

South Florida / Caribbean Network

National Park Service
Inventory and Monitoring Division



Long-Term Monitoring Protocol of Caribbean Spiny Lobster (*Panulirus argus*)

Standard Operating Procedures



Please cite this as:

South Florida/Caribbean Network. 2018. Long-Term Monitoring Protocol of Caribbean Spiny Lobster (*Panulirus argus*): Standard Operating Procedures. South Florida/Caribbean Network, Miami, Florida.

ON THE COVER

Clockwise from the top left; measuring carapace length of a Caribbean spiny lobster (*Panulirus argus*) in Biscayne NP, a lobster walking across the reef in Buck Island Reef NM, and a lobster den under a coral head in Dry Tortugas NP. Photographs by Andy Davis, Lee Richter, and David Bryan.

Contents

Standard Operating Procedure 1

Sample Frame and Habit Classification	SOP 1-1
---	---------

Standard Operating Procedure 2

Stratification—Version 1.00.....	SOP 2-1
----------------------------------	---------

Standard Operating Procedure 3

Sample Allocation—Version 1.00.....	SOP 3-1
-------------------------------------	---------

Standard Operating Procedure 4

Lobster Data Collection and Survey Methods—Version 1.00	SOP 4-1
---	---------

Standard Operating Procedure 5

Training—Version 1.00.....	SOP 5-1
----------------------------	---------

Standard Operating Procedure 6

Data Entry, QA/QC, and Management—Version 1.00	SOP 6-1
--	---------

Standard Operating Procedure 7

Data Analysis and Reporting—Version 1.00	SOP 7-1
--	---------

Standard Operating Procedure 8

Revising the Protocol—Version 1.00.....	SOP 8-1
---	---------

National Park Service
Inventory and Monitoring Division



Standard Operating Procedure 1

Sample Frame and Habitat Classification—Version 1.0

Purpose

This standard operating procedure (SOP) describes the background and development of the sample frame and habitat classification scheme used for sample allocation within this protocol and how the habitat maps will be updated in the future. The sample design for the spiny lobster monitoring protocol uses the sample frame and habitat classification in the previously published reef fish monitoring protocols for Florida and the U.S. Virgin Islands (Brandt et al. 2009; Bryan et al. 2013).

Revision Log

[illegible]

Source Protocol

This SOP is derived from SOP A in the Florida reef fish monitoring protocol and SOP 1 in the Virgin Islands reef fish monitoring protocol:

Brandt, M. E., N. Zurcher, A. Acosta, J.S. Ault, J. A. Bohnsack, M. W. Feeley, D. E. Harper, J. H. Hunt, T. Kellison, D. B. McClellan, M. E. Patterson, and S. G. Smith. 2009. A cooperative multi-agency reef fish monitoring protocol for the Florida Keys coral reef ecosystem. Natural Resource Report NPS/SFCN/NRR—2009/150. National Park Service, Fort Collins, Colorado.

Bryan, D. R., A. J. Atkinson, J. S. Ault, M. E. Brandt, J. A. Bohnsack, M. W. Feeley, M. E. Patterson, B. I. Ruttenberg, S. G. Smith, and B. D. Witcher. 2013. A cooperative multiagency reef fish monitoring protocol for the U.S. Virgin Islands coral reef ecosystem. Natural Resource Report NPS/SFCN/NRR—2013/672. National Park Service, Fort Collins, Colorado.

Introduction

The sample design for the spiny lobster monitoring protocol uses the sample design for the reef fish monitoring protocols for Florida and the U.S. Virgin Islands (Brandt et al. 2009; Bryan et al. 2013). This protocol uses the exact same sample frame and habitat classification as those used in reef fish monitoring. The sample frames for Florida and the U.S. Virgin Islands are updated prior to biennial sampling of fish in each region. SOP A in Brandt et al. (2009) describes the sample frame and habitat classification used for spiny lobster monitoring in Florida. SOP 1 in Bryan et al. (2013) describes the sample frame and habitat classification used for spiny lobster monitoring in the U.S. Virgin Islands.

Updates to reef fish protocols

Since the reef fish monitoring protocols were published there have been a few modifications. In Brandt et al. (2009) the sample frame in Florida utilized a 200×200 meter (656×656 foot [ft]) grid. Due to the availability of more accurate benthic habitat maps, in 2014 the sample frame was revised to a 100×100 meter (328×328 ft) grid. Unfortunately, at the time of this writing there are no publications or updates that document this change.

Since the publication of Bryan et al. (2013) two additional strata are available in the U.S. Virgin Islands. These are “Deep, unknown hard-bottom” and “Shallow, unknown hard-bottom.” These two strata are known to be hard-bottom habitats, but the exact type of hard-bottom is unknown. As more surveys are completed, the habitat information recorded will be used to correctly classify the grid cell to a known habitat stratum. Unfortunately, at the time of this writing there are no publications or updates that document this change.

Literature Cited

- Brandt, M. E., N. Zurcher, A. Acosta, J.S. Ault, J. A. Bohnsack, M. W. Feeley, D. E. Harper, J. H. Hunt, T. Kellison, D. B. McClellan, M. E. Patterson, and S. G. Smith. 2009. A cooperative multi-agency reef fish monitoring protocol for the Florida Keys coral reef ecosystem. Natural Resource Report NPS/SFCN/NRR – 2009/150. National Park Service, Fort Collins, Colorado.
- Bryan, D. R., A. J. Atkinson, J. S. Ault, M. E. Brandt, J. A. Bohnsack, M. W. Feeley, M. E. Patterson, B. I. Ruttenberg, S. G. Smith, and B. D. Witcher. 2013. A cooperative multiagency reef fish monitoring protocol for the U.S. Virgin Islands coral reef ecosystem. Natural Resource Report NPS/SFCN/NRR—2013/672. National Park Service, Fort Collins, Colorado.

National Park Service
Inventory and Monitoring Division



Standard Operating Procedure 2

Stratification—Version 1.0

Purpose

This standard operating procedure (SOP) describes the stratification scheme and post stratification analysis used for this protocol.

Revision Log

[illegible]

Source Protocol

This SOP is derived from SOP A in the Florida reef fish monitoring protocol and SOP 2 in the Virgin Islands reef fish monitoring protocol:

Brandt, M. E., N. Zurcher, A. Acosta, J.S. Ault, J. A. Bohnsack, M. W. Feeley, D. E. Harper, J. H. Hunt, T. Kellison, D. B. McClellan, M. E. Patterson, and S. G. Smith. 2009. A cooperative multi-agency reef fish monitoring protocol for the Florida Keys coral reef ecosystem. Natural Resource Report NPS/SFCN/NRR—2009/150. National Park Service, Fort Collins, Colorado.

Bryan, D. R., A. J. Atkinson, J. S. Ault, M. E. Brandt, J. A. Bohnsack, M. W. Feeley, M. E. Patterson, B. I. Ruttenberg, S. G. Smith, and B. D. Witcher. 2013. A cooperative multiagency reef fish monitoring protocol for the U.S. Virgin Islands coral reef ecosystem. Natural Resource Report NPS/SFCN/NRR—2013/672. National Park Service, Fort Collins, Colorado.

Introduction

The sample design for the spiny lobster monitoring protocol uses the sample design for the reef fish monitoring protocols for Florida and the U.S. Virgin Islands (Brandt et al. 2009; Bryan et al. 2013). The stratification scheme for this protocol is similar to the stratification schemes described in SOP A in Brandt et al. (2009) for Florida parks and SOP 2 in Bryan et al. (2013) for park units in the U.S. Virgin Islands. For this protocol specifically, a reduction of the number of strata is necessary in order to achieve an appropriate number of samples per stratum to allow for sufficient detection of lobsters for statistically robust analyses. Additionally, some of the original strata had areas too small when restricted to park boundaries to warrant sampling in those particular strata. Thus, we have combined several of the strata primarily based on similarities in habitat. The rationale for combining specific strata is provided below in this SOP. The previously published SOPs in the reef fish protocols should be referred to for specific details on how the respective stratification schemes for the reef fish monitoring were decided upon.

There are several benefits to using these previously established stratification schemes for monitoring spiny lobster:

- Reef fish have heterogeneous distributions that are influenced by the physical and biological habitat attributes that the reef fish stratification schemes were based upon (Williams 1991). Spiny lobster also exhibit heterogeneous distributions based upon these same physical and biological attributes (Williams 1965).
- The sample frame, habitat classifications, and stratification schemes for reef fish monitoring have been published and in use for several years. The methods and justifications for them are accepted and well understood by the organizations and agencies that use them.
- Using the same sample frames, habitat classifications, and stratification schemes as the reef fish monitoring streamlines sample design development and maintenance for spiny lobster.

Any fixes or updates to these attributes will already occur as a result of the biennial reef fish monitoring already being conducted.

It is important to note that the reef fish monitoring protocols are designed to monitor several species, whereas the spiny lobster monitoring protocol is designed for a single species. The sample frame, habitat classification, and stratification scheme will remain the same for reef fish and lobster monitoring with little effect on the lobster data. There are however, substantial differences between the reef fish and lobster protocols for sample allocation.

Stratification

A geographic information system (GIS) containing digital layers for benthic habitat, bathymetry, and management zone (e.g., park boundaries) is used to facilitate delineation of the sampling survey domain into strata. The survey domain is divided into a grid with individual cells. The cells are 100×100 meters (328×328 ft) in Florida and are 50×50 meters (164×164 ft) in the Virgin Islands, where each cell belongs to a specific stratum. The size of the grid cells was determined by the resolution and accuracy of the benthic habitat maps. It is important to note that many of these grid cells have only partial habitat coverage, although in many cases hard-bottom habitat exists in the grid cells that is not mapped. These grid cells are designated as primary sample units. The survey sample, which consists of a pair of adjacent 7.5 meter (24.6 ft) radius circular plots, is located within the randomly selected grid cell on hard-bottom habitat following the procedures in SOP 4 *Lobster Data Collection and Survey Methods*.

Survey design symbols and definitions are provided in Appendix D: *Glossary of Statistical Symbols and Computational Formulas* (Richter et al. 2018). The survey domain A is divided into h strata. Each stratum is further subdivided into primary sample units (i.e. grid cells). The survey sample unit (pair of averaged circular plots) j is used to characterize each primary sample unit. At this time each primary unit is not divided into potential lobster and not potential lobster habitat as this is not possible with the maps available.

Original strata (from reef fish monitoring protocols)

Presented here are the original strata from the reef fish monitoring protocols found in each of the park units. Tables SOP 2.1, SOP 2.2, SOP 2.3, SOP 2.4, and SOP 2.5 show the mapped polygon areas, number of possible primary sample units (i.e. grid cells), and grid cell area for each stratum found in Biscayne National Park, Dry Tortugas National Park, Virgin Islands National Park, Salt River Bay National Historical Park & Ecological Preserve, and Buck Island Reef National Monument respectively.

“Mapped polygon area (km^2)” refers to the sum of the areas of mapped habitat polygons in GIS habitat maps for each park unit. “No. grid cells” refers to the number of grid cells that are assigned to each stratum. “Grid area (km^2)” refers to the summed area of the grid cells assigned to each of the strata.

Table SOP 2.1. Number of grid cells (100 × 100 meter [328 × 328 ft]) and total area coverage in each stratum for Biscayne NP. This is a subset of the strata that appear in Brandt et al. (2009) because some of those strata do not occur within Biscayne NP.

Strata	Mapped Polygon Area (km ²)	No. Grid Cells	Grid Area (km ²)
Inshore Patch Reef (0 - 6 m)	0.20	188	1.88
Mid-Channel Patch Reef (0 - 6 m)	7.68	4,788	47.88
Offshore Patch Reef (0 - 6 m)	1.88	738	7.38
Forereef, Low-relief, (0 - 6 m)	3.08	428	4.28
Forereef, Low-relief (6 -18 m)	18.56	3,407	34.07
Forereef, High-relief reef (0 - 18 m)	0.93	116	1.16
TOTAL	32.33	9,665	96.65

Table SOP 2.2. Number of grid cells (100 × 100 meter [328 × 328 ft]) and total area coverage in each stratum for Dry Tortugas NP.

Protection	Strata	Mapped Polygon Area (km ²)	No. Grid Cells	Grid Area (km ²)
Inside RNA	Low-relief continuous reef	25.00	3,164	31.64
Inside RNA	Mid-relief continuous reef	2.93	434	4.34
Inside RNA	High-relief continuous reef	1.65	304	3.04
Inside RNA	Low-relief isolated reef	3.70	649	6.49
Inside RNA	Mid-relief isolated reef	4.93	1,177	11.77
Inside RNA	High-relief isolated reef	1.69	418	4.18
Inside RNA	Low-relief spur and groove	2.60	309	3.09
Inside RNA	High-relief spur and groove	0.36	56	0.56
Outside RNA	Low-relief continuous reef	17.85	2,475	24.75
Outside RNA	Mid-relief continuous reef	3.75	564	5.64
Outside RNA	High-relief continuous reef	0.80	147	1.47
Outside RNA	Low-relief isolated reef	9.42	1,538	15.38
Outside RNA	Mid-relief isolated reef	7.33	1,726	17.26
Outside RNA	High-relief isolated reef	0.26	61	0.61
Outside RNA	Low-relief spur and groove	6.56	776	7.76
Outside RNA	High-relief spur and groove	2.18	296	2.96
	TOTAL	91.02	14,094	140.94

Table SOP 2.3. Number of grid cells (50 × 50 meter [164 × 164 ft]) and total area coverage in each stratum for Virgin Islands NP. Deep = 12–30 meters (39.4–98.4 ft); Shallow = 0–11.9 meters (0–39 ft).

Map and Stratum Classification	Mapped Polygon Area (km ²)	No. Grid Cells	Grid Area (km ²)
Deep, Scattered coral/rock	0.03	69	0.17
Deep, Pavement	1.50	802	2.01
Deep, Bedrock	0.01	7	0.02
Deep, Patch reef	0.18	185	0.46
Deep, Linear reef	0.47	356	0.89
Deep, unknown hard-bottom	0.68	410	1.03
Shallow, Scattered coral/rock	0.44	248	0.62
Shallow, Pavement	2.50	1,186	2.97
Shallow, Bedrock	0.65	374	0.94
Shallow, Patch reef	0.24	122	0.31
Shallow, Linear reef	0.85	392	0.98
Shallow, unknown hard-bottom	0.05	22	0.06
TOTAL	7.61	4,173	10.43

Table SOP 2.4. Number of grid cells (50 × 50 meter [164 × 164 ft]) and total area coverage in each stratum for Salt River Bay NHP&EP. Deep = 12–30 meters (39.4–98.4 ft); Shallow = 0–11.9 meters (0–39 ft). The following strata do not exist in Salt River Bay NHP&EP: Deep Bedrock, Deep Patch Reef, Deep unknown hard-bottom, Shallow Scattered coral/rock, or Shallow unknown hard-bottom.

Map and Stratum Classification	Mapped Polygon Area (km ²)	No. Grid Cells	Grid Area (km ²)
Deep, Scattered coral/rock	0.02	8	0.02
Deep, Pavement	0.20	59	0.15
Deep, Linear reef	0.03	18	0.05
Shallow, Pavement	0.19	276	0.69
Shallow, Bedrock	0.07	29	0.07
Shallow, Patch reef	0.01	4	0.01
Shallow, Linear reef	0.10	41	0.10
TOTAL	0.62	435	1.09

Table SOP 2.5. Number of grid cells (50 × 50 meter [164 × 164 ft]) and total area coverage in each stratum for Buck Island Reef NM. Deep = 12–30 meters (39.4–98.4 ft); Shallow = 0–11.9 meters (0–39 ft). The following strata do not exist in Buck Island Reef NM: Deep Bedrock, Deep unknown hard-bottom, Shallow unknown hard-bottom.

Map and Stratum Classification	Mapped Polygon Area (km ²)	No. Grid Cells	Grid Area (km ²)
Deep, Scattered coral/rock	0.36	168	0.42
Deep, Pavement	0.97	1,870	4.68
Deep, Patch reef	1.36	641	1.60
Deep, Linear reef	0.10	17	0.04
Shallow, Scattered coral/rock	0.82	373	0.93
Shallow, Pavement	7.48	3,165	7.91
Shallow, Bedrock	0.03	6	0.02
Shallow, Patch reef	2.48	1,018	2.55
Shallow, Linear reef	0.51	221	0.55
TOTAL	14.11	7,479	18.70

Rationale for combining strata

For lobster, a reduced number of strata is necessary in order to achieve an appropriate number of samples per stratum to allow for sufficient detection of lobsters for statistically robust analyses. Additionally, some of the original strata have areas too small within park boundaries to warrant sampling separately. Thus, we have combined several of the strata primarily based on similarities in habitat.

Biscayne NP

No strata were combined for Biscayne NP. Table SOP 2.1 shows the mapped polygon area, number of grid cells, and grid cell area for each stratum in Biscayne NP.

Dry Tortugas NP

The original 16 strata in Dry Tortugas NP is reduced to 8 strata by removing Inside/Outside the Research Natural Area (RNA) as a modifier. Specifically for lobster, management practices both inside and outside the RNA are the same and the effect on lobster populations with regard to the location of the RNA is presumed minimal or nonexistent. For this protocol, Table SOP 2.6 shows the mapped polygon area, number of grid cells, and grid cell area for each stratum in Dry Tortugas NP.

Table SOP 2.6. Number of grid cells (100 × 100 meter [328 × 328 ft]) and total area coverage in each stratum for Dry Tortugas NP. Inside RNA and Outside RNA strata are combined by habitat because protection for lobster remains the same (no-take) in both areas.

Strata	Mapped Polygon Area (km ²)	No. Grid Cells	Grid Area (km ²)
Low-relief continuous reef	42.85	5,639	56.39
Mid-relief continuous reef	6.68	998	9.98
High-relief continuous reef	2.45	451	4.51
Low-relief isolated reef	13.12	2,187	21.87
Mid-relief isolated reef	12.26	2,903	29.03
High-relief isolated reef	1.95	479	4.79
Low-relief spur and groove	9.16	1,085	10.85
High-relief spur and groove	2.54	352	3.52
TOTAL	91.02	14,094	140.94

Virgin Islands NP

The original 12 strata in the Virgin Islands NP is reduced to 6 strata by removing depth as a modifier. We recognize that depth may influence lobster distribution and density, however it was important to reduce the number of strata in order to increase the number of samples per stratum to allow for robust analyses. Rather than combining habitat types to decrease the number of strata, we felt removing depth as a modifier was the most logical way to minimize within-stratum variability while increasing the sample size for each stratum. For this protocol, Table SOP 2.7 shows the mapped polygon area, number of grid cells, and grid cell area for each stratum in Virgin Islands NP.

