

Standard Operating Procedure (SOP) #8:

Conducting Marine Benthic Cover and Rugosity Surveys

Version 3.02 (August 16, 2021)

Change History

New Version #	Revision Date	Author	Changes Made	Reasons for Change	Previous Version #
2.00	6/30/2007	Eric Brown	See Track Changes	Response to reviewer's	1.00
2.01	7/20/2007	Larry Basch	See Track Changes	Corrections, additions	2.00
3.00	8/15/2019	Kelly Kozar, Amanda McCutcheon	Updated instructions for newer camera, updated SOP #s, updated datasheet.	To more accurately reflect the current process during sampling. Added a geospatial SOP and had to renumber subsequent SOPs.	2.01
3.01	5/26/2020	Sheila McKenna	Updated instructions so applicable in general to all camera set ups	To accommodate the different camera equipment set ups and fine tune the process for benthic images and rugosity	3.00
3.02	8/16/2021	Kelly Kozar	Updated some survey steps.	To make more consistent with Marine Fish survey SOP.	3.01

Only changes in this specific SOP will be logged here. Version numbers increase incrementally by hundredths (e.g., version 1.01, version 1.02) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0). Record the previous version number, date of revision, author of the revision, changes made, and reason for the change along with the new version number.

Purpose

This SOP explains how to conduct benthic photographic surveys to assess substrate composition (percent cover) of live corals, algae, and other benthic organisms or substrates. It also describes how to measure rugosity and acquire environmental metadata at each transect. The SOP assumes that a monitoring site has been previously established (see SOP #7 Selecting and Marking Subtidal Sampling Transect Locations). Therefore, the SOP will detail relocating the monitoring site, relaying the transect line, and photographing the benthic substrate using a digital camera in an underwater housing. This SOP is designed to be completed by two divers (see SOP #2 Training Observers).

A master equipment list for the entire Benthic Marine Community Vital Sign Monitoring Protocol can be found in Appendix SOP 1.a of SOP #1 Before the Field Season. The master equipment list should be updated simultaneously if this SOP is revised. A list of equipment required to complete the tasks specified in this SOP has been provided in Appendix SOP 8.a in this SOP.

General Procedure

General instructions for each camera set up by park (KAHO, KALA, NPSA, and WAPA) can be found in SOP #6 Pre-Dive Equipment Preparation. Specific instructions for each camera and associated housing and batteries can be found in the manufacturer's instruction provided via link in Table SOP 6.1 of SOP #6 Pre-Dive Equipment Preparation. In this SOP, the instructions have been written in general terms applicable to all camera equipment set ups. The benthic image camera operator should be thoroughly familiar with the manufacturer's instructions for all equipment used in the set up. Use of this equipment, while shown to be effective, is not intended as an endorsement of any manufacturer or model.

The amount of time needed to complete this procedure is approximately 10 minutes for relocating the start pin at fixed sites or a start position for the temporary sites and laying out the transect. It is important to note that if the fish surveys are being done first, the benthic team must wait until the fish observer finishes completely or is far enough down the transect so as not to interfere with the fish process. Further the transect should be secure or taut when taking photos so if the transect is swaying back and forth while the fish person is surveying, the benthic team should wait until the fish observer is done and transect has been secured to minimize or restrict movement. An additional 10-15 minutes will be needed for photographing quadrats along a 25 m transect in ideal conditions. The procedure needed for obtaining a measurement of rugosity takes an additional 15-20 minutes. All safety precautions will be followed as outlined in SOP #3 Safety Protocol.

Equipment

For a complete list of equipment needed to carry out these procedures, please refer to Tables in Appendix SOP 8.a. Also refer to SOP #6 Pre-Dive Equipment Preparation and SOP #1 Before the Field Season for a complete listing of equipment needs. Observers will want to ensure that all equipment is available in working order prior to the scheduled survey dive day. For more detailed information on protocol prior to dive day, please see SOP #6 Pre-Dive Equipment Preparation.

Datasheets needed for this protocol can be found in Appendix SOP 8.b. Datasheets should be photocopied or printed onto plastic paper for use underwater.

