

# South Florida/Caribbean Network

National Park Service  
Inventory and Monitoring Division



## Standard Operating Procedure SL02

### *Stratification—Version 1.1*

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### Purpose

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

### Revision Log

| Revision Date | Author      | Changes Made            | Reason for Change | New Version # |
|---------------|-------------|-------------------------|-------------------|---------------|
| 3/24/20       | Lee Richter | Removed bedrock stratum | Safety concerns   | 1.1           |
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## 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  $100 \times 100$  meters ( $328 \times 328$  feet [ft]) in Florida and are  $50 \times 50$  meters ( $164 \times 164$  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 SFCN SOP SL04 *Lobster Data Collection and Survey Methods—Version 1.1* (SFCN 2020).

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 1, 2, 3, 4, and 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 and Ecological Preserve, and Buck Island Reef National Monument respectively.

“Mapped polygon area (square kilometers [ $\text{km}^2$ ])” 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 ( $\text{km}^2$ )” refers to the summed area of the grid cells assigned to each of the strata.

**Table 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 [m—meters; km—kilometers].

| <b>Strata</b>                       | <b>Mapped Polygon Area (km<sup>2</sup>)</b> | <b>No. Grid Cells</b> | <b>Grid Area (km<sup>2</sup>)</b> |
|-------------------------------------|---------------------------------------------|-----------------------|-----------------------------------|
| 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                              |
| <b>TOTAL</b>                        | <b>32.33</b>                                | <b>9,665</b>          | <b>96.65</b>                      |

**Table 2.** Number of grid cells (100 × 100 meter [328 × 328 ft]) and total area coverage in each stratum for Dry Tortugas NP [km—kilometers].

| <b>Protection</b> | <b>Strata</b>               | <b>Mapped Polygon Area (km<sup>2</sup>)</b> | <b>No. Grid Cells</b> | <b>Grid Area (km<sup>2</sup>)</b> |
|-------------------|-----------------------------|---------------------------------------------|-----------------------|-----------------------------------|
| 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                              |
| <b>–</b>          | <b>TOTAL</b>                | <b>91.02</b>                                | <b>14,094</b>         | <b>140.94</b>                     |

**Table 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) [km—kilometers].

| Map and Stratum Classification | Mapped Polygon Area (km <sup>2</sup> ) | No. Grid Cells | Grid Area (km <sup>2</sup> ) |
|--------------------------------|----------------------------------------|----------------|------------------------------|
| 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                         |
| <b>TOTAL</b>                   | <b>7.61</b>                            | <b>4,173</b>   | <b>10.43</b>                 |

**Table 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 [km—kilometers].

| Map and Stratum Classification | Mapped Polygon Area (km <sup>2</sup> ) | No. Grid Cells | Grid Area (km <sup>2</sup> ) |
|--------------------------------|----------------------------------------|----------------|------------------------------|
| 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                         |
| <b>TOTAL</b>                   | <b>0.62</b>                            | <b>435</b>     | <b>1.09</b>                  |

**Table 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 [ km—kilometers].

| Map and Stratum Classification | Mapped Polygon Area (km <sup>2</sup> ) | No. Grid Cells | Grid Area (km <sup>2</sup> ) |
|--------------------------------|----------------------------------------|----------------|------------------------------|
| 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                         |
| <b>TOTAL</b>                   | <b>14.11</b>                           | <b>7,479</b>   | <b>18.70</b>                 |

## 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 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 sixteen strata in Dry Tortugas NP is reduced to eight 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 6 shows the mapped polygon area, number of grid cells, and grid cell area for each stratum in Dry Tortugas NP.

**Table 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 [km—kilometers].

| <b>Strata</b>               | <b>Mapped Polygon Area (km<sup>2</sup>)</b> | <b>No. Grid Cells</b> | <b>Grid Area (km<sup>2</sup>)</b> |
|-----------------------------|---------------------------------------------|-----------------------|-----------------------------------|
| 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                              |
| <b>TOTAL</b>                | <b>91.02</b>                                | <b>14,094</b>         | <b>140.94</b>                     |

### Virgin Islands NP

The original twelve strata in the Virgin Islands NP is reduced to six 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 7 shows the mapped polygon area, number of grid cells, and grid cell area for each stratum in Virgin Islands NP.

**Table 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 [km—kilometers].

| <b>Map and Stratum Classification</b> | <b>Mapped Polygon Area (km<sup>2</sup>)</b> | <b>No. Grid Cells</b> | <b>Grid Area (km<sup>2</sup>)</b> |
|---------------------------------------|---------------------------------------------|-----------------------|-----------------------------------|
| 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                              |
| <b>TOTAL</b>                          | <b>7.61</b>                                 | <b>4,173</b>          | <b>10.46</b>                      |

## Salt River Bay NHP&EP

The original seven strata in Salt River Bay NHP&EP is reduced to two 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.

Lastly, the “bedrock” stratum was removed due to safety concerns. All the grid cells in this stratum are located in shallow environments close to shore with high wave action. During the first sampling event in 2019, we felt that deploying divers accurately on these sites would put both the boat and divers at unnecessary risk.

For this protocol, Table 8 shows the mapped polygon area, number of grid cells, and grid cell area for each stratum in Salt River Bay NHP&EP.

**Table 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. The bedrock stratum has also been removed due to safety concerns [km—kilometers].

| Map and Stratum Classification  | Mapped Polygon Area (km <sup>2</sup> ) | No. Grid Cells | Grid Area (km <sup>2</sup> ) |
|---------------------------------|----------------------------------------|----------------|------------------------------|
| Pavement & Scattered coral/rock | 0.41                                   | 343            | 0.86                         |
| Linear reef & Patch reef        | 0.14                                   | 63             | 0.16                         |
| <b>TOTAL</b>                    | <b>0.55</b>                            | <b>406</b>     | <b>1.02</b>                  |

## Buck Island Reef NM

The original nine strata in Buck Island Reef NM is reduced to four 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 9 shows the mapped polygon area, number of grid cells, and grid cell area for each stratum in Buck Island Reef NM.

**Table 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 [km—kilometers].

| Map and Stratum Classification | Mapped Polygon Area (km <sup>2</sup> ) | No. Grid Cells | Grid Area (km <sup>2</sup> ) |
|--------------------------------|----------------------------------------|----------------|------------------------------|
| 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                         |
| <b>TOTAL</b>                   | <b>14.11</b>                           | <b>7,479</b>   | <b>18.70</b>                 |

## 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. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/662816> (last accessed June 2020).
- 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. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/2195859> (last accessed June 2020).
- Richter, L. J., M. W. Feeley, A. J. Atkinson, J. M. Patterson, A. D. Davis, and J. Miller. 2020. Long-term monitoring protocol of Caribbean spiny lobster (*Panulirus argus*): Protocol narrative—Version 1.1. Natural Resource Report NPS/SFCN/NRR—2020/2177. National Park Service, Fort Collins, Colorado. Available at: <https://doi.org/10.36967/nrr-2279134>.
- South Florida/Caribbean Network (SFCN). 2020. Lobster data collection and survey methods—Version 1.1. South Florida/Caribbean Network. Standard Operating Procedure NPS/SFCN/SOP—SL04. South Florida/Caribbean Network, Palmetto Bay, Florida. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/2275700> (last accessed July 2020).
- 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.