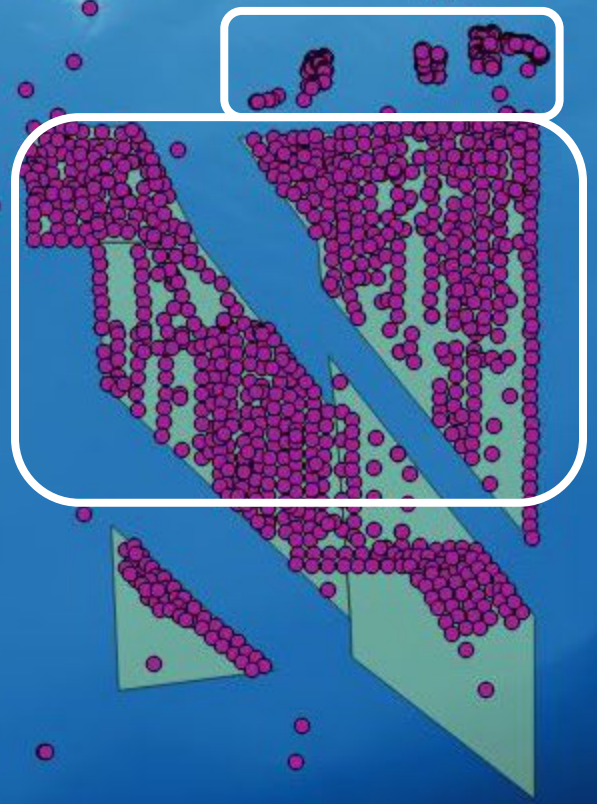
Evaluating the effects of artificial reef size, spacing and materials on fish abundance and diversity in the Alabama Artificial Reef Permit Zone

Mark A. Albins, Crystal Hightower, Trey Spearman, Craig Newton, and Sean Powers

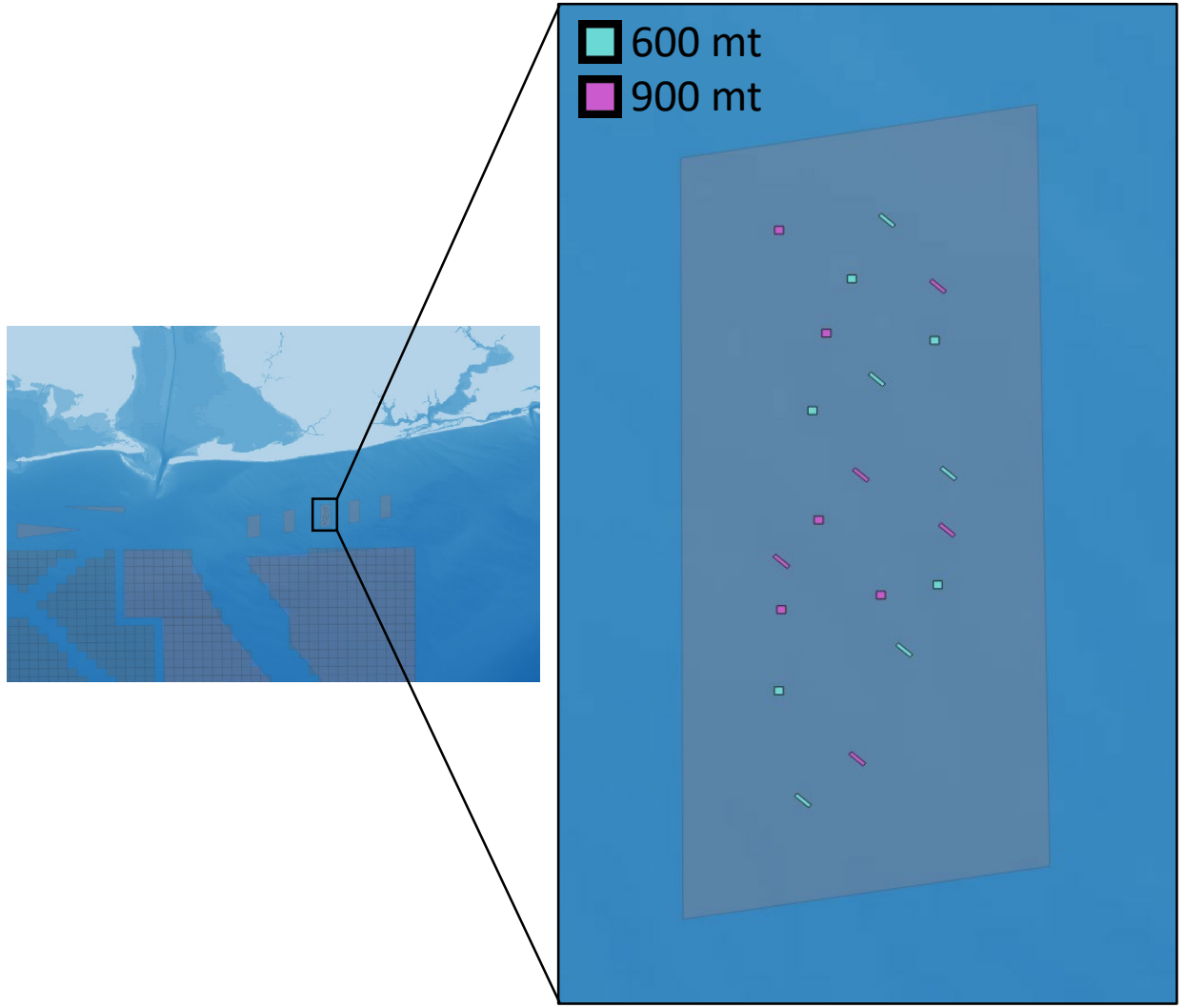
Alabama Artificial Reef Permit Zone (AARPZ)



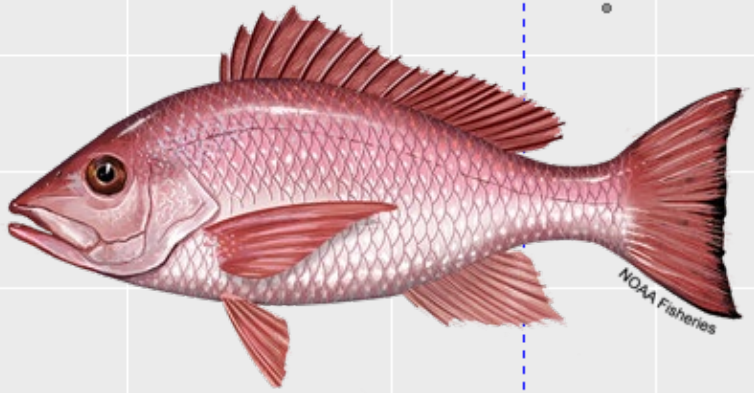
- Inner shelf zone (2019)
  - Limestone aggregate reefs
  - Juvenile fish shelters
- Outer shelf zone (2013-2018)
  - Shipwrecks
  - Super pyramids
  - Small reefs

Inner shelf zone: limestone aggregate reefs

- Design:
  - 20 reefs
  - Two levels of material density (600 mt and 900 mt)
  - One year of baseline data (2016) and three years of post-deployment data (2019-2021)
  - Seasonal (Spring and Fall)
- Response variables:
  - ROV video sampling
    - MaxN counts by species
    - Estimated TL for select species
  - Sabiki sampling
    - Numerical CPUE by species
    - Biomass CPUE by species



ROV MaxN - Red Snapper



MAX.N

0
5
10
15
20

2016 Spring
2016 Fall
2019 Spring
2019 Fall
2020 Spring
2020 Fall
2021 Spring
2021 Fall

TimeStep

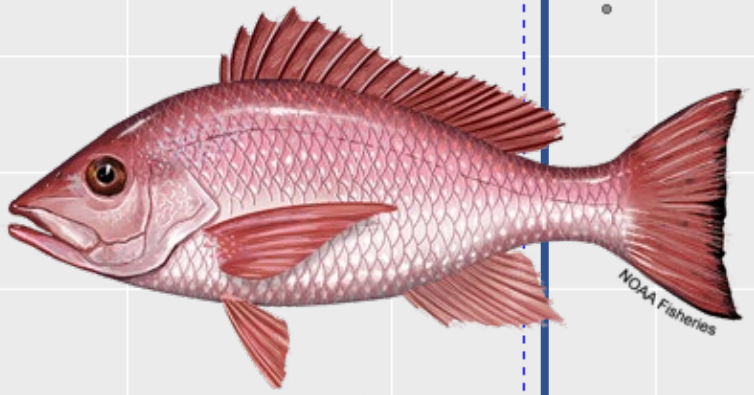
Important Events
Reefs Deployed
Hurricane Sally

Material density
600 mt
900 mt
Pre-deployment

Model results: LS Agg, ROV MaxN, red snapper

- Mixed-effects model with negative binomial distribution
- No significant three-way interaction ($p = 0.32$, Density:Year:Season)
- No significant two-way interaction ($p = 0.27$, Density:Year)
- Significant two-way interactions
  - Density:Season ($p = 0.02$)
    - Max.N was 1.9 times larger on 900 mt than on 600 mt reefs in the Spring season
  - Year:Season ($p < 0.0001$)
    - Max.N was

ROV MaxN - Red Snapper



MAX.N

0
5
10
15
20

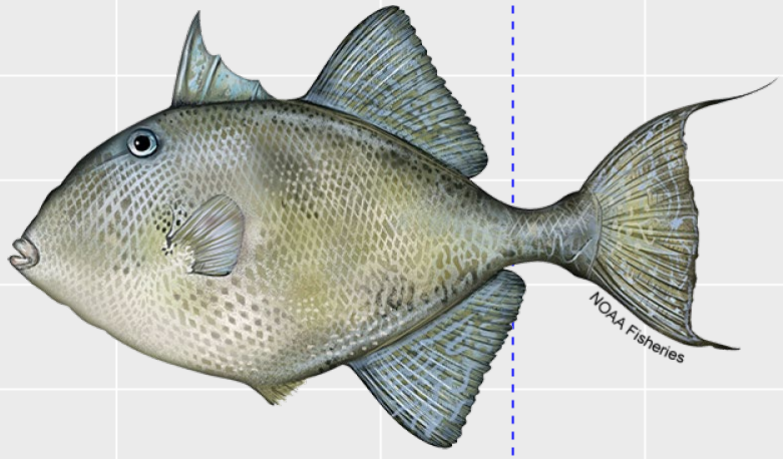
2016 Spring
2016 Fall
2019 Spring
2019 Fall
2020 Spring
2020 Fall
2021 Spring
2021 Fall

TimeStep

Important Events
Reefs Deployed
Hurricane Sally

Material density
600 mt
900 mt
Pre-deployment

ROV MaxN - Gray Triggerfish



MAX.N

50
40
30
20
10
0

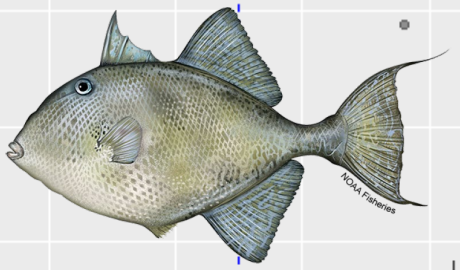
2016 Spring
2016 Fall
2019 Spring
2019 Fall
2020 Spring
2020 Fall
2021 Spring
2021 Fall

