Indices of abundance in the Gulf of Mexico reef fish complex: A comparative approach using spatial data from vessel monitoring systems

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Overview

Comparative analysis using spatial data from vessel monitoring systems

Introduction

What does this fishery look like?

Objective

Can VMS data be used to reliably create relative abundance indices?

Comparison #1

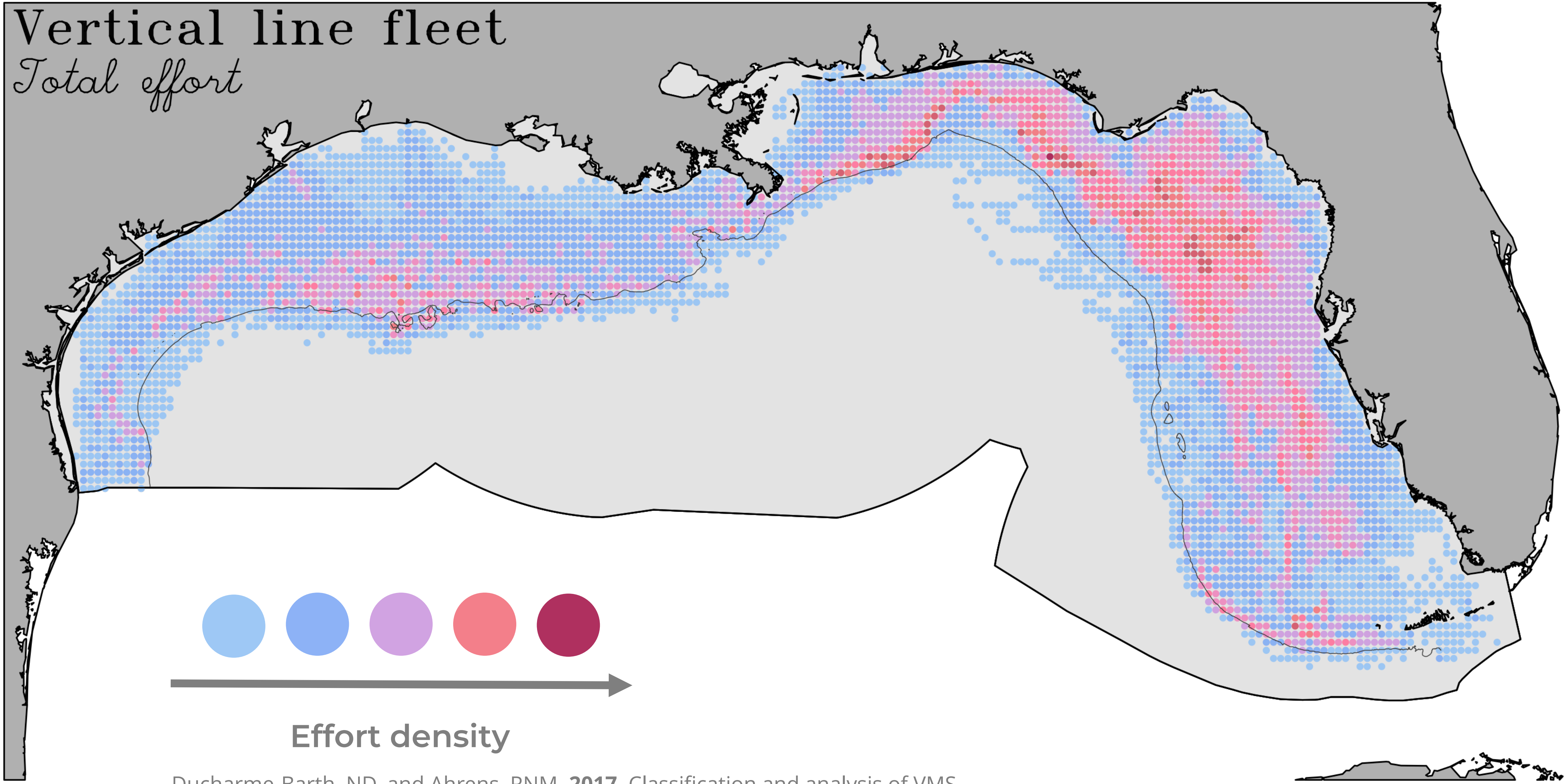
VMS v. delta-GLM

Comparison #2

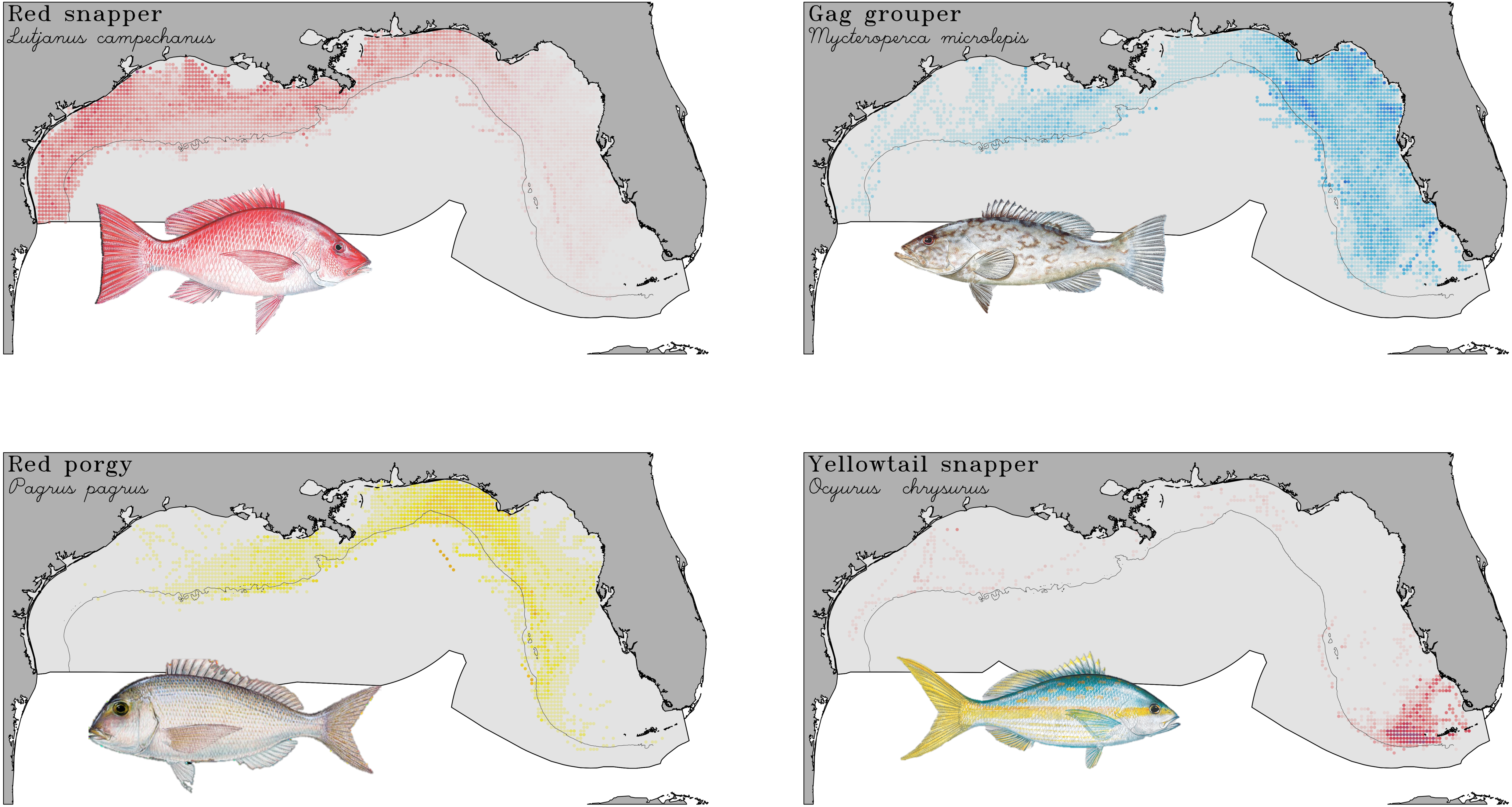
VMS v. delta-GLMM (VAST)