Relocating the Monitoring Site

Step by step procedures:

1. Navigate by boat, or surface swim, to a transect start point using a GPS (Global Positioning System) unit which has the transect start point stored as a Waypoint. If surface swimming, put the GPS in a transparent waterproof container attached to a surface float (e.g. inner tube with dive flag) that has a line and a bottom weight to attach at the transect start point (see SOP #4 Using Garmin® GPS Units for information on using a GPS).
2. At approximately 3 meters from the site, carefully but quickly lower a surface float marker or Pelican® surface float from the boat with a bottom weight (~1 kg) so that it comes to rest as close as possible to the transect start/terminus pin or point.

3. If a permanent mooring buoy-line is available nearby, use it to securely tie off boat's bow line. Then, locate the deployed surface float by taking a compass bearing to it. If live boating be sure to follow all instructions of the boat captain and ensure communication, including hand signals and other procedures as per safety documents (e.g., SOP #3 Safety Protocol, GAR and JHA) are followed.
4. Check to ensure that all dive gear is in working order and that the primary and secondary regulators as well as power inflation devices are working correctly. This procedure also ensures that the divers' air is turned on.
5. Put on dive gear and enter the water.
6. Retake a compass bearing to surface float if needed. For detailed procedures on GPS and taking bearings see SOP #4 Using Garmin® GPS Units.
7. If a surface float is used, swim to the float and descend down the line.

Locate Transect Pin and Lay Transect Line at Permanent Sites

Note: If marine fish surveys are conducted on the same dive, the fish observer will lay the transect line and secure the ends. The benthic diver will assist with step 1 and 2, and then should remain at a safe distance from the fish diver at allow for assistance in an emergency but try not to interfere with the fish survey.

Step by step procedures:

1. Underwater, locate the bottom float marker.
2. Begin a systematic search for the transect start pin marked with one cable tie at KALA, NPSA, and WAPA or two cable ties at KAHO; clean the pin of fouling organisms as needed using gloved hand, scrub, or wire brush. If necessary, move the bottom float marker to the vicinity of the transect start pin.
3. Secure the brass clip end of the transect line/tape around the start.
4. Take the known compass bearing to the end point of transect, pull the line taut, loop the line around the end pin at least twice so that it does not slip and loosen or use a clip to secure the line. Look at the transect, it should now be installed such that the line is straight, suspended just on the bottom and taut over its entire length; adjust as necessary.
5. Once the fish (and benthic) surveys are complete, reel up the transect line.

Lay Transect Line at Temporary Sites

Note: If marine fish surveys are conducted on the same dive, the fish observer will lay the transect line and secure the ends. The benthic diver will assist with step 1 and 2, and then should remain at a safe distance from the fish diver at allow for assistance in an emergency but try not to interfere with the fish survey.

Step by step procedures:

1. Navigate to the temporary site and deploy the Pelican® surface float with a bottom weight (~1 kg) or other surface marker buoy or have the divers disembark from the boat directly above the site.
2. Upon arriving at the temporary site, randomly determine the compass bearing of the transect that is parallel to the shoreline. This can be done on the boat or at the surface prior to beginning the dive. Typically, there are only 2 possible bearings along a depth contour, but this can be adjusted slightly when the divers descend down the float line and scan for homogeneous habitat along with the direction of the substrate contour.
3. As there are no pins at temporary transect locations, tie one end of the transect line securely around a dead coral colony or piece of rubble nearest the bottom weight. The tie-off location will be the first available piece of dead coral or rubble along the selected compass bearing of the transect
4. Once the line is secured, swim the known compass bearing along a depth contour within a homogeneous habitat until 26 m of transect line has been spooled out. Pull the line taut and tie off securely to a dead coral colony or rock. The transect should now be installed such that the line is straight, suspended just above the bottom and taut along its entire length. Make sure to record the compass bearing of the transect lines from the starting point to facilitate plotting of the transects in ArcGIS®.
5. Once the fish (and benthic) surveys are complete, reel up the transect line.

Taking Photographs

Step by step procedures:

1. Turn the camera power on and ensure that the zoom is all the way out (i.e., wide angle). The camera mode should be set at “Program Shooting”, represented by the “P” icon on the On/Off/Mode dial of the camera housing.
2. Ensure the camera is working at the surface by photographing a slate on which the monitoring site identifier metadata is written or the benthic datasheet with the header lines filled in. The metadata identifier should include the following fields identified in Table SOP 8.1.

Table SOP 8.1. Metadata identifiers and format.

