# Absolute Abundance Estimator from Fishery-Independent Visual Surveys


Visual Survey Design and Data:
Jay Grove, PhD, Jeremiah Blondeau, Jerry Ault, PhD

Overview of OFLs using F Proxy:
Adyan Rios

NOAA Fisheries, SEFSC


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Photo credit: Rob Waara

# General Overview

## National Coral Reef Monitoring Program (NCRMP)

- Multi-agency/institutional effort, longer time series (2001–2025), biennial sampling, <30m, in U.S. Caribbean

## Deep Coral Reef Monitoring Program (DCRMP)

- 3-y pilot study (2020–2022), 30–50m, in St. Thomas/St. John, funded in 2027

## Both Programs

- CRCP funded fishery-independent visual surveys
- Survey on hard-bottom habitats
- Stratified-random sampling design
  - design-based (probability) survey intended to scale up to the domain
- Collect data on fishery and ecosystem species

# U.S. Caribbean NCRMP FIS Reef Fish Time Series Overview

## Dates of Survey: 2001 to 2025

## Pre-NCRMP

## Transitional NCRMP

## NCRMP

2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 — **All Islands**

2012 — **St. Croix**

2013 — **St. Thomas/John**

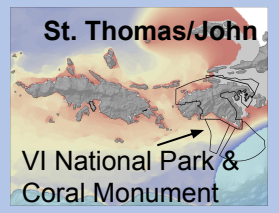
2014 — **Puerto Rico**

2015 — **St. Thomas/John**
**St. Croix**

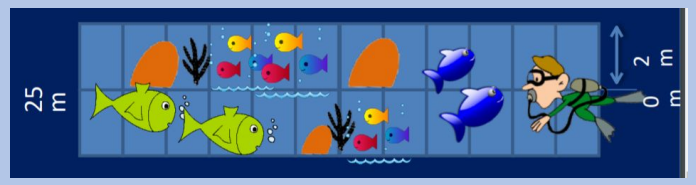
2016 — **Puerto Rico**

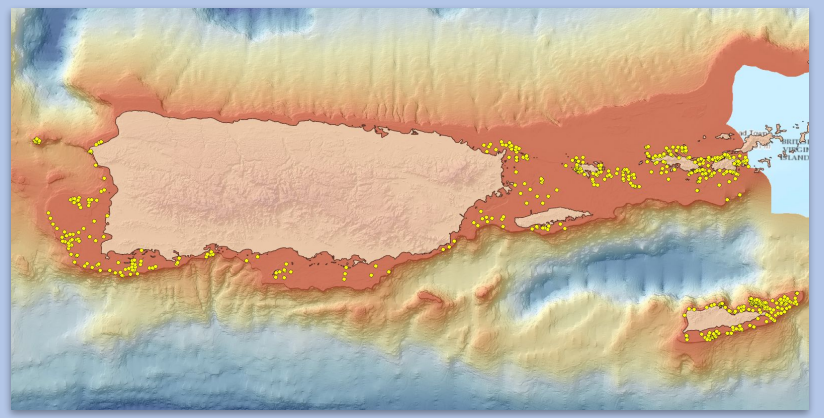
2017 — **St. Thomas/John**
**St. Croix**

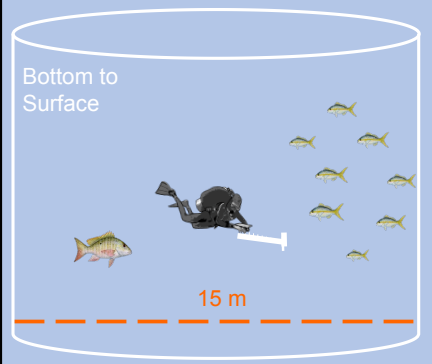
2019 2021 .... Biennial — **All Islands**

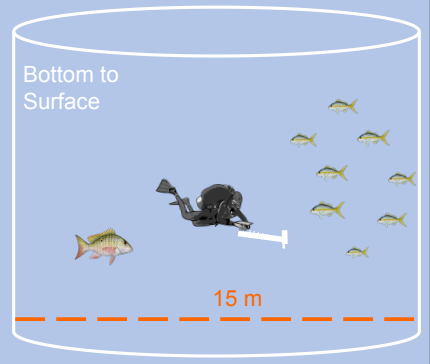









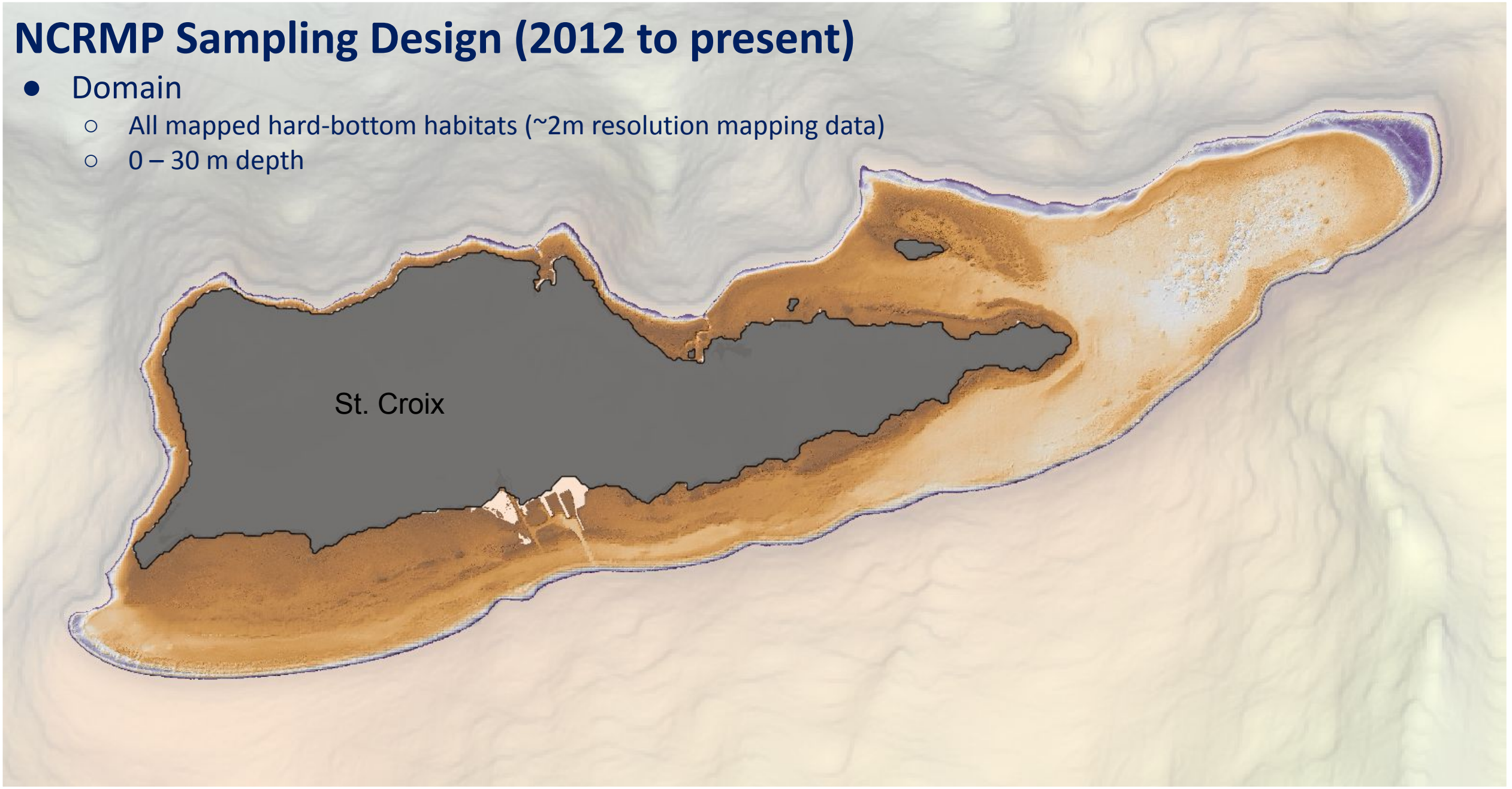

**Survey Area:** Regional
**Survey Design:** Simple Random
**Survey Method:** Belt Transect
**Data Calibrations:** Area & method

**Survey Area:** Island Wide
**Survey Design:** Stratified Random
**Survey Method:** Belt Transect
**Data Calibration:** Method (81 sp)

**Survey Area:** Island Wide
**Survey Design:** Stratified Random
**Survey Method:** Cylinder (RVC-SPC)
**Data Calibration:** None

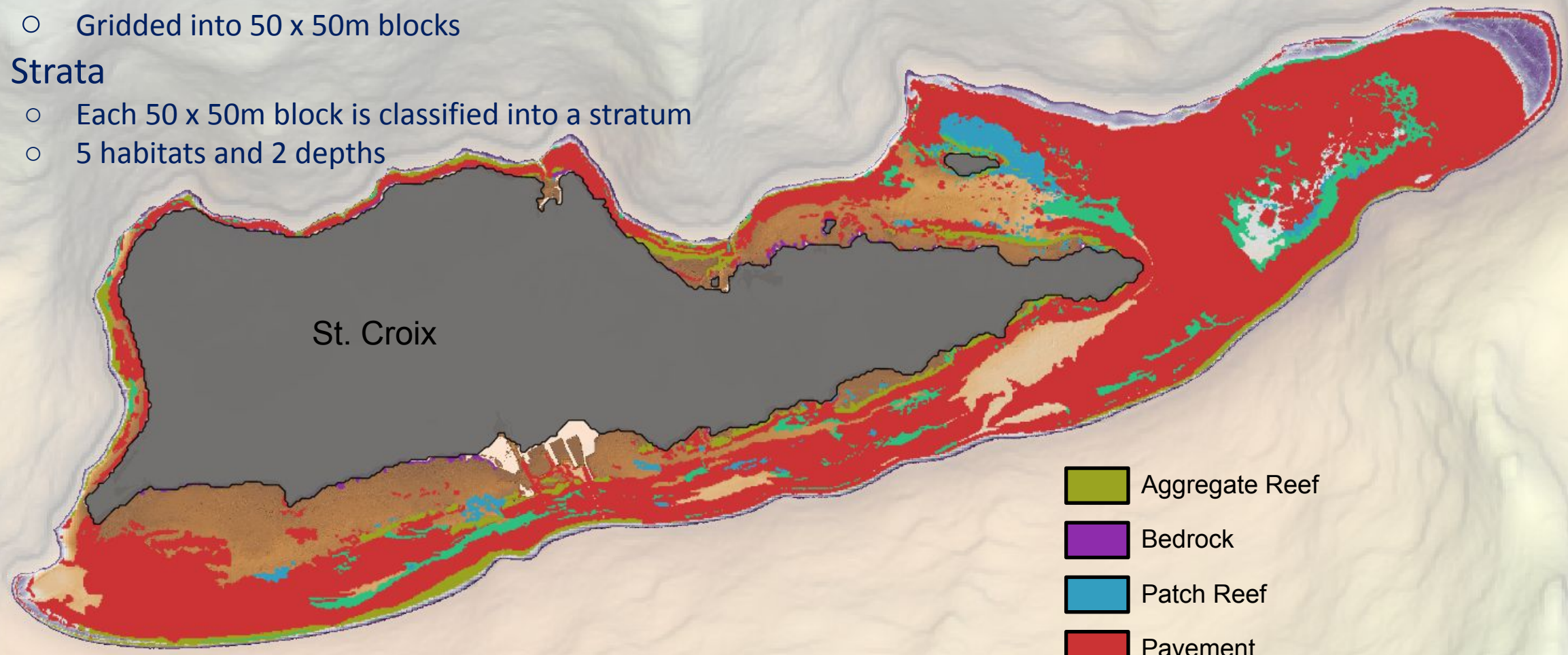
# NCRMP Sampling Design (2012 to present)

