of the stainless steel rods.

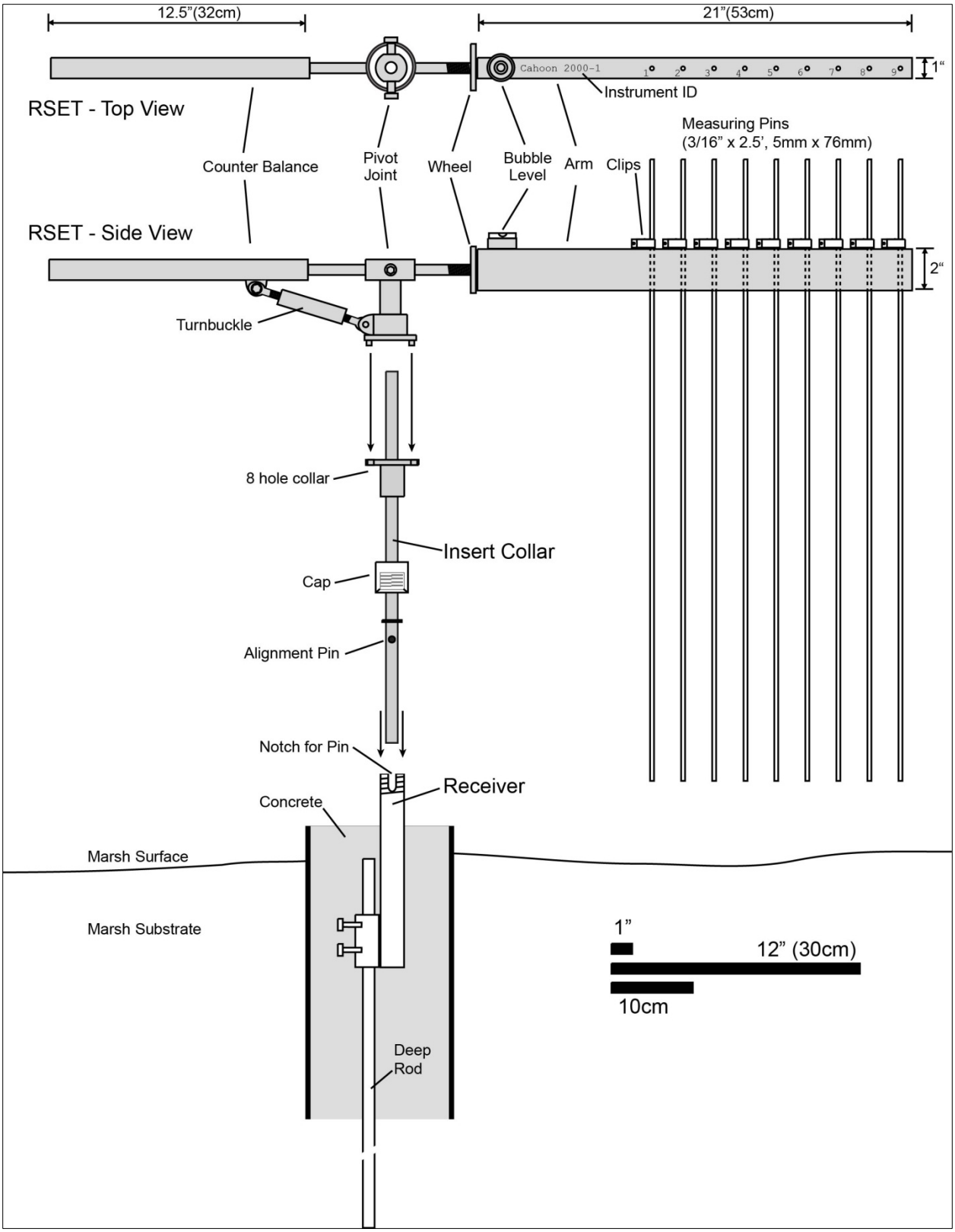

Figure 2. Drawing of a typical RSET with rod and collar. Inset shows close-up detail of RSET-collar coupling (from Callaway et al. 2014).

Procedures

The following procedures of mangrove soil surface elevation monitoring have been adapted from the sampling method developed by Cahoon et al. (2002) and Folse and West (2004).