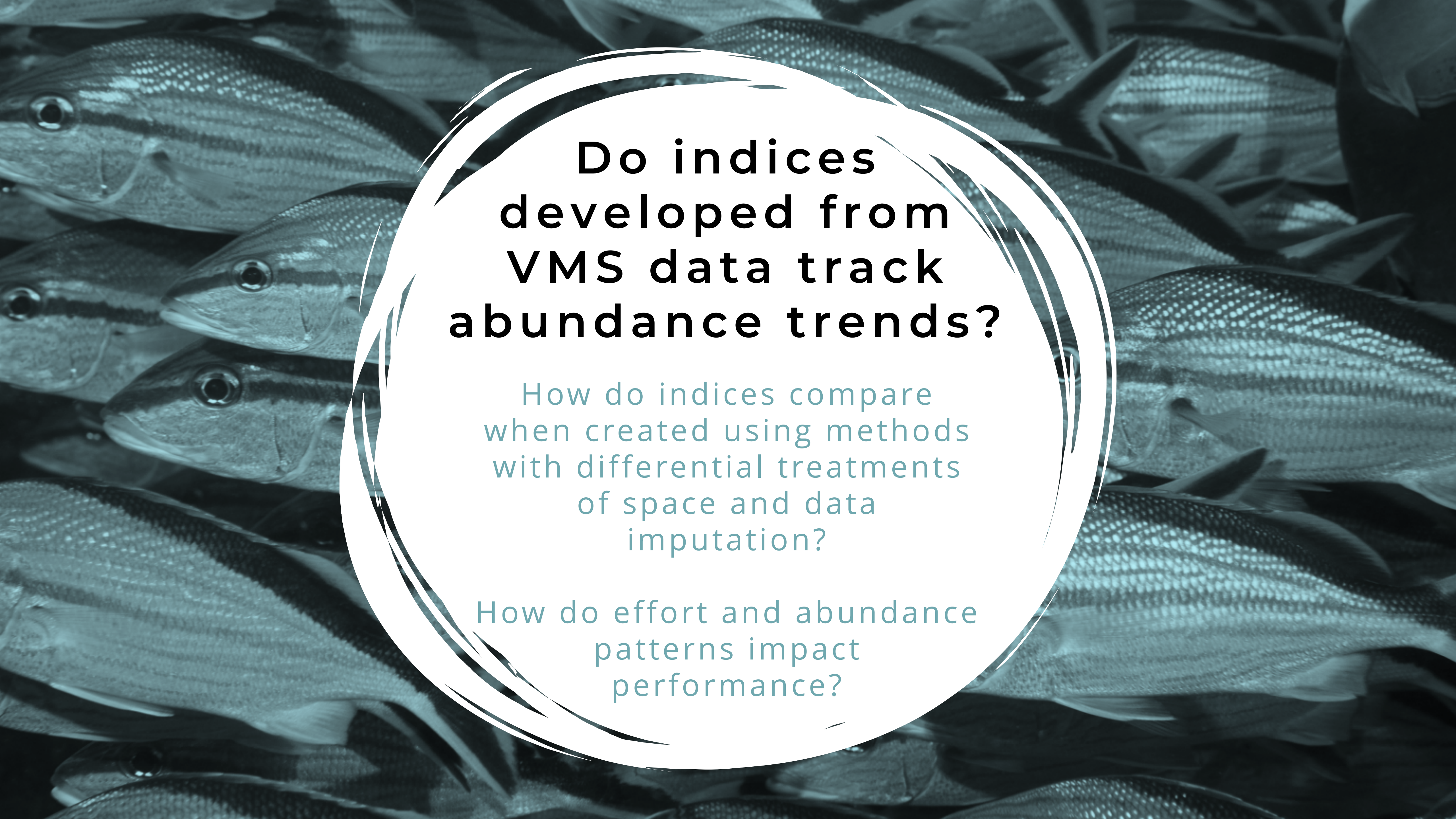
Conclusions

Under what situations do the methods succeed? Fail?



Ducharme-Barth, ND, and Ahrens, RNM. **2017**. Classification and analysis of VMS data in vertical line fisheries: incorporating uncertainty into spatial distributions. *Canadian Journal of Fisheries and Aquatic Sciences 74 (11), 1749-1764.*


Red snapper
Lutjanus campechanus
Gag grouper
Mycteroperca microlepis
Red porgy
Pagrus pagrus
Yellowtail snapper
Ocyurus chrysurus



Do indices developed from VMS data track abundance trends?

How do indices compare when created using methods with differential treatments of space and data imputation?

How do effort and abundance patterns impact performance?

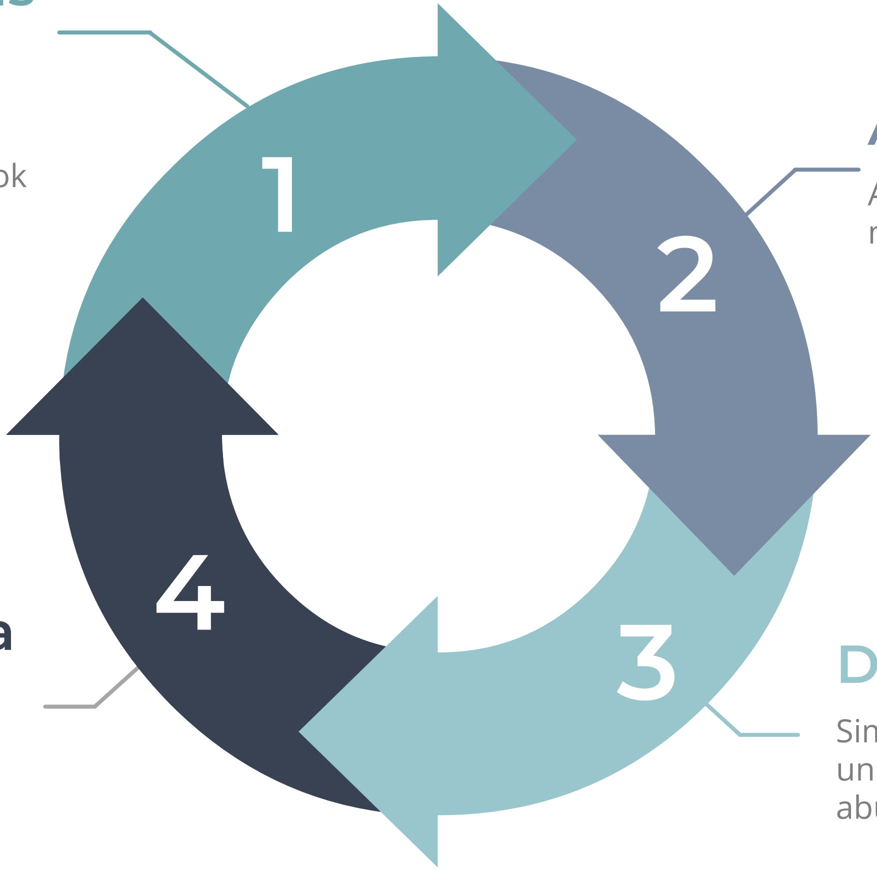
Comparative approach

Define index methods

VMS: temporal imputation and spatial averaging of VMS CPUE distribution

delta-GLM: standardize logbook catch records

delta-GLMM: spatiotemporal smoothing and imputation of VMS CPUE distribution using VAST