- Domain
  - All mapped hard-bottom habitats (~2m resolution mapping data)
  - 0 – 30 m depth



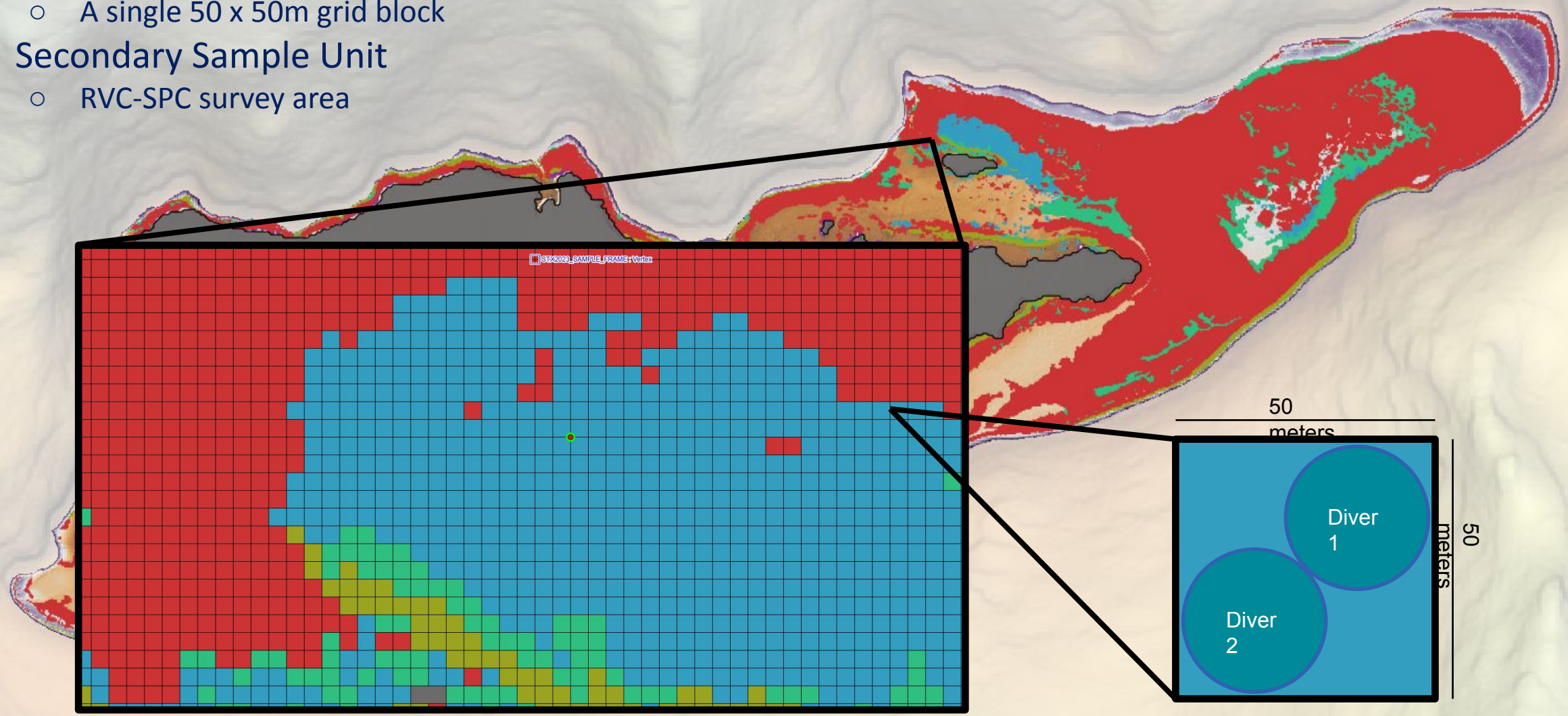
# NCRMP Sampling Design

- Domain
  - Gridded into 50 x 50m blocks
- Strata
  - Each 50 x 50m block is classified into a stratum
  - 5 habitats and 2 depths



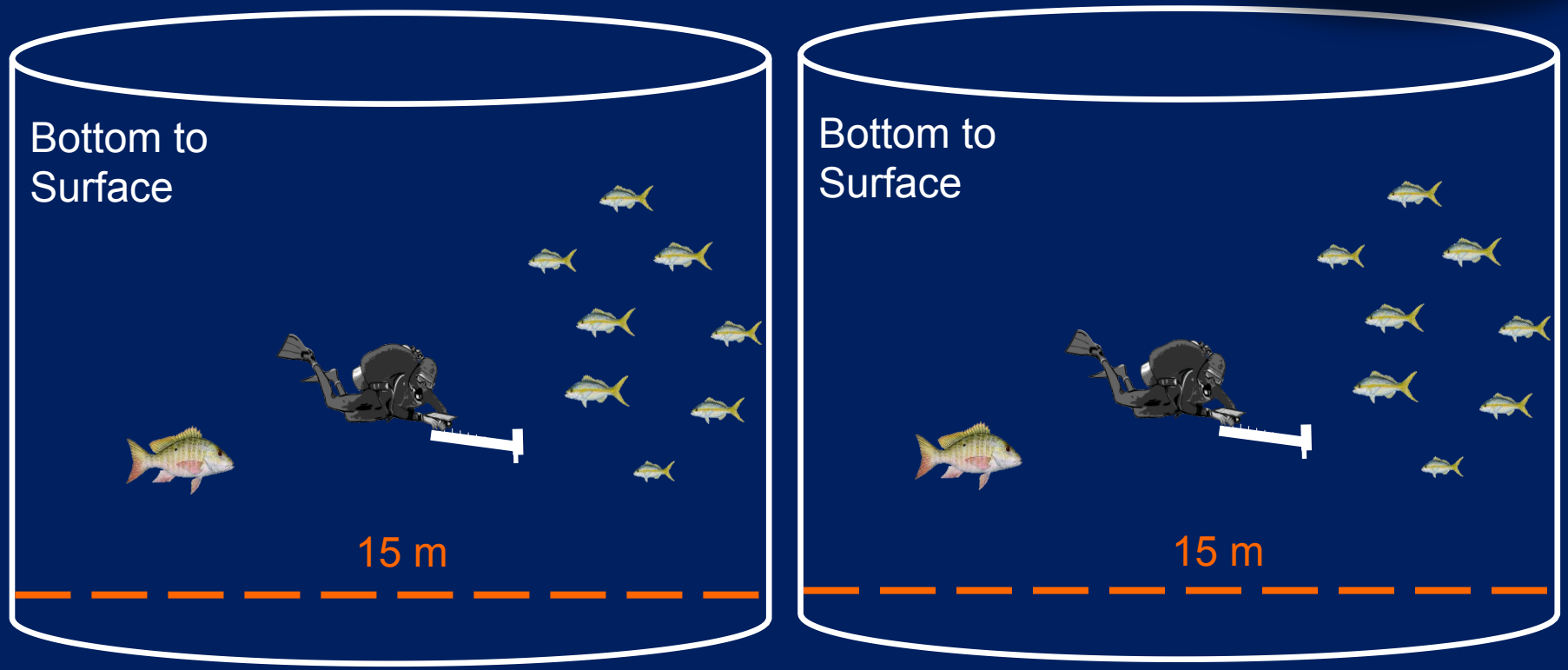
# NCRMP Sampling Design

- Primary Sample Unit
  - A single 50 x 50m grid block
- Secondary Sample Unit
  - RVC-SPC survey area