Field	Format
Date and time	YYYYMMDD, XXXX:XX 24 hr or military time
Station Number	Park Code (four letter) and transect location type and number (e.g., NPSA Temp 1)

3. Ensure the monopod is securely attached to the camera housing with the housing at a fixed height of 0.5 m.
4. Set the white balance by following the steps as provided in the camera’s manual.

5. To conserve batteries, you can turn the camera power off until you are ready to begin photographing.
6. At the start point (0-meter mark) of the transect, take landscape (horizontally oriented) photographs facing magnetic north (0°) and in three subsequent 90-degree directions moving in a clockwise direction. These photographs will provide a general overview of the transect habitat at the transect location.
7. Along the transect, begin photographing the benthos at the 0 m and at each successive 1-meter mark along the transect tape. Place the monopod foot at each line meter mark on the shoreward side of the transect, perpendicular to the substrate and holding the camera as level as possible, depress the Shutter Button on the upper right of the camera housing to take a photo. Check the photo on the camera's LCD monitor back to ensure it is in focus and properly exposed. If it is not, take another exposure. Continue to take photos until a satisfactory one has been obtained but take at least two photos at each location.
 - a. This step may be easiest to do with two divers, especially in heavy surge. One diver controls the camera. The second diver positions the monopod foot in the appropriate position along the transect line and then moves out of the photograph. If necessary, for example, in surge conditions, the second diver can help steady the diver operating the camera by holding his or her tank valve with one hand and the bottom with the other hand.
 - b. It is important to take the photo perpendicular to the substrate even if the substrate is highly uneven (rugose) or nearly vertical. The resulting photograph will be much easier to process. If necessary, reposition camera to be perpendicular, reshoot, and view image until a satisfactory one has been taken. As needed, take field notes of observations within photoquadrats on the benthic datasheet (noting photo number and photoquadrat number [distance on tape]) to facilitate interpretation and accurate collection of data from photos on biotic or other substrate cover types. Although somewhat more time consuming, this step is important data, as photoquadrats alone do not always accurately record all cover categories.
8. Continue to move along the transect, taking a photo at each meter mark on the line. Take the last photograph at the 25 m mark. There will be a total of 26 unique quadrat photos, not counting the duplicates at each location.
9. Take landscape photos at the end pin in the same manner as Step 3. Note the end time on the benthic datasheet.
10. It is encouraged that you also take photos of any unusual species, coral health issues such as coral bleaching or disease, and other interesting items that are encountered on the dive. Be sure to keep good notes on the benthic datasheet of what you photographed. Separate these non-data photos from the transect photos by photographing your slate or hand before and after taking non-data photos and note down photo numbers on the datasheet.

Rugosity Measurement

Step by step procedures:

After the photoquadrat sampling is completed, a rugosity measurement is made on the transect line. Rugosity is measured using the chain and tape method described by McCormick (1994). A light brass “window sash” chain with a weight at the starting end (marked with flagging tape), and marked off in 1 m intervals (See SOP #1 Before the Field Season for construction) is closely draped over the bottom topography along the entire length of each 25 m transect. The amount of chain necessary to span the distance between the two transect marker pins is divided by the straight-line tape measurement to generate an index of rugosity for that transect.

1. Start at the beginning of the transect line with the rugosity chain and set one end of the chain by the transect marker pin. Note: the short length of chain is used due to its weight. Length of the rugosity chain varies depending on park and usually range from 10-20m in length.
2. Spool out and drape the chain on the bottom so that it closely contours the substrate.
3. Use gravity to set the chain on the bottom in a straight line under the transect line.
4. Place the chain down on the substrate manually but do not force the chain into holes or under ledges. Ideally, this would be a more accurate measure of topography, but it may be hazardous to insert your hand or fingers into cracks and crevices within the reef.
5. Continue to drape the chain until the chain ends, mark that spot with a piece of flagging tape tied to a small weight (e.g., a fishing sinker or large bolt is usually sufficient), retrieve the chain and then redeploy it from the marked spot until the end of the 25 m transect tape is reached.
6. Record the length of chain (to 0.1 m) used to reach the 25 m mark. For example, on a 25 m transect line if you have spooled out the first 20m and then spooled out an additional 18.6 m of line you will have used 38.6 m of chain to span the entire transect line. Retrieve the chain.
7. Once finished, untie the transect line, reel it in, and collect the bottom float marker before ascending to your safety stop.
8. The rugosity index is calculated by dividing the total length of chain laid over the entire transect line distance by the transect line length (25 m). In the preceding example, the rugosity index would be: $38.6 \div 25.0 = 1.54$. Note: there is no need to calculate this index in the field.