Apply to real data

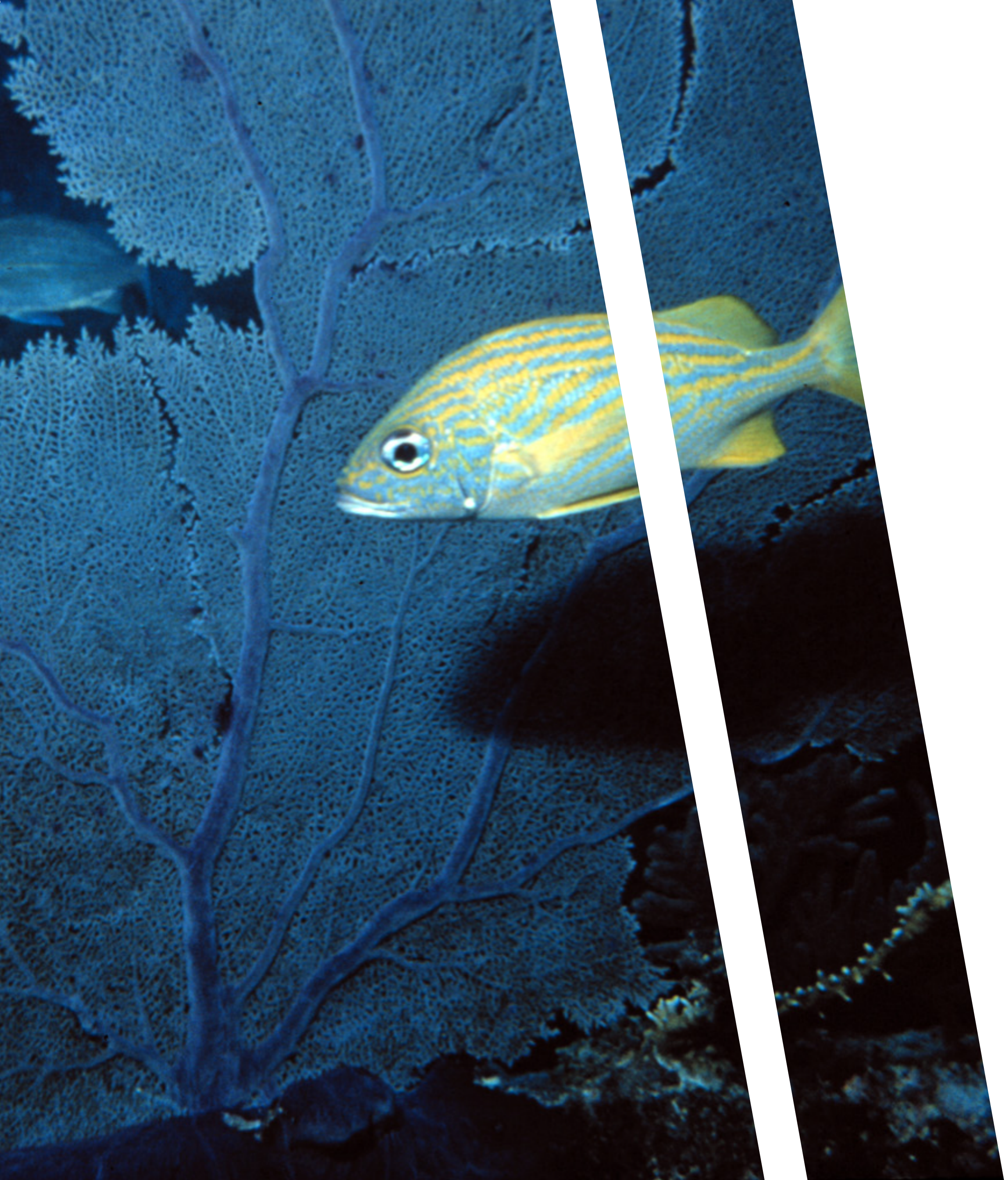
Assess index agreement across multiple species

Define simulations

Simulate fisheries dependent data under a variety of effort and abundance patterns

Apply to simulated data

Assess ability to recover the true abundance trend using each method



Comparison #1

VMS

Folly – Fantasy filling (Walters 2003) of spatial CPUE distributions

Identify temporal "holes" in the distributions

Interpolate "holes" with average of previous two time periods

Spatially average across years for annual relative abundance

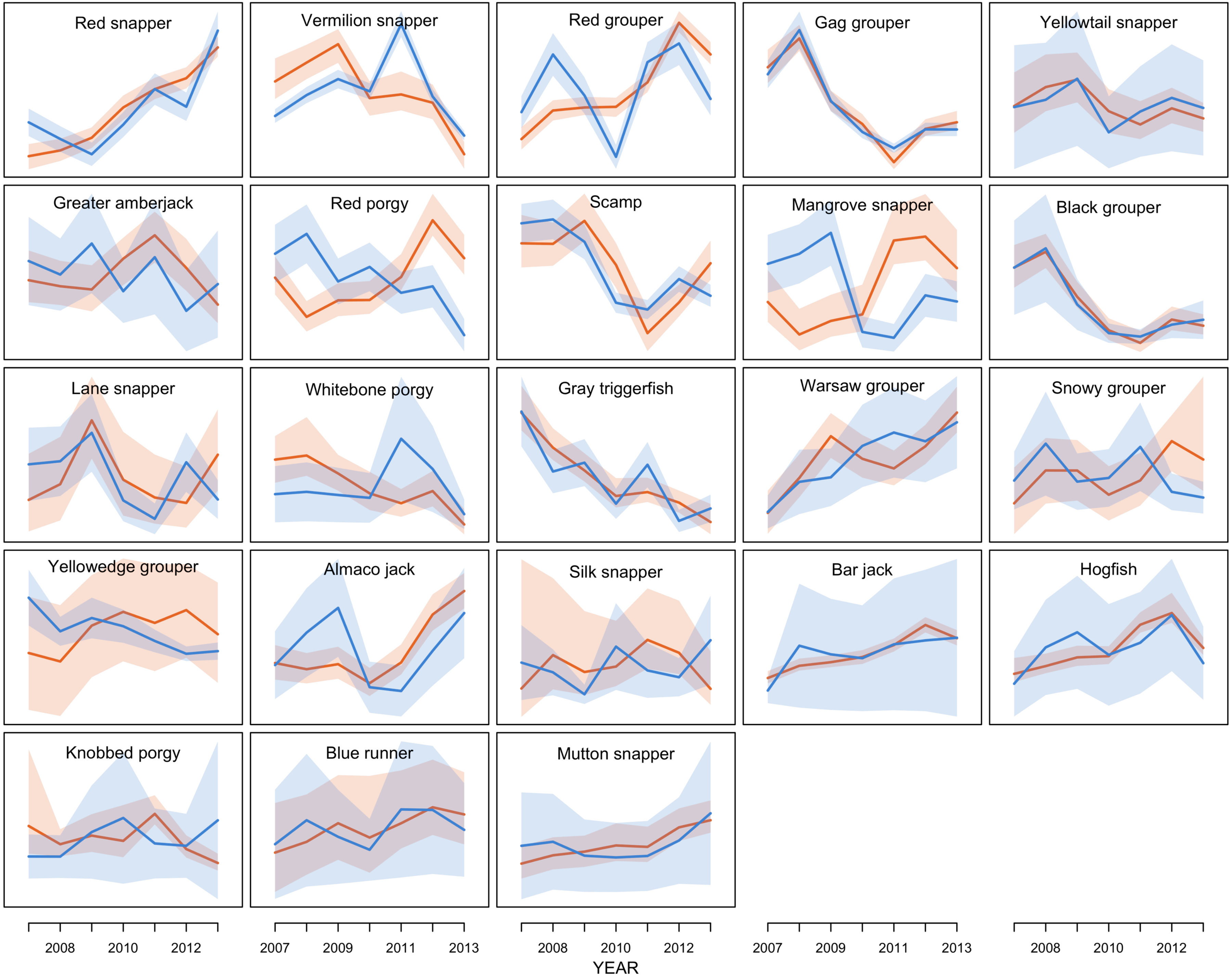
dGLM

Identify trips targeting species using logistic regression (Stephens-MacCall 2004)