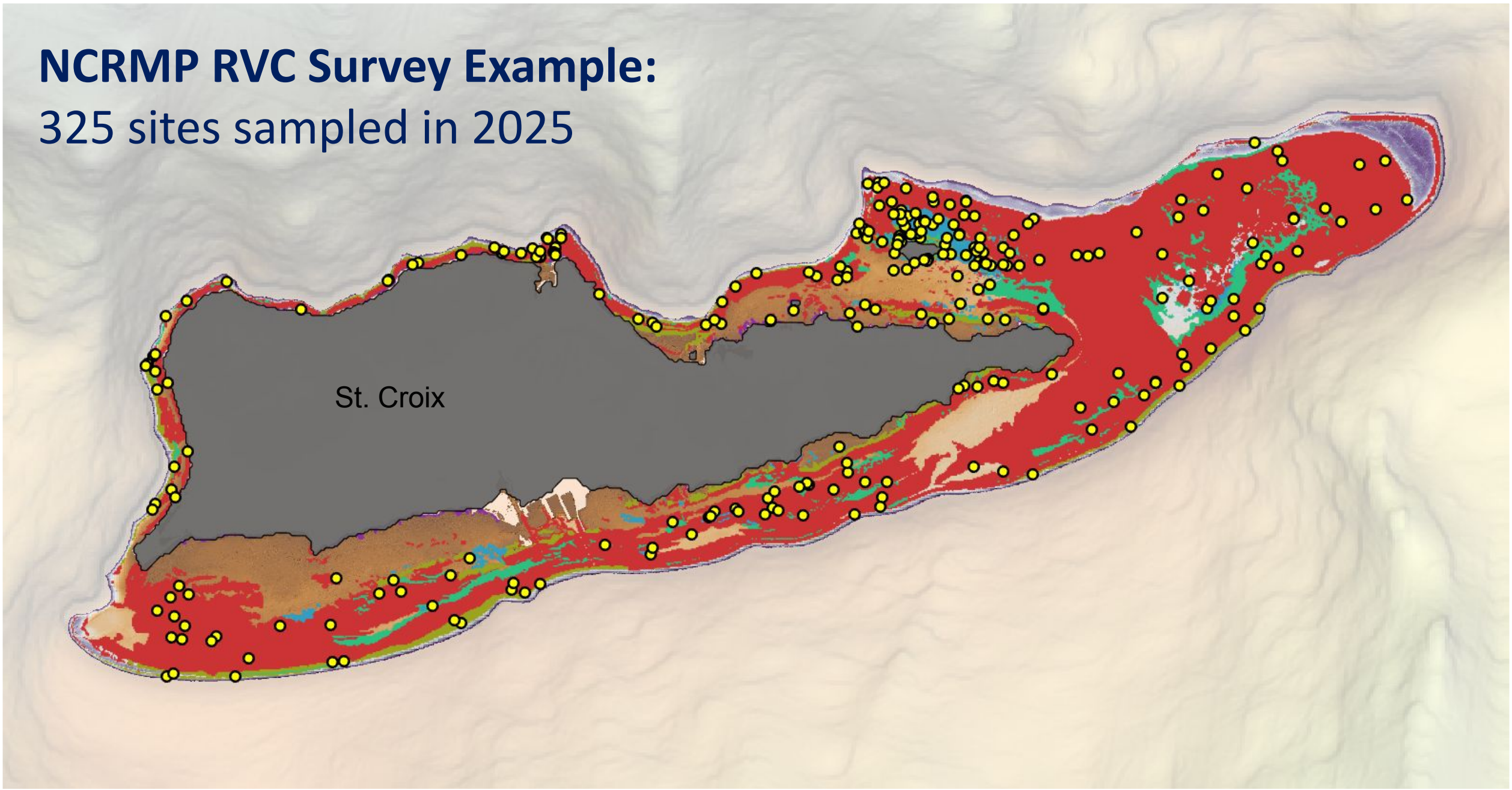
# Survey Method: RVC-SPC Cylinder

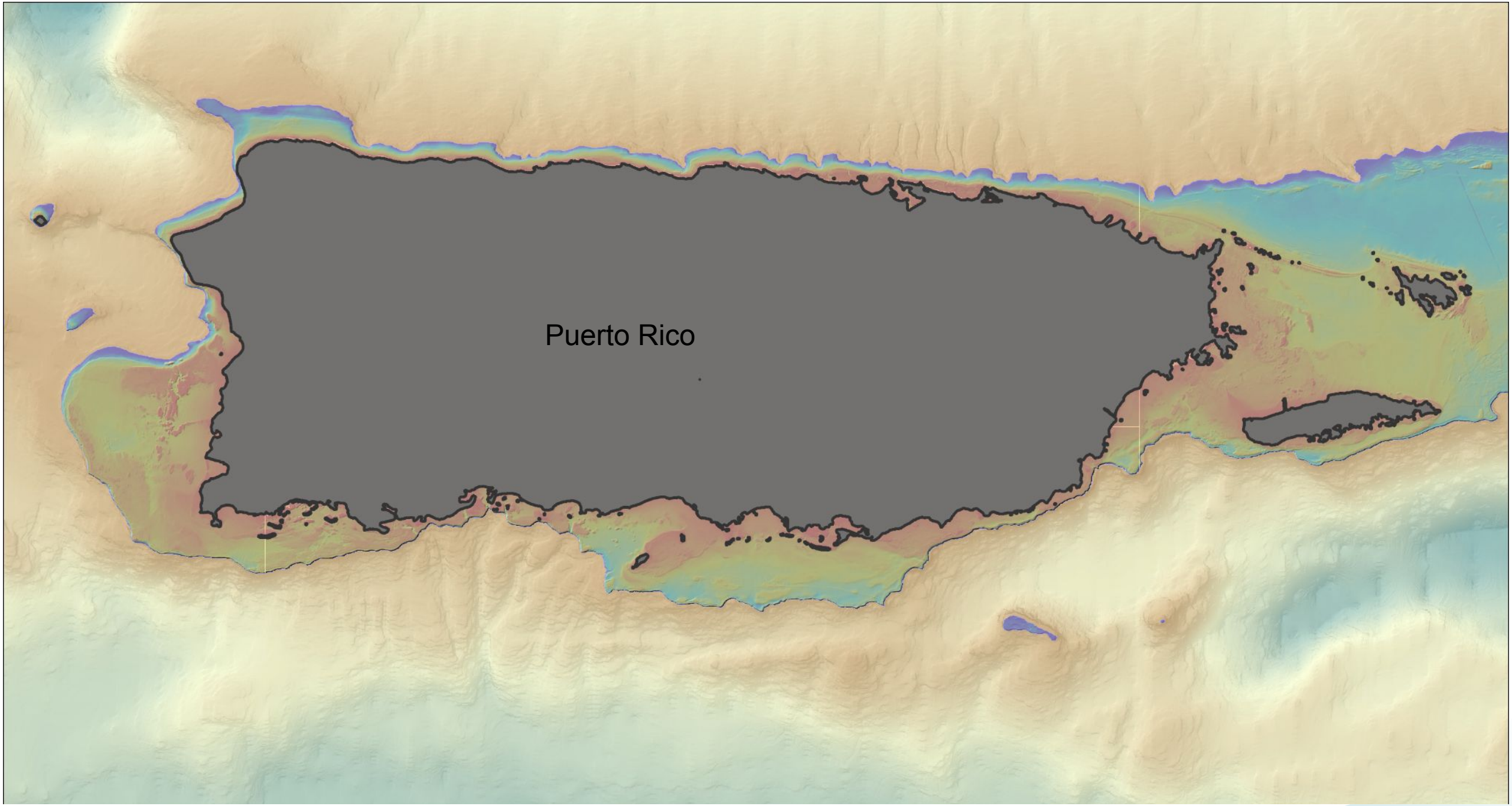
- Standardized time and area
- Collects data on all observed fishes
- Length measured to nearest cm
- Published methods/protocol
  - Feeley et al. 2025 & CRCP et al. 2025