Environmental Metadata

Environmental data collected both above and below the water can provide valuable insight into the validity of, or limitations to, data collected and can be valuable for interpreting monitoring data. The data will be entered on datasheets in Appendix SOP 8.b and ultimately into the environmental data table in the database. In air data should be filled out prior to entering the water, in water data can be entered during, or upon completion of the dive. Data that is required will be subject to all of the data

entry and management requirements of the I&M program. Optional data can be collected by the parks but will not be managed by the I&M data management guidelines.

In Air/On Surface Environmental Variables

Required data collected include the variables and descriptions in Table SOP 8.2.

Table SOP 8.2. Data variables and description for on surface environmental variables.

Data Variable	Description
Park code	Four letter code (e.g., KAHO, KALA, NPSA, WAPA)
Transect number	Site designation code
Date	Year, Month, Date (YYYY, MM, DD)
Time	24 hour universal or military time (HH:MM)
Observers	Specify names and initials of individuals responsible for specific tasks, including vessel operator, deck hands, other scientific divers

Optional data include those fields and descriptions in Table SOP 8.3.

Table SOP 8.3. Optional data fields.

Field	Description
Weather conditions	Estimated percent cloud cover, precipitation (yes/no), air temperature (degrees Celsius)
Beaufort sea state conditions	Can be acquired from local weather station, or use Table SOP 8.4
Sea surface conditions	Specify water clarity from the water surface (is the bottom visible?)

Table SOP 8.4. Beaufort sea state conditions (Modified from Gross 1977).

Beaufort Number	Wind (km/hr)	Speed	Seaman's term	Effects observed at sea
0	<1		Calm	Sea like a mirror
1	1-5		Light air	Ripples with appearance of scales; no foam crests
2	6-11		Light breeze	Small wavelets; crests of glassy appearance, not breaking
3	12-19		Gentle breeze	Large wavelets; crests begin to break; scattered whitecaps
4	20-28		Moderate breeze	Small waves, becoming longer; numerous whitecaps
5	29-38		Fresh breeze	Moderate waves, taking longer form; many whitecaps; some spray
6	39-49		Strong breeze	Larger waves forming; whitecaps everywhere; more spray
7	50-61		Moderate gale	Sea heaps up; white foam from breaking waves begins to be blown in streaks
8	62-74		Fresh gale	Moderately high waves of greater length; edges of crests begin to break into spindrift; foam is blown in well-marked streaks
9	75-88		Strong gale	High waves; sea begins to roll; dense streaks of foam; spray may reduce visibility
10	89-102		Whole gale	Very high waves with overhanging crests; sea takes white appearance as foam is blown in very dense streaks; rolling is heavy and visibility reduced
11	103-117		Storm	Exceptional high waves; sea covered with white-foam patches; visibility still more reduced
12	118-133		Hurricane	Air filled with foam; sea completely white with driving spray; visibility greatly reduced

In Water/Sub-Surface Environmental Variables

Required data include the variables and descriptions in Table SOP 8.5.

Table SOP 8.5. In-water required data variables.

Data Variable	Description
Habitat Type	Specify Hard Bottom, Unconsolidated Sediment, or Other
Subhabitat Type	Specify Spur and Groove, Patch Reef (individual or aggregated), Pavement, Pavement with Sand Channels, Aggregated Reef, Volcanic Rock/Boulder, Reef Rubble, Scattered Rock/Coral in Unconsolidated Sediment.
Depth	Depth at the start of the transect
Compass Bearing	Direction the transect is laid
Start/End Time	Start and end time of the benthic photographs in 24 hr format HH:MM
Miscellaneous notes	Noteworthy observations (e.g., observed spawning, plankton (including larvae), thin layers, thermocline)

Optional data include those fields and descriptions in Table SOP 8.6.

Table SOP 8.6. In-water optional data variables.

Field	Description
Schlieren layers	Presence or absence of "Schlieren layers" – if present approximate depth
Water motion at bottom	Specify calm, mild, moderate or strong surge, apparent current direction and speed

Literature Cited

Gross, G. 1977. Oceanography a view of the earth. Prentice-Hall, Inc. Englewood Cliffs, New Jersey, USA.

McCormick, M.I. 1994. Comparison of field methods for measuring surface topography and their associations with a tropical reef fish assemblage. Marine Ecology Progress Series **112**:87-96.