Table SOP 2.7. Number of grid cells (50 × 50 meter [164 × 164 ft]) and total area coverage in each stratum for Virgin Islands NP. The original strata from the Reef Fish Monitoring Protocol (Bryan et al. 2013) have been combined by removing the depth class.

Map and Stratum Classification	Mapped Polygon Area (km ²)	No. Grid Cells	Grid Area (km ²)
Scattered coral/rock	0.47	317	0.79
Pavement	4.00	1,988	4.98
Bedrock	0.66	381	0.96
Patch reef	0.42	307	0.77
Linear reef	1.32	748	1.87
Unknown hard-bottom	0.73	432	1.09
TOTAL	7.61	4,173	10.46

Salt River Bay NHP&EP

The original 7 strata in Salt River Bay NHP&EP is reduced to 3 strata. This was done by first removing depth as a modifier. We recognize that depth may influence lobster distribution and density, however it was important to reduce the number of strata in order to increase the number of samples per stratum to allow for robust analyses. Rather than combining habitat types to decrease the number of strata, we felt removing depth as a modifier was the most logical way to minimize within-stratum variability while increasing the sample size for each stratum.

Second, the original stratum “Scattered coral/rock” was too small to warrant sampling separately. It is combined with the “Pavement” stratum. The grid cells classified as “Scattered coral/rock” were clustered together adjacent to grid cells classified as “Pavement.” The proximity of the two habitat classes coupled with similarities in structural complexity are the basis for combining the two strata in Salt River Bay NHP&EP.

Third, the original stratum “Patch reef” was too small to warrant sampling separately. It is combined with the “Linear reef” stratum. The grid cells classified as “Patch reef” are clustered together in close proximity to grid cells classified as “Linear Reef.” Review of aerial imagery and benthic habitat maps shows a marked similarity between the cells classified as “Patch reef” and habitats classified as “Linear reef” in this specific area. We felt combining the two strata was appropriate in Salt River Bay NHP&EP.

For this protocol, Table SOP 2.8 shows the mapped polygon area, number of grid cells, and grid cell area for each stratum in Salt River Bay NHP&EP.

Table SOP 2.8 Number of grid cells (50 × 50 meter [164 × 164 ft]) and total area coverage in each stratum for Salt River Bay NHP&EP. The original strata from the Reef Fish Monitoring Protocol (Bryan et al. 2013) have been combined by removing the depth class. Because of its small size, the scattered coral/rock stratum was combined with the pavement stratum based on similarity to surrounding grid cells and assessment of aerial imagery. Also because of its small size, the patch reef stratum was combined with the linear reef stratum based on similarity to surrounding grid cells and assessment of aerial imagery.

Map and Stratum Classification	Mapped Polygon Area (km ²)	No. Grid Cells	Grid Area (km ²)
Pavement & Scattered coral/rock	0.41	343	0.86
Linear reef & Patch reef	0.14	63	0.16
Bedrock	0.07	29	0.07
TOTAL	0.62	435	1.09

Buck Island Reef NM

The original 9 strata in Buck Island Reef NM is reduced to 4 strata. This was done by first removing depth as a modifier. We recognize that depth may influence lobster distribution and density, however it was important to reduce the number of strata in order to increase the number of samples per stratum to allow for sufficient detection of lobsters to allow for robust analyses. Rather than combining habitat types to decrease the number of strata, we felt removing depth as a modifier was the most logical way to minimize within-stratum variability while increasing the sample size for each stratum.

Second, the “Bedrock” stratum was too small to warrant sampling separately. It is combined with the “Linear Reef” stratum. The grid cells classified as “Bedrock” are in close proximity to grid cells classified as “Linear Reef.” Also, the structural complexity of the two habitats is expected to be similar. We felt combining these two strata was appropriate in Buck Island Reef NM.

For this protocol, Table SOP 2.9 shows the mapped polygon area, number of grid cells, and grid cell area for each stratum in Buck Island Reef NM.

Table SOP 2.9. Number of grid cells (50 × 50 meter [164 × 164 ft]) and total area coverage in each stratum for Buck Island Reef NM. The original strata from the Reef Fish Monitoring Protocol (Bryan et al. 2013) have been combined by removing the depth class. Based on its small size the bedrock stratum was combined with the linear reef stratum based on similarity to surrounding grid cells and assessment of aerial imagery.

Map and Stratum Classification	Mapped Polygon Area (km ²)	No. Grid Cells	Grid Area (km ²)
Scattered coral/rock	1.18	541	1.35
Pavement	8.45	5,035	12.59
Patch reef	3.84	1,659	4.15
Linear reef & Bedrock	0.64	244	0.61
TOTAL	14.11	7,479	18.70

Literature cited

- Brandt, M. E., N. Zurcher, A. Acosta, J.S. Ault, J. A. Bohnsack, M. W. Feeley, D. E. Harper, J. H. Hunt, T. Kellison, D. B. McClellan, M. E. Patterson, and S. G. Smith. 2009. A cooperative multi-agency reef fish monitoring protocol for the Florida Keys coral reef ecosystem. Natural Resource Report NPS/SFCN/NRR—2009/150. National Park Service, Fort Collins, Colorado.
- Bryan, D. R., A. J. Atkinson, J. S. Ault, M. E. Brandt, J. A. Bohnsack, M. W. Feeley, M. E. Patterson, B. I. Ruttenberg, S. G. Smith, and B. D. Witcher. 2013. A cooperative multiagency reef fish monitoring protocol for the U.S. Virgin Islands coral reef ecosystem. Natural Resource Report NPS/SFCN/NRR—2013/672. National Park Service, Fort Collins, Colorado.
- Richter, L. R., M. W. Feeley, A. J. Atkinson, J. M. Patterson, A.D. Davis, and J. Miller. 2018. Long-term monitoring protocol of Caribbean Spiny Lobster (*Panulirus argus*): protocol narrative. Natural Resource Report NPS/SFCN/NRR—2018/1850. National Park Service, Fort Collins, Colorado. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/2258540> (last accessed December 2018).
- Williams, A. B. 1965. Marine decapod crustaceans of the Carolinas. U.S. Fish and Wildlife Service Fisheries Bulletin. 65:1–291.
- Williams, D. M. 1991. Patterns and processes in the distribution of coral reef fishes. Pages 437–474 in Sale, P.F., editor. The ecology of fishes on coral reefs. Academic Press, San Diego.

Standard Operating Procedure 3

Purpose

Revision Log

Revision Date	Author	Changes Made	Reason for Change	New Version #

Source Protocol

This SOP is derived from SOP A in the Florida reef fish monitoring protocol and SOP 3 in the Virgin Islands reef fish monitoring protocol:

Brandt, M. E., N. Zurcher, A. Acosta, J.S. Ault, J. A. Bohnsack, M. W. Feeley, D. E. Harper, J. H. Hunt, T. Kellison, D. B. McClellan, M. E. Patterson, and S. G. Smith. 2009. A cooperative multi-agency reef fish monitoring protocol for the Florida Keys coral reef ecosystem. Natural Resource Report NPS/SFCN/NRR—2009/150. National Park Service, Fort Collins, Colorado.

Bryan, D. R., A. J. Atkinson, J. S. Ault, M. E. Brandt, J. A. Bohnsack, M. W. Feeley, M. E. Patterson, B. I. Ruttenberg, S. G. Smith, and B. D. Witcher. 2013. A cooperative multiagency reef fish monitoring protocol for the U.S. Virgin Islands coral reef ecosystem. Natural Resource Report NPS/SFCN/NRR—2013/672. National Park Service, Fort Collins, Colorado.

Introduction

This SOP outlines a single-stage stratified random design that draws heavily upon the sample design for the reef fish monitoring protocols for Florida and the U.S. Virgin Islands (Brandt et al. 2009; Bryan et al. 2013). This protocol utilizes the same sample frame and habitat classifications (SOP 1 *Sample Frame and Habit Classification*) as the reef fish monitoring protocols in the respective regions. The stratification scheme (SOP 2 *Stratification*) is also the same as the reef protocols, though some of the strata have been combined. This was done primarily to reduce the number of strata so that enough samples can occur in each stratum to allow for sufficient detection of lobsters to allow for robust statistical analyses. There were also cases where strata were too small to warrant separate sampling and were combined with similar strata.

An ideal sample allocation reduces the number of samples required to achieve a target level of variance. Initially we will allocate samples evenly across all strata. Once more is known about lobster density, distribution, and associated variances for each of the strata in the sample domain, the allocation scheme will be revised to make sampling more efficient. In general, to improve sampling efficiency, proportionally larger strata and strata with greater variance should have more samples allocated to them than smaller, less variable strata.

Sample regions

The SFCN parks included in this lobster monitoring protocol are located in two distinct regions: Florida and the U.S. Virgin Islands. The Florida region includes Biscayne National Park and Dry Tortugas National Park, and will use the sample frame and habitat classification scheme detailed in Brandt et al. (2009). The U.S. Virgin Islands includes Buck Island Reef National Monument, Salt River Bay National Historical Park and Ecological Preserve, and Virgin Islands National Park, and will use the sample frame and habitat classification scheme detailed in Bryan et al. (2013). All hard-bottom habitats within each of the park units are targeted for sampling (Figure SOP 3.1). The stratification schemes for each park unit are detailed in SOP 2. The amount and type of hard-bottom

habitat in each stratum in each park are listed in tables SOP 2.1, SOP 2.6, SOP 2.7, SOP 2.8 and SOP 2.9. Note that some of the original strata in the reef fish monitoring protocols have been merged for this protocol. For reference, the amount and type of hard-bottom habitat of the original strata in each park is found in tables SOP 2.1, SOP 2.2, SOP 2.3, SOP 2.4, and SOP 2.5.

The mapped polygon area of hard-bottom in each stratum is less than that of the summed area of the grid cells in each stratum. This is because many of the grid cells have only partial coverage of habitat. For stratification and analyses, if we were to use the polygon hard-bottom areas, we would likely underestimate abundance because there are hard-bottom areas that are not mapped. If we treat the entire grid cell area as hard-bottom habitat, then we may overestimate abundance. In this protocol (and in the reef fish monitoring protocols) the entire grid cell area is treated as hard-bottom habitat. Because of uncertainty in the extent of benthic habitat coverage, we emphasize that calculated values for abundance are uncertain. Thus, relative density and relative frequency of occurrence are more appropriate and may be estimated for individual strata. However, due to the uncertainty in map weights, when making park-wide calculations we emphasize that relative density and relative frequency occurrence are unit-less indices.

Using the available benthic habitat maps to either influence selection probabilities of the sample allocation or final calculation of strata weights is inadvisable due to the inaccuracies of the maps. This problem will be reduced over time as maps get more accurate, grid cell size gets smaller, and additional methods are developed to use LiDAR and multi-beam sonar to better map benthic habitats.

This general approach is consistent with that used in the multi-agency reef fish monitoring used in the Florida Keys and in the U.S. Virgin Islands (Brandt et al. 2009; Bryan et al. 2013). As those protocols are modified, the spiny lobster protocol will be modified as well.

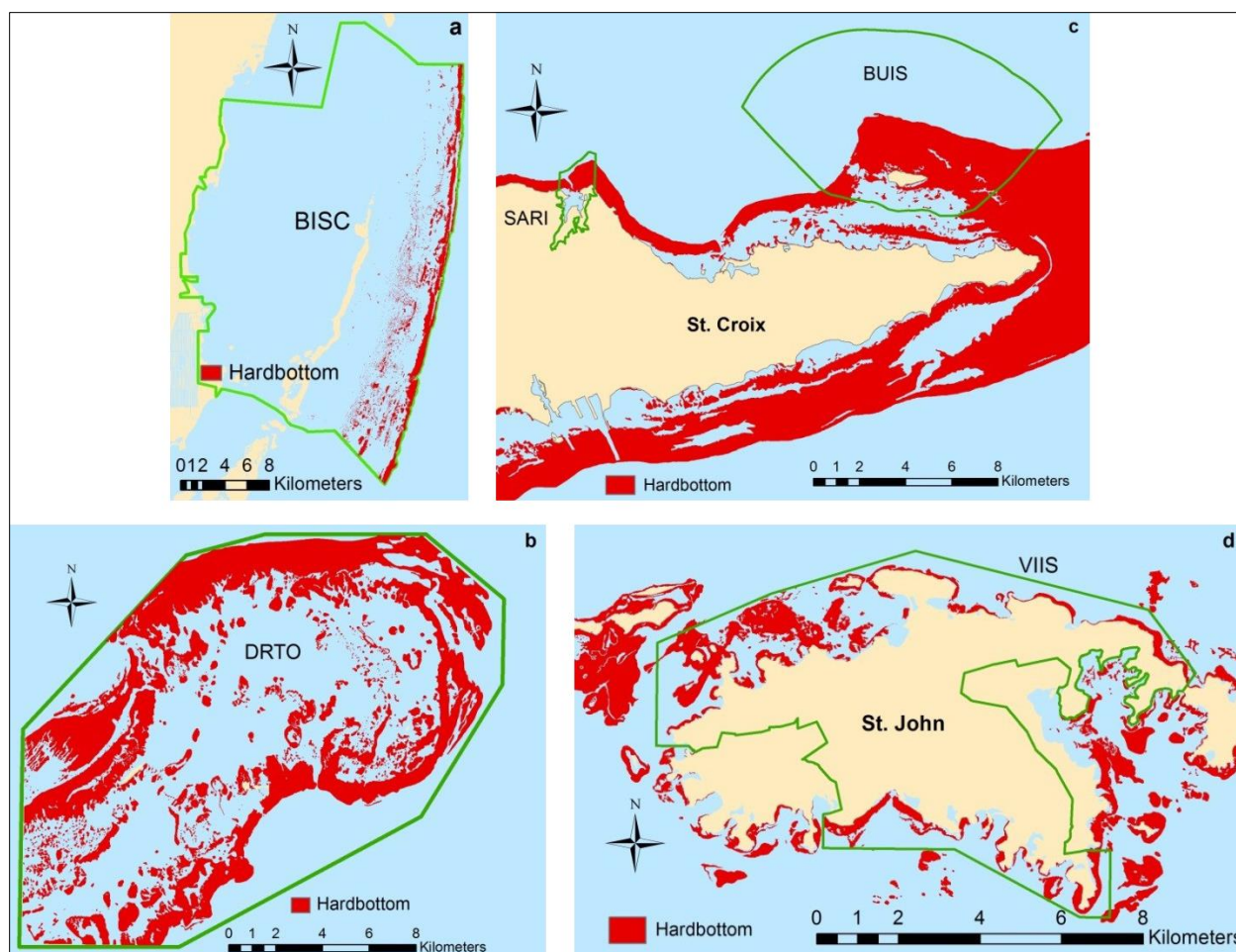


Figure SOP 3.1 Sampling regions in Florida, (a) Biscayne NP and (b) Dry Tortugas NP); and in the U.S. Virgin Islands, (c) Salt River NHP&EP and Buck Island NM and d) Virgin Islands NP. The red areas indicate hard-bottom habitat. The green outline represents the park boundary.

Stratified-random design

In each of the park units, the hard-bottom habitats are split into several strata based upon depth and habitat classification. This was initially done for the reef fish monitoring protocol because fish are heterogeneously distributed among these strata based on physical and biological differences. To determine the efficacy of management zones in protecting and enhancing lobster populations, a management zone stratum may be added if the survey domain expands beyond the park boundaries. Allocation of sites inside and outside protected and unprotected areas allows for direct comparisons between them (Brandt et al., 2009). Brandt et al. (2009) and Bryan et al. (2013) determined that using a stratified random design to sample reef fish improved sampling efficiency over a simple random design. This protocol, while lacking the historical data to show this for spiny lobster, assumes that a stratified random design will also prove more efficient than a simple random design because lobster also exhibit a heterogeneous distribution based on physical and biological differences in habitats.

Sample allocation

An ideal sample allocation reduces the number of samples required to achieve a target level of variance. The reef fish protocols use an optimal (Neyman) sampling allocation (Brandt et al. 2009, Bryan et al. 2013). While a Neyman allocation has proved successful for reef fish monitoring in the Florida and Virgin Islands, we do not have enough data to do this effectively for lobster. It will likely require several sampling events in order to accrue enough data for it to be practical for lobster. Initially we will allocate samples evenly across all strata. Once more is known about lobster density, distribution, and associated variances for each of the strata in the sample domain, the allocation scheme will be revised to make sampling more efficient.

Site selection

Once the total number of primary units is determined, the actual selection of sites is carried out in two stages. First, the primary units sampled per stratum are randomly selected from the complete list of (N_h) cells within a stratum using a discrete uniform probability distribution, which assigns equal selection probability to each grid cell (Law 2007). The total area of a stratum is represented by A_h . The NOAA Sampling Design Tool is used for this and procedures described below. Second, when in the field, the survey sample is haphazardly chosen within a primary unit based on the distribution of target habitat within the primary unit and diving safety considerations.

$$N_h = \frac{A_h}{10,000 \text{ m}^2} \text{ (FL)} \text{ or } N_h = \frac{A_h}{2,500 \text{ m}^2} \text{ (USVI)} \quad \text{SOP 3.1}$$

In general, the South Florida/Caribbean Network will do its own sample draw. However, when strata are identical between this protocol and the reef fish protocol, the primary unit selection for spiny lobster may utilize the sites generated for the most recent reef fish monitoring sampling event (SOP A in Brandt et al. 2009, and SOP 3 in Bryan et al. 2013).

In concern for dive safety and because of possible spatial autocorrelation, each survey sample consists of the average of combined, adjacent 7.5 meter (24.6 ft) radius circular plots. Each plot is to be completed by both divers to limit diver separation while underwater.

In theory, the location of the survey sample within each primary unit should be random or systematic, and not haphazard, but this is not practical in a field sampling situation. During reef fish monitoring, which employs the same sample unit selection, the distribution of surveys within a primary unit was biased toward the center point (Brandt et al. 2009). This is likely due to a combination of the resolution of the grid and the distribution of the habitat within the primary units, and there is a possibility that spatial autocorrelation could affect the results. However, it is deemed unlikely that this affects the overall results of sampling.