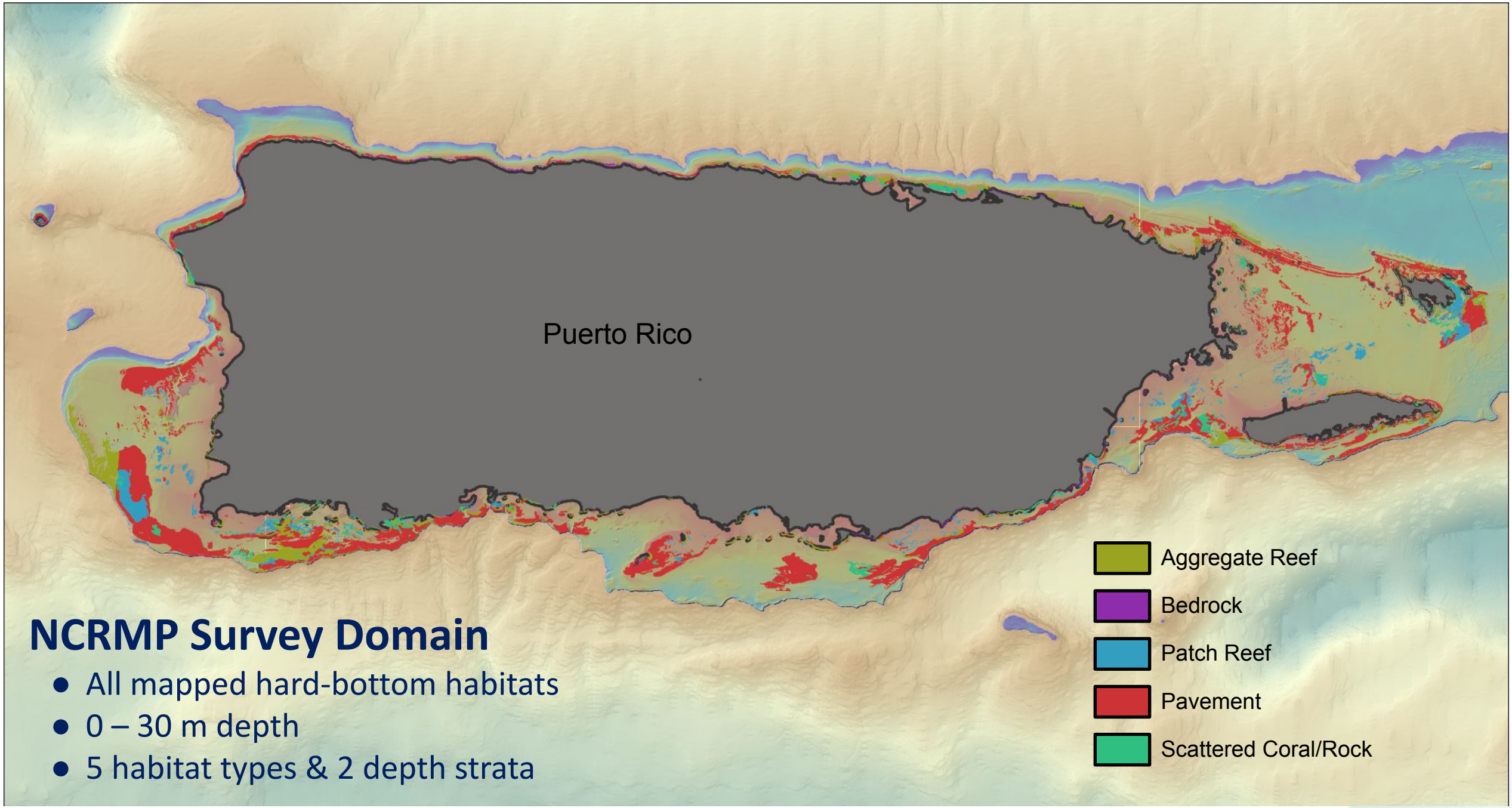


# NCRMP RVC Survey Example:

## 325 sites sampled in 2025




Puerto Rico



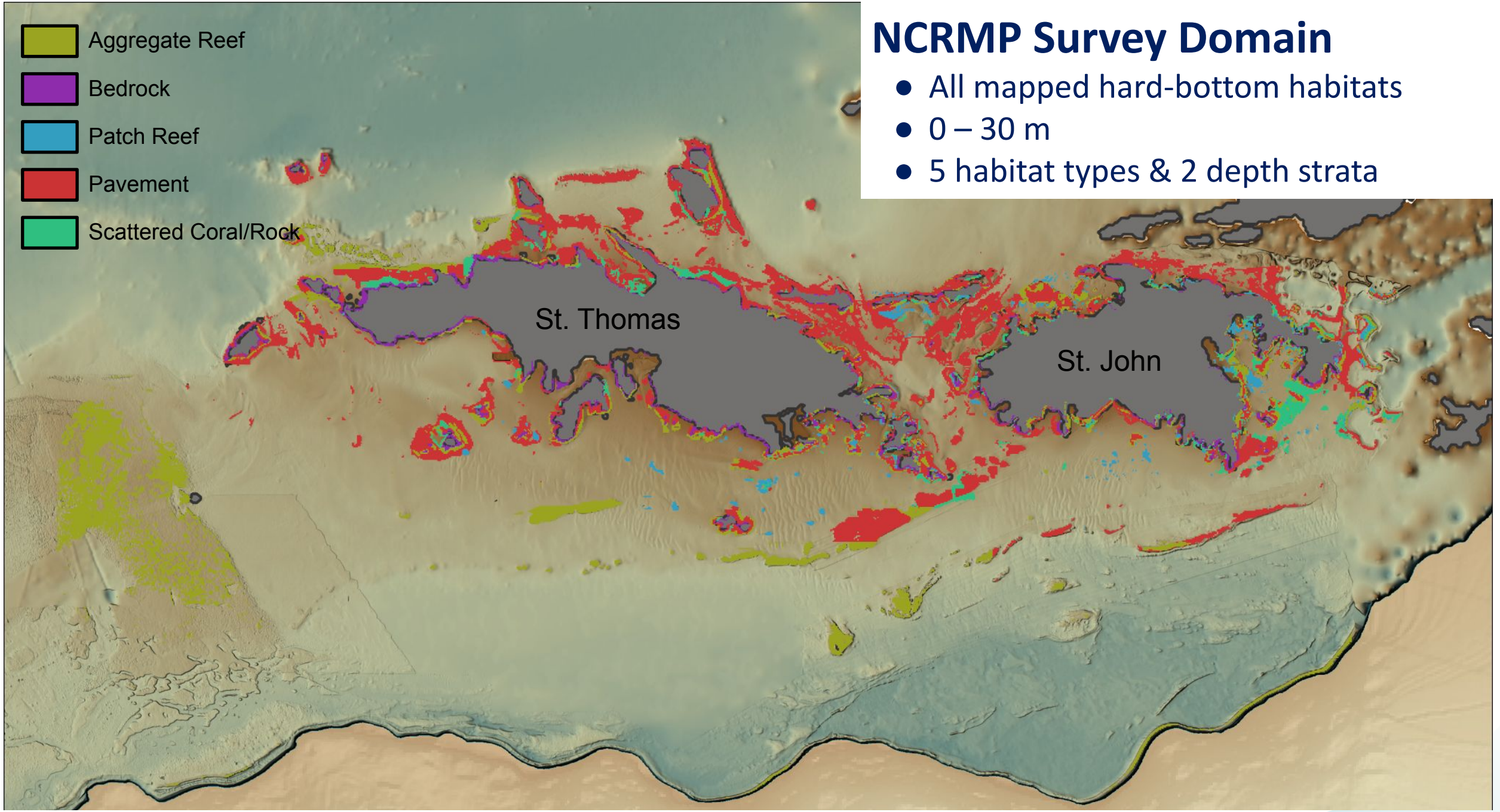

# NCRMP Survey Domain

- All mapped hard-bottom habitats
- 0 – 30 m depth
- 5 habitat types & 2 depth strata

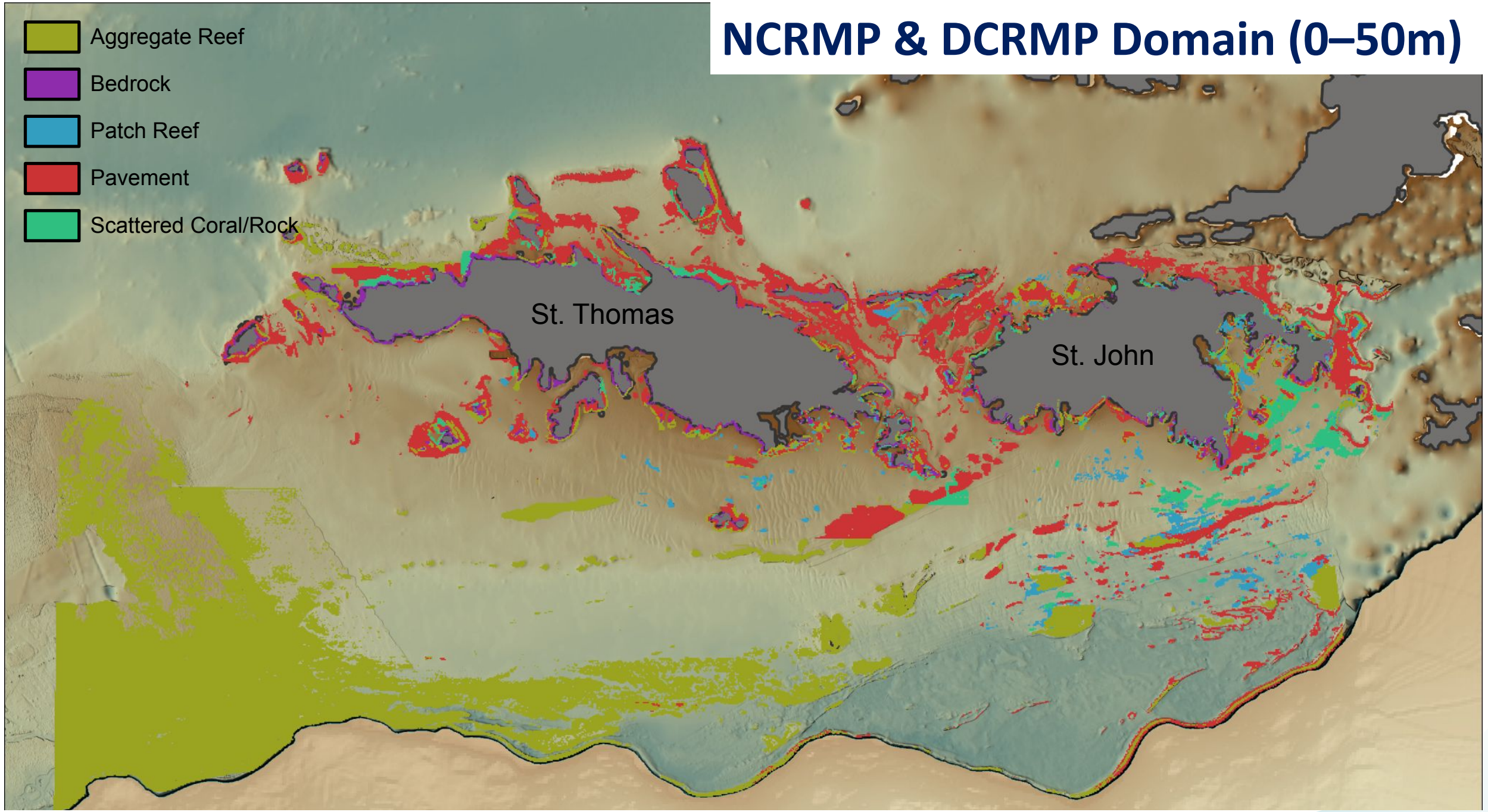

St. Thomas
St. John

# NCRMP Survey Domain

- All mapped hard-bottom habitats
- 0 – 30 m
- 5 habitat types & 2 depth strata



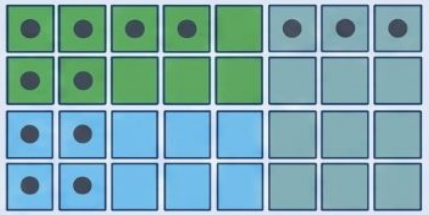
# NCRMP & DCRMP Domain (0–50m)



Sample Frame Breakdown

## Domain

Discrete survey area
All reef habitat 0-30m



Total number of primary sample units (PSUs in domain

$$N = \sum_{h=1}^{N} N_h$$

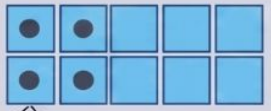
Total number of PSUs in domaitn$_h$

## Strata

Domain partitioned into homogeneous stratum (density and variance)

Number of PSUs sampled in stratum$_h$

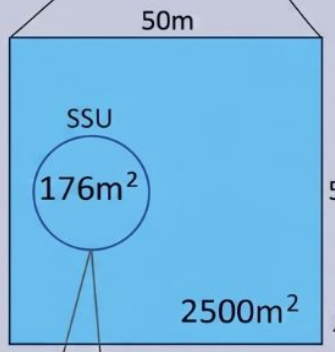
Stratum weight $W_h = \frac{n_h}{N}$



Sampling fraction $f = \frac{n_h}{N_h}$

## Primary Sample Unit

Statistical unit, randomly allocated for each survey

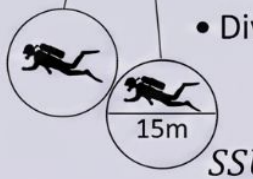



$PSU_i$ in $stratum_h$

## Secondary Sample Unit

In-situ diver collection on hardbottom habitats

- Single diver collection
- Non independent
- Diver data averaged




$SSU_j$ in $PSU_{hi}$

Domain weighted mean density and variance

$$\overline{D} = \sum_h w_h \overline{D}_h \qquad \text{var}[\overline{D}] = \sum_h w_h^2 \text{var}[\overline{D}_h]$$