Equipment and Materials

- RSET unit (contains the RSET and components listed below) (Figure 2)
    - Rod surface elevation table arm
    - Insert collar
    - Nine fiberglass pins (numbered to correspond with numbered holes on arm, respectively)
    - Nine badge clips
    - Two spring clamps
    - Bull's eye level
- Aluminum or stainless steel metric ruler, capable of measuring in millimeters with the end being zero millimeters
- Compass
- Digital camera
- RSET field form(s) (Appendix A)
- Field notebook
- Two 2″ × 12″ × 10′ boards or expandable aluminum planks
- Kneeling pads
- Cleaning supplies (brushes, towels, WD40®, etc.)
- Additional tools
    - Vice grips
    - Files
    - Hex keys

Due to some variability between crucial equipment pieces, the same RSET unit will be used to take the initial reading and all subsequent measurements at a benchmark. Therefore, the unit used for the initial reading should be documented on the RSET field form (Appendix A) to verify that the same unit was used at all data collections. The fiberglass pins are numbered 1 to 9 corresponding with the RSET arm holes, and fiberglass pins will be placed into corresponding holes during each data collection period, further ensuring measurements remain consistent in the future.

Instructions

NOTE: No walking or stepping on the marsh surface is permitted; all work is performed from the boardwalk.

Accretion stations will be established on the same day as the first RSET reading and are to be sampled when the RSET measurements are taken using the SFCN SOP *Measuring Accretion with a Feldspar Marker Horizon* (Whelan and Prats 2016b). Data from the previous RSET sampling should be downloaded from the database in order to review notes about the surface on which pins were previously placed. This ensures consistent measurements between sampling efforts as much as possible.

When working in a marsh site, mud flat, or tidal pond, it is preferred that the surface is not inundated. Exceptions can be made in cases such as erosion.

When possible, the same staff member should read the RSET every time. Due to turnover of staff, this is not always possible. In these cases, it is preferable for a "double-reading" to occur (see "Appendix D—Double Reading the RSET").

1. Visually inspect the site and verify that the platform is in good shape. Repair if necessary.

2. Place one or two boards across the two existing boardwalks (Figure 3).

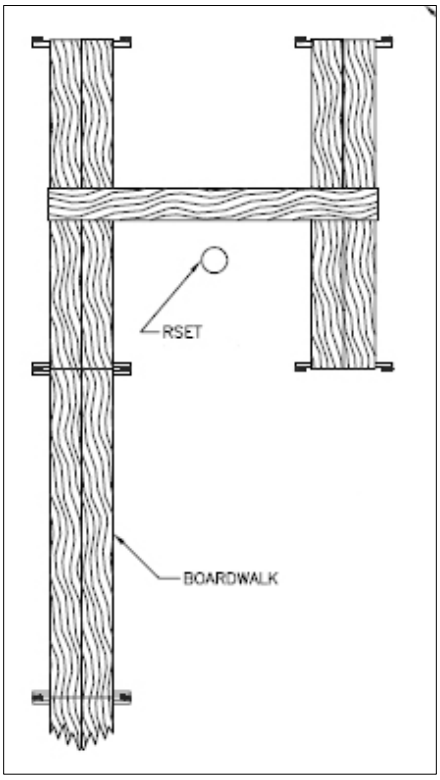

Figure 3. Diagram of board placement (modified from Folse and West 2004).

3. Move any material that has grown or accumulated on the receiver. This must be performed gently to ensure that the marsh surface is not disturbed.

4. Fill out the top of the RSET field form (Appendix A) including: RSET ID, feature name, sampling date and time, field personnel/organization name, and establishment date and time.

5. Remove the cap from the receiver (Figure 4).

Figure 4. Deep rod benchmark / monument and receiver capped (right) and receiver uncapped (left; from "Taking Your SET Readings" in Cahoon and Lynch 2003).

6. Attach the insert collar to the receiver.

7. Using the locking wheel, lock the RSET arm into position 6 centimeters from the exterior edge of the pivot joint (Figure 5).

Figure 5. RSET arm locked into position 6 centimeters from the exterior edge of the pivot joint.

8. One at a time, insert the nine fiberglass pins from the bottom into their corresponding numbered holes on the arm of the RSET (Figure 6) and secure them with badge clips so that the pins are just below the bottom of the RSET arm. Verify that the pin used matches the arm hole.

Figure 6. Fiberglass pins installed in the RSET with badge clips.

9. Slide the RSET onto the insert collar, aligning the collar pins with the holes in the collar (Figure 7) such that the arm points in the direction as close to 0° as possible.

Figure 7. RSET insert collar mounted to receiver. Inset: close-up of insert collar (modified from "Taking Your SET Readings" in Cahoon and Lynch 2003).