Procedure for selecting random sample sites (grid cells) using the NOAA Sampling Design Tool

1. Open the NOAA Sampling Design Tool within ArcGIS. If necessary, the tool can be downloaded and installed from the NOAA website:
<https://coastalscience.noaa.gov/projects/detail?key=185>.
2. Within the “Sampling Design Tool” window:
 - a. Under “Sampling type”, choose “Select Samples from Frame.”
 - b. Under “Sampling design”, Choose “Stratified Random.”
 - c. Check the “Export selected features” box.
 - d. ***NOTE: This will export a shapefile of the random sample sites to the location chosen in step 3.g. below.***
 - e. In “Sample frame,” select the grid shapefile from which the random sample sites will be drawn.
 - f. Under “Strata field,” select the field in the attribute table containing the strata of interest.
 - g. Click “Run.”
3. Within the “Select Stratified Inputs” window:
 - a. Under “Allocation Method,” click on the “Even” button.
 - b. In the “Sample units to allocate” box, enter the total number of samples desired.
 - c. ***NOTE: This will evenly allocate samples within each stratum. The “Define the number of sample unites to select in each stratum” window will show the number of samples allocated in each stratum.***
 - d. Do not check the “Keep minimum distance between points” box.
 - e. Click “Run.”
 - f. In the “Save a feature class” window, navigate to the location where the shapefile of the random sample sites will be exported.
 - g. Under “Name:” type an appropriate name for the shapefile.
 - h. Under “Save as type:” select “Feature classes.”
4. Click “Save.”

Literature cited

- Brandt, M. E., N. Zurcher, A. Acosta, J.S. Ault, J. A. Bohnsack, M. W. Feeley, D. E. Harper, J. H. Hunt, T. Kellison, D. B. McClellan, M. E. Patterson, and S. G. Smith. 2009. A cooperative multi-agency reef fish monitoring protocol for the Florida Keys coral reef ecosystem. Natural Resource Report NPS/SFCN/NRR—2009/150. National Park Service, Fort Collins, Colorado.
- Bryan, D. R., A. J. Atkinson, J. S. Ault, M. E. Brandt, J. A. Bohnsack, M. W. Feeley, M. E. Patterson, B. I. Ruttenberg, S. G. Smith, and B. D. Witcher. 2013. A cooperative multiagency reef fish monitoring protocol for the U.S. Virgin Islands coral reef ecosystem. Natural Resource Report NPS/SFCN/NRR—2013/672. National Park Service, Fort Collins, Colorado.
- Law, A. M. 2007. Simulation modeling and analysis. 4th Edition McGraw-Hill, New York.
- Richter, L. R., M. W. Feeley, A. J. Atkinson, J. M. Patterson, A.D. Davis, and J. Miller. 2018. Long-term monitoring protocol of Caribbean Spiny Lobster (*Panulirus argus*): protocol narrative. Natural Resource Report NPS/SFCN/NRR—2018/1850. National Park Service, Fort Collins, Colorado. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/2258540> (last accessed December 2018).

Standard Operating Procedure 4

Purpose

Revision Log

[illegible]

Equipment

- Weighted dive flag.
- GPS and dry bag.
- Tickle stick and net (to capture lobster).
- Measurement aid in millimeters (this can be attached to the tickle stick to help with carapace length estimates).
- Gloves.
- Several 30 meter (98 ft) transect tapes (at least two per buddy pair)
- Plastic Vernier calipers (millimeters).
- Underwater slate and datasheets.
- Dive watch.
- Underwater camera.

Procedures

Locating and assessing the sample site

Sample sites are located using a vessel-mounted or hand-held GPS unit. The centroid of the primary sample units (e.g., grid cells) are provided on a list of latitude-longitude site positions prior to sampling. Upon arrival at the primary sample unit, divers should attempt to determine (e.g., using the sonar or if visibility permits, simply looking over the side of the boat) whether the benthic habitat at the survey location is reef habitat. In the Virgin Islands, where 50 × 50 meter (164 × 164 ft) cells are used, this means remaining within 25 meters (82 ft) of the centroid to the north, south, east and west or within 35 meters (115 ft) to the northeast, southeast, northwest, and southwest. In Florida, where 100 × 100 meter (328 × 328 ft) cells are used, this means remaining within 50 meters (164 ft) of the centroid to the north, south, east, and west, or within 71 meters (233 ft) to the northeast, southeast, northwest, and southwest. With updates to existing benthic maps anticipated, the Florida program expects to convert to a 50 × 50 meter (164 × 164 ft) grid in 2020 (Steve Smith, Research Scientist, University of Miami pers. comm., August 14, 2018). If the target habitat type cannot be located, the sampling should proceed, with divers recording the new habitat type on the Boat Log. If no hard-bottom habitat can be located, that site should be omitted from sampling and an alternate site selected from the list provided. At each sample site, one set (replicate) of two paired surveys occur (Figure SOP 4.1).

The recommended approach to sampling is to use live-boating with 3–4 personnel. When four divers are present, two teams of divers are formed for the day of sampling, where one team is underwater and the second team is top-side to pilot the vessel. Duties rotate every other dive. When three divers are present, divers rotate at each sample site in a format such that each diver remains at the surface at every third sample site to pilot the vessel.

Diver deployment, descent, and plot setup

Once divers are deployed at a site, they descend to the bottom. If divers are not deployed over hard-bottom but it is within view, they swim to the nearest visible hard-bottom within the cell to set up the survey. It is possible that in some situations, divers may unknowingly drift outside of the grid cell. These surveys should still proceed and be included in analyses, but the divers should always attempt to conduct the survey on hard-bottom habitat inside the designated grid cell. If no habitat is visible, the dive is aborted and an alternative site chosen.

When the divers are deployed over hard-bottom habitat, the buddy team will secure their reel (with dive flag and surface GPS) to the substrate. Divers should not bias the survey toward habitat edges or based on habitat quality where more (or less) lobster are expected to be found. The plots however, should occur over as much hard-bottom habitat as possible at the site (i.e. plot center greater than or equal to 7.5 meters [24.6 ft] from the habitat edge if feasible). The first plot is established haphazardly without respect to habitat edge or habitat quality. The second plot is set up adjacent to the first, opposite the dive flag. In situations where a patch reef is not large enough to accommodate the two plots and another patch is visible nearby (less than 20 meters [66 ft] away) and within the cell, the second plot is placed there and sampled. In situations where a patch reef is smaller than two circular plots, the dive reel is placed to maximize the amount of hard bottom surveyed within each cylinder. The divers note the percentage of the plot that was hard-bottom habitat.

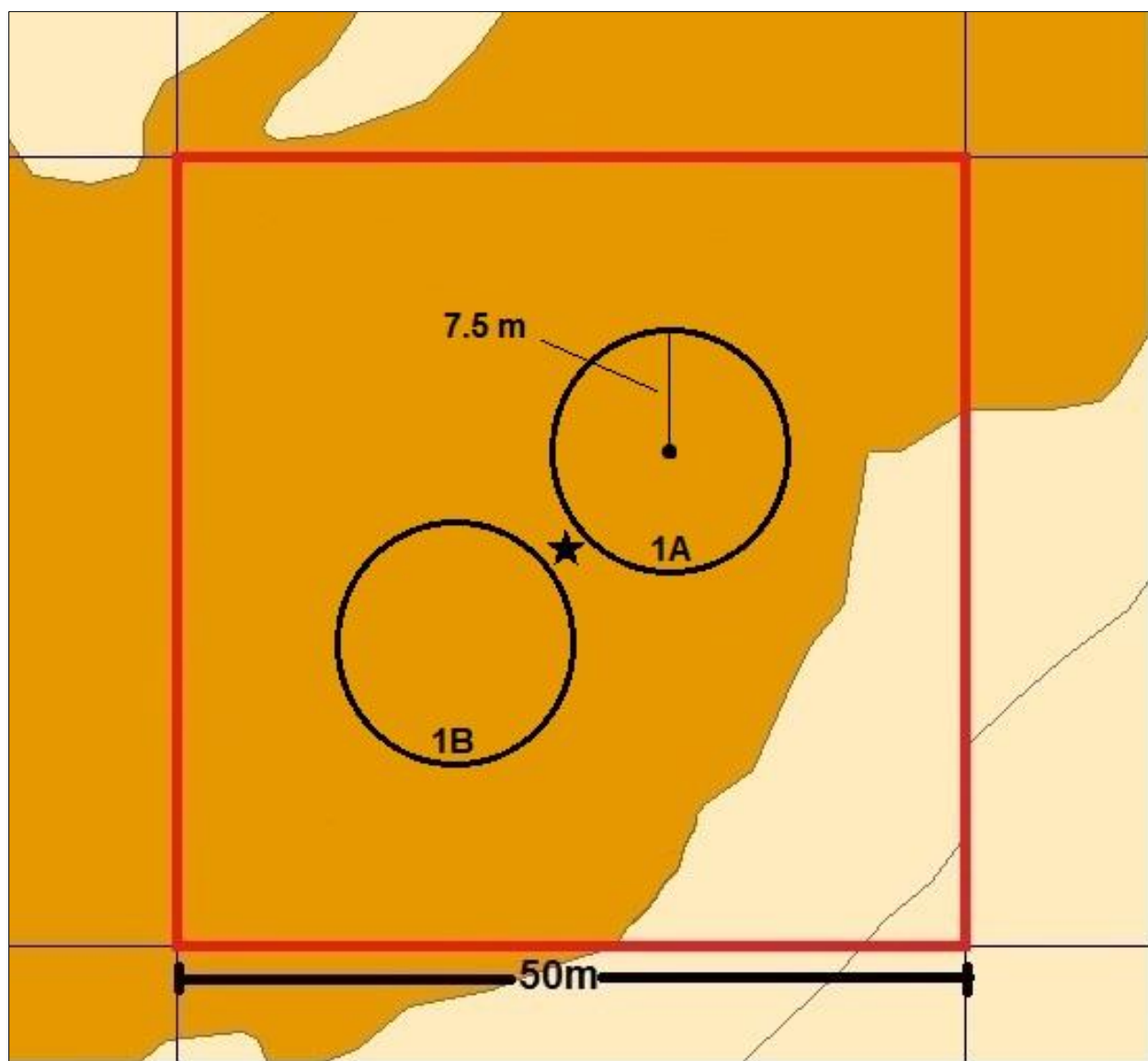


Figure SOP 4.1. Example of how the two averaged circular plots may be located at a site. Tan is non-target habitat (e.g., sand) and orange is target habitat (e.g., reef). The 50 × 50 meter (164 × 164 ft) grid used in the US Virgin Islands is overlain on the habitat and is outlined in red. Divers descend and attach the dive flag with surface GPS at the star. Two non-overlapping 7.5 meter (24.6 ft) radius circular plots are completed adjacent to one another.

The reel secured to the bottom acts as the edge of both adjacent circular plots. To avoid diver separation, both divers assess one circular plot together, then assess the second. Each plot occurs over hard-bottom habitat. While there are several ways to survey a circular plot thoroughly for lobster, we suggest a quadrant method is most appropriate and efficient.

To set up the first circular plot, a transect tape is attached to the substrate next to the reel and run out 15 meters (49 ft), marking the diameter of the plot. A second transect tape is run by one diver perpendicular to this first transect, beginning at the 7.5 meter (24.6 ft) mark, separating half of the

circular plot into two quadrants (Figure SOP 4.2). The other diver repeats this on the opposite half of the circular plot. Thus, each diver is responsible for surveying two of the four quadrants in each circular plot.

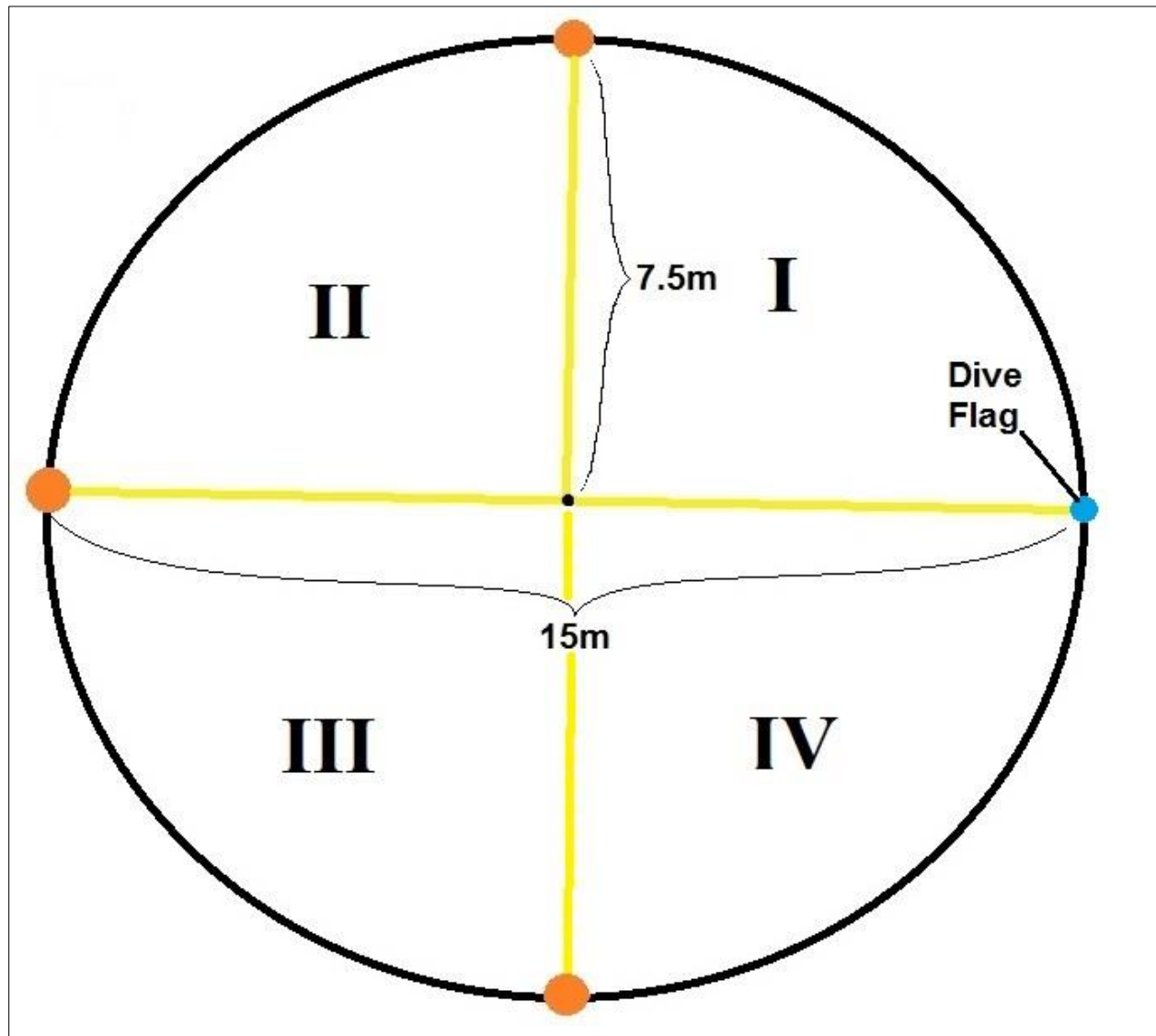


Figure SOP 4.2. Example of how a circular plot is established. A transect tape is run 15 meters from where the dive flag is tied off to the substrate. A second transect tape is run perpendicular to the first, beginning at 7.5 meters, separating the top half of the plot into two quadrants. The other diver repeats this on the opposite side of the plot. This separates the entire plot into four quadrants. Quadrant I is located in directly in front of the observer when the dive flag is located immediately to the right of the observer. Quadrants II, III, and IV are located counter-clockwise from quadrant I.

Data collection

Boat log

Field personnel not diving at a site fill out the field/boat log (Figure SOP 4.9, printable form available in Appendix C: *Printable Field Forms* in the protocol narrative [Richter et al. 2018]).

1. Dive of day: This is the cumulative site number (e.g., 1, 2, 3...) completed throughout a day.
2. Site ID: This is a code listed on the sample list (this should match the ID used during the most recent fish survey in the region).
3. Estimated time: Estimated time of beginning of dive.
4. Dive team: This should be one. While this field is not entirely necessary, because typically only one dive team will be used for lobster surveys, the format is consistent with the reef fish protocol.
5. Diver A / Diver B: Divers' names associated with who is Diver A and B.
6. Latitude and longitude in decimal degrees: Position of vessel at surface when divers are deployed at a site (dd.ddddd).
7. Habitat type: This should be the divers' consensus of the habitat type that was sampled. While the divers are targeting a specific habitat based upon the stratification, it is possible that they may complete a survey on a habitat that did not match the stratum initially targeted by the sample allocation.
8. GPS / Flag #: The specific GPS and Flag # used for the surveys.
9. Comments: Any additional information judged to be important by the surface data collector.

General site information

Figure SOP 4.10 is an example of the datasheet used for general site information, habitat assessment, and lobster encountered within the circular plots (printable form available in Appendix C: *Printable Field Forms* in the protocol narrative [Richter et al. 2018]). Prior to each dive, the divers enter their name (i.e. observer), name of dive buddy, date, park, and site ID on their datasheet. The site ID is unique to each primary unit and is followed by an underscore and a 1 (designating the dive team) and an A or B (designating the diver within the team). For example, "1088_1A" would represent diver A on team 1 at site 1088.

After reaching the bottom, each diver records the depth of the station, visibility (in feet), and the start and end times for each circular plot survey completed. One of the divers also takes a photo of the datasheet with the site name clearly visible, and then four photos in each of the cardinal directions that represent the habitat where the survey will occur.

Lobster assessment

Each diver is responsible for surveying two of the four quadrants in each circular plot. Once the quadrants are established, the diver surveys all area within each quadrant, paying attention to crevices, cracks, under ledges, and structures that lobsters use as shelter.

If a spiny lobster is encountered, where any part of the lobster is within the plot, a visual estimate of carapace length to the nearest millimeter is recorded prior to any attempts to capture the lobster. If there are several lobsters clustered together, first record the number of lobsters that are present.

Second, try to obtain visual estimates of carapace lengths of all of the lobsters. Only after these are recorded should any attempt at capture be made. This is because when capturing a lobster within a group, the water can become silty and the other lobsters may hide, hindering visual assessments of the other lobsters in the cluster. In this manner, at least some information is retained by recording the number of lobsters observed and estimating their carapace lengths prior to an attempt at capture.

Capturing lobster with a tickle stick and net requires skill and practice to capture lobster effectively without injuring them. A tickle stick is a thin stick about 1 meter (3.2 ft) in length with a bent tip. When a lobster is encountered, the bent tip is gently placed under the tail/body of the lobster to coax it out into the open. If done too aggressively, the lobster will frighten and try to escape by flipping its tail and moving quickly backwards. A flat-bottomed net is placed behind the lobster (in between the lobster and the den), so when the lobster is then startled, it swims backwards into the net (Figure SOP 5.1 in SOP 5 *Training*). The open side of the net can be placed on the bottom, making it more difficult for the lobster to escape. Once the lobster is inside the net, hold with a gloved hand to measure the actual carapace length and record the biological condition of the lobster. Once a lobster has been captured and assessed, to create the least disturbance, release it back to its original location.