TimeStep

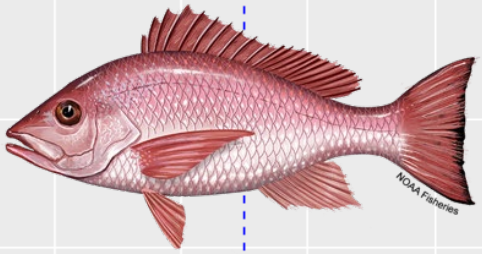
Important Events
Reefs Deployed
Hurricane Sally

Material density
600 mt
900 mt
Pre-deployment

ROV Total Length



gray triggerfish



red snapper

TL_mean

350
300
250
200
150

2016 Spring
2016 Fall
2019 Spring
2019 Fall
2020 Spring
2020 Fall
2021 Spring
2021 Fall

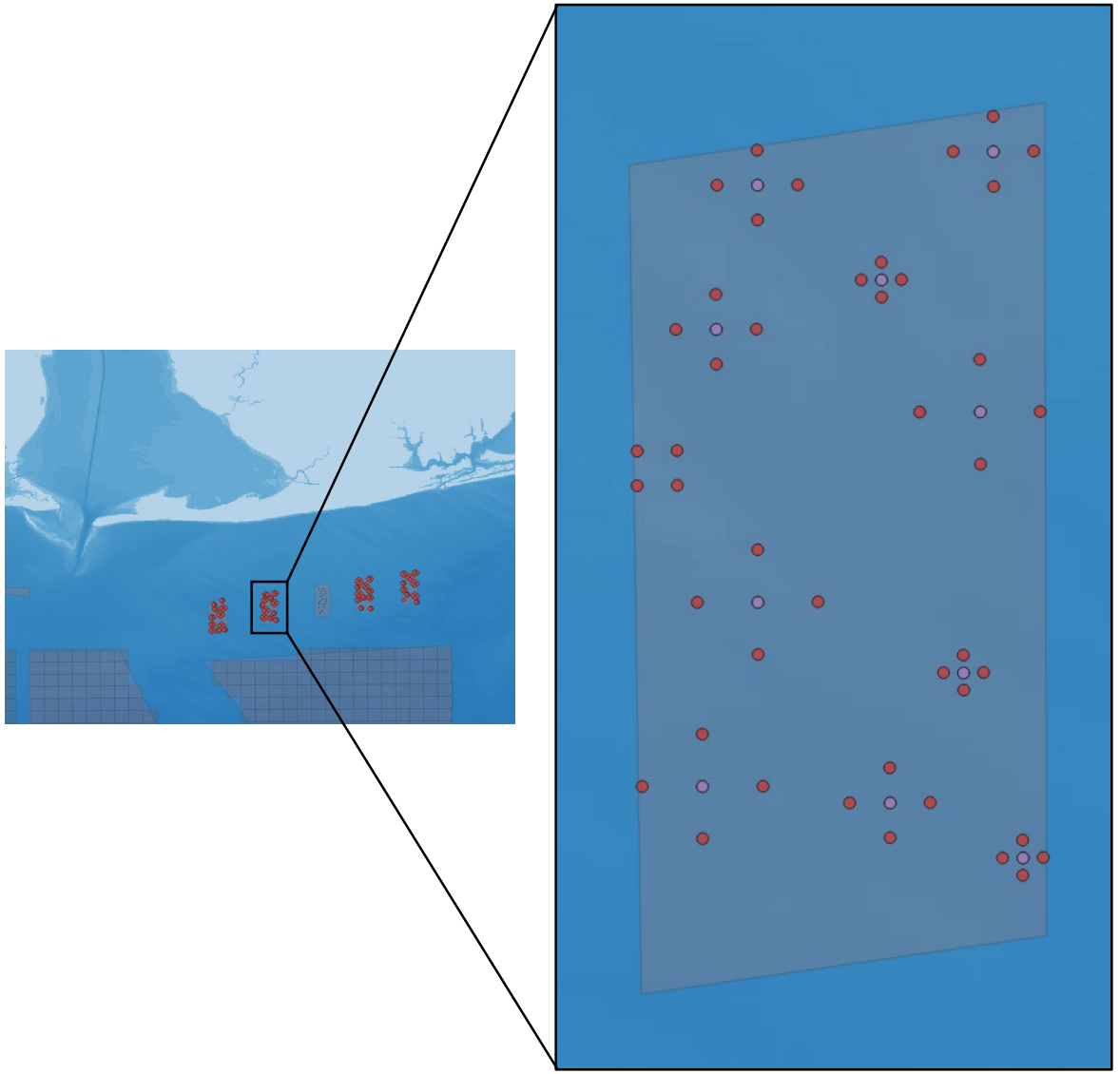
TimeStep

Material density
600 mt
900 mt

Important Events
Reefs Deployed
Hurricane Sally

Inner shelf zone: juvenile fish shelters

- Design:
  - 50 reef arrays
  - Reef cluster size (1, 2, and 4 modules)
  - Reef spacing (100, 200, and 300 m between core and outer reefs)
  - One year of baseline data (2016) and three years of post-deployment data (2019-2021)
  - Seasonal (Spring and Fall)
- Response variables:
  - ROV video sampling
    - MaxN counts by species
    - Estimated TL for select species
  - Vertical longline sampling
    - Numerical CPUE by species
    - Biomass CPUE by species



ROV MaxN - Red Snapper

MAX.N

80
60
40
20
0

2016 Spring
2016 Fall
2019 Spring
2019 Fall
2020 Spring
2020 Fall
2021 Spring
2021 Fall

TimeStep

Important Events
Reefs Deployed
Hurricane Sally

Reef cluster size
1 module
2 modules
4 modules
Pre-deployment

ROV MaxN - Red Snapper

MAX.N

80
60
40
20
0

2016 Spring
2016 Fall
2019 Spring
2019 Fall
2020 Spring
2020 Fall
2021 Spring
2021 Fall

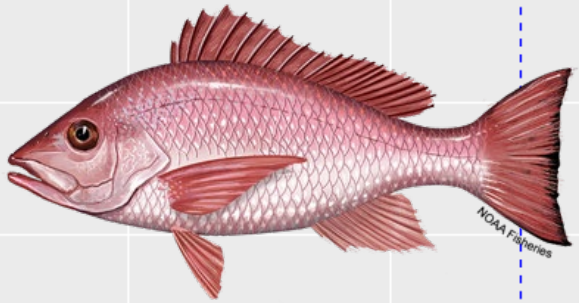
TimeStep

Important Events
Reefs Deployed
Hurricane Sally

Reef array spacing
100 m
200 m
300 m
Pre-deployment

ROV Total Length

red snapper



TL_mean

800
600
400
200

2016 Spring
2016 Fall
2019 Spring
2019 Fall
2020 Spring
2020 Fall
2021 Spring
2021 Fall

TimeStep

Important Events
Reefs Deployed
Hurricane Sally

Reef cluster size
1 module
2 modules
4 modules

ROV Total Length

red snapper

TL_mean

800
600
400
200

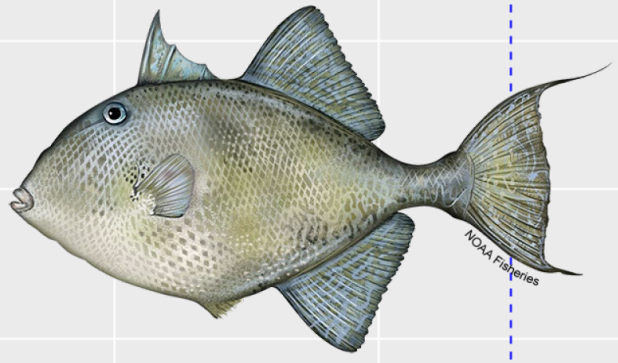
2016 Spring
2016 Fall
2019 Spring
2019 Fall
2020 Spring
2020 Fall
2021 Spring
2021 Fall

TimeStep

Important Events
Reefs Deployed
Hurricane Sally

Reef array spacing
100 m
200 m
300 m

ROV MaxN - Gray Triggerfish



MAX.N

0
5
10
15

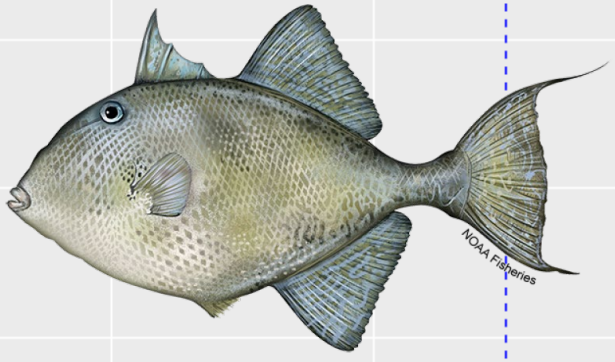
2016 Spring
2016 Fall
2019 Spring
2019 Fall
2020 Spring
2020 Fall
2021 Spring
2021 Fall