$stratum_h$ mean density and variance

$$\overline{D}_h = \frac{1}{n_h} \sum_i D_{hi} \qquad \text{var}[\overline{D}_h] = (1-f)\frac{s_h^2}{n_h}$$

sampling fraction

$stratum_h$ sample variance among PSUs

$$s_h^2 = \frac{\sum (D_{hi} - \overline{D}_h)^2}{n_h - 1}$$

$PSU_i$ density in $stratum_h$

$$D_{hi} = \left( \sum_{j=1}^{2} D_{hij} \right) / 2$$

## Example Metrics

**Single species or multiple taxa/groups**

- Density
- Biomass
- Abundance
- Lbar - mean length

Smith et al. 2011; Feeley et al. 2025

Metric Estimation Buildup

# NCRMP Data Overview

| Year | St. Croix (n) | St. Thomas/ St. John (n) | Puerto Rico (n) | |
|---|---|---|---|---|
| 2001 | 86 | 25 | 36 | |
| 2002 | 76 | 72 | 71 | |
| 2003 | 165 | 109 | 82 | |
| 2004 | 114 | 128 | 83 | |
| 2005 | 170 | 128 | 95 | |
| 2006 | 185 | 127 | 100 | |
| 2007 | 90 | 129 | 173 | |
| 2008 | 167 | 134 | 86 | |
| 2009 | 157 | 132 | 116 | |
| 2010 | 118 | 134 | 74 | |
| 2011 | 41 | 133 | 51 | **Regional scale** |
| 2012 | 262 | - | 35 | **Island-wide scale** |
| 2013 | - | 275 | - | |
| 2014 | - | - | 223 | |
| 2015 | 239 | 255 | - | Belt transect method |
| 2016 | - | - | 240 | RVC-SPC (cylinder) method |
| 2017 | 181 | 237 | - | |
| 2018 | - | - | - | |
| 2019 | 314 | 322 | 203 | |
| 2020 | - | - | - | |
| 2021 | 148 | 165 | 234 | |
| 2022 | - | - | - | |
| 2023 | 275 | 287 | 248 | |
| 2024 | - | - | - | |
| 2025 | 325 | 340 | 232 | |

**Sampling: Annual**
**Biennial**



NOAA FISHERIES

# DCRMP Data Overview

## Sample Size

| Year | St. Thomas/ St. John (n) |
|---|---|
| 2020 | 162 |
| 2021 | 98 |
| 2022 | 89 |



NOAA FISHERIES

## Puerto Rico

**51** species ≤ 25% CV

**19** species on the island-based FMP list

| Puerto Rico 2025 | | |
|---|---|---|
| Species | Density | CV |
| *Sparisoma aurofrenatum* | 2.79 | 7.28 |
| *Holocentrus rufus* | 1.47 | 8.30 |
| *Acanthurus coeruleus* | 3.60 | 9.40 |
| *Acanthurus bahianus* | 8.40 | 9.57 |
| *Halichoeres garnoti* | 4.86 | 9.60 |
| *Halichoeres bivittatus* | 5.03 | 9.71 |
| *Thalassoma bifasciatum* | 21.53 | 9.81 |
| *Canthigaster rostrata* | 0.73 | 9.86 |
| *Serranus tigrinus* | 0.96 | 9.90 |
| *Scarus iseri* | 3.84 | 10.21 |
| *Chaetodon capistratus* | 0.99 | 10.38 |
| *Scarus taeniopterus* | 1.95 | 11.19 |
| *Cephalopholis cruentata* | 0.39 | 11.25 |
| *Stegastes partitus* | 22.27 | 11.92 |
| *Ocyurus chrysurus* | 3.32 | 11.93 |
| *Halichoeres maculipinna* | 0.95 | 12.85 |
| *Balistes vetula* | 0.59 | 13.56 |
| *Epinephelus guttatus* | 0.56 | 13.61 |
| *Sparisoma viride* | 0.97 | 13.86 |
| *Cephalopholis fulva* | 0.98 | 13.90 |
| *Pseudupeneus maculatus* | 0.74 | 13.98 |
| *Stegastes variabilis* | 1.60 | 14.18 |
| *Chaetodon striatus* | 0.29 | 14.42 |
| *Chromis cyanea* | 3.36 | 15.03 |
| *Sphyraena barracuda* | 0.13 | 16.89 |
| *Stegastes adustus* | 1.71 | 16.93 |
| *Malacanthus plumieri* | 0.27 | 17.26 |
| *Microspathodon chrysurus* | 0.31 | 17.48 |
| *Bodianus rufus* | 0.26 | 17.49 |
| *Holocentrus adscensionis* | 0.50 | 18.87 |
| *Halichoeres poeyi* | 1.34 | 19.18 |
| *Hypoplectrus unicolor* | 0.07 | 19.64 |
| *Coryphopterus glaucofraenum* | 0.52 | 20.70 |
| *Pomacanthus arcuatus* | 0.17 | 20.81 |
| *Haemulon plumierii* | 0.58 | 20.86 |
| *Hypoplectrus chlorurus* | 0.05 | 21.36 |
| *Sparisoma rubripinne* | 0.48 | 21.45 |
| *Hypoplectrus puella* | 0.07 | 21.58 |
| *Calamus pennatula* | 0.13 | 21.96 |
| *Acanthurus chirurgus* | 0.90 | 22.08 |
| *Opistognathus aurifrons* | 0.52 | 22.18 |
| *Stegastes planifrons* | 0.26 | 22.28 |
| *Malacoctenus triangulatus* | 0.22 | 22.49 |
| *Holacanthus tricolor* | 0.14 | 22.64 |
| *Pomacanthus paru* | 0.08 | 23.19 |
| *Lachnolaimus maximus* | 0.09 | 23.32 |
| *Sparisoma atomarium* | 1.42 | 23.45 |
| *Elacatinus evelynae* | 0.14 | 23.51 |
| *Holacanthus ciliaris* | 0.05 | 24.38 |
| *Serranus tabacarius* | 0.20 | 24.41 |
| *Stegastes leucostictus* | 0.21 | 24.52 |

## St. Croix

**49** species ≤ 25% CV

**16** species on the island-based FMP list

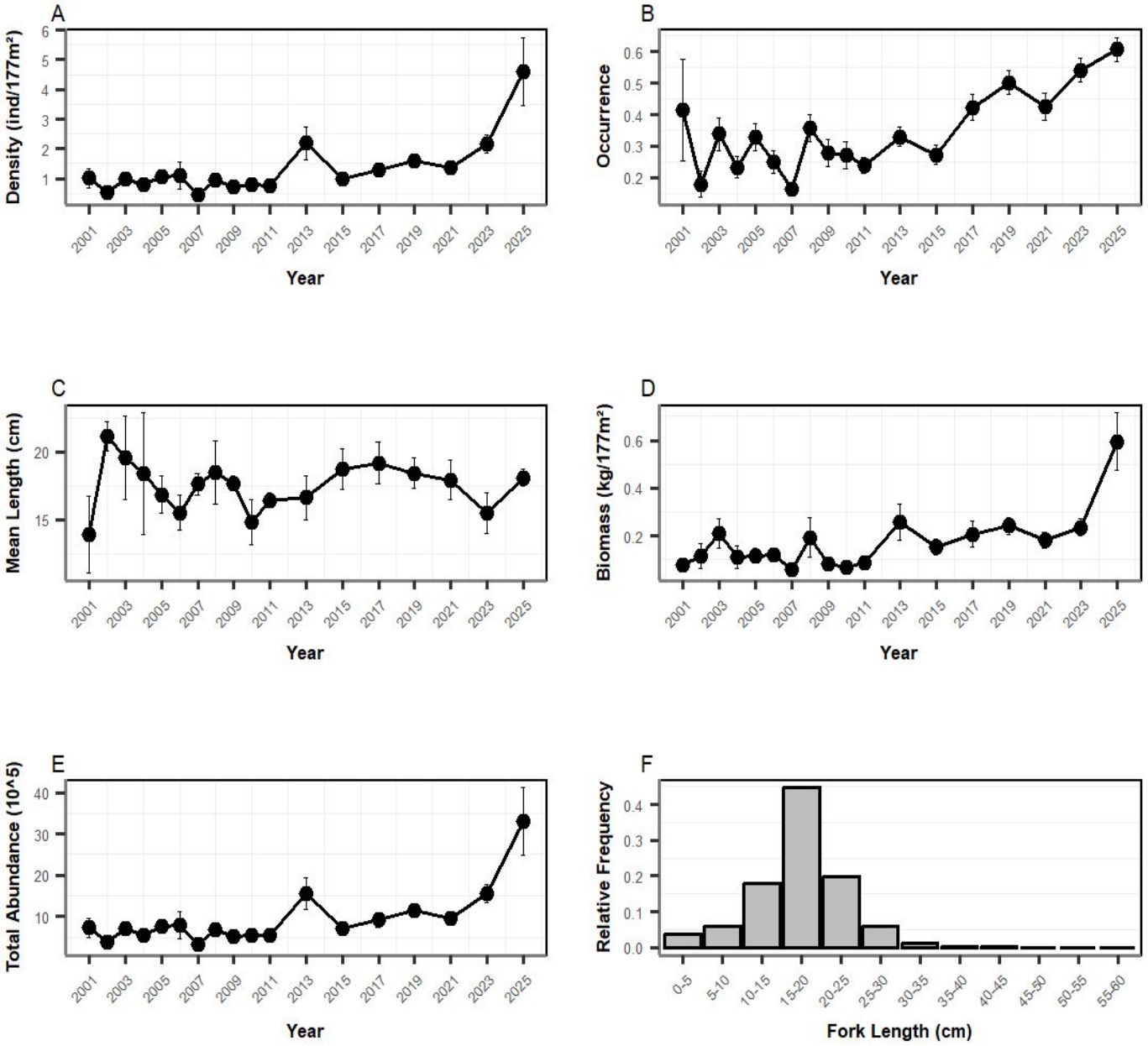
| St. Croix 2025 | | |
|---|---|---|
| Species | Density | CV |
| *Thalassoma bifasciatum* | 35.53 | 5.60 |
| *Acanthurus bahianus* | 8.83 | 6.72 |
| *Sparisoma aurofrenatum* | 4.82 | 7.27 |
| *Stegastes partitus* | 38.75 | 7.65 |
| *Cephalopholis fulva* | 1.47 | 8.01 |
| *Halichoeres garnoti* | 6.77 | 8.45 |
| *Halichoeres bivittatus* | 18.63 | 8.70 |
| *Holocentrus rufus* | 1.14 | 9.21 |
| *Acanthurus coeruleus* | 3.27 | 9.29 |
| *Epinephelus guttatus* | 0.38 | 10.36 |
| *Chaetodon striatus* | 0.54 | 10.45 |
| *Serranus tigrinus* | 0.69 | 10.66 |
| *Halichoeres maculipinna* | 1.55 | 11.26 |
| *Holocentrus adscensionis* | 0.69 | 12.09 |
| *Scarus taeniopterus* | 2.77 | 12.36 |
| *Sparisoma viride* | 0.69 | 12.76 |
| *Chaetodon capistratus* | 0.31 | 13.10 |
| *Holacanthus tricolor* | 0.19 | 14.58 |
| *Scarus iseri* | 2.19 | 14.63 |
| *Haemulon flavolineatum* | 0.52 | 15.48 |
| *Halichoeres radiatus* | 0.28 | 15.56 |
| *Stegastes leucostictus* | 0.57 | 15.65 |
| *Chromis cyanea* | 4.99 | 15.73 |
| *Gramma loreto* | 0.20 | 16.15 |
| *Cephalopholis cruentata* | 0.14 | 16.23 |
| *Malacanthus plumieri* | 0.33 | 16.62 |
| *Scarus vetula* | 0.14 | 17.23 |
| *Sparisoma chrysopterum* | 0.28 | 17.29 |
| *Canthigaster rostrata* | 0.60 | 17.45 |
| *Balistes vetula* | 1.73 | 17.56 |
| *Pseudupeneus maculatus* | 0.58 | 17.83 |
| *Ocyurus chrysurus* | 0.67 | 18.61 |
| *Lutjanus apodus* | 0.05 | 19.43 |
| *Acanthurus chirurgus* | 2.62 | 19.83 |
| *Bodianus rufus* | 0.13 | 20.04 |
| *Chromis multilineata* | 0.88 | 20.10 |
| *Sphyraena barracuda* | 0.13 | 20.32 |
| *Stegastes adustus* | 1.02 | 20.42 |
| *Clepticus parrae* | 0.46 | 20.52 |
| *Stegastes diencaeus* | 0.29 | 21.00 |
| *Sparisoma radians* | 0.39 | 21.02 |
| *Melichthys niger* | 0.70 | 21.56 |
| *Microspathodon chrysurus* | 0.27 | 22.14 |
| *Halichoeres poeyi* | 0.31 | 22.28 |
| *Stegastes variabilis* | 0.31 | 22.51 |
| *Mulloidichthys martinicus* | 0.07 | 22.92 |
| *Myripristis jacobus* | 0.04 | 23.91 |
| *Abudefduf saxatilis* | 0.23 | 24.70 |
| *Ophioblennius macclurei* | 0.06 | 24.82 |