Use delta-GLM with spatial strata and covariates to model probability of encounter and positive catch rate based on commercial logbook catch records

Average predictions across temporal and weighted spatial strata for annual relative abundance (Campbell 2015)

Ducharme-Barth, ND, Ahrens, RNM, and Shertzer, K. **2018**. Indices of abundance in the Gulf of Mexico reef fish complex: A comparative approach using spatial data from vessel monitoring systems . *Fisheries Research 198, 1-13.*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Gag grouper
Yellowtail snapper
Greater amberjack
Red porgy
Scamp
Mangrove snapper
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Lane snapper
Whitebone porgy
Gray triggerfish
Warsaw grouper
Snowy grouper
Yellowedge grouper
Almaco jack
Silk snapper
Bar jack
Hogfish
Knobbed porgy
Blue runner
Mutton snapper
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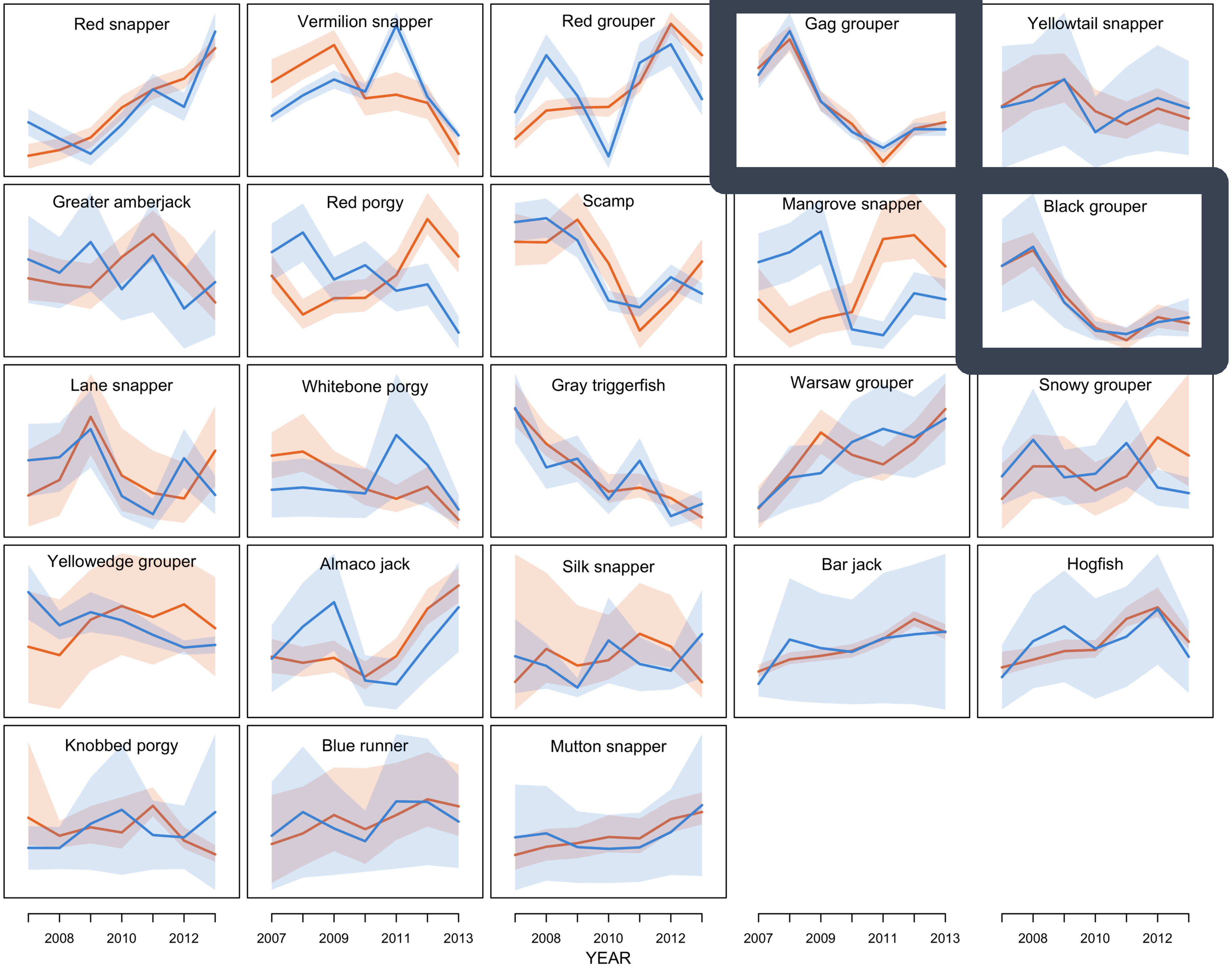
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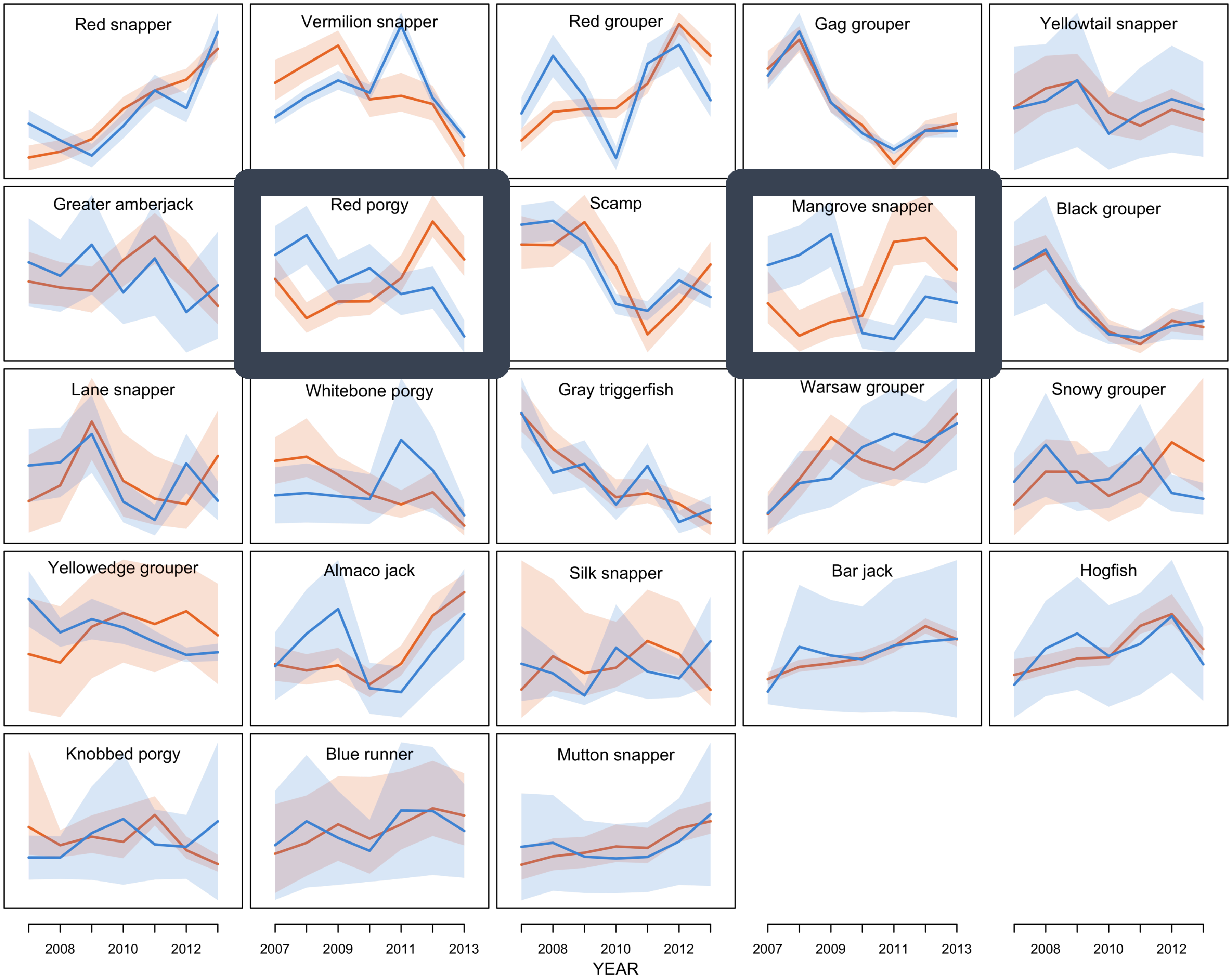
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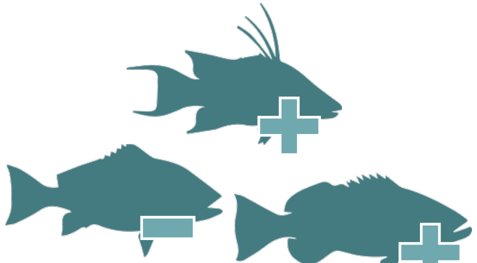
Fisheries dependent data