Appendix SOP 8.a. Equipment list

Table SOP 8.7. Equipment list for conducting marine benthic cover surveys. This equipment list refers to SOP #6 Pre-Dive Equipment Preparation.

Equipment (#/quantity)	Preparation & Maintenance
Digital still camera prepared and mounted into U/W housing and monopod	See SOP #6 Pre-Dive Equipment Preparation and SOP #8 Conducting Marine Benthic Cover and Rugosity Surveys
Small wire brush	Ensure that this equipment is available
30 m transect line	Labeled at 50 cm intervals, see SOP #1 Before the Field Season
Coordinates, depths, compass headings, or maps of transect locations	Ensure that this equipment is available; See SOP #7 Selecting and Marking Subtidal Sampling Transect Locations
GPS (1)	Ensure in working order; See SOP #4 Using Garmin® GPS Units
Transparent waterproof container for GPS (1)	Ensure that this equipment is available
U/W compass (1)	Ensure that this equipment is available
Surface float marker (2)	One for back-up; Ensure that this equipment is available
U/W slate with pencils (2)	Ensure that this equipment is available
U/W field data forms	See SOP #8 Conducting Marine Benthic Cover and Rugosity Surveys
U/W lights (2)	Ensure equipment is in working order
U/W light batteries (2 sets)	Ensure equipment has sufficient power
Pelican case	Ensure that this equipment is available
Scuba gear	See SOP #6 Pre-Dive Equipment Preparation and SOP #23 After the Field Season
Boat, motor, and trailer	See SOP #6 Pre-Dive Equipment Preparation and SOP #23 After the Field Season

Table SOP 8.8. Equipment list for conducting benthic rugosity measurements. This equipment list refers to SOP #6 Pre-Dive Equipment Preparation.

Equipment (#/quantity)	Preparation & Maintenance
10-20 m rugosity chain on spool	See SOP #1 Before the Field Season
30 m transect line	See SOP #1 Before the Field Season
Coordinates, depths, compass headings, maps of sampling locations	Ensure that this equipment is available; See SOP #7 Selecting and Marking Subtidal Sampling Transect Locations, SOP #6 Pre-Dive Equipment Preparation, and check database and log book.
GPS (1)	Ensure in working order; See SOP #4 Using Garmin® GPS Units
Transparent waterproof container for GPS (1)	Ensure that this equipment is available
U/W compass (1)	Ensure that this equipment is available
U/W slate with pencils (2)	Ensure that this equipment is available
U/W field data forms	See SOP #8 Conducting Marine Benthic Cover and Rugosity Surveys
U/W lights (2)	Ensure equipment is in working order
U/W light batteries (2 set)	Ensure equipment has sufficient power
Scuba gear	See SOP #6 Pre-Dive Equipment Preparation" and SOP #23 After the Field Season
Boat, motor, and trailer	See SOP #6 Pre-Dive Equipment Preparation" and SOP #23 After the Field Season

Appendix SOP 8.b. Datasheet for Collection of Benthic Cover

Park: _____ Transect Type: *Fixed / Temp* Transect #: _____

Benthic Date: ____/____/____ Benthic Start Time: ____:____ Benthic End Time: ____:____

Observer Name	Role

Start Latitude: _____ Start Longitude: _____

Geo Datum: *WGS 1984* Accuracy Notes: _____

Habitat Type: _____ Sub-habitat: _____

Start Depth (m): _____ Compass Bearing: _____

Fish Transect Date*: ____/____/____ ☐ No fish data Sonde Date*: ____/____/____ ☐ No sonde data

*Water quality sonde and fish transects should happen on the same date

Fish/WQ Notes:

Was Rugosity measured? Yes / No

Rugosity Notes:

Chain Length (m): _____

Transect Length (m): _____

Benthic Notes:

In Lab:

Analysis Date: ____/____/____

Frame Identifier: _____

Additional Comments:

Habitat Codes

HB Hard Bottom

US Unconsolidated Sediment

OT Other

Subhabitat Codes

SG Spur and Groove

AR Aggregate Reef

PRI Patch Reef (Individual)

PV Pavement

PRA Patch Reef (Aggregated)

VRB Volcano Rock/Boulder

PVS Pavement with Sand Channels

RR Reef Rubble

SR Scattered Rock/Coral in Unconsolidated Sediment