The following characteristics will be recorded for each lobster captured:

1. Quadrant: The observer marks which quadrant of the circular plot the lobster was encountered in.
2. Actual carapace length (millimeters): This is done using plastic Vernier calipers. The carapace length is the distance from the rigid part between the horns to the rear edge of the top part of the carapace (Figure SOP 4.3).

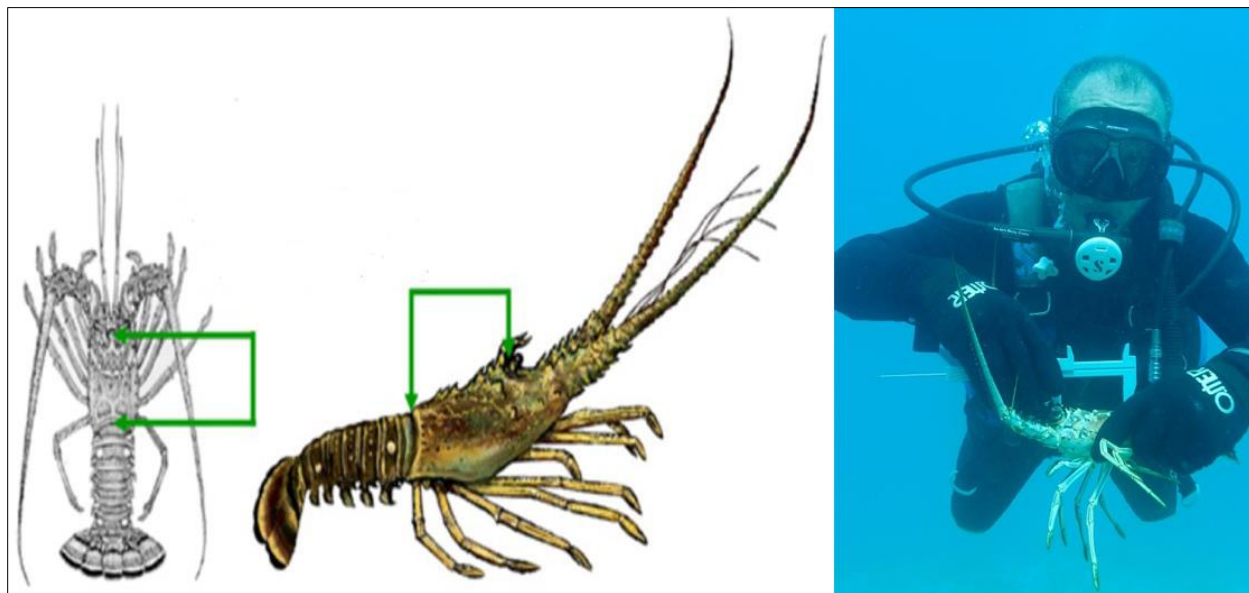


Figure SOP 4.3. The left image shows where the carapace length is measured from (the rigid part between the horns to the rear edge of the carapace) (FWC 2017). The right image shows the carapace being measured with a plastic Vernier caliper (photo by SFCN volunteer Elissa Connolly-Randazzo).

3. Sex (male or female): The sex of a spiny lobster is most easily determined by looking at the underside of its abdomen (this is the “tail” that is typically taken by the fishery). Females have two pairs of pleopods, or swimming appendages, per abdominal segment and the pleopods are feathery in appearance (Figure SOP 4.4). Males have a single pair of pleopods per abdominal segment, which do not appear feathery, and will also have a slightly thinner tail than a similarly sized female.

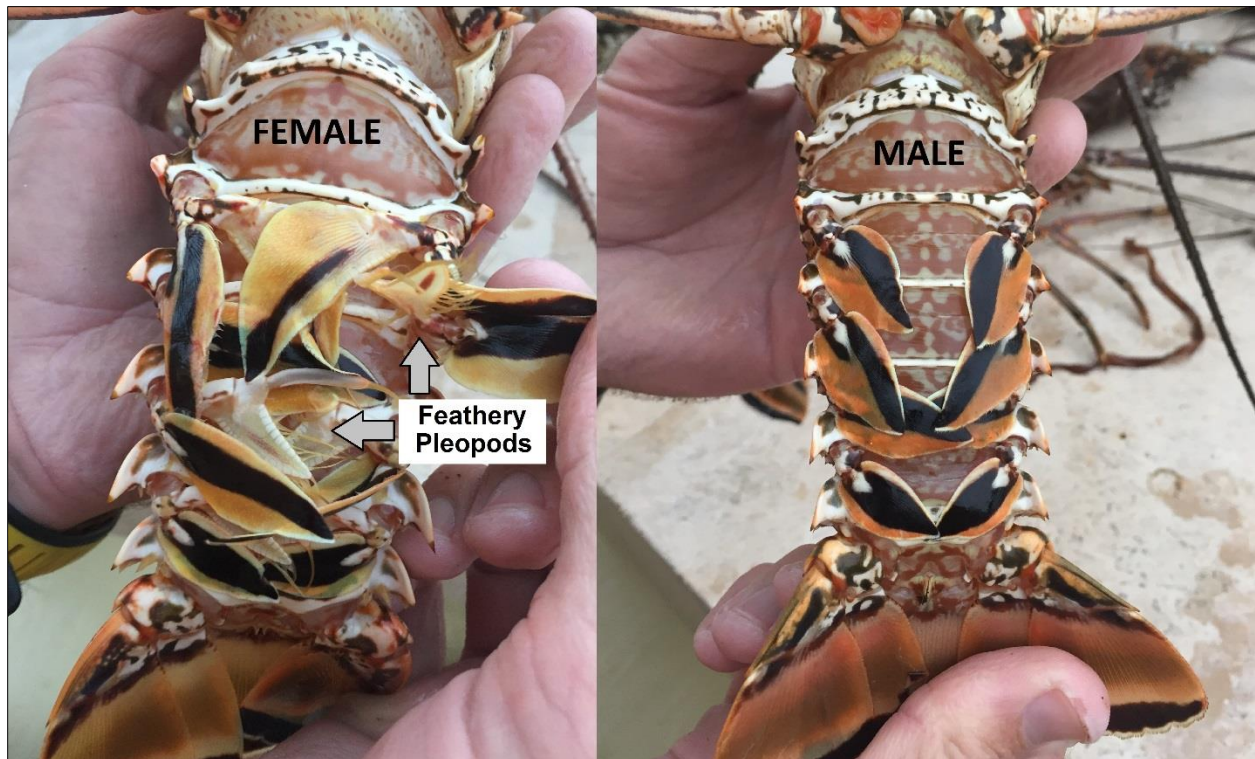


Figure SOP 4.4. The difference between a female and male lobster can be seen on their abdomen. Females are most easily identifiable by the two pairs of pleopods, or swimming appendages, per abdominal segment, which are feathery in appearance. Males have a single pair of pleopods per abdominal segment and the pleopods are not feathery.

4. Molt condition (pre-molt, post-molt, intermolt): Spiny lobsters molt as they grow. Post-molt lobsters have a soft carapace that has not hardened since a previous molt. Pre-molt lobsters have a resorptive or ecdysial line along the branchiostegites (Figure SOP 4.5). A few hours prior to molting, the fleshy area between the carapace and tail may appear swollen. The majority of lobsters observed will be in the intermolt phase, where the carapace is hard and no ecdysial line is observed. For more information on the molting cycle of *Panulirus argus*, consult Travis (1954).

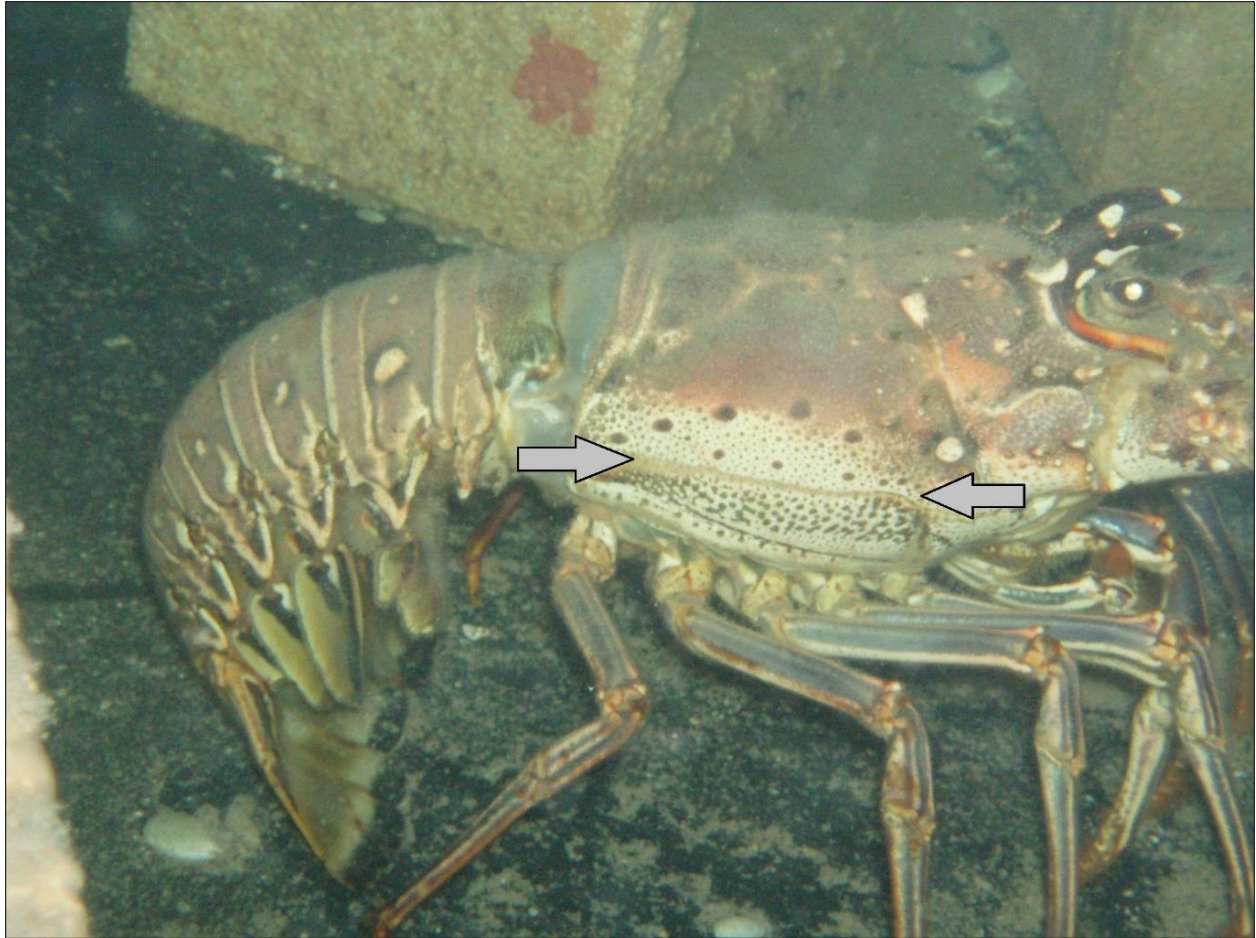


Figure SOP 4.5. Photo of a pre-molt lobster a few hours prior to molting. The arrows point to the resorptive or ecdysial line. The fleshy area between the carapace and tail appears swollen (photo used with permission by FWC/Tom Matthews 2017).

5. Eggs (orange or brown): If a female lobster is carrying eggs, the eggs will be more orange in color if they are new (Figure SOP 4.6), or brown if they are close to hatching (Figure SOP 4.7). If eggs are present, a photo is taken of the datasheet showing the data for that particular lobster and a second photo of the eggs, ideally with the calipers in the frame for scale.
6. Spermatophore (eroded or fresh): Male lobsters deposit a spermatophore or “tar patch” on the underside of female lobster during reproduction. The spermatophore is black and has a tar-like consistency (Figure SOP 4.6). To fertilize the eggs, the female lobster will scratch at the tar patch with her legs. Figure SOP 4.7 shows an example of an eroded spermatophore. A female with no eggs and an eroded tar patch has recently reproduced. If a spermatophore is present, a photo is taken of the datasheet showing the data for that particular lobster and a second photo of the spermatophore, ideally with the calipers in the frame for scale.

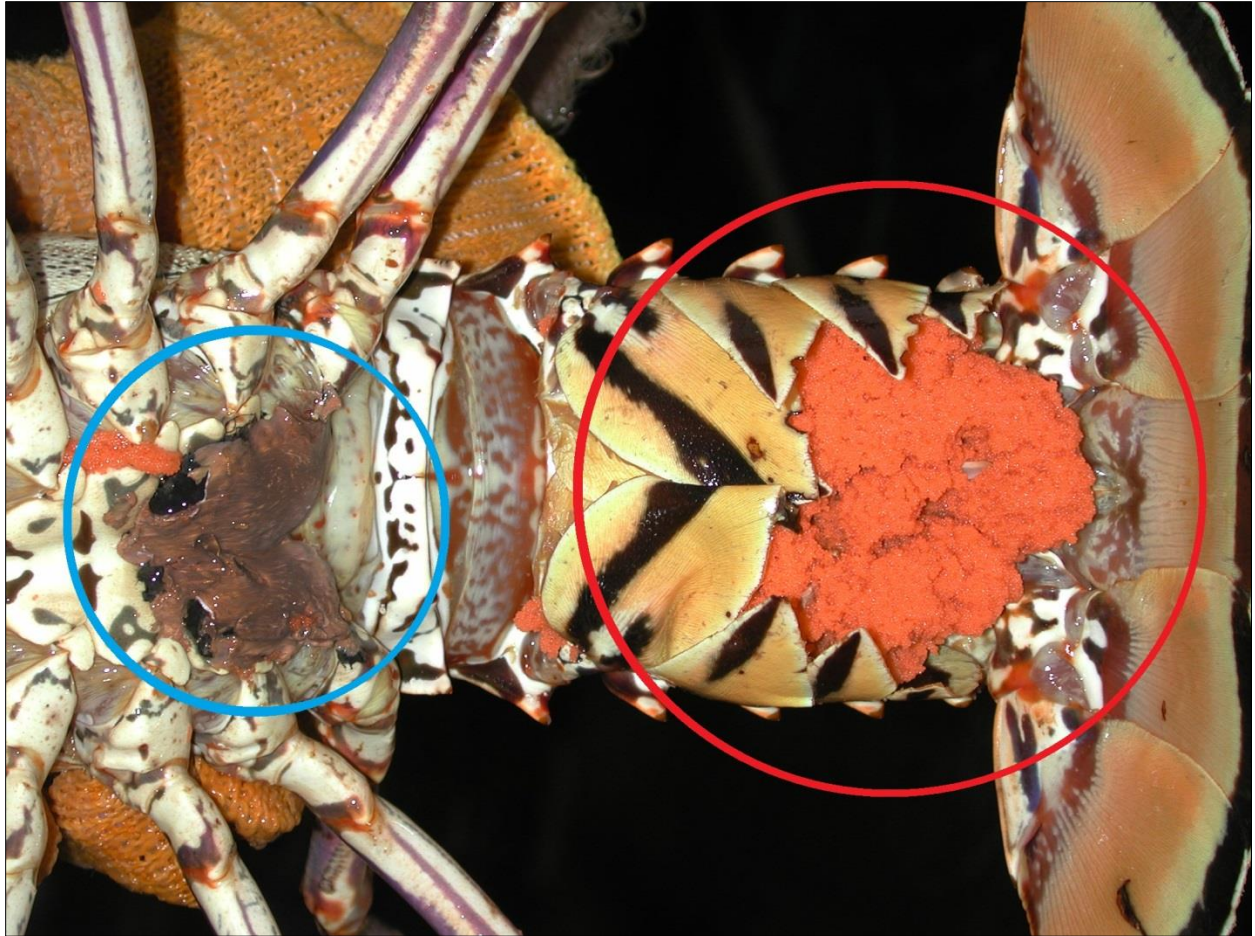


Figure SOP 4.6. Figure shows a female lobster with orange eggs under tail (red circle) and a fresh, non-eroded spermatophore (blue circle) under her belly (photo used with permission from FWC/Tom Matthews 2017).

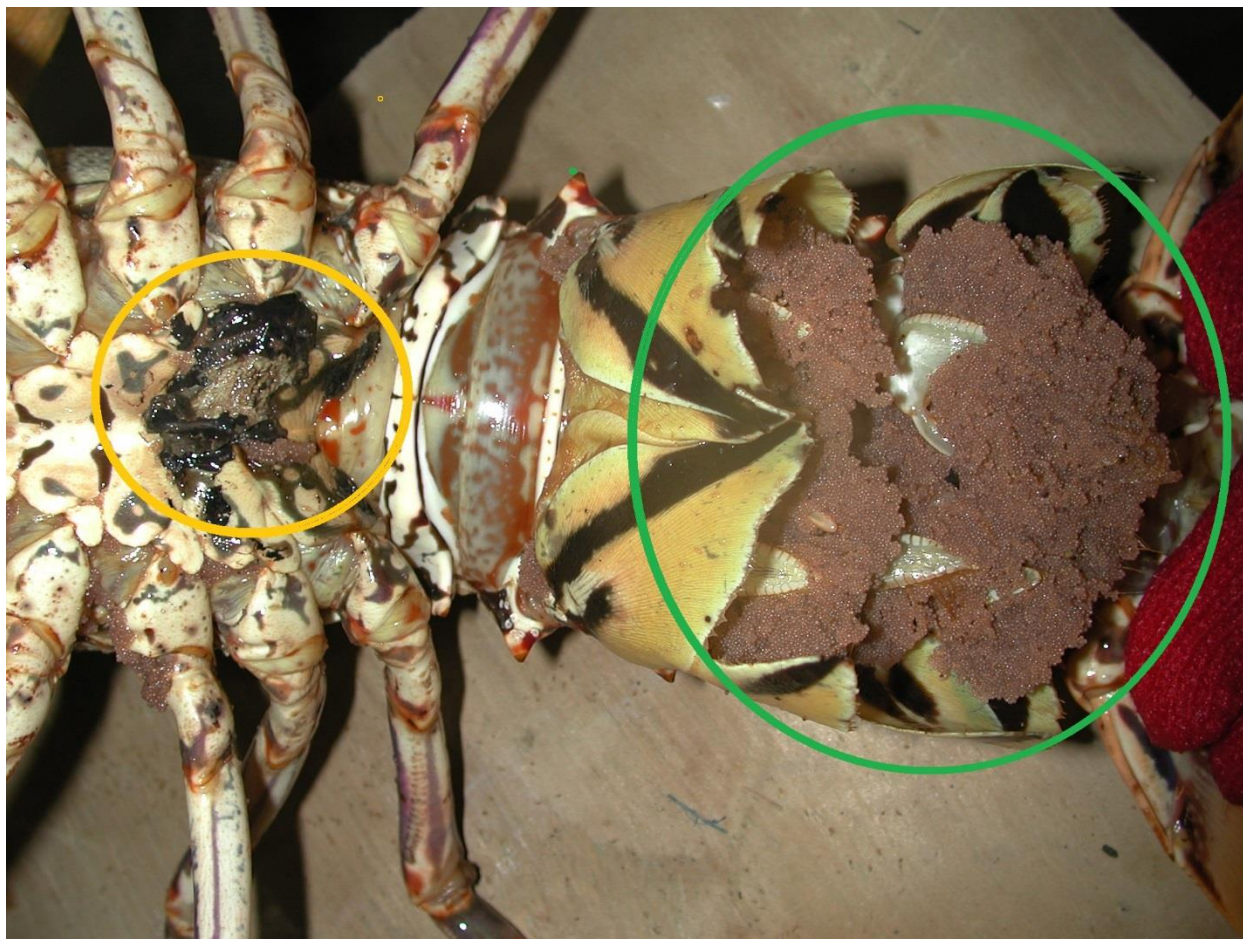


Figure SOP 4.7. Figure shows a female lobster with brown eggs under tail (green circle) and an eroded spermatophore (orange circle) under her belly (photo used with permission by FWC/Tom Matthews 2017).