10. Identify four measurement directions.

NOTE: From a single RSET collar (Figure 8), there is a choice of eight directions (lines in Figure 8) from which to take readings. Take readings at four of the eight possible directions, starting with the direction closest to north (0°). Typically, the four directions are chosen so they are 90° from each other (i.e., as close to north, east, south, and west as possible), although other spatial patterns may be required for a particular site.

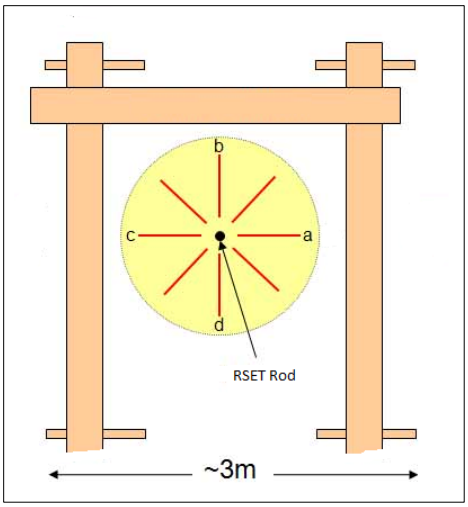

Figure 8. Permanent platform showing plot layout and potential directions for the RSET (modified from "Taking Your SET Readings" in Cahoon and Lynch 2003).

NOTE: Unless later disturbed, directions of measurement remain consistent throughout monitoring. Extra directions can be used should a problem arise—for example, if the site receives storm damage in one of the sampling plots or there is now a deep horse hoof print. In these cases, start another baseline using one of the four remaining directions.

If a disturbance occurs that would alter a majority of the readings in a particular direction, rotate the arm 45° from the initial direction to obtain new readings. Establishment of new directions should be well-documented and subsequent readings should be taken from this position. Human disturbance and large-scale animal disturbances (muskrat mounds, alligator trails) are reasons to move directions. If the disturbance is not human induced and it affects all possible directions, continue to measure the RSET if possible.

11. Clamp the RSET to the insert collar using two spring clamps (Figure 9). Level the RSET arm vertically and horizontally using the turn buckle and level bubble. Lock it into place with the locking wheel.

Figure 9. Clamp RSET to collar using spring clamps.

NOTE: The RSET arm should be perfectly level in order to get precise measurements. Make sure there are no plants or roots pushing on the pins or the arm when you level the arm. If the table arm is bumped during data acquisition, re-level it.

12. Using the compass, determine the measurement direction from the center of the RSET and out along the arm.

13. Record the compass bearing on the RSET field form (Appendix A).

14. Using a metric ruler, measure the distance between the top of the pivot joint and the top of the cap in millimeters. Record the value on the RSET field form (Appendix A).

NOTE: This value is recorded to account for any differences between the RSETs. If only one RSET is being used this value does not need to be recorded. The South Florida / Caribbean Network is utilizing a number of SETs during data collection, and although the network plans to use the same RSET at a given site, recording this value will account for any variability in equipment.

15. One at a time, unclip the badge clip on each pin and lower the pin until it touches the surface (Figure 10). Make sure the pin does not penetrate the marsh surface.

16. Place the clip back on the pin and repeat this for the other eight pins.

Figure 10. RSET with fiberglass pins being lowered to the marsh surface. Place the clip back on the pin and repeat this for the other eight pins.

17. As the RSET pins are being placed on the surface, follow the list of placement recommendations and take notes as directed (see "Appendix B—Guidelines for Placing RSET Pins").

18. If there is something in the location where the pin touches the surface, note it on the field form using "Appendix C—Pin Obstruction Abbreviations."

19. Recheck the bubble level to make sure the arm is still level. If the arm is no longer level, raise the pins, re-level the arm, and place the pins again.

    Using a metric ruler, measure from the top of the RSET arm (Figure 11) to the top of the pin and record the distance in millimeters on the field form in the "Observed Pin Height Soil (mm)" field. Read the nearest mm tick marker on the ruler visible in line with or above the top of the fiberglass pin. "Observed Pin Height Sea Grass (mm)" is for when there is a large amount of sea grass present at the site and two measurements are recorded.

NOTE: The measurer should make sure his/her eyes are level with the ruler. The person recording the measurements should verbally repeat the measurement back to the measurer to assure that the correct number was understood and recorded.