## St. Thomas/ St. John

**61** species ≤ 25% CV

**19** species on the island-based FMP list

| ST. Thomas/ St. John 2021 | | |
|---|---|---|
| Species | Density | CV |
| *Epinephelus guttatus* | 1.00 | 6.54 |
| *Sparisoma aurofrenatum* | 4.60 | 6.82 |
| *Acanthurus bahianus* | 4.04 | 7.15 |
| *Holocentrus rufus* | 1.40 | 7.45 |
| *Acanthurus coeruleus* | 2.41 | 7.50 |
| *Chromis cyanea* | 13.10 | 7.60 |
| *Hypoplectrus chlorurus* | 0.64 | 7.68 |
| *Scarus taeniopterus* | 7.71 | 7.75 |
| *Halichoeres garnoti* | 5.76 | 7.77 |
| *Stegastes partitus* | 11.58 | 7.85 |
| *Sparisoma viride* | 1.86 | 8.53 |
| *Canthigaster rostrata* | 0.85 | 8.93 |
| *Chaetodon capistratus* | 1.49 | 9.00 |
| *Cephalopholis cruentata* | 0.69 | 9.22 |
| *Thalassoma bifasciatum* | 14.40 | 9.36 |
| *Scarus iseri* | 6.23 | 9.43 |
| *Serranus tigrinus* | 0.41 | 10.09 |
| *Hypoplectrus puella* | 0.36 | 10.13 |
| *Holacanthus tricolor* | 0.54 | 10.14 |
| *Ocyurus chrysurus* | 1.44 | 10.19 |
| *Pseudupeneus maculatus* | 1.20 | 10.43 |
| *Bodianus rufus* | 0.53 | 11.21 |
| *Cephalopholis fulva* | 0.88 | 11.26 |
| *Balistes vetula* | 0.69 | 11.62 |
| *Halichoeres maculipinna* | 0.74 | 11.93 |
| *Halichoeres bivittatus* | 3.15 | 12.16 |
| *Stegastes variabilis* | 0.55 | 12.22 |
| *Acanthurus chirurgus* | 2.11 | 12.38 |
| *Stegastes leucostictus* | 0.72 | 12.52 |
| *Chaetodon striatus* | 0.33 | 12.82 |
| *Prognathodes aculeatus* | 0.26 | 13.44 |
| *Haemulon flavolineatum* | 1.52 | 15.11 |
| *Pomacanthus arcuatus* | 0.24 | 15.79 |
| *Holocentrus adscensionis* | 0.73 | 16.14 |
| *Malacanthus plumieri* | 0.19 | 16.34 |
| *Stegastes adustus* | 0.25 | 16.92 |
| *Pterois volitans* | 0.24 | 17.16 |
| *Sphyraena barracuda* | 0.19 | 17.48 |
| *Calamus calamus* | 0.22 | 17.76 |
| *Lutjanus analis* | 0.21 | 18.13 |
| *Pomacanthus paru* | 0.15 | 18.17 |
| *Holacanthus ciliaris* | 0.19 | 18.36 |
| *Halichoeres radiatus* | 0.11 | 18.50 |
| *Coryphopterus personatus* | 14.76 | 18.52 |
| *Chaetodon sedentarius* | 0.30 | 19.04 |
| *Opistognathus aurifrons* | 1.27 | 19.05 |
| *Scarus vetula* | 0.30 | 19.19 |
| *Clepticus parrae* | 19.14 | 19.44 |
| *Cantherhines pullus* | 0.10 | 20.20 |
| *Stegastes planifrons* | 0.48 | 20.40 |
| *Aulostomus maculatus* | 0.08 | 20.64 |
| *Serranus tabacarius* | 0.60 | 21.30 |
| *Hypoplectrus unicolor* | 0.17 | 21.40 |
| *Caranx ruber* | 4.93 | 21.65 |
| *Microspathodon chrysurus* | 0.36 | 21.66 |
| *Hypoplectrus nigricans* | 0.13 | 21.74 |
| *Halichoeres pictus* | 0.14 | 23.45 |
| *Sparisoma chrysopterum* | 0.10 | 23.64 |
| *Elacatinus evelynae* | 0.06 | 23.78 |
| *Gramma loreto* | 0.66 | 24.39 |
| *Coryphopterus glaucofraenum* | 0.12 | 24.47 |



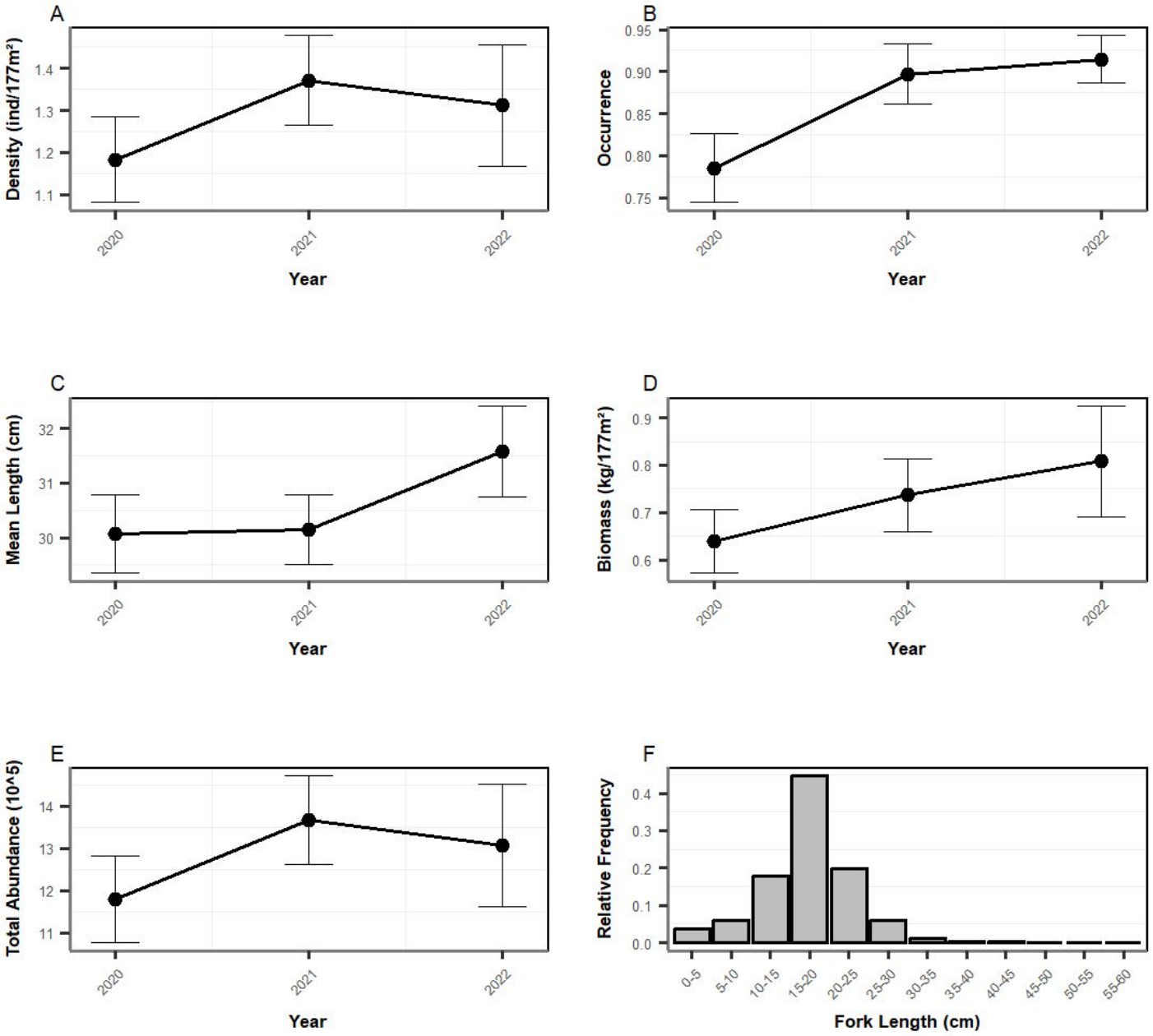

# NCRMP Example

- St. Thomas and St. John
- 2001–2025 (years) & 0–30 m (depth)
- Yellowtail snapper (*Ocyurus chrysurus*)