TimeStep

Important Events
Reefs Deployed
Hurricane Sally

Reef cluster size
1 module
2 modules
4 modules
Pre-deployment

ROV MaxN - Gray Triggerfish



MAX.N

0
5
10
15

2016 Spring
2016 Fall
2019 Spring
2019 Fall
2020 Spring
2020 Fall
2021 Spring
2021 Fall

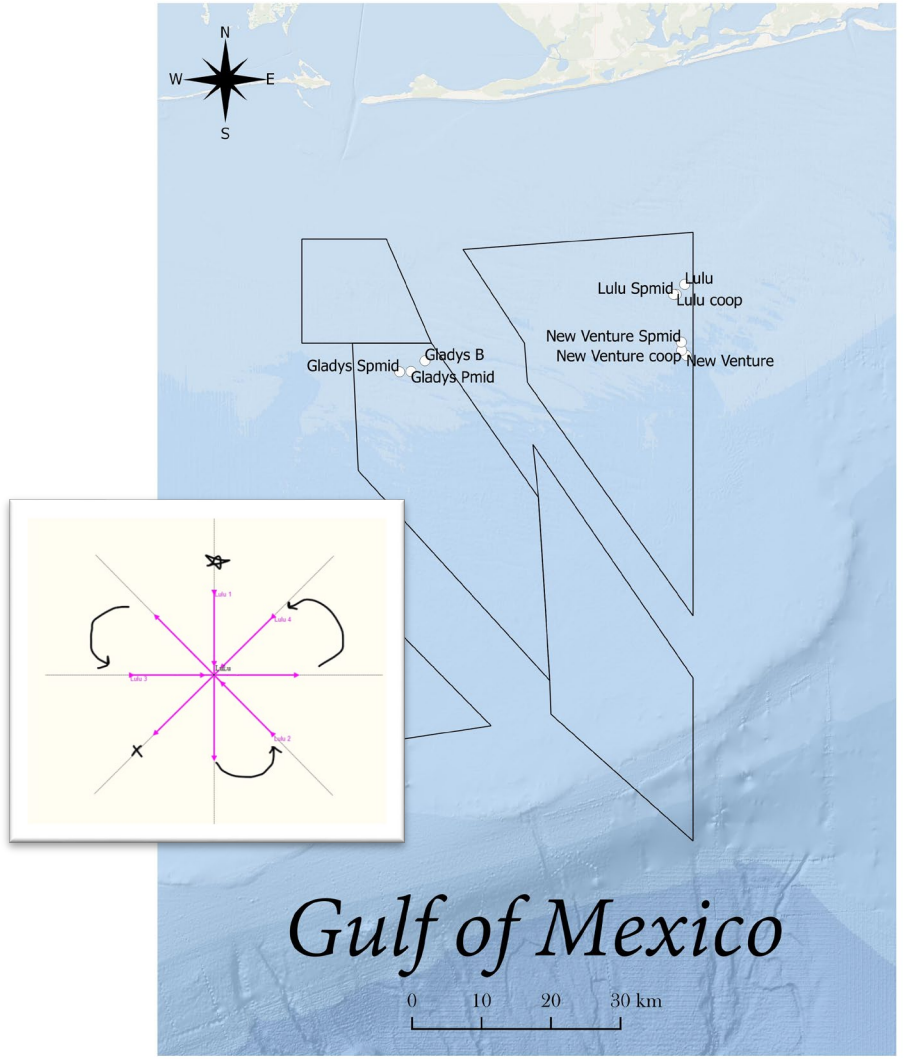
TimeStep

Important Events
Reefs Deployed
Hurricane Sally

Reef array spacing
100 m
200 m
300 m
Pre-deployment

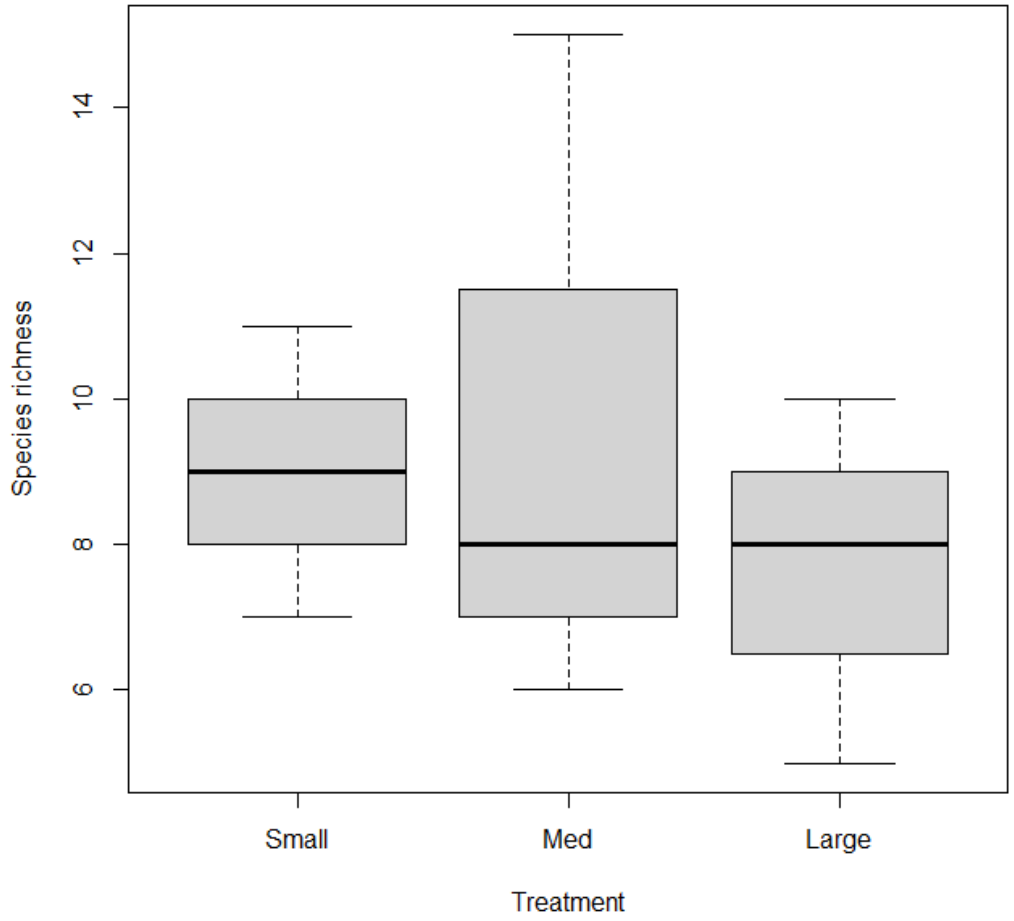
Comparison of large, medium, and small reefs

- Snapshot (Fall 2022)
- Large reefs: Gladys B, New Venture, Lulu
  - Lulu, 271’ coastal freighter, 2013
  - Gladys B, 102’ tugboat, 2018
  - New Venture, 250’ survey vessel, 2018
- Medium reefs: Super pyramids near these shipwrecks
- Small reefs: Standard pyramids and chicken coops near these shipwrecks
- Ran standard ROV survey plus EK80 fisheries echosounder on each

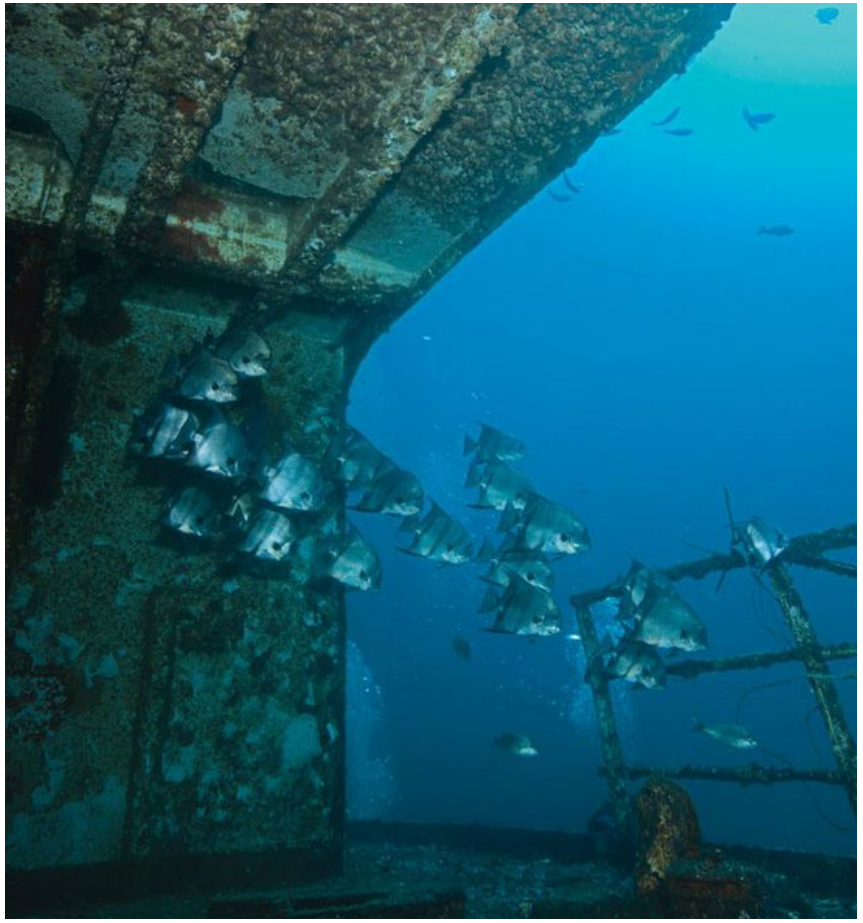


ROV results: species richness

- No significant differences among reef sizes
- Caveat: potential differences in detectability
  - Higher minimum safe approach distance for large reefs
  - Fewer observations of small fishes = richness estimates for large reefs likely to be too low



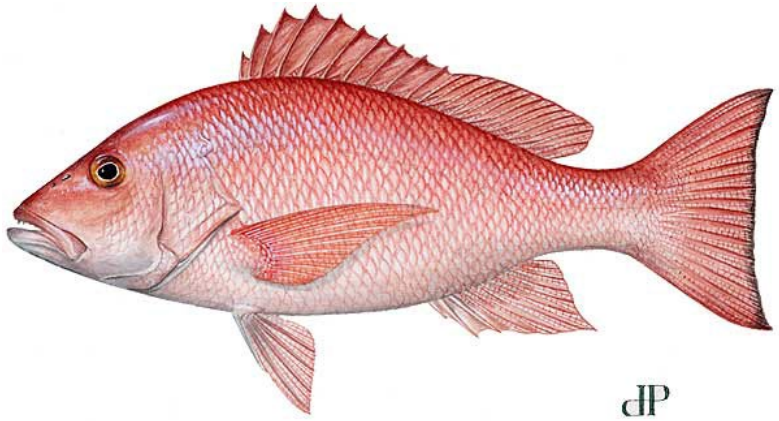
ROV results: species observed

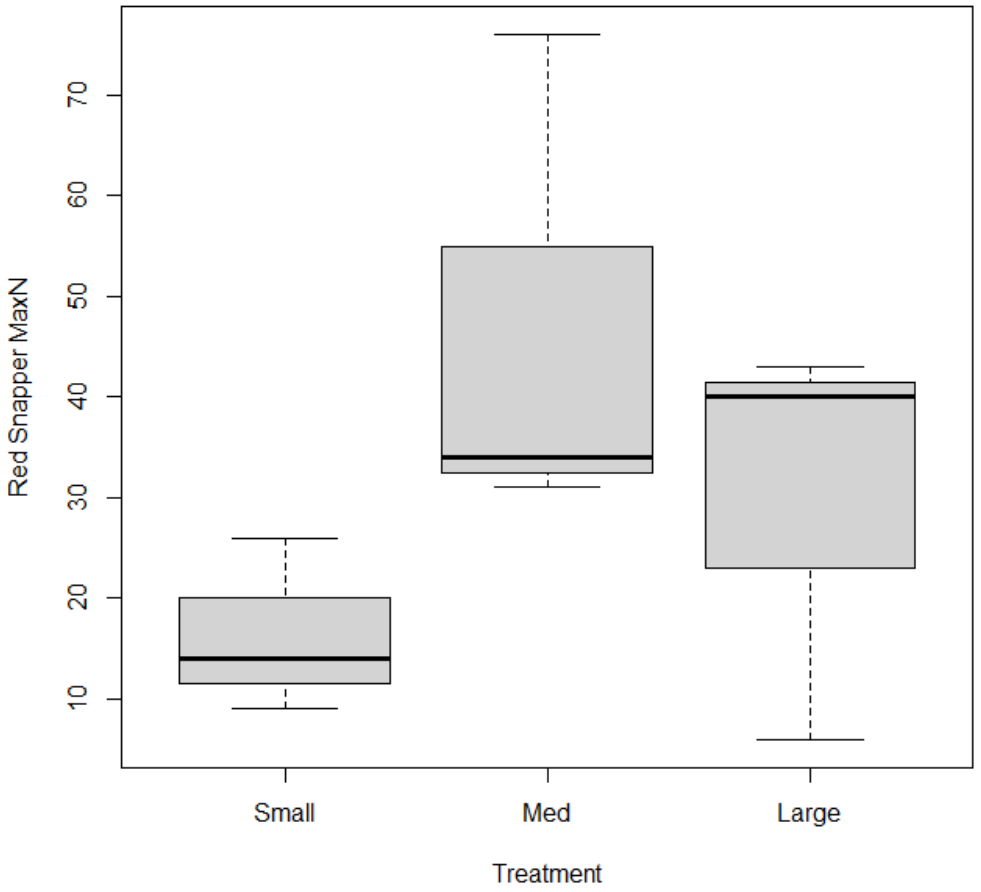


Species	Large	Medium	Small
Almaco Jack	X	X	X
Gray Snapper	X	X	X
Lane Snapper	X	X	X
Red Snapper	X	X	X
Sheepshead	X	X	X
Vermilion Snapper	X	X	X
Atlantic Spadefish	X	X	
Blue Angelfish	X	X	
Greater Amberjack	X	X	
Gray Triggerfish		X	X
Red Lionfish		X	X
Whitespotted Soapfish		X	X
Scad	X		X
Rainbow Runner		X	
Regal Demoiselle		X	
Sharpnose Puffer		X	
Spotfin Butterflyfish		X	
Unicorn filefish		X	
Yellow Garden Eel		X	
Great Barracuda	X		
Grouper sp.	X		
Jackknife Fish	X		
Whitebone Porgy	X		
Yellow Jack	X		
Centropristis spp.			X
Halichoeres spp.			X
Margate			X
Pareques spp.			X
Tomtate			X