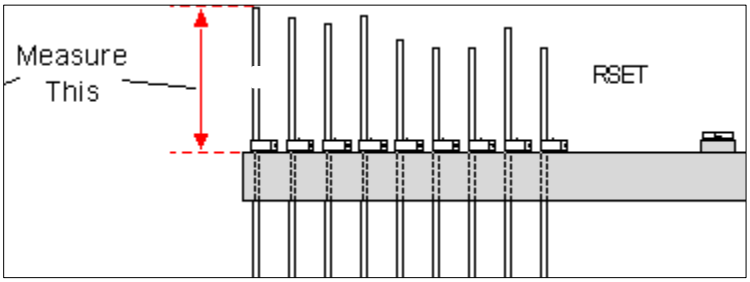

Figure 11. Diagram of pin measurement (modified from "Taking Your SET Readings" in Cahoon and Lynch 2003).

20. After recording measurements, raise each pin about two-thirds of its length up and clip each with a badge clip so that the bottoms of the pins do not interfere with rotating the RSET arm.

21. Unclamp, lift, and rotate the RSET arm 90° clockwise.

22. Repeat steps 11 through 21 until nine pin measurements have been obtained at each of the four cardinal points. Figure 12 is an example of how the data will be recorded in the field.

DEEP BISC SITE 1								SET Reader:		
Installation date 9/27/2010 -First Reading 2/11/2011								Data Recorder/other field members:		
SET instrument: BISC Whelar Ruler-Type: Stainless twopart ruler								Date:		
Fiberglass- 2 ft Height of Arm above monument:										
Date	**9/3/2014**			**02/12/15**			**09/24/15**			
Days										
	Seagrass is present but no double reading. Puddles present - tide out. Send out old feldspar notes Set 2 (107) a lot of seagrass present no double measurement.			**Seagrass is present but no double reading. Puddles present - tide out. Send out old feldspar notes Set 2 (107) a lot of seagrass present no double measurement.**						
	Observed Pin Height Soil (mm)	Observed Pin Height SeaGrass (mm)		Observed Pin Height Soil (mm)	Observed Pin Height SeaGrass (mm)		Observed Pin Height Soil (mm)	Observed Pin Height SeaGrass (mm)		
set #1 (001°) 1	241			244						
2	235			235						
3	230		root b	240		near root b- no hole				
4	232		near root b	238						
5	238			238						
6	230			231						
7	235			242						
8	233			231		near root b, no hole				
9	230		near root b	233		near root b				
1 (092°) 1	249			251						
2	242		near root b	235		moved leaves				
3	237		no hole	239		moved leaves				
4	242			243		root b				
5	249			246		near root b				
6	244			245						
7	244			244						
8	244			244						
9	240			242						
1 (138°) 1	248			245						
2	248		near root b	247		root b				
3	242		near root b	251		root b				
4	240		moved leaf	248						
5	244		moved leaf	247						
6	244		b	243		root b				
7	249		moved leaf	246						
8	246		moved leaf	243						
9	244		moved leaf	239						
1 (270°) 1			c hole - no measurement	238		near wood- not a c hole				
2	248			246						
3	251			254						
4	249			248						
5	245		root b	240		root b				
6	244			242						
7	246			243						
8	246			250						
9	245		lip of hole	245		no hole, root b				
set #2 (018°) 1	186		root w	186		root w				
2	187			196						
3	188			190						
4	187			191						
5	190			197						
6	183			193						
7	186		moved leaf	194						
8	185		moved leaf	195						
9	184		moved leaf	194						
2 (107°) 1	193			196						
2	192			194						
3	193			195						
4	192			192						
5	192			192						
6	189			201		moved leaf				
7	171		low spot	196		moved leaf				
8	194		moved sargasm weed	200		moved leaf				
9	190		moved sargasm weed	189						

Figure 12. Example of recorded data from a field sample. Nine separate height measurements are collected at each of the cardinal points for a total of 36 measurements taken at each RSET location. SET#1 (001°) 1 is SET number 1 on a bearing of 001° and the first pin.

23. Describe the condition of the RSET plot in the “comment” box on the field form:
    - Vegetative health (healthy, stressed, dead)
    - Disturbance to the RSET plot and the cause of the disturbance, if known (fire, grazing, other animal activity [trails, nests], human, other)
24. Measure water depth in the RSET plot in three or more locations and estimate average depth if the mangrove forest is flooded. If the forest is not flooded, note whether it is wet or dry. Provide additional notes if it is very dry and cracked.
25. Take a digital picture of the RSET plot (above) from the long platform facing the RSET plot and the short platform.
26. Take a digital picture of the close-up view of the marsh surface and base of dominant vegetation within the RSET plot that is representative of the site surface.
27. Verify the field form is complete, break down and store the RSET, replace the threaded cap, remove planks, and proceed to the next site.