Photo credit: Jay Grove




# DCRMP Example

- St. Thomas and St. John
- 2020–2022 (years) & 30–50 m (depth)
- Red Hind (*Epinephelus guttatus*)





Photo credit: Jay Grove

# NCRMP & DCRMP Example

- St. Thomas and St. John
- 2021 (year) & 0–50 m (depth)
- Stoplight parrotfish (*Sparisoma viride*)

| Density (Ind/177m²) | Occurrence |
|---|---|
| 4.59 ± 0.31<br>CV = 6.8% | 91.2% |

| Absolute Abundance | Absolute Biomass (kg) |
|---|---|
| 7,877,122 ± 1,713,031<br>CV = 6.8% | 344,831 ± 32,322<br>CV = 9.4% |

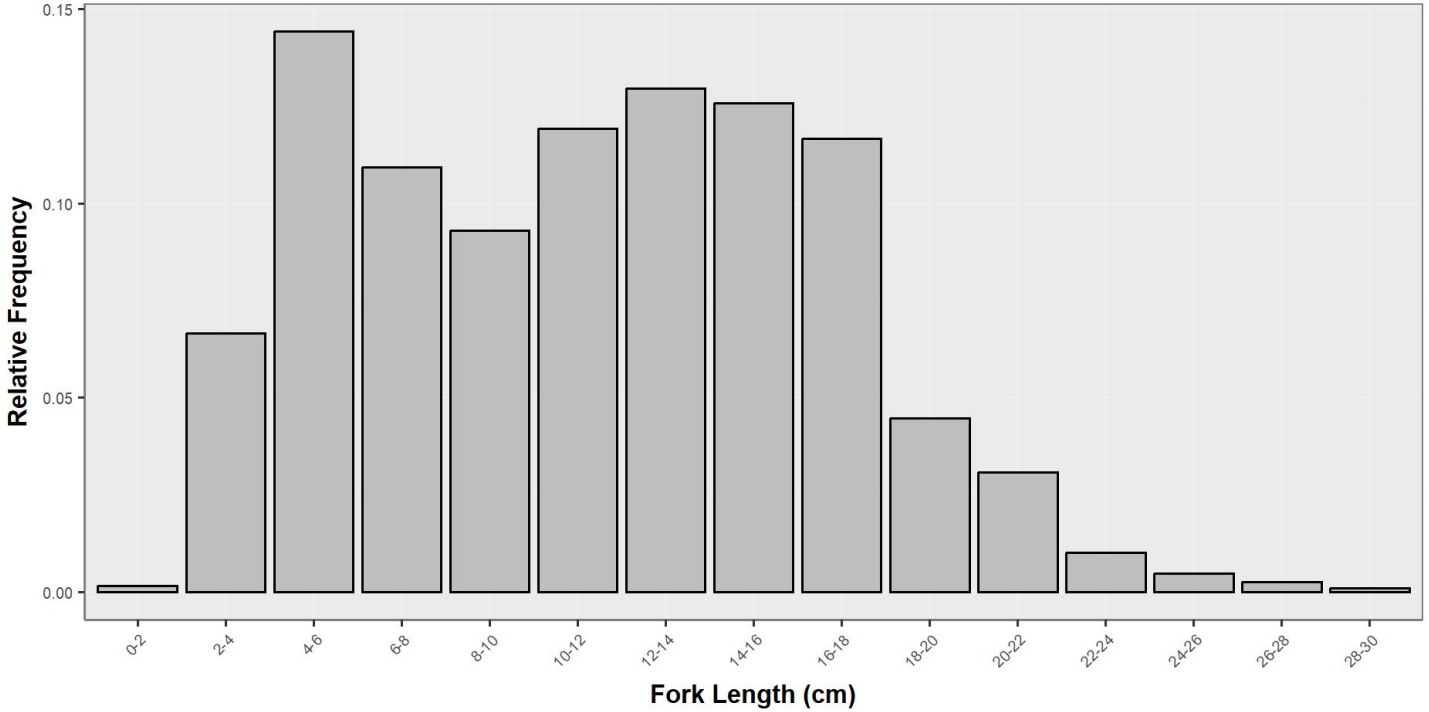





Photo credit: Jiangang Luo

# Use $F_{MSY}$ proxies to determine Overfishing Limit

OFL = $F_{MSY}$ proxy * Absolute Fishable Biomass

| $F_{MSY}$ proxy | Caveats | Data requirements |
|---|---|---|
| Spawning potential ratio ($F_{SPRxx\%}$) | Preferred proxy; $F_{40\%}$- $F_{45\%}$ is generally recommended default | Natural mortality, growth parameters, maturity-at-age/length, fishery selectivity |
| Yield-per-recruit ($F_{0.1}$ or $F_{MAX}$) | Less robust but acceptable when maturity data are lacking; $F_{0.1}$ is more conservative proxy | Natural mortality, weight-at-age, fishery selectivity |



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# Use $F_{MSY}$ proxies to determine Overfishing Limit

OFL = $F_{MSY}$ proxy * Absolute Fishable Biomass

## Baranov Catch Equation

*Account for simultaneous F & natural mortality*

C: Total catch (number of fish)
F: Instantaneous fishing mortality rate
N: Initial population size

$$C = \frac{F}{F+M} N(1 - e^{-(F+M)})$$



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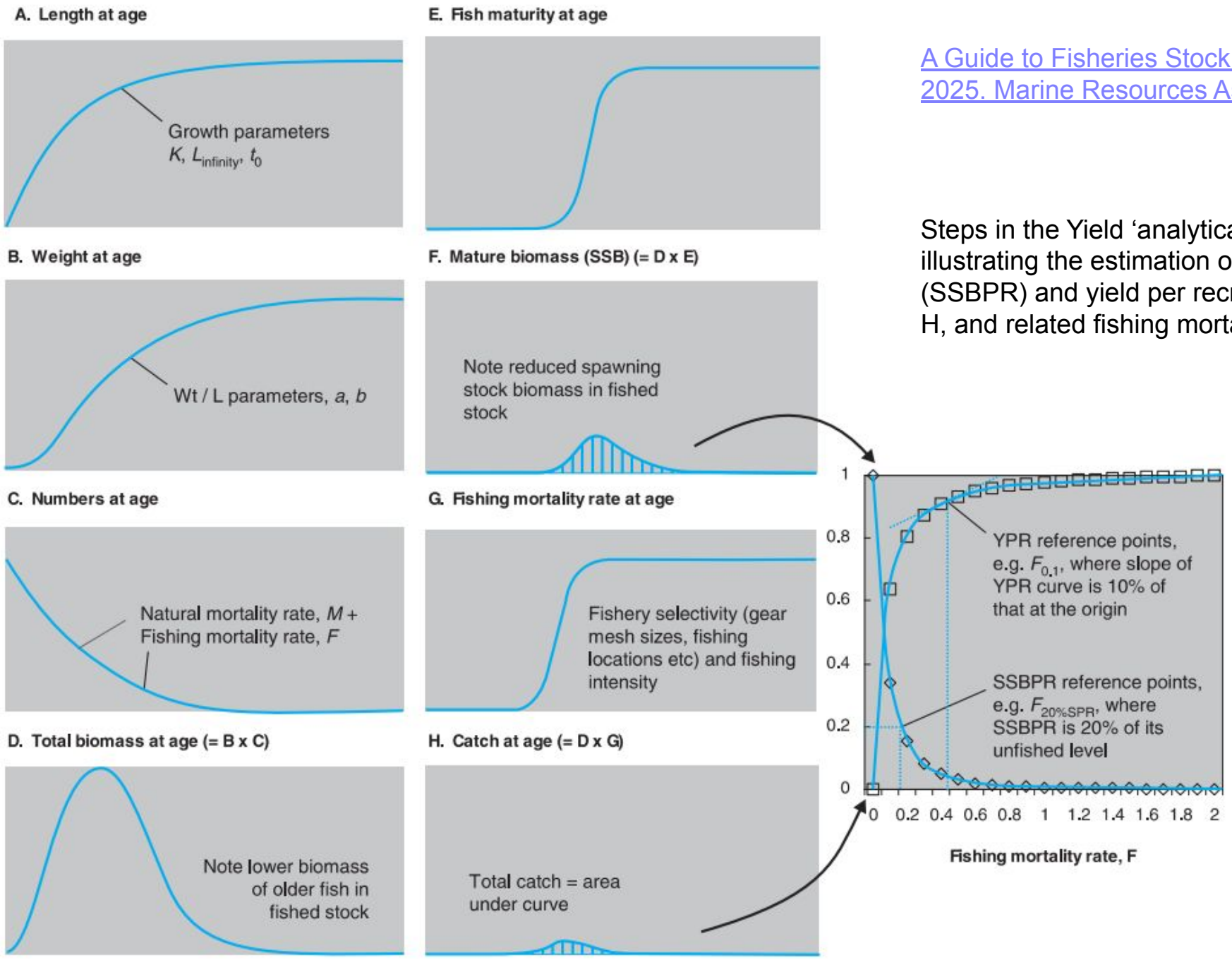


[A Guide to Fisheries Stock Assessment using the FMSP Tools. 2025. Marine Resources Assessment Group (MRAG), London.]