Simulation Design

Individual vessels and trips simulated over 7 years in a multi-species fishery. Effort is allocated spatially according to a gravity model. Catch and effort locations are recorded at the trip level for input into the VMS and delta-GLM methods.

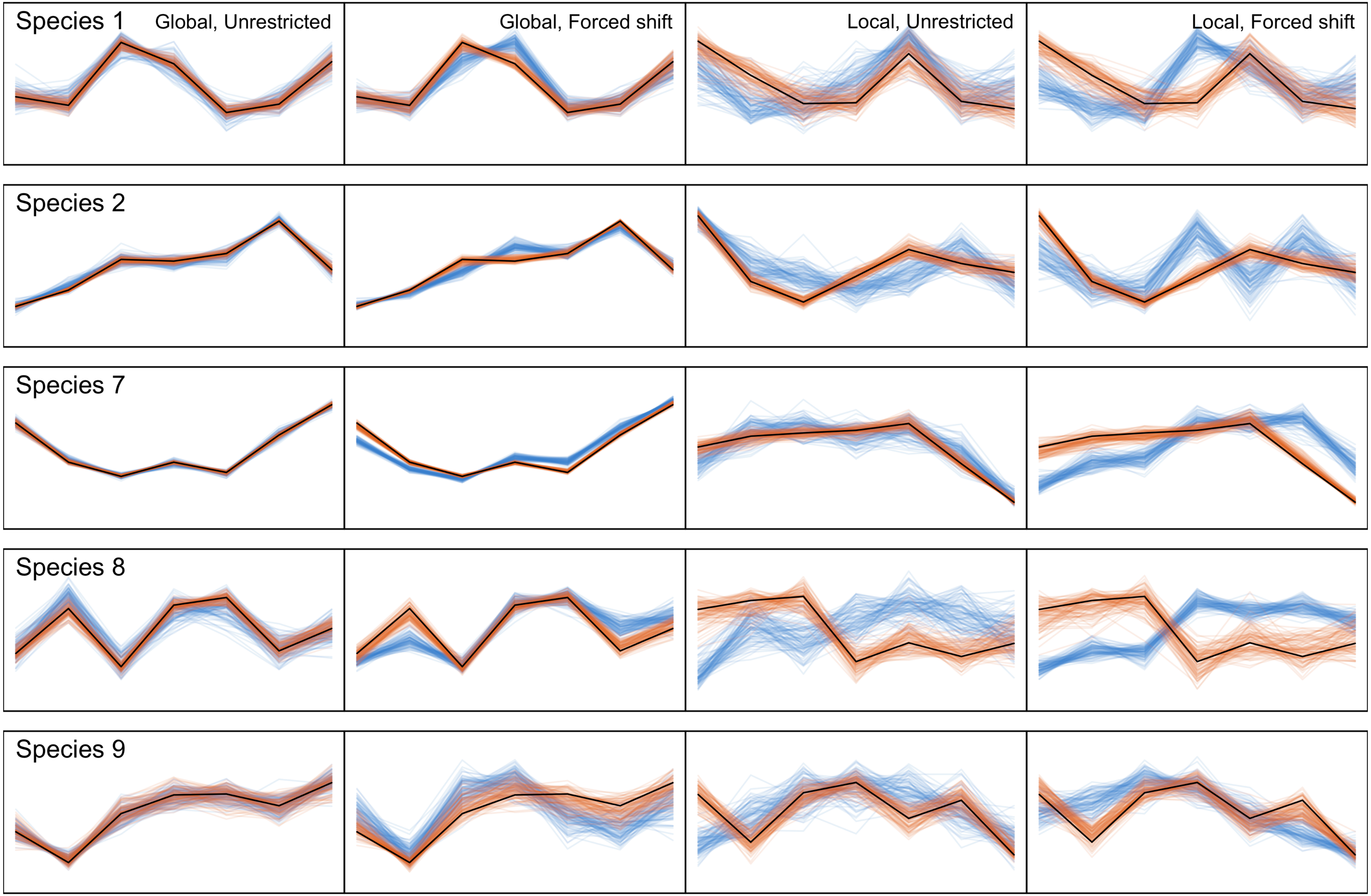


Species distribution

Consider two patterns in species abundance distributions: **global trends** and **local trends**.

Effort pattern

Consider two patterns in effort distributions: **unrestricted effort allocation** and **forced shift in regional targeting**.