Literature Cited

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Whelan K. R. T. and M. C. Prats. 2016b. Measuring accretion with a feldspar marker horizon—Version 1.00. South Florida / Caribbean Network Standard Operating Procedure NPS/SFCN/SOP—SET06. National Park Service, Miami, Florida

Appendix A—RSET Field Form

Figures A-1 and A-2 contain the RSET field form (divided in two parts) with examples of recorded data. The text following the figures provides additional information about recording data in the field form.

DEEP BISC SITE 1							SET Reader:		
Installation date 9/27/2010 -First Reading 2/11/2011							Data Recorder/other field members:		
SET instrument: BISC Whelar Ruler-Type: Stainless twopart ruler							Date:		
Fiberglass- 2 ft Height of Arm above monument:									
Date Days	9/3/2014			02/12/15			09/24/15		
	Seagrass is present but no double reading. Puddles present - tide out. Send out old feldspar notes Set 2 (107) a lot of seagrass present no double measurement.			Seagrass is present but no double reading. Puddles present - tide out. Send out old feldspar notes Set 2 (107) a lot of seagrass present no double measurement.					
	Observed Pin Height Soil (mm)	Observed Pin Height SeaGrass (mm)		Observed Pin Height Soil (mm)	Observed Pin Height SeaGrass (mm)		Observed Pin Height Soil (mm)	Observed Pin Height SeaGrass (mm)	
set #1 (001°) 1	241			244					
2	235			235					
3	230		root b	240		near root b- no hole			
4	232		near root b	238					
5	238			238					
6	230			231					
7	235			242					
8	233			231		near root b, no hole			
9	230		near root b	233		near root b			
1 (092°) 1	249			251					
2	242		near root b	235		moved leaves			
3	237		no hole	239		moved leaves			
4	242			243		root b			
5	249			246		near root b			
6	244			245					
7	244			244					
8	244			244					
9	240			242					
1 (138°) 1	248			245					
2	248		near root b	247		root b			
3	242		near root b	251		root b			
4	240		moved leaf	248					
5	244		moved leaf	247					
6	244		b	243		root b			
7	249		moved leaf	246					
8	246		moved leaf	243					
9	244		moved leaf	239					
1 (270°) 1			c hole - no measurement	238		near wood- not a c hole			
2	248			246					
3	251			254					
4	249			248					
5	245		root b	240		root b			
6	244			242					
7	246			243					
8	246			250					
9	245		lip of hole	245		no hole, root b			

Figure A-1. Example of RSET field form with recorded data, part 1 of 2.

set #2 (018°) 1	186		root w	186		root w			
2	187			196					
3	188			190					
4	187			191					
5	190			197					
6	183			193					
7	186		moved leaf	194					
8	185		moved leaf	195					
9	184		moved leaf	194					
2 (107°) 1	193			196					
2	192			194					
3	193			195					
4	192			192					
5	192			192					
6	189			201		moved leaf			
7	171		low spot	196		moved leaf			
8	194		moved sargasm weed	200		moved leaf			
9	190		moved sargasm weed	189					
3 (280°) 1	244			259					
2	248			261		root b			
3	260		high spot - root b	281		high spot			
4	269		high spot - root b	269		root b			
5	263		high spot - root b	262		root b			
6	261			259					
7	266			261					
8	257			258					
9	257			256					
all reading waterdepth checked	Dry Site Yes			Dry Site Yes					
	Low Tide @ 11:07 am	High Tide @ 5:05 pm		Low Tide @ 9:34 am	High Tide @ 3:22 pm		Low Tide	High Tide	
	start	stop		start	stop		start	stop	
set 1	10:15 AM	11:43 AM		9:00 AM	10:45 AM	site			
set 2									
set 3									

Figure A-2. Example of RSET field form with recorded data, part 2 of 2.