ROV results: Red Snapper MaxN

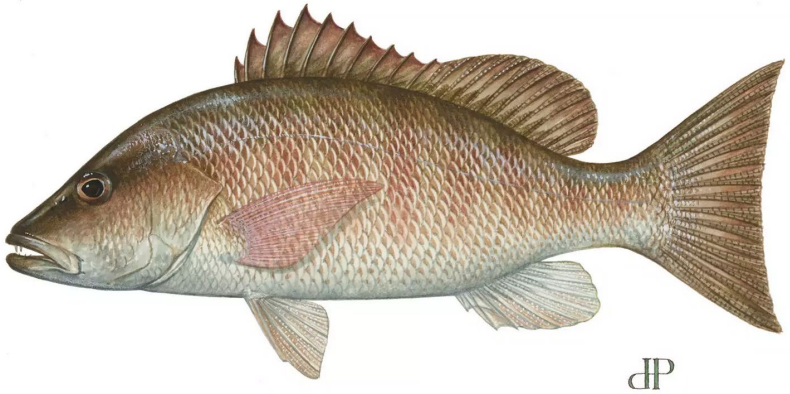
- 2.9 times higher on Medium than on Small (95% CI: 2.1-4.0)
- 1.8 times higher on Large than on Small (95% CI: 1.3-2.6)
- 1.6 times higher on Medium than on Large (95% CI: 1.2-2.1)

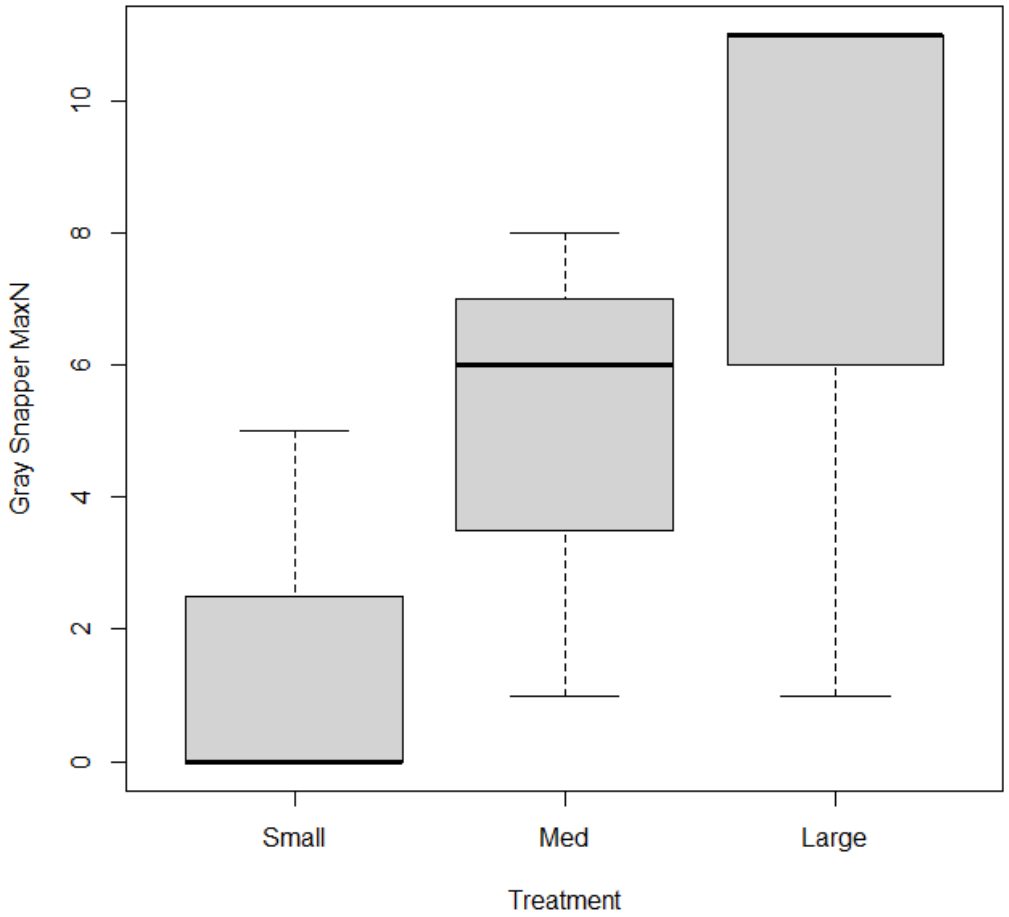




ROV results: Gray Snapper MaxN

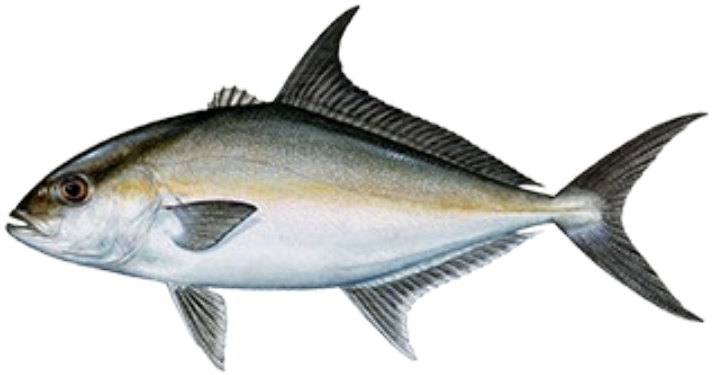
- 3.0 times higher on Medium than on Small (95% CI: 1.1-8.3)
- 4.6 times higher on Large than on Small (95% CI: 1.7-12.1)
- No significant difference between Medium and Large

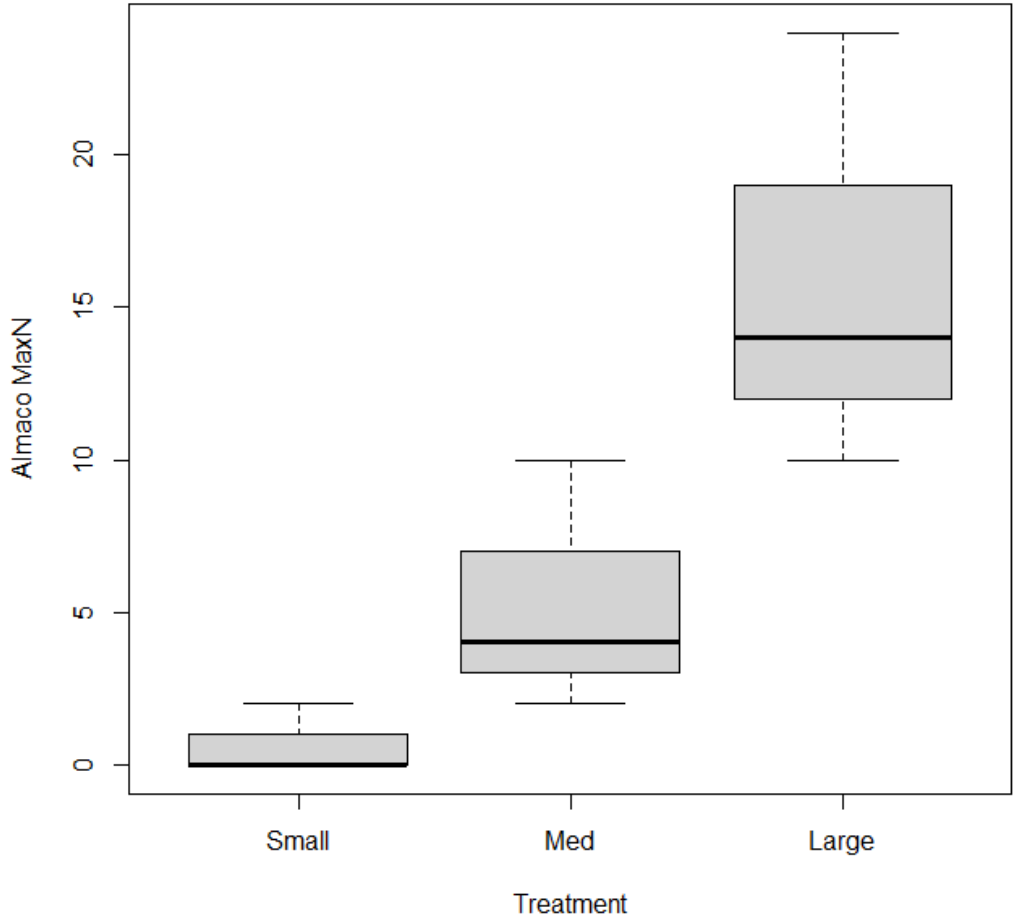




ROV results: Almaco Jack MaxN

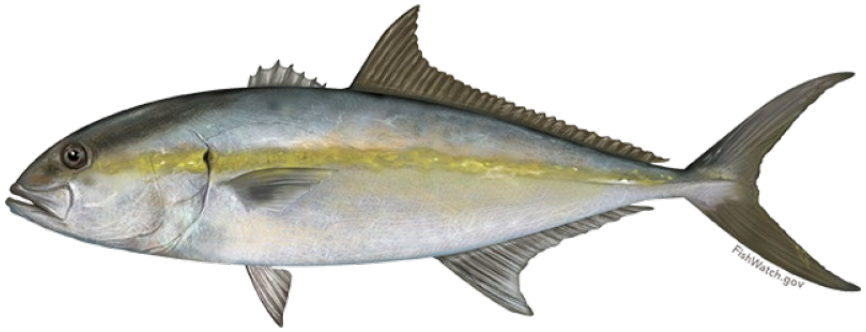
- 8 times higher on Medium than Small (95% CI: 1.8-34.8)
- 24 times higher on Large than Small (95% CI: 5.8-98.7)
- 3 times higher on Large than Medium (95% CI: 1.7-5.3)