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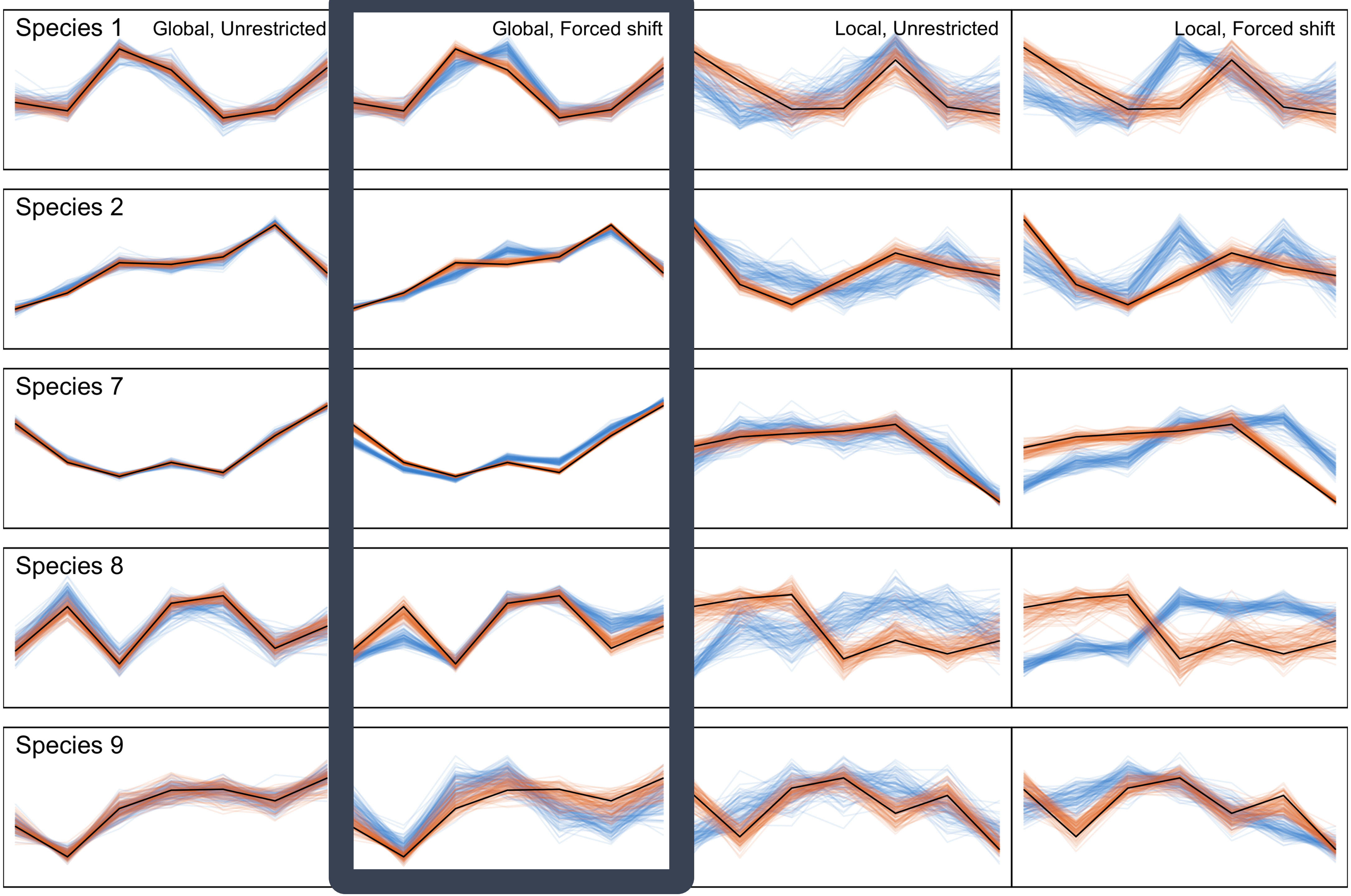
Global, Unrestricted
Global, Forced shift
Local, Unrestricted
Local, Forced shift
Species 2
Species 7
Species 8
Species 9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Global, Forced shift
Local, Unrestricted
Local, Forced shift