Key for filling out RSET field form

- Bottom part of field form: use for location time and water conditions
- **RSET ID**: Park four letter code plus one-digit site code; i.e., BISC1
- **Date**: Date of sampling
- **Installation Date** : Date of RSET installation
- **SET Reader**: Name of person reading SET
- **Data Recorder/other field members**: Name of person recording data
- **Field personnel / Organization**: Name(s) of other field member(s)
- **SET Instrument**: RSET equipment ID; here, "BISC1 Whelan"
- **Height of Arm above monument**: Distance in millimeters between the top of the arm and the top of the receiver/monument
- **Observed Pin Height** columns: Record in millimeters with three digits
- **Comments (**columns to right of Pin Height**)**: Text notes
- **Site Conditions** (blank boxes at top of RSET form): Text notes
- **LowTide** and **HighTide start** and **stop**: Record start and end time in four-digit military time
- **Dry Site**: Record Yes or No

Appendix B—Guidelines for Placing RSET Pins

Though it is nearly impossible to remove all subjectivity from the readings, the following guidelines help limit the level of subjectivity by creating a standard.

- Surface of marsh should not be inundated. Exceptions can be made in cases such as erosion.
- It is easiest to lower pins in order of the farthest from the reader to the closest to the reader.
- Push vegetation aside when necessary, but only if it does not affect the marsh surface at all.
- Detritus, leaves, and other materials on the surface should be left untouched.
- Remove manmade materials in the gentlest manner possible if on site.
- If a pin rests on an unusual surface, such as an oyster shell, branch, or crab hole, make a note on the data sheet using the list of abbreviations in Appendix C.
- If it is not possible to place the pins on the surface and the pin is on an unrepresentative surface for that site, record the pin height and mark an “X” to omit the pin. Include an explanation.
- Placing the pins on a dry surface is mainly accomplished visually.
- If water is on the surface, it may be necessary to place pins by “feel” using resistance.
- If it is necessary to take actions that are not outlined here, take notes in the “comments” section to explain actions. Note anything (shell, plants, obstructions, etc.) in the way of any pins. It is always better to make a note so we can decide to keep or discard the data. Also, if you step in the plot or drop the ruler in the plot, just make a note of it on the datasheet.
- Interpreting the surface can be subjective; take as many notes as is necessary for the methods to be repeatable.

Appendix C—Pin Obstruction Abbreviations

Table C-1. Abbreviations for RSET pin obstructions, to be used when filling out RSET field form (see Appendix A).

Abbreviation	Description
Hill	Transitional slope referring to a small knoll or mound above the rest of the marsh surface
Hole/inhole	Deep hole within the mangrove soil surface and usually excluded from analysis
No Hole	Was a hole in previous sample but the hole has filled in
Low spot	Depression—area below the rest of the mangrove soil surface (not a hole or crab burrow) and usually included in analysis
Chole	Crab burrow within the mangrove soil surface
Chill/Lip of hole	Crab burrow chimney within the mangrove soil surface; pin lands on the chimney of the crab burrow.
Root b	Black mangrove (*Avicennia germinans*) pneumatophore
Root r	Red mangrove (*Rhizophora mangle*) root
Root w	White mangrove (*Laguncularia racemosa*) root
Wood	Pile of vegetation or stem that cannot be moved without compromising soil surface
S	Shell
AP	Animal print

Appendix D—Double Reading the RSET

In an ideal situation as described by Cahoon and Lynch (2003) in the "Taking Your SET Readings" section of the SET website, "the same person [should] read the [R]SET from sampling to sampling. This approach will maintain a consistent sampling protocol when taking the readings and minimize sampling errors." But, with a high turnover of field personnel, this proves difficult. When possible, double reading the RSET is preferred. The other less desirable option is to develop a new baseline with the new reader, adjusting the data trends accordingly.

"For example, suppose [R]SET reader #1 has been reading the data since the project started, but is leaving for a new job. [R]SET reader #2 is going to replace him/her. The best situation would be for both readers to go and sample the site together [(i.e., a double reading)]. Reader #1 would take their final set of readings with the [R]SET [(i.e., collect data following steps 1–22]. Then reader #2 would take a repeat set of readings [following steps 4–22]" ("Taking Your SET Reading, in Cahoon and Lynch 2003).

Cahoon and Lynch (2003) also recommend performing a double-read when switching pins. For example, if longer pins are necessary, a double reading with both sets of pins will account for the change. Take "a final reading with the original pins and a baseline reading with the new pins" ("Taking Your SET Reading", in Cahoon and Lynch 2003).

Literature Cited

Cahoon, D. R., and J. C. Lynch. 2003. Surface elevation table website. United States Geological Survey, Patuxent Wildlife Research Center, Laurel, Maryland. Available at http://www.pwrc.usgs.gov/set/ (accessed 8 June 2016).