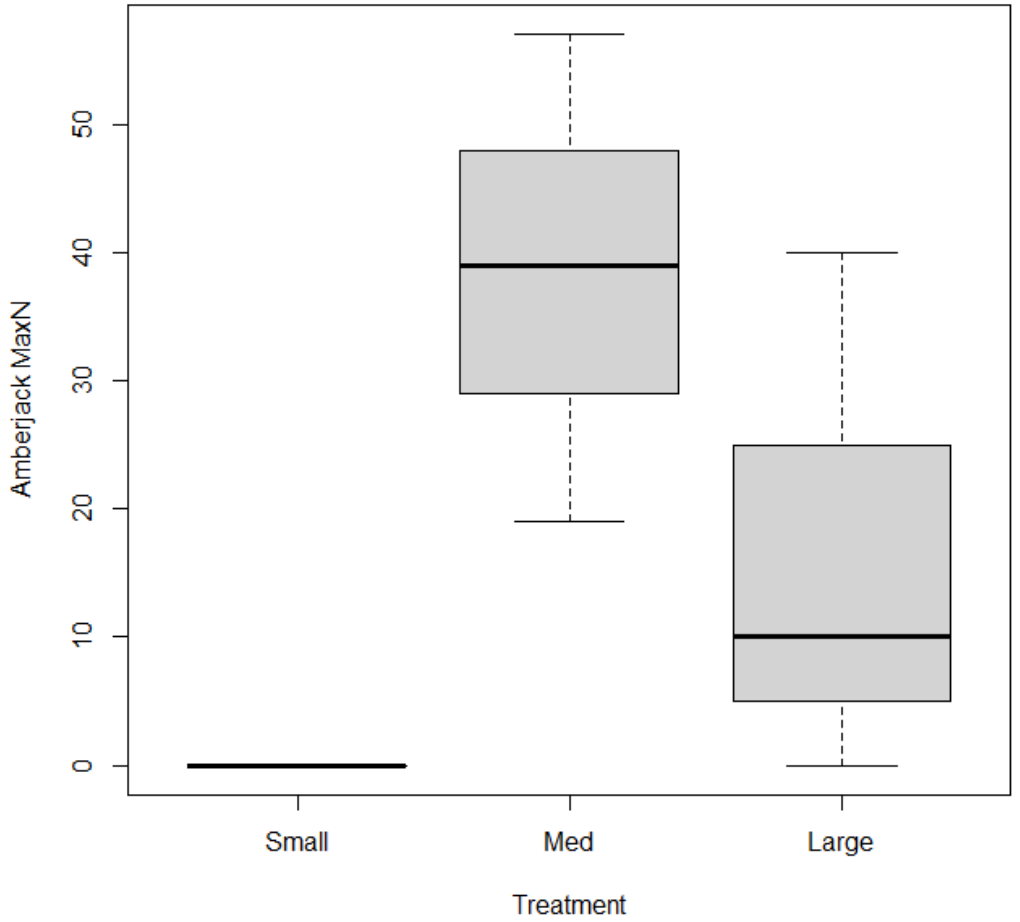




ROV results: Greater Amberjack MaxN

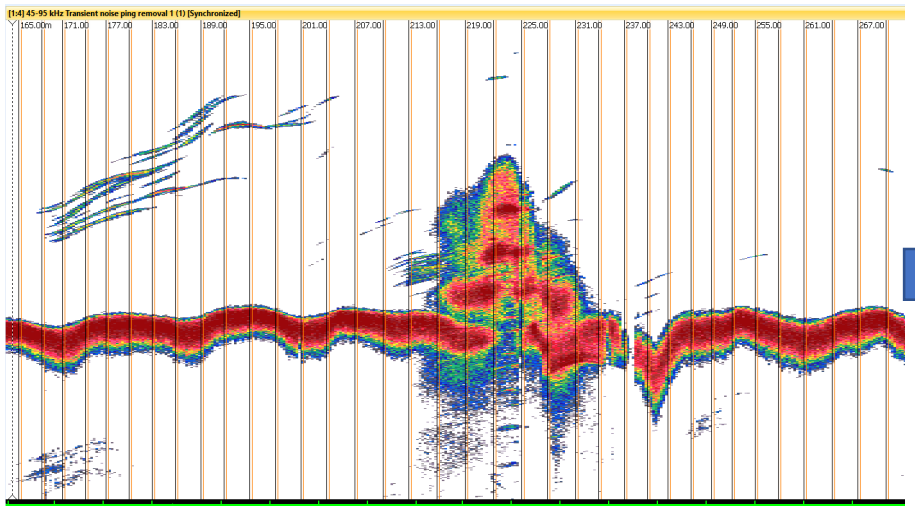
- No AJ observed on small reefs
- 2.3 times higher on Medium than Large (95% CI: 1.7-3.2)

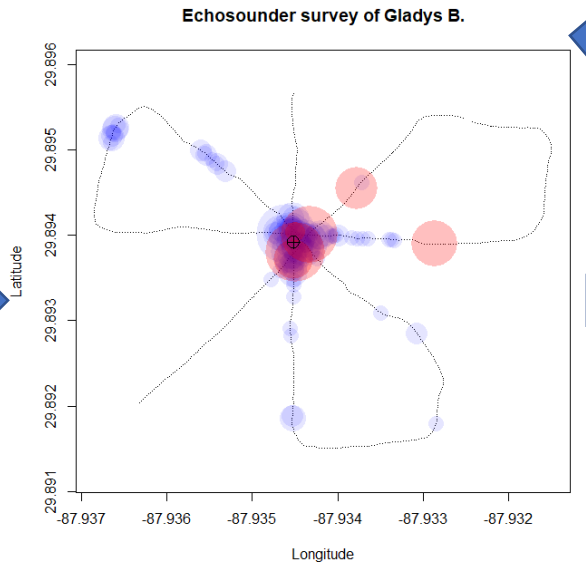


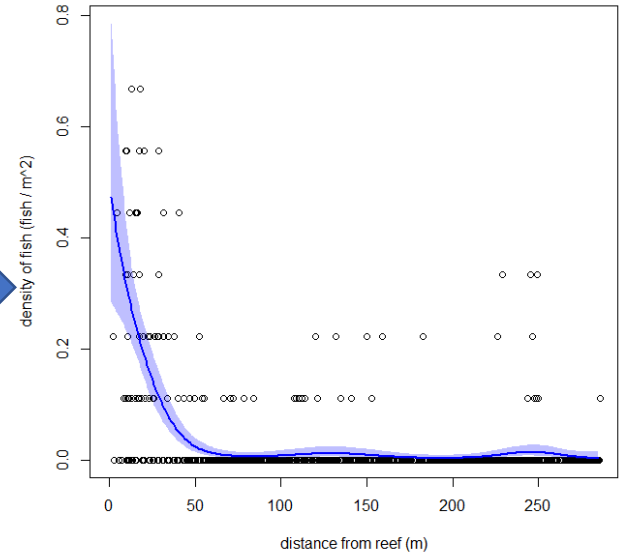


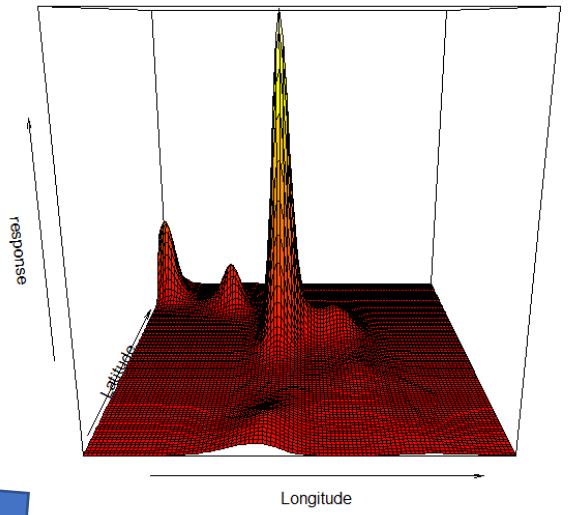
Echosounder analysis

- Manual counts of fish from echosounder data
- Two modelling approaches:
  - Fit GAM to estimate density as function of distance from reef - area under curve (rotated around center point) gives est. of absolute abundance
  - Fit spatial GAM to estimate density across area - area under surface gives est. of absolute abundance





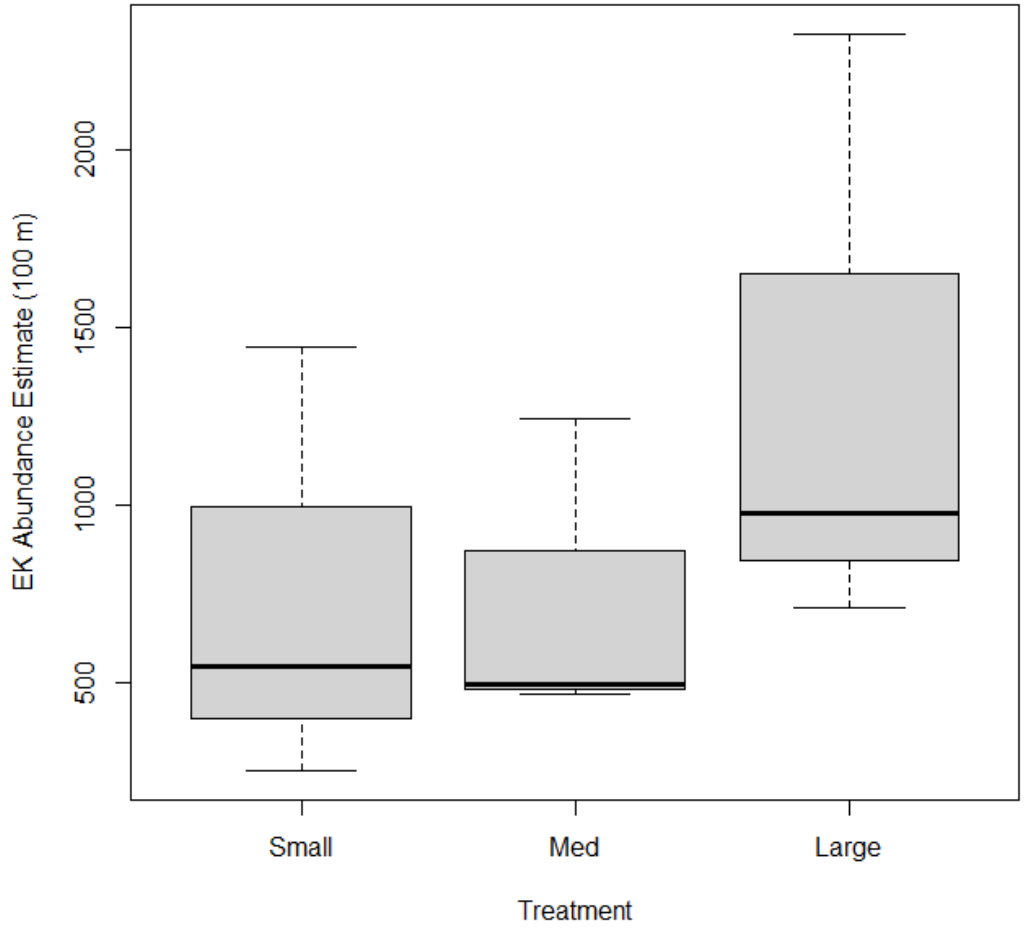




Preliminary echosounder results: non baitfish

- Estimated number of fish within 100m from center of reef (~31.4ha)
- Includes all species and all sizes (except baitfish)