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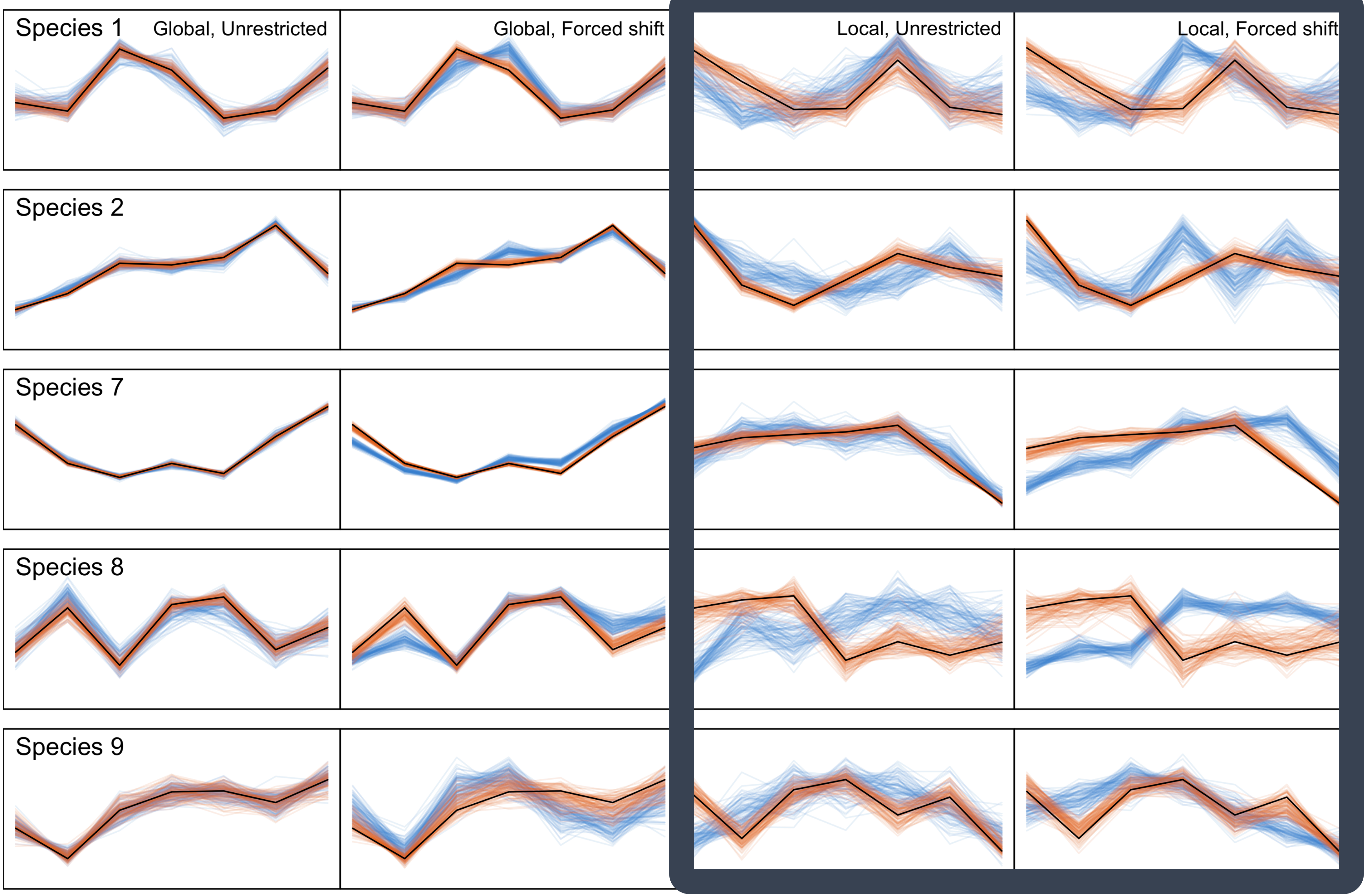
Species 7
Species 8
Species 9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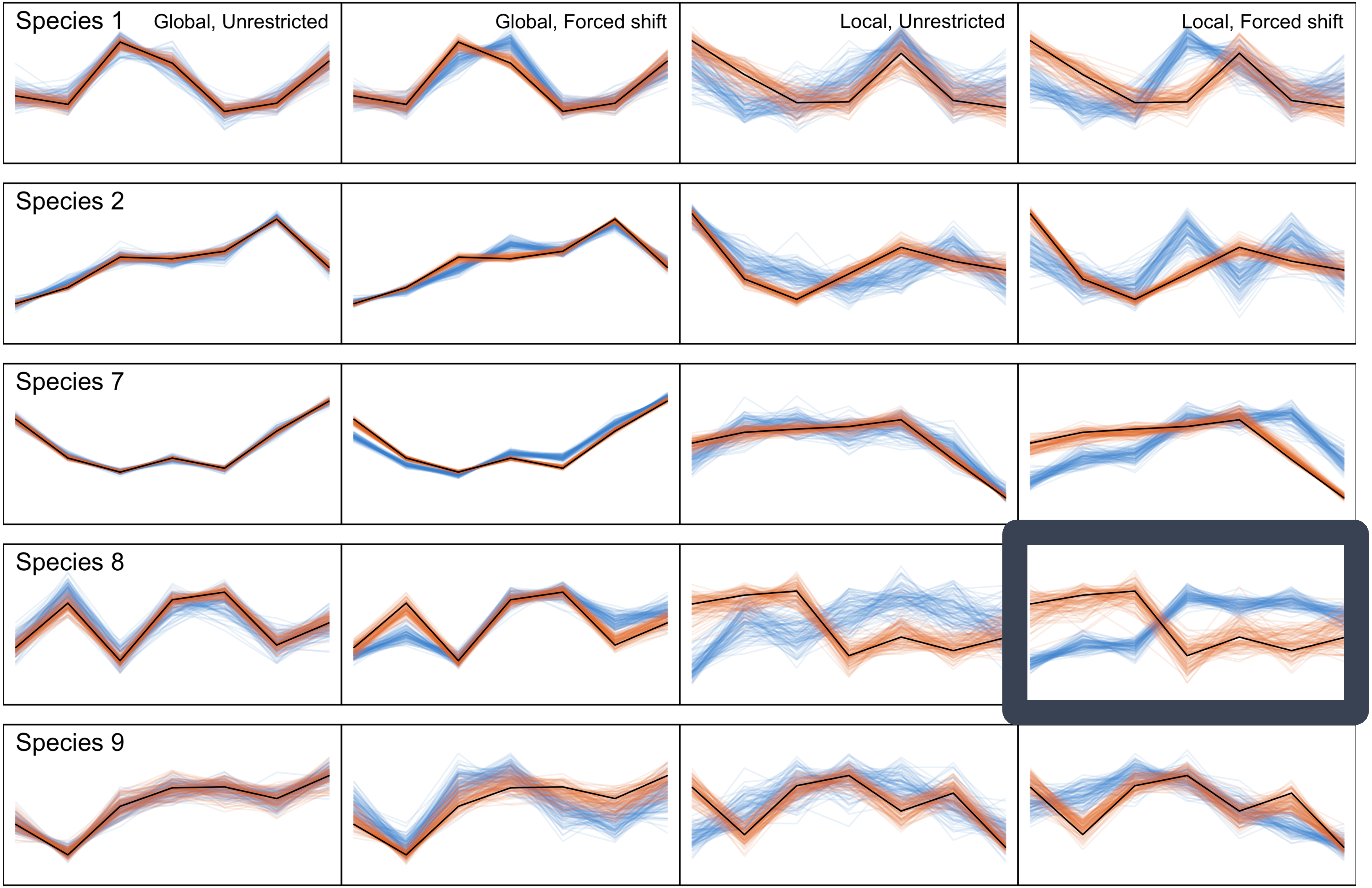
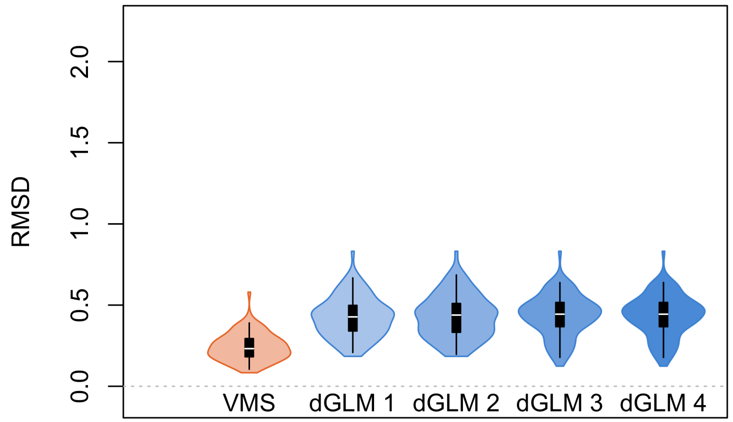
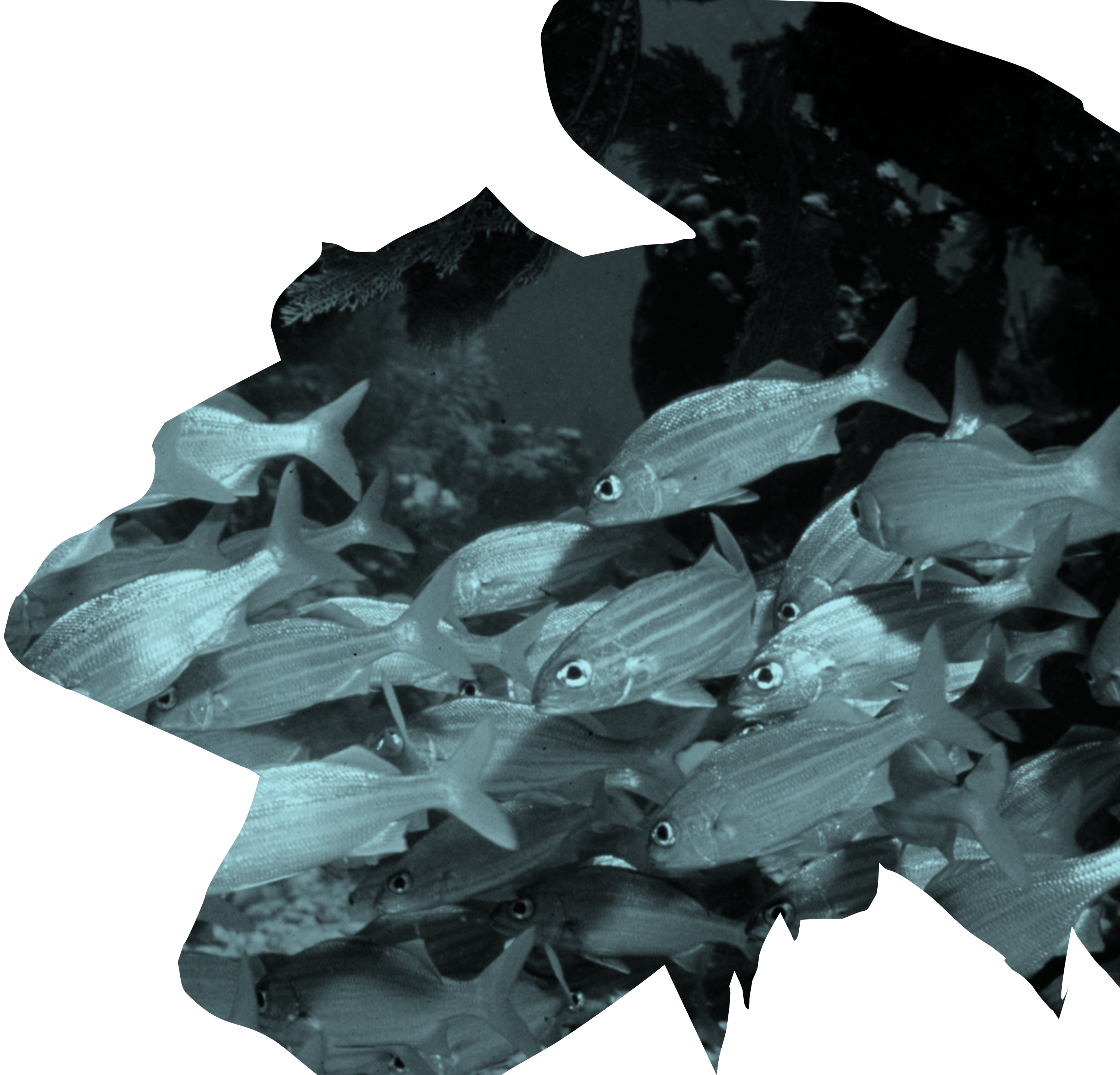
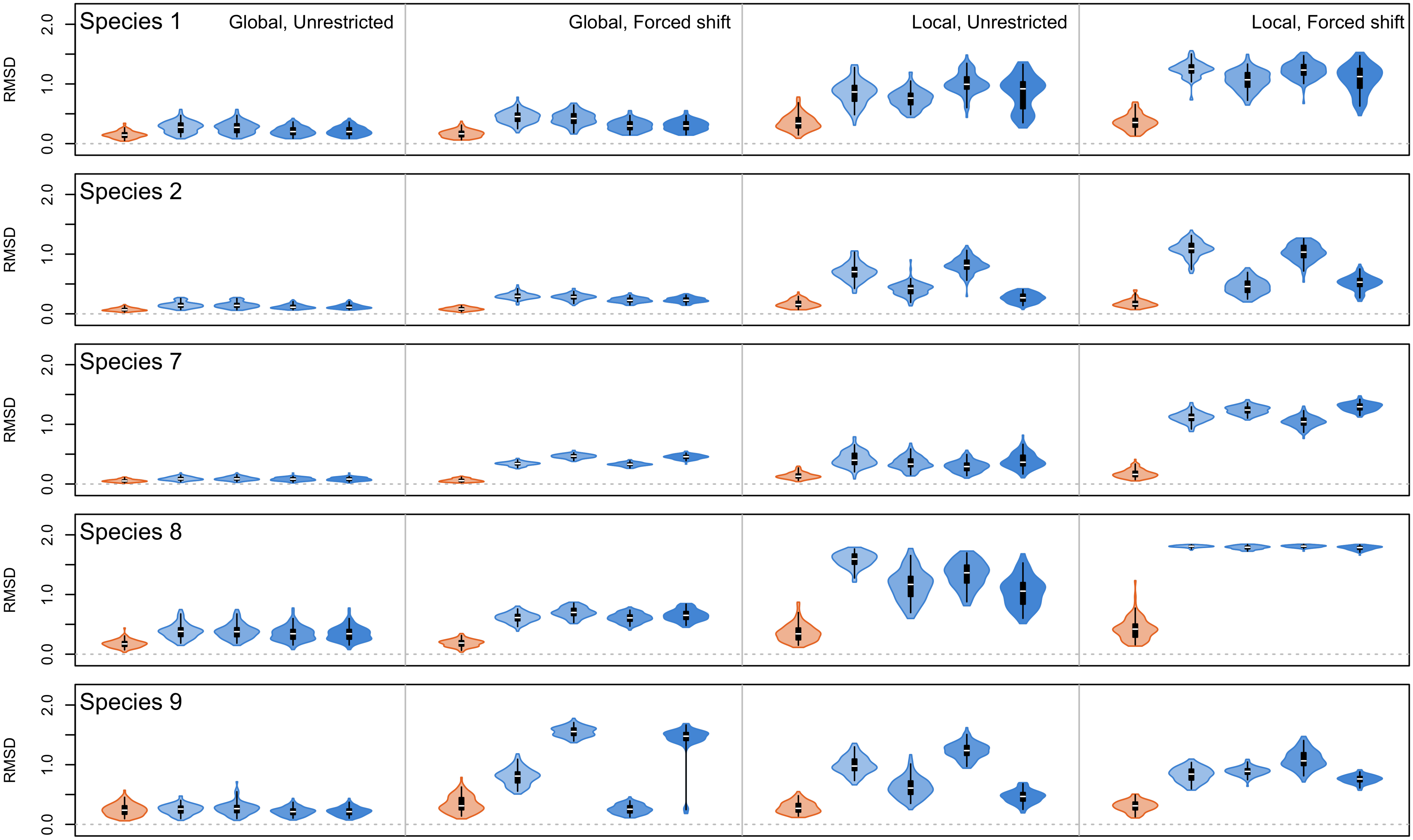