Steps in the Yield 'analytical' model for an exploited fish stock illustrating the estimation of spawning stock biomass per recruit (SSBPR) and yield per recruit (YPR) indicators in graphs F and H, and related fishing mortality (F)-based reference points






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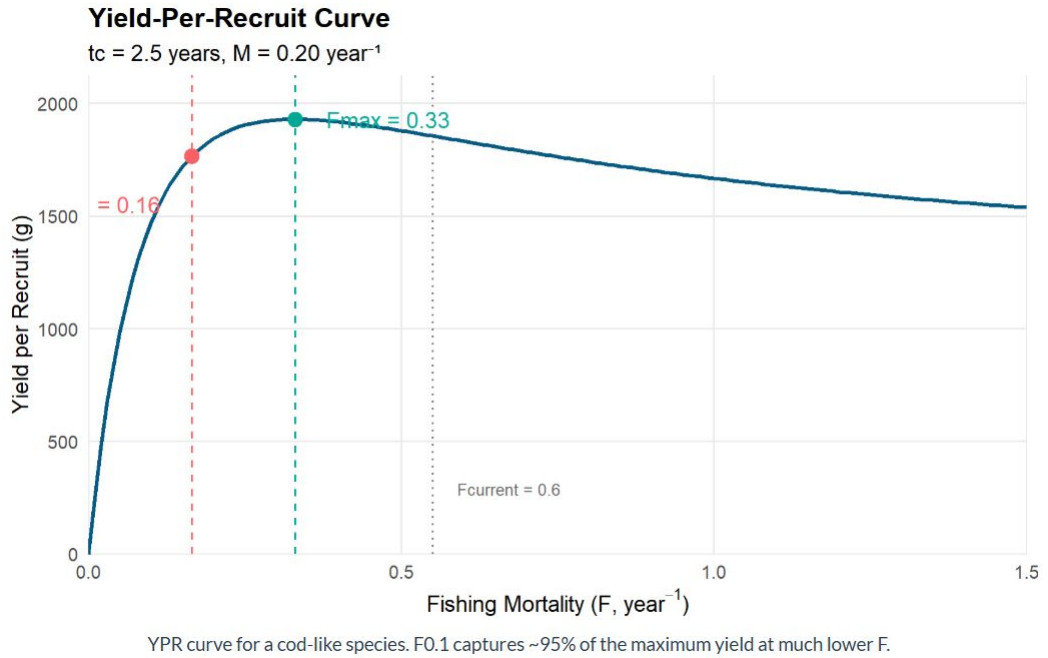
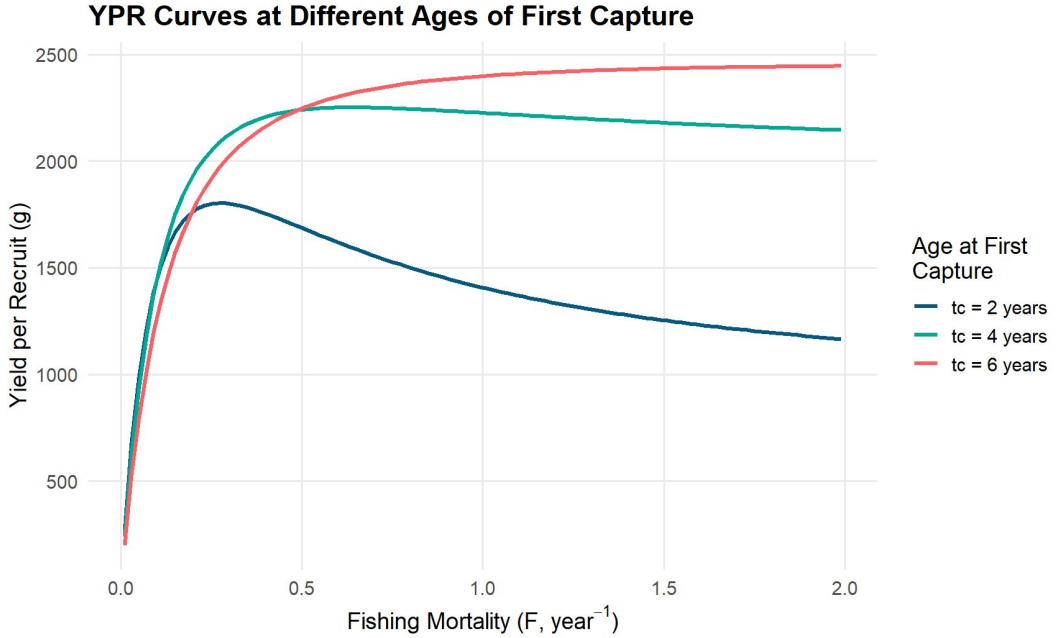
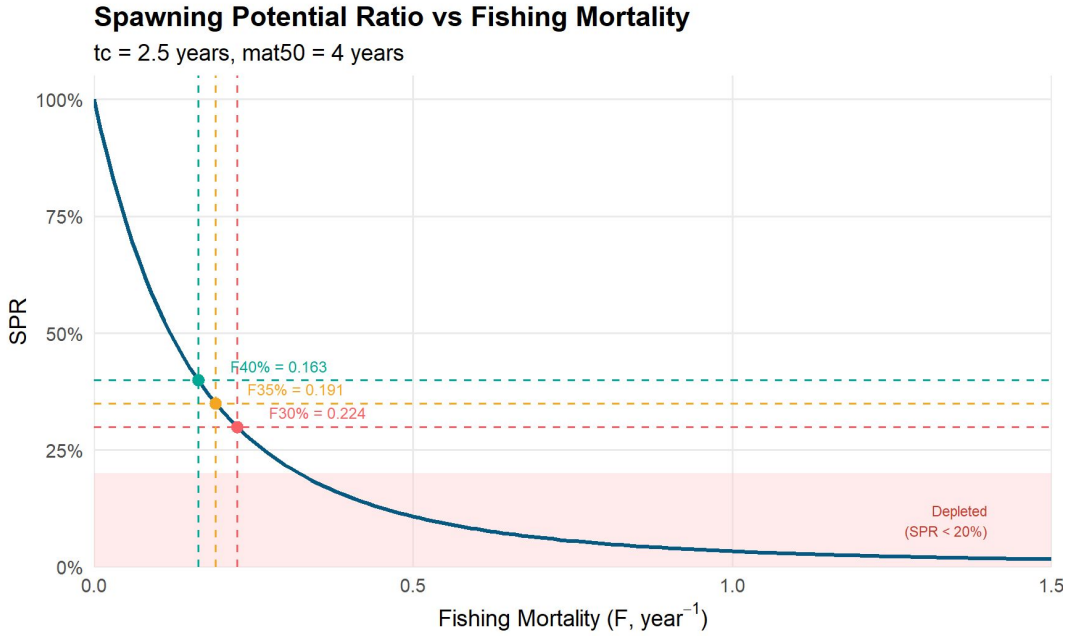



YPR curve for a cod-like species. F0.1 captures ~95% of the maximum yield at much lower F.




RPubs

[Coelho, 2026. Yield-Per-Recruit (YPR) and Spawning Potential Ratio (SPR) Analysis]

**Several resources/R packages:**
FishLife, {rfishbase},
{LBSPR}, {fishmethods}, …

Shertzer, K.W.; Damiano, M.D.; Williams, E.H. **Spawning Potential Ratio Can Provide Reference Points for Fishery Management That Are Robust to Environmental Variability.** Fishes 2024, 9, 497.

- Evaluated variability in SPR-based reference points for 8 reef-associated species in the SE US
- SPR-reference points are generally robust to plausible levels of variability in life-history traits

- Values of F40 conditional on mean life-history traits from **FishLife**.
- Also shown is the probability of overfishing (P) given the target fishing rate of **F = 75%F40** and the coefficient of variation (CV) in the probability density of F40, assuming nondirectional variation in life-history parameters.
- Each value is shown for selectivity that occurs before maturity ( 0.75τm), coincides with maturity τm), or occurs after (1.25τm).

| Species | $\tau_s=0.75\tau_m$ | | | $\tau_s=\tau_m$ | | | $\tau_s=1.25\tau_m$ | | |
|---|---|---|---|---|---|---|---|---|---|
| | $\overline{F_{40}}$ | P | CV | $\overline{F_{40}}$ | P | CV | $\overline{F_{40}}$ | P | CV |
| Red snapper | 0.18 | 0.01 | 0.15 | 0.22 | 0.04 | 0.18 | 0.28 | 0.09 | 0.25 |
| Vermilion snapper | 0.21 | 0.11 | 0.24 | 0.25 | 0.14 | 0.27 | 0.32 | 0.16 | 0.38 |
| Red grouper | 0.16 | 0.02 | 0.14 | 0.26 | 0.09 | 0.21 | 0.57 | 0.29 | 0.62 |
| Gag grouper | 0.19 | 0.03 | 0.14 | 0.35 | 0.09 | 0.20 | 0.94 | 0.33 | 0.52 |
| Black sea bass | 0.50 | 0.17 | 0.30 | 0.69 | 0.18 | 0.30 | 1.05 | 0.21 | 0.35 |
| Red porgy | 0.22 | 0.07 | 0.19 | 0.29 | 0.11 | 0.24 | 0.42 | 0.19 | 0.42 |
| Greater amberjack | 0.42 | 0.20 | 0.35 | 0.55 | 0.20 | 0.34 | 0.78 | 0.21 | 0.40 |
| White grunt | 0.62 | 0.10 | 0.23 | 0.90 | 0.10 | 0.22 | 1.45 | 0.16 | 0.25 |

**Selectivity**: Before Maturity | At Maturity | After Maturity

# Use $F_{MSY}$ proxies to determine Overfishing Limit

- Derives domain OFLs for actionable catch limits
- Low implementation barrier (existing data, R examples/packages)
- Does not rely on historical catch histories
- Missing life history parameters can be borrowed across taxa
- Tends to produce conservative limits for data-limited stocks
- Does not consider recruitment
- Subject to static equilibrium assumptions and limited by spatial overlap with survey domains (e.g., NCRMP)



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# Additional details on the NCRMP and DCRMP sampling methods, changes over time, and their inter-calibration

Fishery-Independent Reef Fish Visual Survey Data in the U.S. Caribbean: National Coral Reef Monitoring Program

Laura Jay W. Grove, Jeremiah Blondeau, and Jerald S. Ault

SEDAR103-DW-4

3 August 2026

Fishery-Independent Reef Fish Visual Survey Data in the U.S. Caribbean: Deep Coral Reef Monitoring Program

Laura Jay W. Grove and Jeremiah Blondeau

SEDAR103-DW-03

3 August 2026