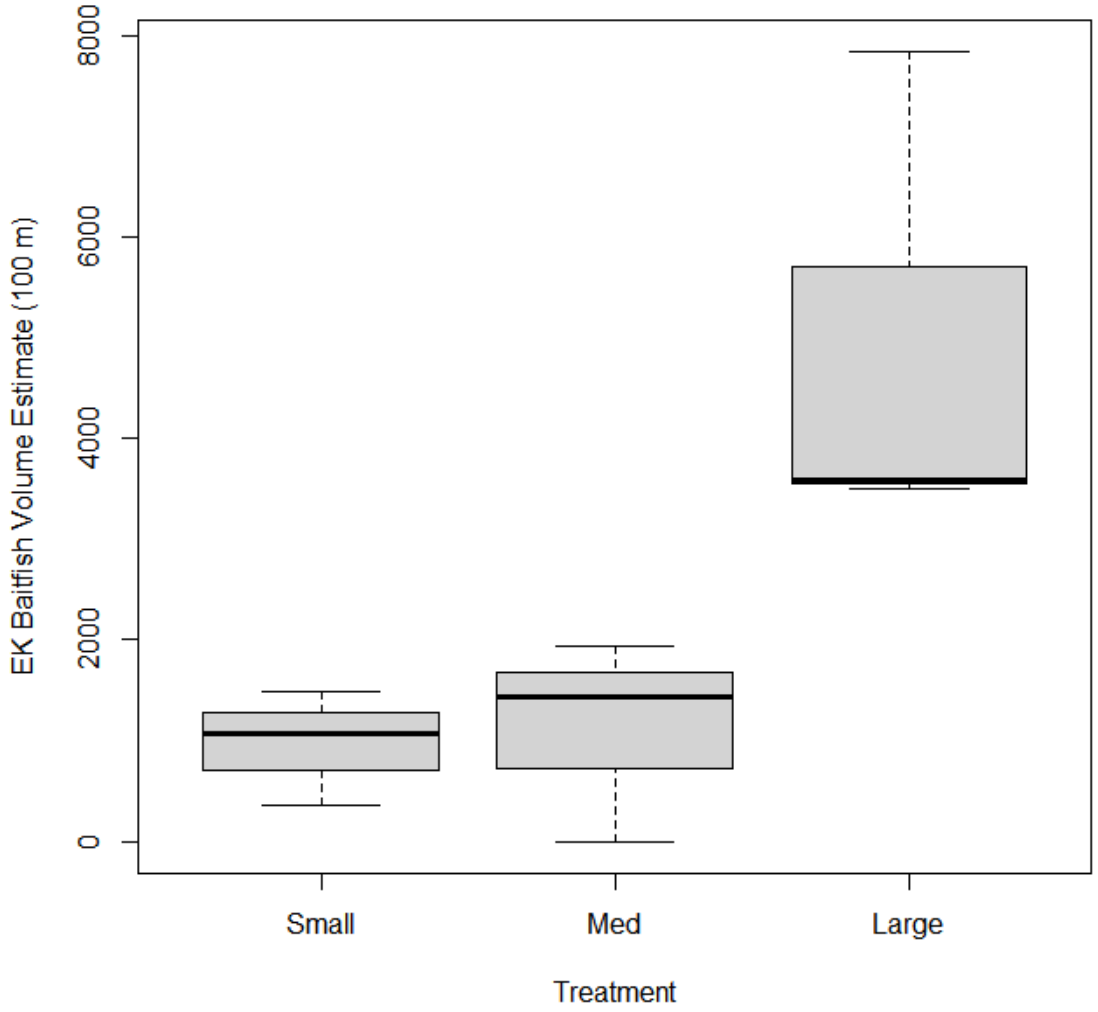
- No significant difference between Small and Medium
- 1.8 times higher on Large than Small (95% CI: 1.7-1.9)
- 1.8 times higher on Large than Medium (95% CI: 1.7-1.9)



Preliminary echosounder results: baitfish

- Estimated volume of baitfish within 100m from center of reef (~31.4ha)
- Includes baitfish (too small to discern individual targets)

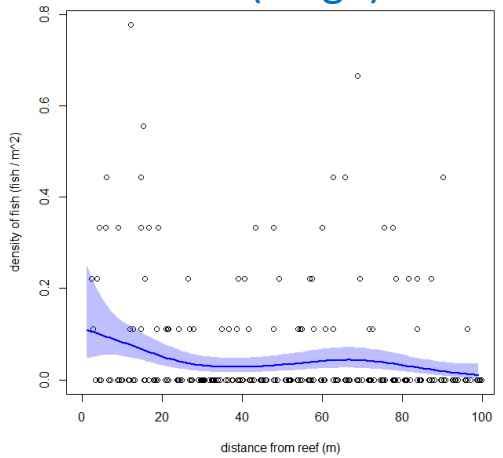
- 1.15 times higher on Medium than Small (95% CI: 1.10-1.22)
- 5.13 times higher on Large than Small (95% CI: 4.93-5.34)
- 4.44 times higher on Large than Medium (95% CI: 4.27-4.61)



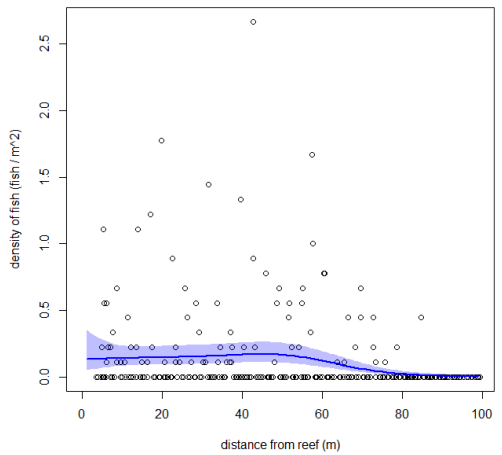
Echosounder results: caveats

- Current estimates may not capture the entire halo of fish around Large reefs and may be too low for these reefs
  - Working to account for this with alternative spatial density models and better reef maps
- Current estimates are for numerical abundance of non-baitfish and ignore any differences in fish size among the reefs
  - We are working on calculating estimates of biomass for baitfish and non-baitfish

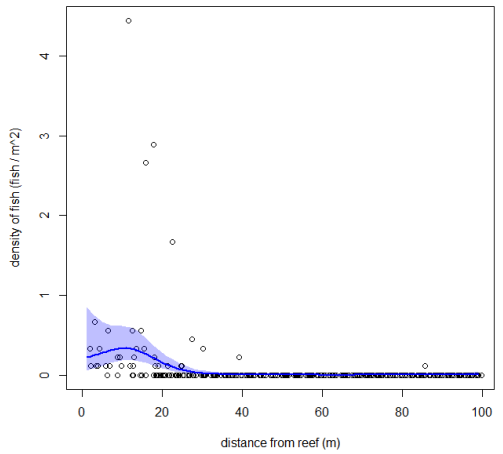
Lulu (Large)



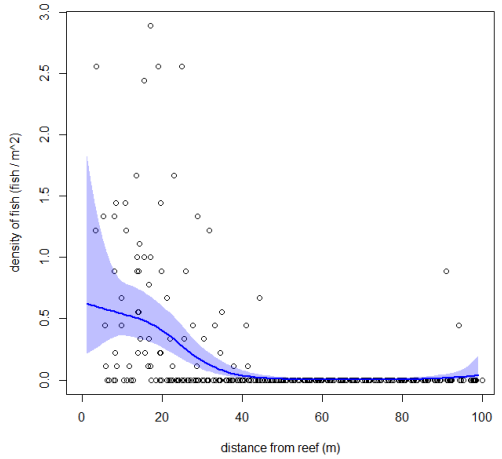
New Venture (Large)



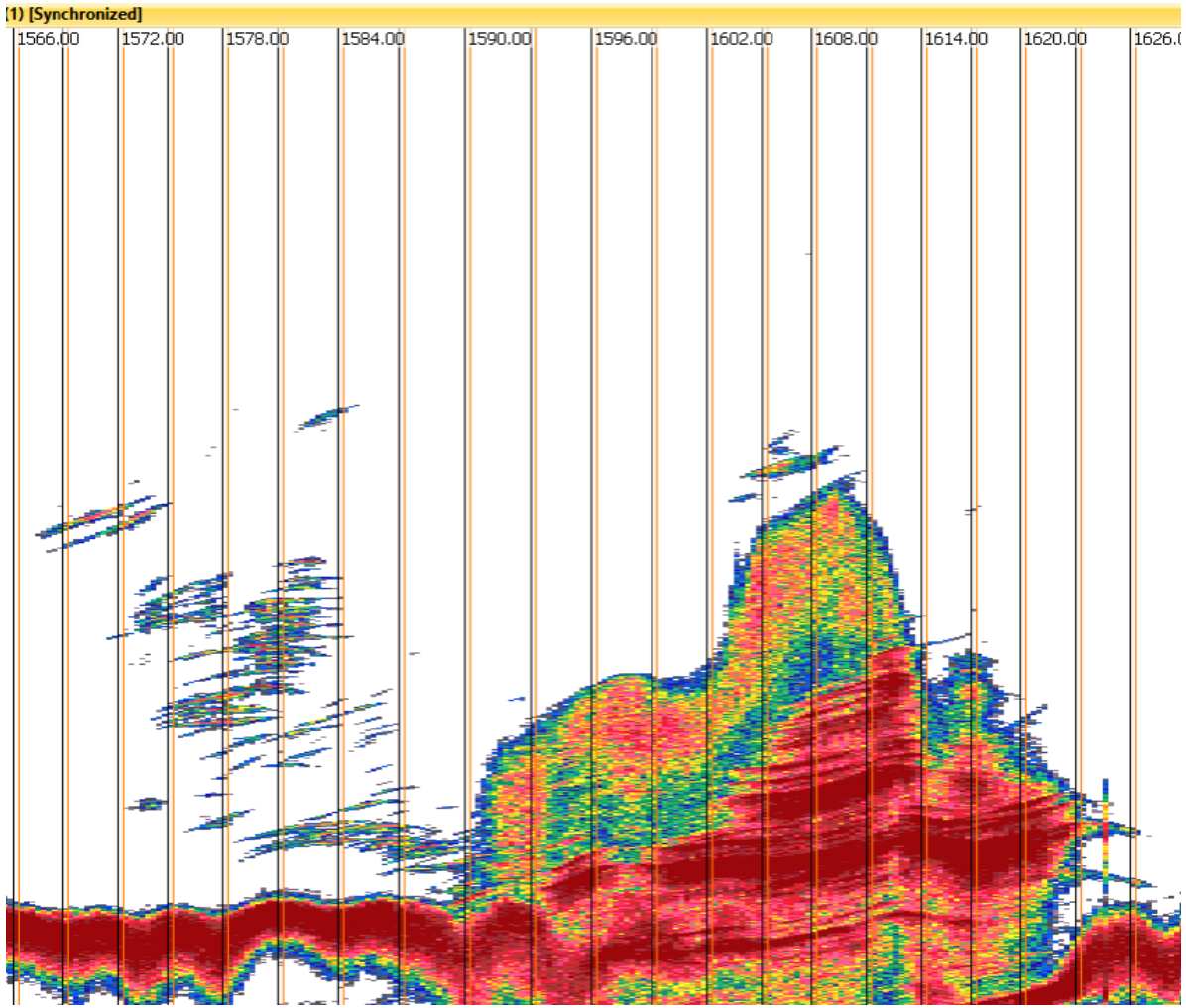
Super pyramid (Medium)