7. Distance to edge (meters): Here, an edge is defined as a soft bottom-hard bottom interface. When a lobster is encountered, the observer estimates, in meters, how far the lobster is from an edge if one is visible. This distance can extend outside the circular plot. If an edge is not within sight, then “n/a” is recorded.

Prior to surfacing, the divers mark the time that they complete the survey and make sure all fields are filled out on their data sheet. Upon finishing the plots, the divers will reconvene, end their dive, surface, and get picked up by the boat before travelling to the next location.

Habitat assessment

Only one diver needs to take habitat photos for a site. They take a photo of the datasheet so the site name is clearly visible and then take four photos in each of the cardinal directions that show the habitat where the survey will occur. Both divers will make a basic habitat assessment (Figure SOP 4.8) for each circular plot. First, the diver assesses how much actual habitat is present inside the plot and fills in the field “% Plot = Habitat” to the nearest whole percent (1%). Most of the time, this should equal 100%, but there are instances where the plot may extend into non-target habitat. This

could occur, for example, if the plot occurs on a patch reef which is smaller than the size of the actual plot. This percentage will be used to determine the actual area of surveyed habitat within a plot.

Second, the assessment of habitat type, abiotic footprint, and surface relief coverage categories match that of the reef fish monitoring protocol, presented in SOP C *Field Data Collection* of Brandt et al. (2009). It is kept exactly the same for consistency so that habitat characteristics may be directly comparable. Following data collection, the divers should discuss these values. While the estimates may vary slightly, the divers should achieve a consensus on the type of habitat the plot(s) were completed on. If no consensus is achieved, the habitat type designation will default to the more experienced of the two observers. All discrepancies in habitat designation will be assessed by the lobster project lead or marine ecologist by referring to the habitat photos for verification.

1. Habitat type: On the datasheet, the habitat choices will differ depending on whether the surveys are completed in Florida or the Virgin Islands, because the habitat maps used in stratification for the two regions are different. For surveys in Florida, the following habitats may be chosen: contiguous reef (spur and groove), contiguous reef (other), isolated reef structure, rubble, seagrass/rubble/sand matrix, or sand. For surveys in the Virgin Islands, the following habitats may be chosen: bedrock, linear reef, patch reef, pavement, or scattered coral/rock. Matrix and sand habitat types (in parentheses on the datasheet) are not target habitats and are not sampled. If surveyors are deployed on these habitats without any target hard-bottom habitat in sight nearby, the survey will be aborted.
2. Abiotic footprint: This is an estimate of percent cover of sand, rubble, and hard-bottom in the entire circular plot. Each category is estimated to the nearest 10%, and the percentages must sum to 100%. Sand is defined as coarse biogenic or oolitic sand (grain sizes typically between 0.5–2 millimeters [0.01–0.07 inches]) and finer silt sized particles (less than 0.2 millimeters [0.007 inches]). Sand is considered the substratum when sediment depth is 2–3 centimeters (0.7–1.1 inches) in depth or greater. It excludes a surface “dusting” of sediment particles overlying a consolidated substratum. Rubble ranges from coarse gravel (greater than 5 millimeters [0.19 inches]) to unconsolidated and moveable rocks (e.g., dislodged and moveable coral fragments). This category differs from consolidated hard-bottom because of its loose and moveable nature. Consolidated hard-bottom includes solid, consolidated lithogenic or biogenic substratum, including living and dead coral, and non-coral hard-bottom. Areas covered by seagrass are coded as sand, since the biotic “grass” is growing in the abiotic sand substrate.
3. Slope: This is the maximum and minimum depths of the substrate slope within the sample circular plot. These values refer to the maximum and minimum depths on the imaginary plane underlying the sample cylinder. If there is a slope, these depths will be different; if the minimum depth = maximum depth there is no slope.
4. Surface relief coverage: This is recorded by estimating the percentage, to the nearest 10%, of the circular plot that falls within five different categories of surface relief (less than 0.2 meters [0.6 ft], 0.2–0.5 meters [0.6–1.6 ft], 0.5–1.0 meters [1.6–3.2 ft], 1.0–1.5 meters [3.2–

4.9 ft], and greater than 1.5 meters [4.9 ft]). The percentages must sum to 100%. Surface relief is described here as the height of hard features (not soft corals or sponges) measured perpendicular from the plane of the benthos.

Habitat type (circle one)			
Contiguous S&G		Rubble	
Contiguous Other		(Matrix)	
Isolated		(Sand)	
Abiotic Footprint (%)		Surface Relief Coverage (%)	
SAND	%	<0.2 m	%
RUBBLE	%	0.2-0.5 m	%
HARD-B	%	0.5-1.0 m	%
Total	100%	1.0-1.5 m	%
Slope (ft)		>1.5 m	
Min___ Max___		Total	100%

Habitat type (circle one)			
Bedrock		Pavement	
Linear Reef		Scat'd coral/rock	
Patch Reef		(Sand)	
Abiotic Footprint (%)		Surface Relief Coverage (%)	
SAND	%	<0.2 m	%
RUBBLE	%	0.2-0.5 m	%
HARD-B	%	0.5-1.0 m	%
Total	100%	1.0-1.5 m	%
Slope (ft)		>1.5 m	
Min___ Max___		Total	100%

Figure SOP 4.8. Habitat assessment portion of the lobster survey datasheet for Florida (left) and the Virgin Islands (right). Habitat type, abiotic footprint, slope and surface relief coverage are all recorded here.

[illegible]

Florida Lobster Survey Datasheet

Observer: _____ Date: _____ Site ID: _____ Sample Start: _____ Visibility (ft): _____

Buddy: _____ Park: _____ Depth (ft): _____ Sample End: _____ % Plot = Habitat: _____

Plot	Quadrant											Habitat type (circle one)			
	Estimate of CL (mm)											Contiguous S&G		Rubble	
	Measured CL (mm)											Contiguous Other		(Matrix)	
	Sex (M/F)											Isolated		(Sand)	
	Molt Condition (PR/PO/INT)											Abiotic Footprint (%)		Surface Relief Coverage (%)	
	Eggs (O/B)											SAND	%	<0.2 m	%
	Spermat (E/F)											RUBBLE	%	0.2-0.5 m	%
	Dist. to edge (m)											HARD-B	%	0.5-1.0 m	%
	Notes											Total	100%	1.0-1.5 m	%
												Slope (ft)		>1.5 m	
Min												Max	Total	100%	

Observer: _____ Date: _____ Site ID: _____ Sample Start: _____ Visibility (ft): _____

Buddy: _____ Park: _____ Depth (ft): _____ Sample End: _____ % Plot = Habitat: _____

Plot	Quadrant											Habitat type (circle one)			
	Estimate of CL (mm)											Contiguous S&G		Rubble	
	Measured CL (mm)											Contiguous Other		(Matrix)	
	Sex (M/F)											Isolated		(Sand)	
	Molt Condition (PR/PO/INT)											Abiotic Footprint (%)		Surface Relief Coverage (%)	
	Eggs (O/B)											SAND	%	<0.2 m	%
	Spermat (E/F)											RUBBLE	%	0.2-0.5 m	%
	Dist. to edge (m)											HARD-B	%	0.5-1.0 m	%
	Notes											Total	100%	1.0-1.5 m	%
												Slope (ft)		>1.5 m	
Min												Max	Total	100%	

Sex: **M** = Male, **F** = Female (feathery swimmerets) / Molt condition: **PR** = pre, **PO** = post, **INT** = intermediate
 Eggs: **O** = Orange (new), **B** = Brown (near hatching) / Spermat: **E** = Eroded (appears scratched), **F** = Fresh

Figure SOP 4.10. Example of datasheet.

Literature Cited

- Brandt, M. E., N. Zurcher, A. Acosta, J.S. Ault, J. A. Bohnsack, M. W. Feeley, D. E. Harper, J. H. Hunt, T. Kellison, D. B. McClellan, M. E. Patterson, and S. G. Smith. 2009. A cooperative multi-agency reef fish monitoring protocol for the Florida Keys coral reef ecosystem. Natural Resource Report NPS/SFCN/NRR—2009/150. National Park Service, Fort Collins, Colorado.
- Florida Fish and Wildlife Conservation Commission (FWC). 2017. Spiny Lobster – *Panulirus Argus* Florida Regulations website. Available at: <http://myfwc.com/fishing/saltwater/recreational/lobster/> (last accessed December 2018).
- Richter, L. R., M. W. Feeley, A. J. Atkinson, J. M. Patterson, A.D. Davis, and J. Miller. 2018. Long-term monitoring protocol of Caribbean Spiny Lobster (*Panulirus argus*): protocol narrative. Natural Resource Report NPS/SFCN/NRR—2018/1850. National Park Service, Fort Collins, Colorado. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/2258540> (last accessed December 2018).
- Travis, D.F. 1954. The molting cycle of the spiny lobster, *Panulirus argus* Latreille. I. Molting and growth in laboratory-maintained individuals. The Biological Bulletin 107(3): 433–450.

National Park Service
Inventory and Monitoring Division



Revision Date	Author	Changes Made	Reason for Change	New Version #

Source Protocol

This SOP is derived from SOP 7 in the Virgin Islands reef fish monitoring protocol:

Bryan, D. R., A. J. Atkinson, J. S. Ault, M. E. Brandt, J. A. Bohnsack, M. W. Feeley, M. E. Patterson, B. I. Ruttenberg, S. G. Smith, and B. D. Witcher. 2013. A cooperative multiagency reef fish monitoring protocol for the U.S. Virgin Islands coral reef ecosystem. Natural Resource Report NPS/SFCN/NRR—2013/672. National Park Service, Fort Collins, Colorado.

Introduction

Accurate lobster surveys require participants to be proficient in the following skill sets:

1. Species identification;
2. Habitat characterization;
3. Circular plot layout;
4. Ability to detect spiny lobster, when present;
5. Visual estimation of carapace length;
6. Ability to capture lobster effectively without injury; and
7. Ability to measure carapace length and assess biological condition of lobster.

In-water training is the best way to demonstrate and learn these skill sets, though the participants should familiarize themselves with species identification, methods, and the biological characteristics to be recorded prior to entering the water. The in-water training is split into two sections. In the first, emphasis is put on species identification, visual estimation of carapace length, ability to capture lobster, and assessing the biological condition of the lobster. The second section focuses on plot layout and habitat characterization. Once trained, new divers are paired with an experienced surveyor when actual surveys are conducted.

Species identification

Participants making observations must be competent in the identification of spiny lobster (*Panulirus argus*). This monitoring protocol is assessing only the spiny lobster (*P. argus*), so proper identification of this species and differentiation from similar species is necessary. The spotted lobster (*Panulirus guttatus*) is common in the park units and can be easily confused with the spiny lobster. The Spanish slipper lobster (*Scyllarides aequinoctialis*) is also occasionally found in the parks, but does not resemble the spiny lobster in appearance. The most recent edition of Reef Creature Identification: Florida and the Caribbean by Humann et al. (2013) is a good resource for lobster species identification.

Habitat characterization

All participants must be familiar with the habitat classification scheme used in the stratified survey design for the park unit in which the surveys will take place (Appendix A: *Benthic Habitat Classifications in Florida* and Appendix B: *Benthic Habitat Classifications in the U.S. Virgin Islands* [Richter et al. 2018]). Participants must be capable of distinguishing habitat types and classifying the abiotic characteristics (e.g., abiotic footprint, surface relief coverage) of the habitat that is measured.

Plot layout

Participants must be able to lay out the circular plots following the decision rules presented SOP 4 *Lobster Data Collection and Survey Methods*. Participants must be able to determine which quadrant they are surveying within a circular plot. A new diver is paired with an experienced surveyor when actual surveys commence. The experienced surveyor lays out the plots until the new diver feels confident they can do so accurately. The new diver can then lay the plots under the supervision of the experienced surveyor.

Ability to detect spiny lobster

The spiny lobster is a cryptic species and uses hard-bottom structure for shelter during the daytime. They can be difficult to detect. It is imperative that observers are trained how to adequately search for lobster. This includes looking in cracks, crevices, and caves in the reef structure, as well as under ledges and overhangs. In many cases, only the lobster antennae may be seen protruding from a shelter. Observers that develop a “search image” for this will be able to detect lobsters more effectively. There will be situations where the complexity of the reef habitat is such that not all shelters can be adequately searched by a diver. The goal is to ensure that all shelters that are possible to search at a site will be adequately searched during a survey.

Capture of spiny lobster

This protocol uses a tickle stick and net to capture spiny lobster. This capture method requires skill and practice to capture lobster effectively without injuring them. A tickle stick is a thin stick about 1 meter (3.2 ft) in length with a bent tip. When a lobster is encountered, the bent tip is gently placed under the tail or body of the lobster to coax it out into the open. If done too aggressively, the lobster will frighten and try to escape by flipping its tail and moving quickly backwards. A flat-bottomed net is placed behind the lobster (in between the lobster and the den), so that when the lobster is then startled, it swims backwards into the net (Figure SOP 5.1). The open side of the net can be placed on the bottom, making it more difficult for the lobster to escape. Once the lobster is inside the net, hold with a gloved hand to measure the actual carapace length and record the biological condition of the lobster. Participants should be generally familiar with how to do these tasks prior to in-water training for capturing lobster.

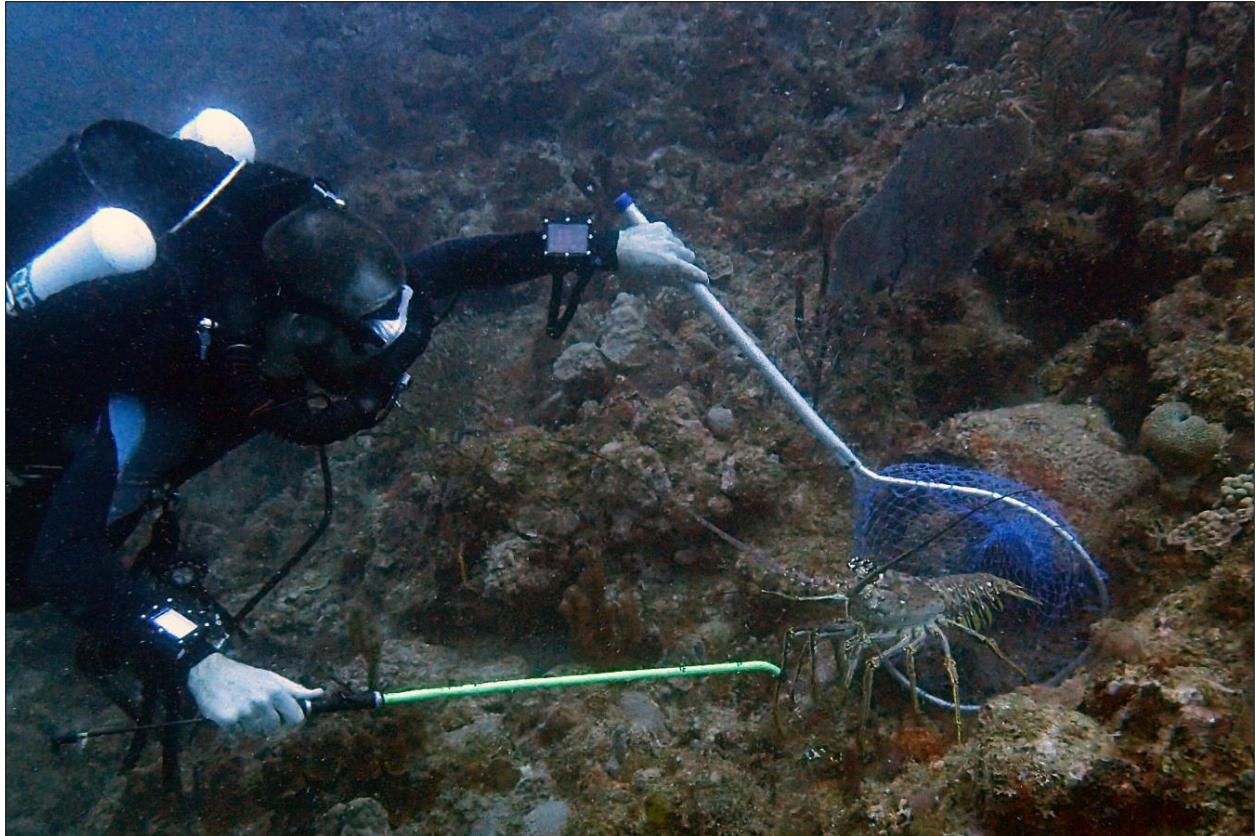


Figure SOP 5.1. A diver demonstrating how to catch a lobster that has been coaxed out into the open with a tickle stick and net placed behind (Photo by Jeff “CCR” Miller).

Biological Characteristics

Prior to surveying, participants must familiarize themselves with how to identify the following characteristics once captured:

1. Actual carapace length (to the nearest millimeter).
2. Sex (male or female).
3. Molt condition (pre-molt, post-molt, or intermolt).
4. Presence and condition of eggs (orange or brown).
5. Presence and condition of a spermatophore or “tar-patch” (eroded or fresh).

Standard Operating Procedure 4 *Lobster Data Collection and Survey Methods* presents basic information and figures on how to identify these characteristics, but participants should also refer to other literature, images, or an experienced lobster surveyor for further information. Identifying these traits is confirmed during in-water training when possible. However, some conditions (e.g., pre-molt, presence of brown eggs) may be too infrequent to be adequately assessed during in-water training of new divers.