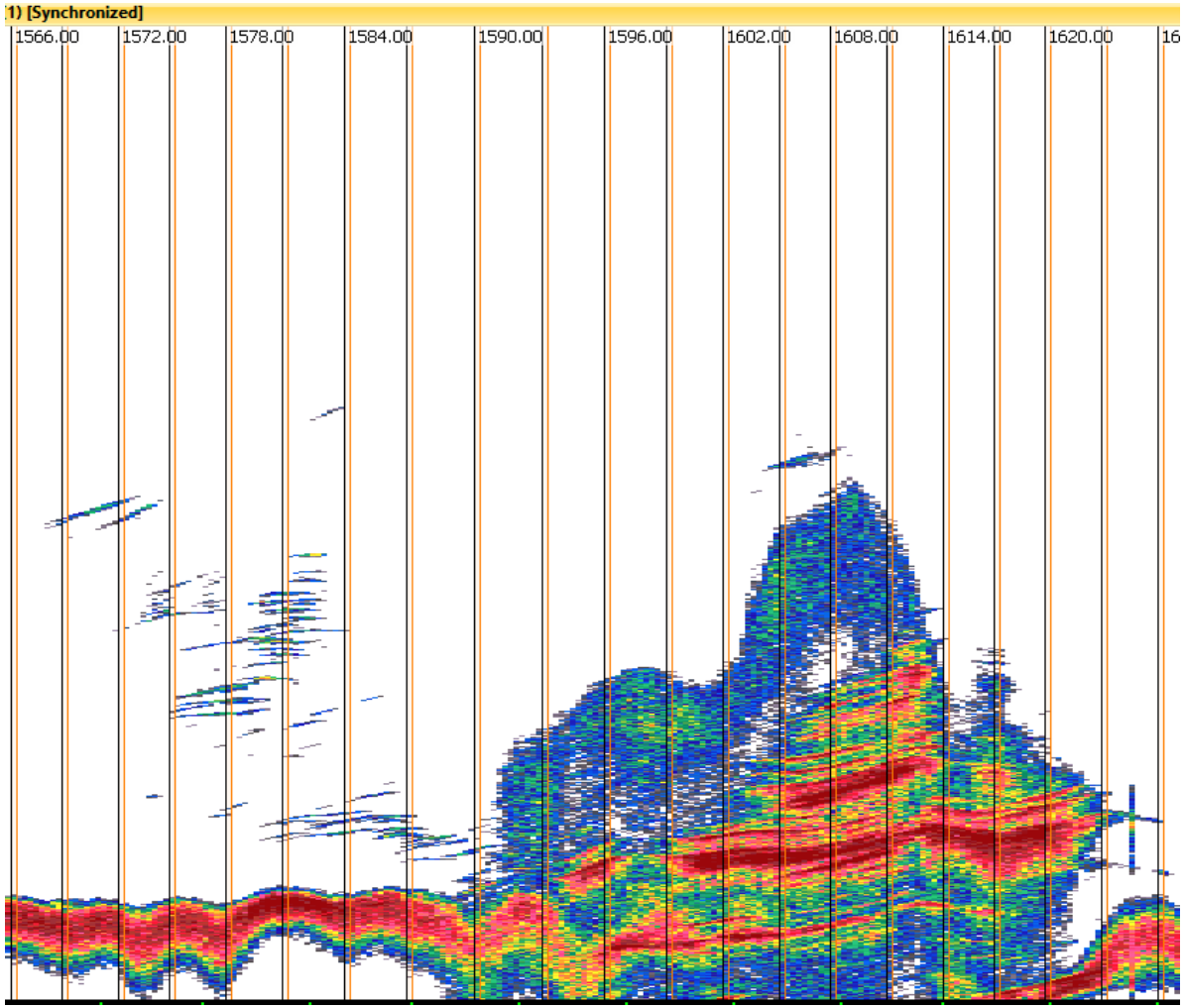


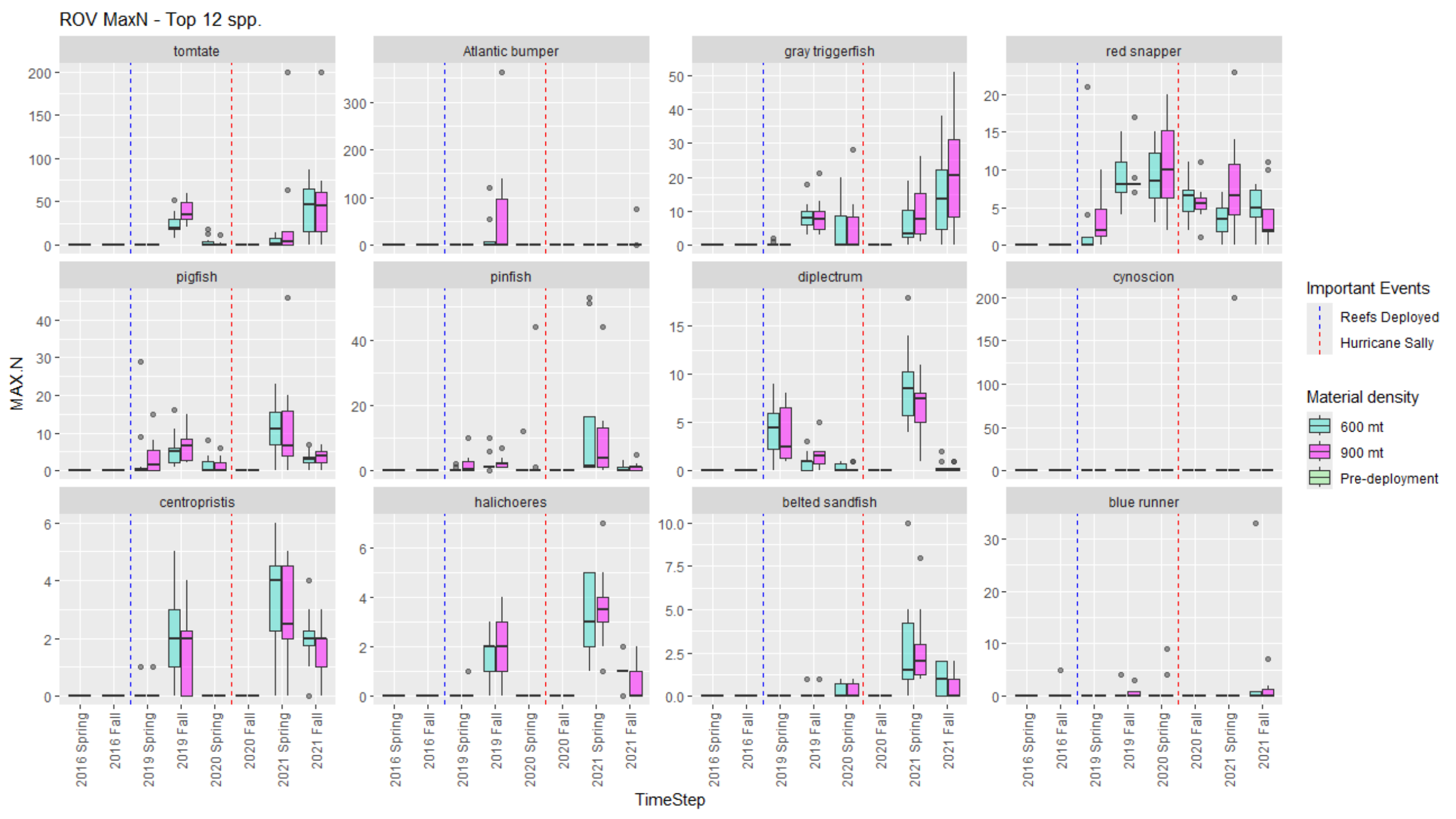
Standard pyramid (Small)



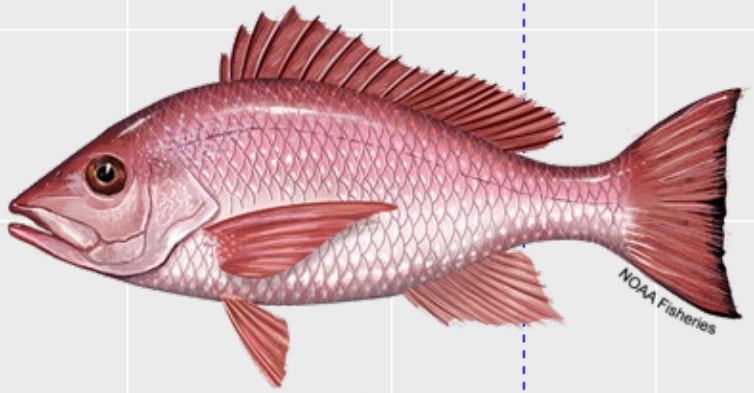
Baitfish around Gladys B.






ROV MaxN - Top 12 spp.
tomtate
Atlantic bumper
gray triggerfish
red snapper
pigfish
pinfish
diplectrum
cynoscion
centropristis
halichoeres
belted sandfish
blue runner
MAX.N
TimeStep
2016 Spring
2016 Fall
2019 Spring
2019 Fall
2020 Spring
2020 Fall
2021 Spring
2021 Fall
Important Events
Reefs Deployed
Hurricane Sally
Material density
600 mt
900 mt
Pre-deployment

Sabiki CPUE (fish/3-rigs) - Red Snapper



COUNT

10

5

0

2016 Spring

2016 Fall

2019 Spring

2019 Fall

2020 Spring

2020 Fall

2021 Spring

2021 Fall

TimeStep

Important Events

Reefs Deployed

Hurricane Sally

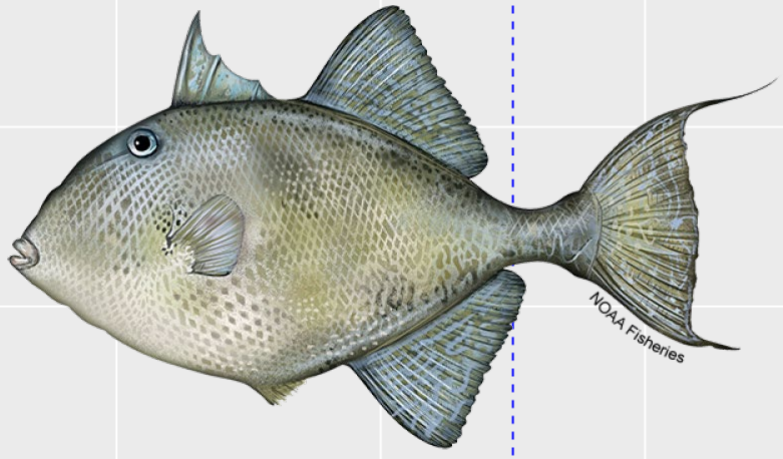
Material density

600 mt

900 mt

Pre-deployment

Sabiki CPUE (fish/3-rigs) - Gray Triggerfish



COUNT

15
10
5
0

2016 Spring
2016 Fall
2019 Spring
2019 Fall
2020 Spring
2020 Fall
2021 Spring
2021 Fall

TimeStep

Important Events
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Material density
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900 mt
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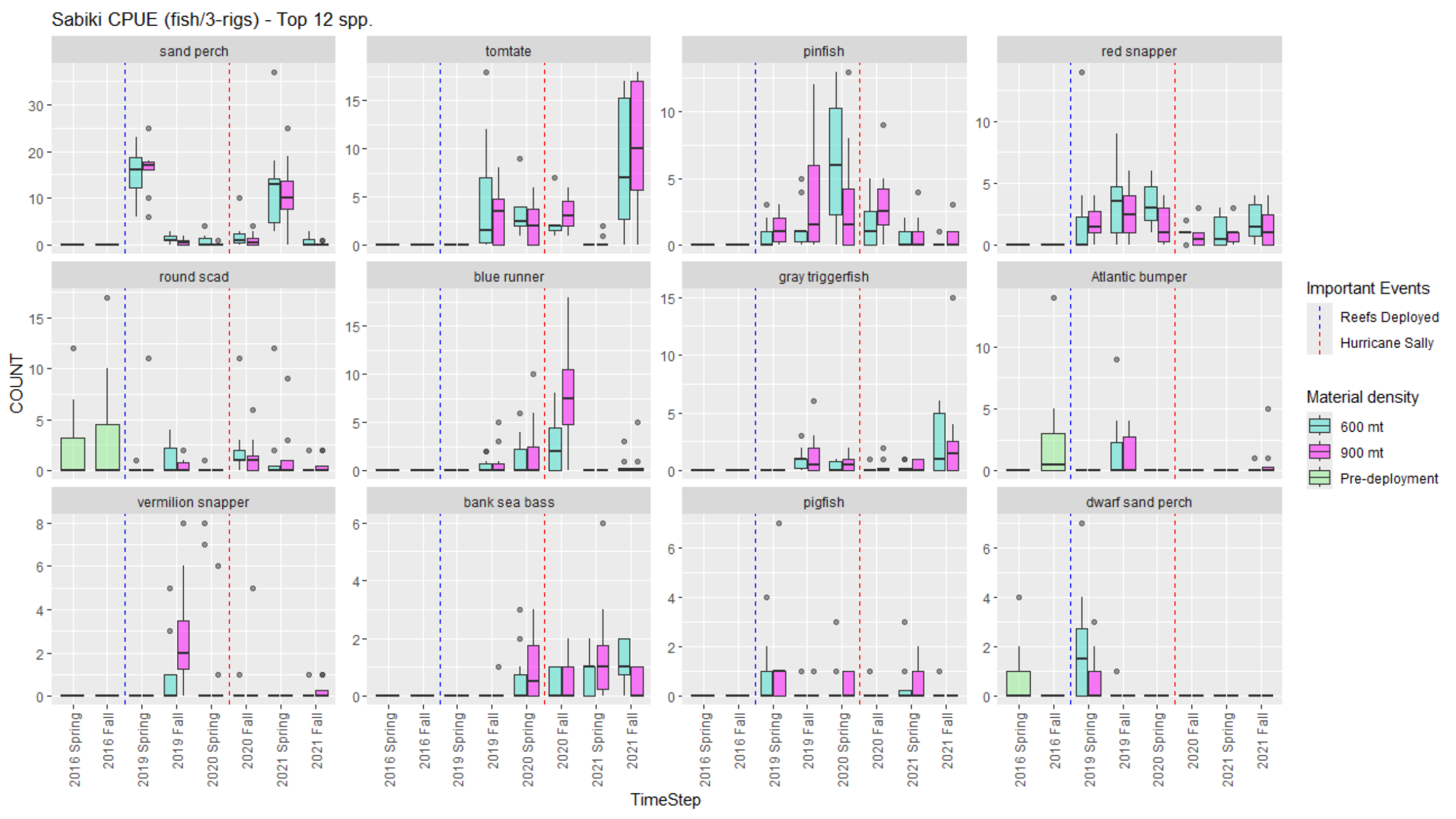
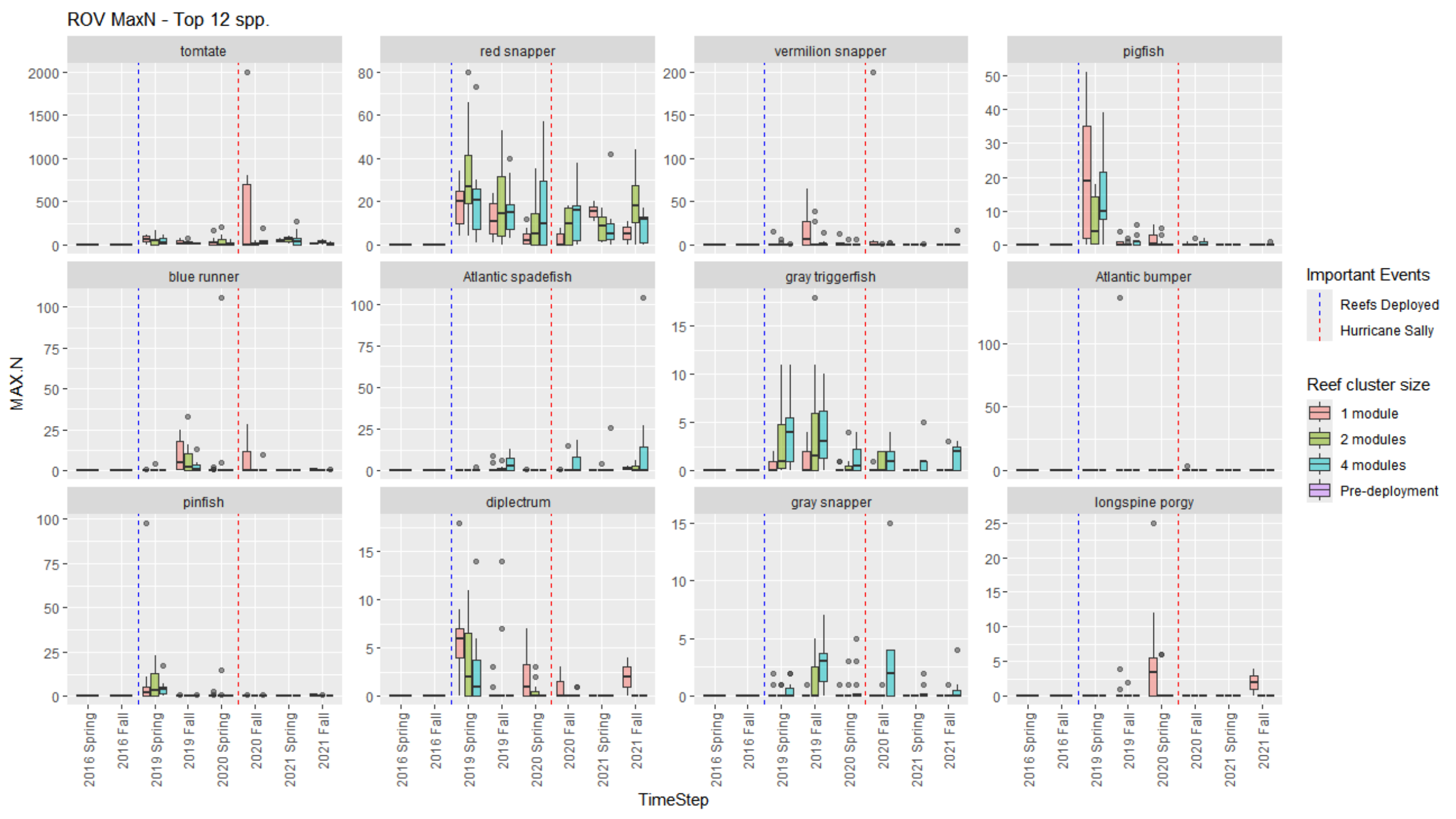
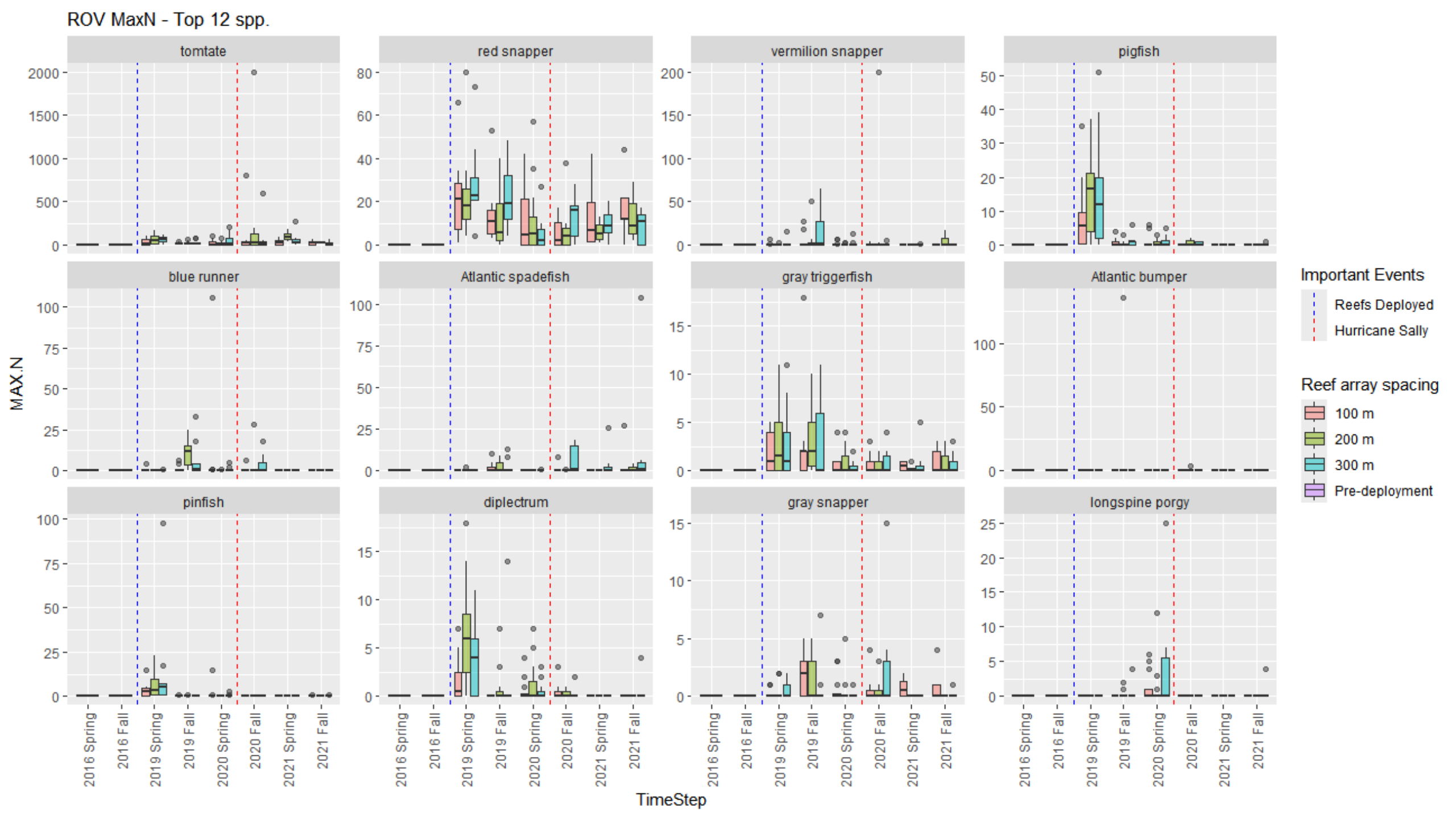

Sabiki CPUE (fish/3-rigs) - Top 12 spp.
sand perch
tomtate
pinfish
red snapper
round scad
blue runner
gray triggerfish
Atlantic bumper
vermilion snapper
bank sea bass
pigfish
dwarf sand perch
COUNT
TimeStep
2016 Spring
2016 Fall
2019 Spring
2019 Fall
2020 Spring
2020 Fall
2021 Spring
2021 Fall
Important Events
Reefs Deployed
Hurricane Sally
Material density
600 mt
900 mt
Pre-deployment


ROV MaxN - Top 12 spp.
tomtate
red snapper
vermilion snapper
pigfish
blue runner
Atlantic spadefish
gray triggerfish
Atlantic bumper
pinfish
diplectrum
gray snapper
longspine porgy
MAX.N
TimeStep
2016 Spring
2016 Fall
2019 Spring
2019 Fall
2020 Spring
2020 Fall
2021 Spring
2021 Fall
Important Events
Reefs Deployed
Hurricane Sally
Reef cluster size
1 module
2 modules
4 modules
Pre-deployment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Atlantic bumper
pinfish
diplectrum
gray snapper
longspine porgy
MAX.N
TimeStep
2016 Spring
2016 Fall
2019 Spring
2019 Fall
2020 Spring
2020 Fall
2021 Spring
2021 Fall
Important Events
Reefs Deployed
Hurricane Sally
Reef array spacing
100 m
200 m
300 m
Pre-deployment