In-water training: size estimation, capture, and characteristics assessment

In-water training is separated into two parts. The first portion focuses on how to search for lobster effectively, species identification, carapace length estimation, capture, and biological condition assessment. This is most effective if the in-water training occurs in an area where many lobster are expected to be seen. No plots are established for this section of training so new divers may interact with as many lobsters as possible.

1. An experienced observer (trainer) brings the new diver(s) to a location where many lobster are expected. A suitable test area should also be relatively shallow, with visibility exceeding 10 meters (32.8 ft), and with minimal current.
2. If possible, the trainer should try and locate a spotted lobster (*P. guttatus*) to compare with the spiny lobster (*P. argus*). The spotted lobster, which look most similar to the spiny lobster, is typically smaller and more reclusive, hiding in darker recesses in the reef.
3. The trainer should locate a spiny lobster. The trainer first estimates its carapace length. The trainees also estimate the carapace length. Following the visual estimates, the trainer demonstrates how to capture the lobster effectively. If captured successfully, the trainer demonstrates how to handle the lobster without injury. The trainer also demonstrate how to measure the actual carapace length with calipers and identify any key biological characteristics of the lobster. The trainer then releases the lobster.
4. Another spiny lobster should be located. The trainer and all of the trainees visually estimate the carapace length. A trainee is then given an opportunity to capture the lobster. If captured successfully, the trainee measures the actual carapace length with calipers and records biological characteristics. The trainer provides guidance or notes any new characteristics if observed.
5. For the rest of the dive, the trainees are given the opportunity to find, estimate size, capture, and assess as many spiny lobsters as possible.
6. Following the dive, the trainer and trainees compare the visual estimates of carapace lengths to the actual carapace lengths recorded. Estimates should be within 20 millimeters (0.6 inches) of the actual length. Additional training is provided for a trainee that exhibits consistent and considerable (greater than 20%) error until error rates are less than 20%.

It is important to note that the ability to visually estimate carapace length can be honed throughout the actual surveys. The visual estimates can continuously be compared to the actual recorded values. Use these comparisons to generate a correction factor for individuals, when enough samples have been accrued.

It is unlikely that all of the biological characteristics (e.g., a pre-molt lobster) will be seen during the training. The trainee should however be comfortable with the identification of most of the characteristics and know where and how to identify less-frequently observed traits. Once training is

completed, the new diver will carry a camera with them so they can document characteristics they are unsure of and confirm them with an experienced surveyor.

In-water training: circular plot establishment and habitat characterization

The second portion of in-water training focuses on circular plot establishment and habitat characterization. Here, the trainees are assessed as to whether they can establish a pair of circular plots (comprising the whole survey sample) following the decision rules in SOP 4 *Lobster Data Collection and Survey Methods*. Trainees must be able to identify which quadrant is which and also characterize the habitat according to the “habitat assessment” section in that same SOP. Plot layout in-water training occurs in a few different habitats so the trainee gains experience with how circular plots may differ among surveys.

1. Before entering the water, the trainer verbally discusses the decision rules and methods in order to establish the circular plots at each site. The trainer also answers any questions the trainees may have prior to entering the water.
2. The trainee attempts to establish a circular plot and identify the quadrants under the supervision of the trainer.
3. Once the trainee has established the plot properly, they will characterize the habitat in the plot using the datasheet, the “habitat assessment” section in SOP 4. The trainer also does this and compares with the trainee after surfacing.
4. If any lobster are encountered in the plot, the sizes are visually estimated, an attempt at capture made, and pertinent biological characteristics recorded. This is done by the trainee and trainer for comparison. This step will also task load the trainee in a manner that is representative of an actual survey.

Surveys conducted by new divers, post-training

A new diver’s first lobster surveys will occur with an experienced lobster surveyor. The experienced surveyor will provide guidance and answer any questions. The new diver will also be calibrating their size estimates by comparing their size estimates to those of the experienced surveyor and with actual measurements of captured lobsters. It is recommended that during actual surveys, the experienced diver establishes the circular plots (SOP 4) until the new diver understands and can execute the decision rules of establishing circular plots correctly in a variety of habitats and situations. Regardless of experience, after a survey both divers discuss how the survey was laid out, compare habitat characterizations, and discuss any notable observations of lobster during the survey.

Size estimation calibration

Prior to a sampling event it is important that all participants are able to estimate carapace length sizes underwater consistently. Estimating size of plastic lobster models is a great way to calibrate size estimation among participants. The carapace lengths of the models are known and the participants can directly compare their estimates to the actual lengths. All surveyors practice size estimation until their estimates are consistently within 20 millimeters (0.6 inches) of the actual length. A measuring

aid (e.g., the ruler on the side of many clipboards or markings on the tickle stick) may be used to aid in estimation, as it would be used on an actual survey.

Data entry and proofing training

All participants should be instructed on data entry methods and be familiar with SOP 6 *Data Entry, QA/QC, and Management* before using the Microsoft Access database. Once data entry is complete, participants will be briefed on how to perform basic QA/QC checks of the data. The data manager will assist in this process.

Literature cited

- Bryan, D. R., A. J. Atkinson, J. S. Ault, M. E. Brandt, J. A. Bohnsack, M. W. Feeley, M. E. Patterson, B. I. Ruttenberg, S. G. Smith, and B. D. Witcher. 2013. A cooperative multiagency reef fish monitoring protocol for the U.S. Virgin Islands coral reef ecosystem. Natural Resource Report NPS/SFCN/NRR—2013/672. National Park Service, Fort Collins, Colorado.
- Humann, P., N. DeLoach, and L. Wilk. 2013. Reef Creature Identification: Florida, Caribbean, Bahamas, 3rd Edition. New World Publications, Jacksonville, Florida.
- Richter, L. R., M. W. Feeley, A. J. Atkinson, J. M. Patterson, A.D. Davis, and J. Miller. 2018. Long-term monitoring protocol of Caribbean Spiny Lobster (*Panulirus argus*): protocol narrative. Natural Resource Report NPS/SFCN/NRR—2018/1850. National Park Service, Fort Collins, Colorado. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/2258540> (last accessed December 2018).

National Park Service
Inventory and Monitoring Division

[illegible]

Source Protocol

This SOP is derived from SOP 8 in the Virgin Islands reef fish monitoring protocol:

Bryan, D. R., A. J. Atkinson, J. S. Ault, M. E. Brandt, J. A. Bohnsack, M. W. Feeley, M. E. Patterson, B. I. Ruttenberg, S. G. Smith, and B. D. Witcher. 2013. A cooperative multiagency reef fish monitoring protocol for the U.S. Virgin Islands coral reef ecosystem. Natural Resource Report NPS/SFCN/NRR—2013/672. National Park Service, Fort Collins, Colorado.

Introduction

Data management is an important multilevel process that involves all participants. Steps taken to manage the data once they have been collected include data entry, proofing, and storage. The specific steps and the person responsible for each step are outlined in Table SOP 6.1 and explained in detail in the following sections.

Table SOP 6.1. Data entry and proofing steps, responsible person, and forms and programs used.

Steps	Responsible Person	Forms / Programs Used
1. Field data collection	Diver	Lobster datasheet & Boat log
2. Scan datasheets and boat logs and store on server	Diver	SFCN server
3. Enter datasheets and boat logs and proof against the originals	Diver	SFCN lobster database
4. Save photos to server	Diver	SFCN server
5. Save GPS files to server	Field lead	SFCN server
6. Verification of entered data against datasheets	Second Diver	SFCN lobster database
7. Storage of hard-copies of datasheets	Diver	Conference room (FL) or file cabinet in building 3 (VI)
8. Check that all data have been entered and accounted for	Data Manager	SFCN lobster database
9. Run automated QA/QC checks and proof data; mark as accepted or certified (dependent on existence of QAP)	Marine Ecologist and Data Manager	SFCN lobster database
10. Data storage on server and upload to IRMA Data Store	Data Manager	IRMA Data Store

Post Field Procedures

After a site visit, the datasheets and boat logs should be scanned and saved on the SFCN server in the following location:

- Z:\SFCN\Vital_Signs\Lobster\data\scanned_datasheets\PARK\YEAR

Additional PARK and YEAR subfolders should be created as needed to organize the files. After scanning, the original datasheets should be subset by diver to facilitate data entry.

Data Entry Procedures

Divers are responsible for accurately entering their data into the database within one month of collection. Memory of the sampling event will fade with time, so entering data as soon as possible after collection is recommended.

Opening the Database

1. Open the SFCN Lobster Data by browsing to Z:\SFCN\Vital_Signs\Lobster\data\SFCN_Lobster.accdb.
2. A Startup screen will appear and display buttons for various Database Tasks.

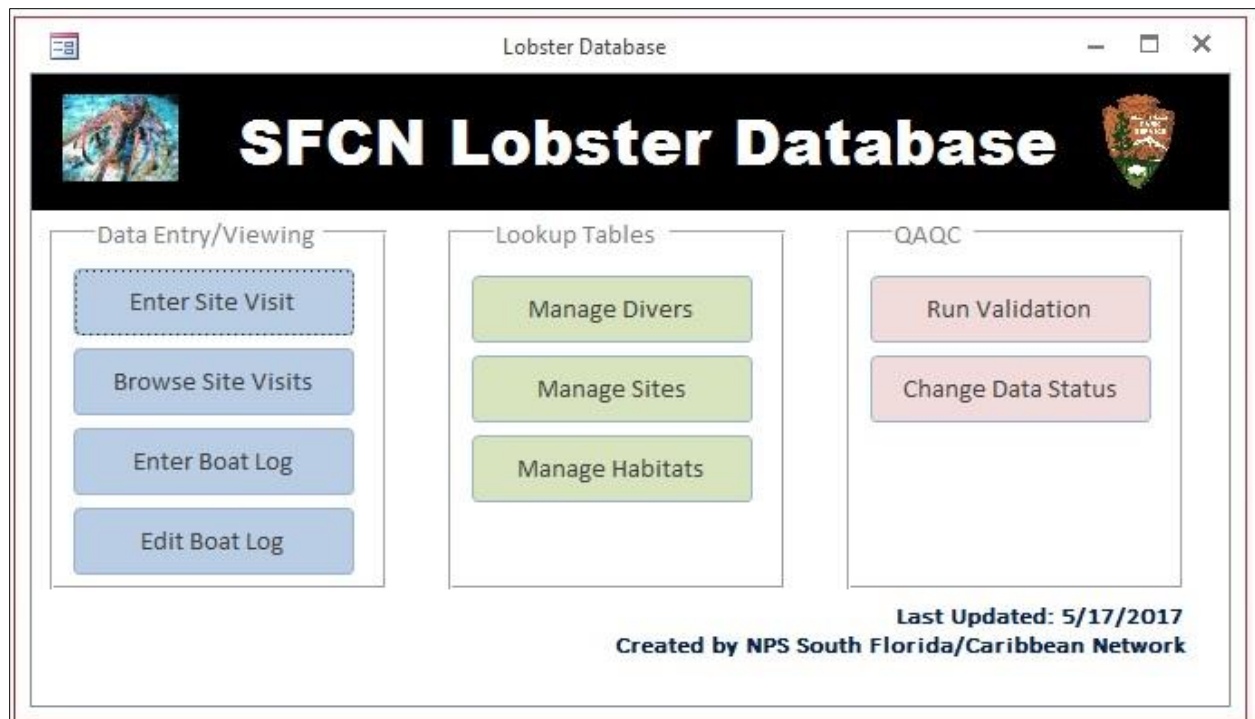


Figure SOP 6.1. Screenshot of startup screen.

Entering a Site Visit

1. Click on the button for "Enter Site Visit."

2. A new form will display and show the site visit data entry screen.

SFCN Lobster Database

Site Visit

Observer: Park: Site ID: Start Time: Visibility (ft):
 Buddy: Date: Plot: End Time: % Plot = Habitat:
 Depth (ft):

Lobsters ☐ No Lobsters Found

Quadrant	
Estimate of CL (mm)	
Measure of CL (mm)	
Sex	
Molt Condition	
Eggs	
Spermat	
Distance to edge (m)	
Notes	

Observed Habitat Type

Abiotic Footprint %
 Sand:
 Rubble:
 HardB:

Surface Relief Coverage %
 <0.2 m:
 0.2-0.5 m:
 0.5-1.0m:
 1.0-1.5m:
 >1.5 m:

Verified Date:
 Verified By:

Transect Visit: 1 of 1

Figure SOP 6.2. Site Visit data entry screen.

3. Referring to the original datasheet, enter each of the parameters across the top, including “Observer,” “Buddy,” “Park,” “Date,” “Site ID,” “Plot,” “Start Time,” “End Time,” “Depth (ft),” “Visibility (ft),” and “% Plot = Habitat.”
4. Select the appropriate value from the “Observed Habitat Type” drop-down list.
5. Fill in the appropriate values for “Abiotic Footprint %” as whole numbers. An automated check ensures the values total 100 (%).
6. Fill in the appropriate values for “Surface Relief Coverage %” as whole numbers. An automated check ensures the values total 100 (%).
7. If no lobsters were found by a diver in the quadrants surveyed in the circular plot, tick the “No Lobsters Found” box and data entry is complete.
8. If lobsters were found, continue to the “Lobsters” subform and enter “Estimate of CL (millimeter),” “Measure of CL (millimeter),” “Sex,” “Molt Condition,” “Eggs,” “Spermat,” “Distance to edge (m),” and “Notes” for the first lobster.
9. Additional lobster can be added to this plot by clicking the new record button (inside the red square below) and repeating step 9.

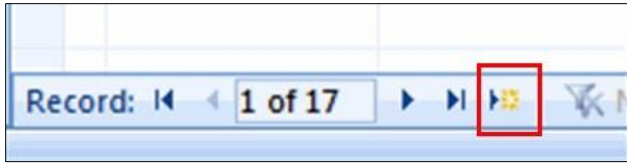


Figure SOP 6.3. Additional lobster can be added to this plot by clicking the new record button (inside the red square below) and repeating step 9.

10. Leave the “Verified Date” and “Verified By” fields blank during initial data entry. These will be filled in during verification by a second person in the “Data Verification and Additional QA/QC” section below.
11. Once all lobsters have been entered for a site, click “Add Site Visit” to bring up a new form to add data collected from other sites. Close the form after all data have been entered.

Entering a Boat Log

1. Click on the button for “Add Boat Log.”
2. A new form will display and show the boat log data entry screen.

Figure SOP 6.4. The boat log data screen.

3. Referring to the original boat log, enter each line across the top, including “Park,” “Date,” “Dive of Day,” “Site Name,” “Estimated Time,” “Dive Team,” “Diver A,” “Diver B,” “Latitude,” “Longitude,” “Target Habitat,” “GPS #,” and “Notes.”
4. As each line is added, a new, blank line will appear. Continue typing in additional boat log rows.
5. Close the form after all boat log rows have been entered.

Saving GPS Data

One person is designated as a field lead who will collect the GPS units upon returning from the field each day. The tracks from the GPS units are downloaded and saved as a .gpx file to the server at this location:

- Z:\SFCN\Vital_Signs\Lobster\spatial_info\GPS_tracks\PARK\YEAR

Create additional PARK and YEAR subfolders as needed to organize the files. The naming convention for the individual GPX files should be: YYYYMMDD_PARK_lobster_GPS#_track.gpx.

- “YYYYMMDD” is the year, month, and day the track was collected.
- “PARK” is the four-letter code of the park unit where the surveys were conducted.
- The word “lobster” identifies the track as a lobster survey.
- “GPS#” is the name of the GPS that was used to collect the data. This should match the GPS# column values found in the boat log (SOP 4 *Lobster Data Collection and Survey Methods*).
- The word “track” identifies the file as a track file.

For example, a file named 20170424_Biscayne NP_lobster_GPS4_track.gpx would be a track file during a lobster survey that was completed in Biscayne NP on April 24, 2017 on GPS #4.

Saving Photos

All photos are saved to the SFCN server by the individual diver who took them. In the event a diver does not have access to the SFCN server, the photos may be saved on a local server, then transferred and organized on the SFCN server by the lobster project lead. All photos taken at a site (slate photos, habitat photos, egg/spermatophore photos, and any miscellaneous photos) are saved to a site-specific folder on the SFCN server following the naming convention below:

- Z:\SFCN\Vital_Signs\Lobster\images\Survey_photos\YEAR\PARK\SITE

The YEAR, PARK, and SITE subfolders may not have been created yet for the sample event when photos are downloaded to the server. The photos themselves are not renamed, but the subfolders will need to be created to identify the year (e.g., 2017), park (e.g., BISC), and site (e.g., 1011) at which the photos were taken.

The four habitat photos taken at each site are preceded by a photo of the datasheet with the site name clearly visible. Use this photo of the slate to organize the subsequent photos into the respective site folders.

Data Verification and Additional QA/QC

Each diver must enter their data within one month of each survey and then conduct a 100% review of their data after entry into the database to ensure it was accurately entered from the datasheets. Early data entry is preferred as it is easier to remember surveys and catch any mistakes. Subsequent proofing of the data, using copies of the originals, may be done by the diver as long as the entry and proofing tasks are separated by several days. This will serve as an independent verification of 100% of the entered data.

Quality Assurance Methods during Data Collection

There are several methods in place during data collection itself that ensure that consistent, quality data are collected during surveying:

- When divers are deployed at a site, coordinates of their deployment point are written on the boat log as a backup, while the towed GPS serves as the primary record of location.
- Each diver independently completes the habitat assessment of a site to be compared at the surface following a survey. Divers communicate and ask questions and review each other's data and interpretation of percent habitat cover and habitat classification. The habitat photos may be consulted by the lobster project lead or marine ecologist if a discrepancy between divers cannot be resolved in the field.
- All surveyors practice size estimation of plastic models of lobster prior to a sampling event to ensure that estimation methods are routinely calibrated among observers.
- Estimates of lobster size are taken prior to capture of lobster to measure actual size. A comparison of estimates, when compared to the actual sizes of captured lobsters, provide real-time calibration of size estimation during a sample event.

Verifying Site Visit Data

1. Click on the button for "Edit Site Visit."
2. A new form will display and show existing site visits.
3. Use the forward and backward navigation arrows at the bottom of the form to move between records and locate the batch of records that need verification by a second diver.
4. Review each of the entered values and compare it to the original datasheet. Be sure to check both site level fields and all lobster observations. Correct errors in the database as they are found. If there are questions about what was written on the original datasheets, consult the diver who recorded the original data. Bring major or recurring errors to the attention of the data manager and marine ecologist.
5. When verification of a site is complete, fill in the "Verified By" and "Verified Date" fields at the bottom of the form and move to the next record.

6. Repeat steps 3–5 until all records have been verified.

Verifying Boat Log Data

1. Click on the button for “Edit Boat Log.”
2. A new form will display and show existing boat log entries.
3. Use the scroll bars to locate the batch of records that need verification by a second diver.
4. Review each of the entered values and compare it to the original boat log. Correct errors in the database as they are found. If there are questions about what was written on the original datasheets, consult the diver who recorded the original data. Bring major or recurring errors to the attention of the data manager and marine ecologist.
5. When verification of a site is complete, fill in the “Verified By” and “Verified Date” fields at the bottom of the form and move to the next record.
6. Repeat steps 3–5 until all records have been verified.

Additional QA/QC

Once all data for a season have been entered and verified, the data manager will check to make sure that all survey sites are accounted for and will run QA/QC checks to ensure a complete data set. The marine ecologist will review the data to look for any unusual aspects (e.g., anomalous or missing) in the data set and flag any suspicious values. Any suspicious values will be brought to the attention of the surveyor to be either validated or corrected. In extreme circumstances a site or a portion of a site’s data may have unresolvable errors and may need to be invalidated with the approval of the marine ecologist or protocol lead. The checks that are run will include, but are not limited to:

- Check that all assigned sites were completed.
- Check that data (boat log, lobster, and habitat data) have been entered and verified.
- Check that all required fields were entered.
- Check that the fields under “Abiotic footprint %” and “Surface relief coverage %” each add up to a total of 100% on a site visit.
- Check that all site visits have lobsters or the “No lobster found” box is checked.
- Flag plots where one or more divers recorded habitat classification that deviated from the expected habitat (from benthic map) and provide these to the marine ecologist/protocol lead to determine if they are explainable (e.g., visibility or drop location) or should be removed from analyses.
- Check the GPS track logs and the planned coordinates to make sure sampling occurred in the appropriate area. Any sites that originated outside of the target cell should be reviewed by the marine ecologist and/or the protocol lead.

Data storage and distribution

Data will be stored locally on the SFCN server where it will be included in routine SFCN onsite and offsite backups. Each year after verification/validation and certification are completed a new cumulative version of the database will be uploaded to the National Parks Service's Integrated Resource Management Applications portal (IRMA). The version that will be accessible to the public will have specific locations of surveys obscured by changing their location by random direction and random distance less than 1 kilometer (0.6 miles). This is done because the spiny lobster is a commercial species and specific locations of surveys are considered protected data.

Literature cited

Bryan, D. R., A. J. Atkinson, J. S. Ault, M. E. Brandt, J. A. Bohnsack, M. W. Feeley, M. E. Patterson, B. I. Ruttenberg, S. G. Smith, and B. D. Witcher. 2013. A cooperative multiagency reef fish monitoring protocol for the U.S. Virgin Islands coral reef ecosystem. Natural Resource Report NPS/SFCN/NRR—2013/672. National Park Service, Fort Collins, Colorado.

Standard Operating Procedure 7

Purpose

Revision Log

[illegible]

Source Protocol

This SOP is derived from SOP 9 in the Virgin Islands reef fish monitoring protocol:

Bryan, D. R., A. J. Atkinson, J. S. Ault, M. E. Brandt, J. A. Bohnsack, M. W. Feeley, M. E. Patterson, B. I. Ruttenberg, S. G. Smith, and B. D. Witcher. 2013. A cooperative multiagency reef fish monitoring protocol for the U.S. Virgin Islands coral reef ecosystem. Natural Resource Report NPS/SFCN/NRR—2013/672. National Park Service, Fort Collins, Colorado.

Introduction

Data analyses first focus on relative frequency of occurrence, relative density, and average size of all observed exploited phase lobsters. It is important to keep in mind that estimates of frequency of occurrence and density are *relative*. When calculating these metrics, it is assumed the entire grid cell area is hard-bottom habitat when many of the grid cells have only partial habitat coverage. This is because of map resolution and limitations in our current knowledge of benthic habitats. These relative metrics should not be treated as true estimates of frequency of occurrence and density. Estimates of relative density and relative frequency of occurrence apply to individual strata. For park-wide calculations, unit-less indices of relative density and relative frequency of occurrence are used because of the underlying uncertainty in map weights for individual strata. Also, this protocol is written with the understanding that our knowledge of benthic habitats will likely improve in the future, which could decrease the grid cell sizes that are used. If and when this occurs, historical values of the relative metrics will be re-computed. This may cause some shifts in the historical estimates of relative metrics but will not cause a shift in trends. Thus, it is important to make sure the most recent report that reflects any such changes is used for interpretation.

Other descriptive statistics apply to only lobsters that were successfully captured and assessed. These descriptive statistics concentrate on sex ratio, molt stage ratio, proportion of females bearing eggs, and proportion of females with spermatophores. Additional data analyses and reporting will be specific to management questions for each park. Other analyses include those that may refine allocation of samples across strata in future sampling.

Documenting summary statistics for strata

A list including the number of sites selected within each stratum, the actual number of sites surveyed within each stratum, and the total number of grid cells per stratum is imperative for estimates of relative density and relative frequency of occurrence and should be included in each report. The strata classifications from the survey datasheet (diver team classification, not the habitat map) are used for all subsequent calculations. Tables SOP 7.1, SOP 7.2, SOP 7.3, SOP 7.4, and SOP 7.5 are based on current stratification schemes and will be updated with any changes to strata or management.

Table SOP 7.1. Summary statistics for strata in Biscayne NP. This is a subset of the strata that appear in Brandt et al. (2009) because some of them do not occur within Biscayne NP.

Stratum Classification	Total # Grid Cells	# Grid Cells Selected	# Grid Cells Surveyed
Inshore Patch Reef (0 - 6 m)	–	–	–
Mid-Channel Patch Reef (0 - 6 m)	–	–	–
Offshore Patch Reef (0 - 6 m)	–	–	–
Forereef, Low-relief, (0 - 6 m)	–	–	–
Forereef, Low-relief (6 -18 m)	–	–	–
Forereef, High-relief reef (0 - 18 m)	–	–	–

Table SOP 7.2. Summary statistics for strata in Dry Tortugas NP. These strata are not separated by depth and range from 0–30 meters (0–98.4 ft).

Stratum Classification	Total # Grid Cells	# Grid Cells Selected	# Grid Cells Surveyed
Low-relief continuous reef	–	–	–
Mid-relief continuous reef	–	–	–
High-relief continuous reef	–	–	–
Low-relief isolated reef	–	–	–
Mid-relief isolated reef	–	–	–
High-relief isolated reef	–	–	–
Low-relief spur and groove	–	–	–
High-relief spur and groove	–	–	–

Table SOP 7.3. Summary statistics for strata in Virgin Islands NP.

Stratum Classification	Total # Grid Cells	# Grid Cells Selected	# Grid Cells Surveyed
Scattered coral/rock	--	--	--
Pavement	--	--	--
Bedrock	--	--	--
Patch reef	--	--	--
Linear reef	--	--	--
Unknown hard-bottom	--	--	--

Table SOP 7.4. Summary statistics for strata in Buck Island NM.

Stratum Classification	Total # Grid Cells	# Grid Cells Selected	# Grid Cells Surveyed
Scattered coral/rock	–	–	–
Pavement	–	–	–
Patch reef	–	–	–
Linear reef & Bedrock	–	–	–

Table SOP 7.5. Summary statistics for strata in Salt River Bay NHP.

Stratum Classification	Total # Grid Cells	# Grid Cells Selected	# Grid Cells Surveyed
Pavement & Scattered coral/rock	–	–	–
Linear reef & Patch reef	–	–	–
Bedrock	–	–	–

Analyses for lobster surveys

The analyses for the lobster data deviate from the methods presented in the reef fish protocols. While it would be beneficial to maintain consistency between the two protocols there are several reasons why a separate approach to analysis is needed.

The analyses in the reef fish monitoring data assume normality in the data set. This is possible due to the central limit theorem, which states that survey design estimates (e.g., population means and totals) are normally distributed if sample size is large. The reef fish monitoring data include multiple species, achieve a greater number of individuals observed per survey, and attain higher sample sizes per stratum than is currently possible with lobster monitoring. We cannot assume that the lobster sample data are normally distributed. Thus, it becomes necessary to fit the lobster sample data to an underlying probability distribution (e.g. Poisson, negative binomial).

The data collected in this protocol are count data (non-negative integers) and are expected to be approximated by a Poisson, negative binomial, or similar probability distribution. Based upon the pilot data collected in 2017 in Biscayne NP and in Virgin Islands NP, it is expected that a Poisson distribution may be the most appropriate for the data set. However, if the data are over-dispersed, a negative binomial distribution may be more appropriate.

Another check to determine whether a particular regression is an appropriate fit for the data set is an examination of the summary of the model in R. This is determined by dividing the residual deviance by the degrees of freedom. A resulting value less than 2 (closer to 1 is better) indicates that the regression is acceptable. Values between 2 and 5 may be acceptable, but other regressions should be

considered. Values greater than 5 mean that the selected regression results in an unacceptable distortion of the data and another type of regression is more appropriate.

The free software, R, is used for all analyses of lobster data. Code provided in Appendix G: *R code* in the protocol narrative (Richter et al. 2018) is used to determine the appropriate distribution for the data set as well as goodness of fit.

During the pilot studies, there were several sites with non-detections. A concern with a high number of non-detections is zero-inflation of the data set and how this affects the underlying distribution. In such instances, a zero-inflated Poisson or zero-inflated negative binomial distribution could potentially better approximate the data. For a regular Poisson distribution a minimum of 3-5 sites with detections is necessary. For a zero-inflated Poisson, 5 or more sites with detections is needed; and at least 8-10 sites is required for a zero-inflated non-binomial (Tom Philippi, personal communication, 26 November 2018). Yet, when the mean number of lobsters per site with lobster present is low (near 1 lobster per site), a zero-inflated model is not appropriate. If the mean number of lobster per site is higher (e.g. greater than 3 lobsters per site), a zero-inflated model is more relevant. R-code provided in Appendix G can be used to determine whether a zero-inflated model is appropriate for the sample data. For the Biscayne NP and Virgin Islands NP pilot studies conducted in 2017, a Vuong test determined that an ordinary Poisson regression was more appropriate than a zero-inflated Poisson regression in both cases.

A second concern about a data set with many non-detections is the ability to calculate accurate and useful confidence intervals. Increasing the sample size per stratum or increasing samples with detections are two methods to improve the variance. By combining some of the strata, we have reduced the overall number of strata for each park unit, which in turn allows us to allocate more samples per stratum. Initially, an even allocation of samples across strata also keeps the number of samples per stratum high. We will also use a non-parametric bootstrap (R code provided in Appendix G) to calculate adjusted 95% confidence intervals.

The following methods are used in analyses to calculate relative frequency of occurrence, relative density, and average size. All lobster observed in plots, including those that have evaded capture but have visual size estimates, will be included in these analyses. The methods presented below are used to calculate the aforementioned metrics for all observed lobsters. These analyses should also be conducted separately for exploited phase and unexploited phase lobsters. The exception is for average size, where only calculations for exploited phase and all observed lobsters are conducted.

Relative density

Mean density

A primary motivation of monitoring lobster is to evaluate changes in population structure which may fluctuate in response to environmental changes or fishing pressure. Robust estimators of population condition for focal species include average relative density of lobster at different life stages (all observed, exploited phase, unexploited phase) and average length of exploited phase (or “legal”) individuals (Ault et al. 2001; Ault et al. 2005). These two biological indicators must be calculated

and compared to previous years and between strata, with consideration to habitat. Mean density of life stages must also be considered spatially across the domain.

Mean lobster relative density can be estimated for each individual stratum (e.g. bedrock) in a park unit. An index of relative density is generated for the whole park unit by combining the means of relative density in each stratum, weighted by the proportional coverage of the stratum in the entire park unit. At the time of this writing, uncertainty in the underlying benthic coverage and associated map weights means that the index of relative density calculated for a park unit is unit-less. This value is not intended to represent the true density of lobsters within the park unit, but may be tracked through time to determine whether the relative density is increasing or decreasing.

A Poisson distribution is expected to approximate the sample data the best, though this can be confirmed with R-code provided in Appendix G: *R code* in the protocol narrative (Richter et al. 2018). The methods below describe how to determine mean relative density and calculate 95% confidence intervals per stratum using the Poisson distribution and a non-parametric bootstrap. Lobster relative density, D_{hj} , is the number of individuals observed per site or pair of circular plots (e.g., individuals observed / 353 square meters [3,804 square feet]). It is assumed the data collected at the survey sample is representative of the whole primary unit in which it was collected. Therefore, the mean relative density ($\bar{D}_h$) for each stratum h is estimated as:

$$\bar{D}_h = \frac{1}{n_h} \sum_j D_{hj} \quad (\text{SOP 7.1})$$

Where n_h is the number of primary units sampled in stratum h .

The Poisson distribution is approximated by the equation

$$P(x; \lambda) = \frac{(e^{-\lambda})(\lambda^x)}{x!} \quad \text{SOP 7.2)}$$

Where x represents the number of successes that result from the experiment, λ is the mean of the distribution, and e is a mathematical constant equal to approximately 2.718.

To create a Poisson distribution for the sample data in each stratum, only the stratum mean, λ_h , is needed. This is approximated by $\bar{D}_h$ in Equation SOP 3.2.

$$\bar{D}_h = \lambda_h \quad (\text{SOP 7.3})$$

A non-parametric bootstrap is performed on the sample data using the `boot()` function in R. A parametric bootstrap resamples from a known distribution function and is more appropriate for continuous datasets. The non-parametric bootstrap resamples from the data that was actually collected and is more appropriate for a discrete dataset. Thus, a non-parametric bootstrap is used in this protocol to calculate adjusted confidence intervals for relative density. From the bootstrapped data, adjusted 95% confidence intervals are generated for each stratum as well as for the entire sample domain using the `boot.ci()` function in R.

To calculate the index of relative mean density for the domain, the stratum relative densities and a weighting factor are used:

$$\bar{D}_{st} = \sum_h (w_h \bar{D}_h) \quad (\text{SOP 7.4})$$

where w_h is the stratum weighting factor

$$w_h = \frac{N_h}{\sum_h N_h} \quad (\text{SOP 7.5})$$

N_h is the total possible number of primary units that can be sampled in stratum h .

Relative frequency of occurrence

The relative frequency of occurrence for lobster is generated for each stratum in each park. Lobster relative frequency of occurrence, P , is the proportion of sites (paired circular plots) where at least one lobster was observed to the total number of sites visited. Relative frequency of occurrence is calculated first by stratum ($\bar{P}_h$). Calculations of relative frequency of occurrence are similar to that of relative density, where a non-parametric bootstrap is used to determine 95% confidence intervals. Unlike the relative density dataset however, frequency of occurrence follows a binomial distribution. n_h is the total number of primary units visited in each stratum. j is the individual sample.

$$\bar{P}_h = \frac{1}{n_h} \sum_j P_{hj} \quad (\text{SOP 7.6})$$

To determine the index of relative frequency of occurrence across the entire park domain, the stratum relative frequencies of occurrence are multiplied by a weighting factor (w_h) and summed to provide an overall estimate ($\bar{P}_{st}$). This weighting factor is calculated for each stratum as:

$$w_h = \frac{N_h}{\sum_h N_h} \quad (\text{SOP 7.5})$$

The total number of primary units (grid cells) in a stratum, N_h , is dependent on stratum area, so values for N_h are derived directly from GIS habitat maps.

$$\bar{P}_{st} = \sum_h w_h \bar{P}_h \quad (\text{SOP 7.7})$$

The R-code for calculating relative frequency of occurrence and the 95% confidence intervals for each stratum and across the entire park domain can be found in Appendix G: *R code* in the protocol narrative (Richter et al. 2018).

Average size in the exploited phase ($\bar{L}_{exp}$)

Average size in the exploited phase should be calculated at the end of each survey season. This metric is calculated by averaging the size of all lobster that are already greater than or equal to the exploited phase size limit. In Florida any lobster with a carapace length greater than 3 inches (76 millimeters [mm]) is considered in the exploited phase. In the Virgin Islands, any lobster with a carapace length greater than 3.5 inches (89 mm) is considered in the exploited phase. At this time, lengths are not weighted by strata.

$\bar{L}_{exp}$ is defined as the average length of lobsters in the exploited phase:

$$\bar{L}_{exp} = \frac{1}{n_{exp}} \sum L_{exp} \quad (\text{SOP 7.8})$$

where n_{exp} is defined as the number of lobster in the exploited phase and L_{exp} is the carapace length of an exploited phase lobster.

Average size in all observed lobsters

Average size in the exploited phase is the most important size metric to track over time. However, average size of all observed lobsters should also be tracked. This can be done, using the same equation SOP 7.8, but by replacing n_{exp} with n_{all} and L_{exp} with L_{all} where n_{all} is the number of all observed lobster and L_{all} is the carapace length of an observed lobster.

$$\bar{L}_{all} = \frac{1}{n_{all}} \sum L_{all} \quad \text{SOP 7.9)}$$

Assessing changes to lobster metrics

There are two approaches we will use to detect change to lobster metrics over time: determining whether a significant difference between two time periods exists and determining whether a trend exists over multiple (more than two) sampling events. In the first scenario, the differences between two time periods are bootstrapped to create a 95% confidence intervals of the differences. These time periods can be individual sample events or grouped sample events from consecutive years. In this approach, a sample is taken from the first time period (T_1) and a sample from the second time period (T_2) is subtracted from it. This value is stored and the process repeated 10,000 times (the bootstrap). From this distribution, the 2.5 and 97.5 percentiles are identified (two-tailed test for $\alpha = 0.05$). If the value 0 falls outside of these percentiles, then the two time periods are significantly different. The R-code for this process is found in Appendix G: *R code* in the protocol narrative (code forthcoming; Richter et al. 2018). This process should be completed for park-wide estimates and for each stratum individually.

Second, to test for trends that occur over three or more time periods, a generalized linear model (GLM) is used. Time, stratum, and time by stratum interactions are included. Time is included as a

linear regression variable where possible but if change appears to be non-linear, then time must be included as a categorical variable. For the metric in question, the GLM uses the distribution that is most appropriate for the data set. The GLM for relative density (count data) should use a Poisson or other distribution (e.g., negative binomial). The distribution of best fit is determined by methods previously discussed in this section using R-code provided in Appendix G. For frequency of occurrence data, a logistic regression (for binary variables) is most appropriate, especially if numbers in some strata are less than 5%. The results of the GLM are examined in R to determine whether sample events are significantly different for the metric of interest and whether a time by strata interaction is occurring. If a time by stratum interaction is occurring, reporting and graphing results by individual strata is advised. With sufficient data, additional factors such as distance from edge will be explored to determine if fit of the models are improved.

Analyses for Demographics and Biological Condition

The following analyses should only include lobsters that were successfully captured with biological characteristics recorded. There are several assumptions when analyzing these particular lobster data:

1. The sample of captured lobsters accurately represents the lobster population in the domain.
2. The capture method does not select for particular types of lobster (e.g., larger lobster are not easier to catch, or when lobsters are in groups they are captured irrespective of size or condition).
3. The skill of catching lobster (success rate) is similar among observers.
4. The timing of surveys is consistent.

It is important to note lobsters exhibit seasonality in reproductive characteristics. For example, in Florida, late May is peak egg-bearing time for lobsters (Bertelsen and Matthews 2001). When lobsters release eggs, they also tend to migrate to deeper water (Crawford 1921; Butler and Herrnkind 1997). Because of this, consistency in timing of surveys is extremely important when trying to establish trends of lobster conditions affected by reproduction. Sampling will occur in a single sampling pulse in May to reduce any issues caused by migration of female lobsters.

Sex ratio and molt stage ratio are included on summary reports. These should be presented as the number of males to females (males : females) and as number of pre-molt to intermolt to post-molt (pre : inter : post) when reported (Table SOP 7.4).

Proportion of egg-bearing females is calculated by dividing the number of egg-bearing females by the total number of females captured in the survey. Proportion of females with a spermatophore is calculated by dividing the number of females with a spermatophore by the total number of females captured in the survey (Table SOP 7.4).

The following are possible descriptive statistics of a lobster population that a park may be interested in:

1. Size distribution of all observed lobsters;
2. Size distributions by sex; and
3. Size distribution of egg-bearing females;
4. Spatial distribution of lobsters during a sample event

Size distributions may be presented in tables or histograms (see Figures SOP 7.1 and SOP 7.2 for examples).

A park unit may also request specific analyses not listed here. These will be assessed upon request by a park unit.

Summary reporting

At the end of each survey season a report shall be prepared containing the analyses described in the above sections. This report will provide park managers and interested parties a single document from which to evaluate spatial and temporal trends of population level metrics. Specifics of this report are described below.

The data calculations used to generate these reports are dependent on the map grid product used. Updates in the map grid require recalculation of metrics in all previous years of sampling. This may cause shifts in the relative metrics (density, frequency of occurrence) but not in the direction of trends. This will be made explicitly clear in any published report released to the parks and/or public.

Table SOP 7.6. Lobster metrics to include in summary report.

Variable	Specific Metrics
Index of relative frequency of occurrence	Exploited Phase (Mean, SE) Unexploited Phase (Mean, SE) Total (Mean, SE)
Index of relative density	Exploited Phase (Mean, SE, CV) Unexploited Phase (Mean, SE, CV) Total (Mean, SE, CV)
Carapace Length	Average Exploited Length (mm) Average Overall Length (mm)
Length Frequency	Number of lobster in 10 mm carapace length bins Number of males in 10 mm carapace length bins Number of females in 10 mm carapace length bins
Descriptive Statistics	
Total sites completed	Total sites completed
Total lobster observed	Total lobster observed
Total lobster captured	Total lobster captured
Maximum length	Max. carapace length (mm) observed
Minimum length	Min. carapace length (mm) observed
Sex Ratio	Males : Females
Molt Stage Ratio	Pre-molt : Intermolt : Post-molt
Proportion of egg-bearing females	% of females that are egg-bearing
Proportion of females with spermatophore	% of females with spermatophore

Caribbean spiny lobster (*Panulirus argus*)

SAMPLE report

*All data presented here are fictional

Table A. Average size of lobsters (carapace length, mm)

Life Stage	Variable	2018	2022	2026
Exploited Phase	Avg ± SE	107 ± 8	105 ± 6	112 ± 10
Total Observed Lobsters	Avg ± SE	80 ± 10	78 ± 9	70 ± 11

Table B. Descriptive statistics

Metric	2018	2022	2026
Total sites completed	51	49	53
Total lobster observed	22	22	26
Total lobster captured	18	15	20
Max carapace length	190 mm	165 mm	182 mm
Sex Ratio (Males/Females)	0.9	1.1	1.0
Molt Stage Ratio (Pre : Inter : Post)	0 : 3 : 1	0 : 3 : 1	0 : 3 : 1
Proportion of females with eggs	80.00%	50.00%	60.00%
Proportion of females with spermatophore	80.00%	70.00%	65.00%
Prevalence of PaV1	0.00%	0.00%	0.00%

Note:

Indices of relative density and relative frequency of occurrence are intentionally presented without units. They should not be interpreted as true density or true frequency of occurrence because of uncertainty in map weights.

Data calculations used to generate this report depend on the map grid product used. Updates to the grid require recalculation of relative density and relative frequency of occurrence for ALL sample years. Thus results presented here may not exactly match data in previously published reports, but being based on a more accurate map grid, should provide the best estimates available.

Table C. Calculated metrics

Metric	Life Stage	Variable	2018	2022	2026
Index of relative density	Exploited Phase	Avg ± SE	7.2 ± 1.9	8.0 ± 2.1	8.5 ± 2.1
		CV (%)	24.2	23.3	22.1
	Unexploited Phase	Avg ± SE	5.1 ± 1.2	4.2 ± 0.9	4.1 ± 1.1
		CV (%)	26.1	24.3	21.6
	Total Observed Lobsters	Avg ± SE	12.3 ± 3.1	12.2 ± 3.0	12.6 ± 3.2
		CV (%)	19.5	18.6	18.4
Index of relative frequency of occurrence	Exploited Phase	Avg ± SE	0.5 ± 0.2	0.5 ± 0.2	0.6 ± 0.2
	Unexploited Phase	Avg ± SE	0.2 ± 0.1	0.1 ± 0.1	0.2 ± 0.1
	Total Observed Lobsters	Avg ± SE	0.6 ± 0.2	0.6 ± 0.2	0.8 ± 0.3

Table D. Size class distribution of all observed lobster (carapace length, mm)

Year	40-49	50-59	60-69	70-79	80-89	90-99	100-109	110-119	120-129	130-139	140-149	150-159	160-169	170-179	180+
2018	1	0	2	2	4	1	4	3	1	0	0	1	2	0	1
2022	2	1	2	2	1	3	4	1	1	3	1	0	1	0	0
2026	0	2	2	3	0	2	4	3	4	2	0	2	0	1	1

Figure SOP 7.1. Microsoft Excel spreadsheet illustrating summary tables of a hypothetical data summary report.

Caribbean spiny lobster (*Panulirus argus*) SAMPLE report

*All data presented here are fictional

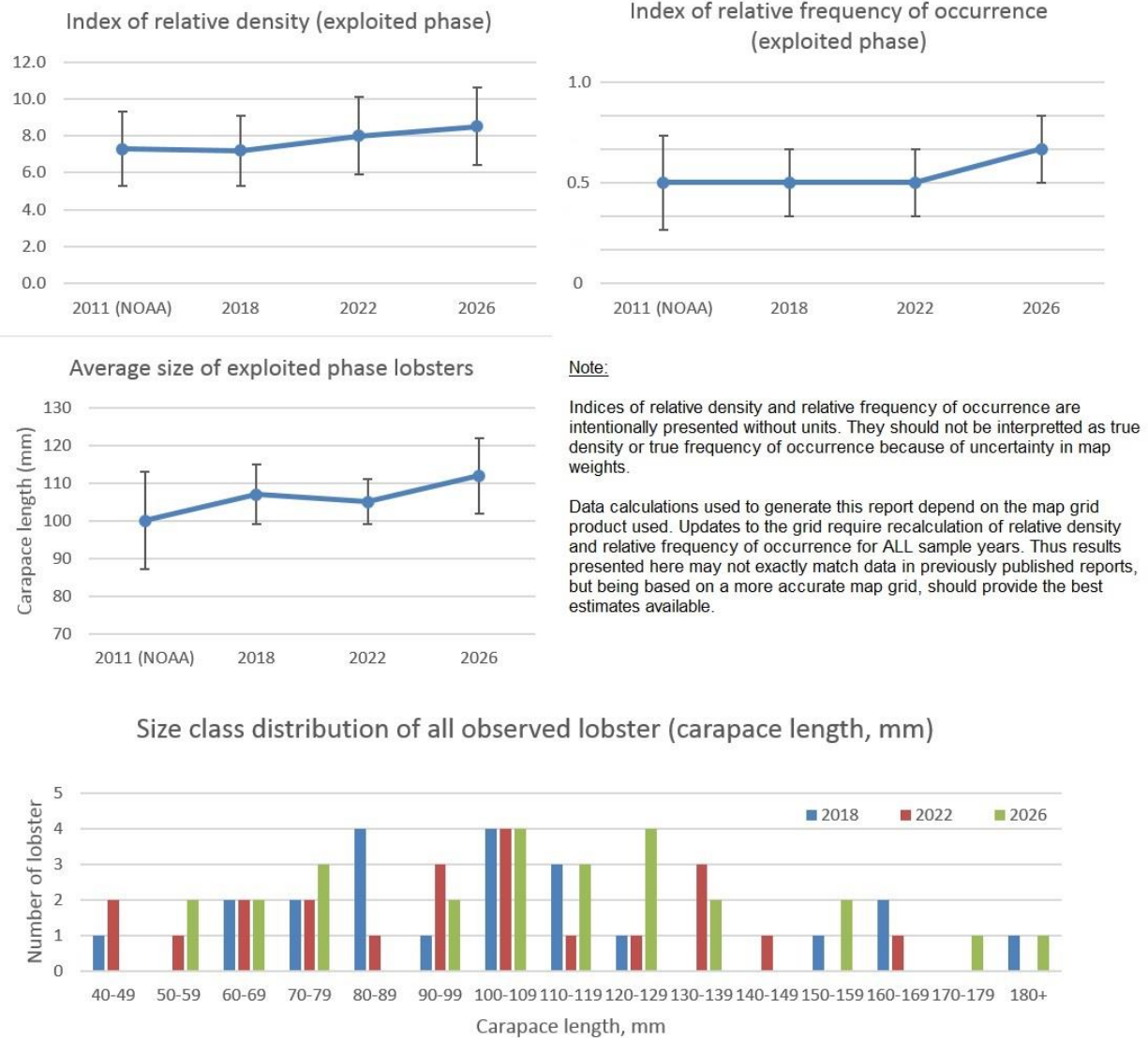


Figure SOP 7.2. Microsoft Excel spreadsheet illustrating summary figures of a hypothetical data summary report.

Changes to Map Grid and Limitations of Benthic Habitat Maps

At present, the sample frame in Florida uses a grid made of 100×100 meter (328×328 ft) cells and the sample frame in the Virgin Islands uses a grid made of 50×50 meter (164×164 ft) cells. The cell sizes are due to limitations in map resolution and/or accuracy. Because of the limitations, we do not have the ability to apply a correction for the proportion of hard-bottom habitat within each mapped grid cell during the selection draw, during the field visit, or during the final calculation of strata weights. Using currently available benthic habitat maps to influence selection probabilities of the sample draw or final calculation of strata weights is inadvisable due to the inaccuracies of the maps at this time. This problem will be reduced over time as maps get more accurate, grid cell size gets smaller, and as additional methods are developed (e.g., LiDAR, multi-beam sonar) to better map benthic habitats.

In the coming years, we do expect better mapping technology and coverage to become available. The grid cells have the potential to be reduced in size in order to reflect the more accurate benthic habitat maps. Specifically, we expect the grid cell size in Florida may be reduced to 50×50 meters (164×164 ft) by as soon as 2020 (Steve Smith, pers. comm.). If and when this happens, the stratum designation of each grid cell will be re-classified in order to reflect the more accurate benthic habitat. This will change the strata weights used for calculations in analysis. It is imperative that when these changes occur, the new strata weights are applied to the data in all previous sample years. This avoids the appearance of artificial trends, but may change the values of historical relative metrics. The justification of doing this is that the newer map grid is a truer estimate of strata weights during all years, because the geologic structural features that define the habitats change very little through in the biological time frame of monitoring. It is important to remember that the density and frequency of occurrence metrics are *relative*, and should not be interpreted as true estimates. These metrics should first be calculated for each individual stratum in a park. For park-wide estimates, indices of relative density and relative frequency of occurrence should be used. The unit-less indices are presented because of the uncertain map weights used to calculate park-wide estimates.

In the event that strata definitions change in the future (e.g., establishment of a management zone within a park unit), the strata weights for the older years will be calculated with the new grid by using the original strata definitions.

Literature cited

- Ault, J. S., J. A. Bohnsack, S. G. Smith, and J. G. Luo. 2005. Towards sustainable multispecies fisheries in the Florida, USA, coral reef ecosystem. *Bulletin of Marine Science* 76:595–622.
- Ault, J. S., S. G. Smith, G. A. Meester, J. Luo and J. A. Bohnsack. 2001. Site characterization for Biscayne National Park: assessment of fisheries resources and habitats. NOAA Technical Memorandum NMFS-SEFSC-468. 185 p.
- Bertelsen, R. D. and T. R. Matthews. 2001. Fecundity dynamics of female spiny lobster (*Panulirus argus*) in a south Florida fishery and Dry Tortugas National Park lobster sanctuary. *Marine and Freshwater Research* 52:1559–1565.
- Bryan, D. R., A. J. Atkinson, J. S. Ault, M. E. Brandt, J. A. Bohnsack, M. W. Feeley, M. E. Patterson, B. I. Ruttenberg, S. G. Smith, B. D. Witcher. 2013. A cooperative multiagency reef fish monitoring protocol for the U.S. Virgin Islands coral reef ecosystem. Natural Resource Report NPS/SFCN/NRR—2013/672. National Park Service, Fort Collins, Colorado.
- Butler, M. J. IV and W. F. Herrnkind. 1997. A test of recruitment limitation and the potential for artificial enhancement of spiny lobster (*Panulirus argus*) populations in Florida. *Canadian Journal of Fisheries and Aquatic Science* 54:452–463.
- Crawford, D. R. 1921. Spawning habits of the spiny lobster (*Panulirus argus*) with notes on artificial spawning. *Transactions of the American Fisheries Society* 50:312–319.
- Richter, L. R., M. W. Feeley, A. J. Atkinson, J. M. Patterson, A.D. Davis, and J. Miller. 2018. Long-term monitoring protocol of Caribbean Spiny Lobster (*Panulirus argus*): protocol narrative. Natural Resource Report NPS/SFCN/NRR—2018/1850. National Park Service, Fort Collins, Colorado. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/2258540> (last accessed December 2018).

National Park Service
Inventory and Monitoring Division



Standard Operating Procedure 8

Revising the Protocol—Version 1.0

Purpose

This standard operating procedure (SOP) describes how changes in the protocol and SOP's will occur and how they will be tracked.

Revision Log

[illegible]

Source Protocol

This SOP is derived from SOP 10 in the Virgin Islands reef fish monitoring protocol:

Bryan, D. R., A. J. Atkinson, J. S. Ault, M. E. Brandt, J. A. Bohnsack, M. W. Feeley, M. E. Patterson, B. I. Ruttenberg, S. G. Smith, and B. D. Witcher. 2013. A cooperative multiagency reef fish monitoring protocol for the U.S. Virgin Islands coral reef ecosystem. Natural Resource Report NPS/SFCN/NRR—2013/672. National Park Service, Fort Collins, Colorado.

Introduction

Once published in the Natural Resource Report Series, the *Long-Term Monitoring Protocol of the Caribbean Spiny Lobster (Panulirus argus): Protocol Narrative* (Richter et al. 2018) can only be modified through the use of a versioning system. However, much of sample design in the protocol is derived from the existing reef fish monitoring protocols used by the South Florida/Caribbean Network: *A Cooperative Multi-agency Reef Fish Monitoring Protocol for the Florida Keys Coral Reef Ecosystem* and *A Cooperative Multiagency Reef Fish Monitoring Protocol for the U.S. Virgin Islands Coral Reef Ecosystem* (Brandt et al. 2009; Bryan et al. 2013). It is possible that changes to the reef fish monitoring protocols will have direct effects on how lobster monitoring is conducted according to this document. In such cases, modifications will also have to be made to this protocol according to the following guidance:

1. Minor editorial changes and formatting can proceed provided they do not affect the content or substance of the protocol and are communicated to all parties. Except for changes to the SOP's, which require in-house review by SFCN staff only, changes to the narrative or Quality Assurance Plan (QAP) require review from the regional program manager. If changes are indeed minor, there will not be an external review. Suggestions can be made at any time, but the South Florida/Caribbean Network may choose to compile them over the course of a year before releasing a new version.
2. Major changes, including those affecting content and substance of the protocol or SOP's, will require external review and approval by the regional program manager.
3. Protocol edits and versioning are tracked in the Revision History Log attached to the narrative and each individual SOP. Major changes result in updates by whole numbers (e.g., version 1.0 to 2.0) and minor changes by tenths (e.g., version 1.1 to 1.2). The new version number, date of revision, author of the revision, a description of the change, and rationale for the change must be included in the Revision History Log.
4. Any major changes to an individual SOP must be also tracked in the protocol's Revision History Log and the version number must be updated.
5. A digital version of the protocol narrative, SOP's, supporting documents, and scripts will be made available on the [SFCN website](#) and at <http://irma.nps.gov>.

Literature Cited

- Brandt, M. E., N. Zurcher, A. Acosta, J. S. Ault, J. A. Bohnsack, M. W. Feeley, D. E. Harper, J. H. Hunt, T. Kellison, D. B. McClellan, M. E. Patterson, and S. G. Smith. 2009. A cooperative multi-agency reef fish monitoring protocol for the Florida Keys coral reef ecosystem. Natural Resource Report NPS/SFCN/NRR—2009/150. National Park Service, Fort Collins, Colorado.
- Bryan, D.R., A.J. Atkinson, J.S. Ault, M.E. Brandt, J.A. Bohnsack, M.W. Feeley, M.E. Patterson, B.I. Ruttenberg, S.G. Smith, and B.D. Witcher. 2013. A cooperative multiagency reef fish monitoring protocol for the U.S. Virgin Islands coral reef ecosystem. Natural Resource Report NPS/SFCN/NRR—2013/672. National Park Service, Fort Collins, Colorado.
- Richter, L. R., M. W. Feeley, A. J. Atkinson, J. M. Patterson, A.D. Davis, and J. Miller. 2018. Long-term monitoring protocol of Caribbean Spiny Lobster (*Panulirus argus*): protocol narrative. Natural Resource Report NPS/SFCN/NRR—2018/1850. National Park Service, Fort Collins, Colorado. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/2258540> (last accessed December 2018).