Species 1
Global, Unrestricted
Global, Forced shift
Local, Unrestricted
Local, Forced shift
Species 2
Species 7
Species 8
Species 9

deltaGLM form

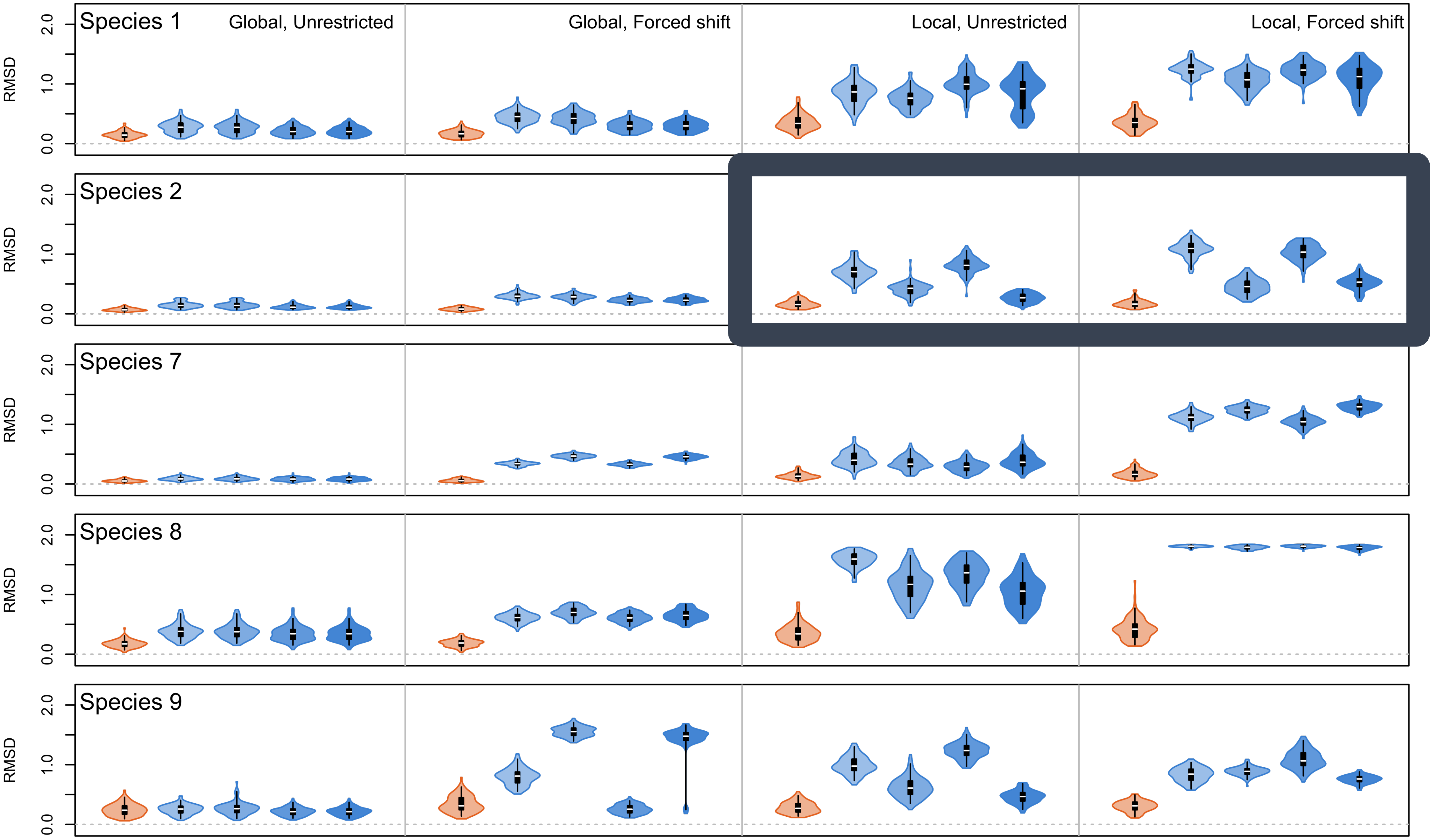
1. No spatiotemporal interaction & 4 spatial regions
2. Spatiotemporal interaction & 4 spatial regions
3. No spatiotemporal interaction & 10 spatial regions
4. Spatiotemporal interaction & 10 spatial regions







Species 1
Global, Unrestricted
Global, Forced shift
Local, Unrestricted
Local, Forced shift
Species 2
Species 7
Species 8
Species 9
RMSD
0.0
1.0
2.0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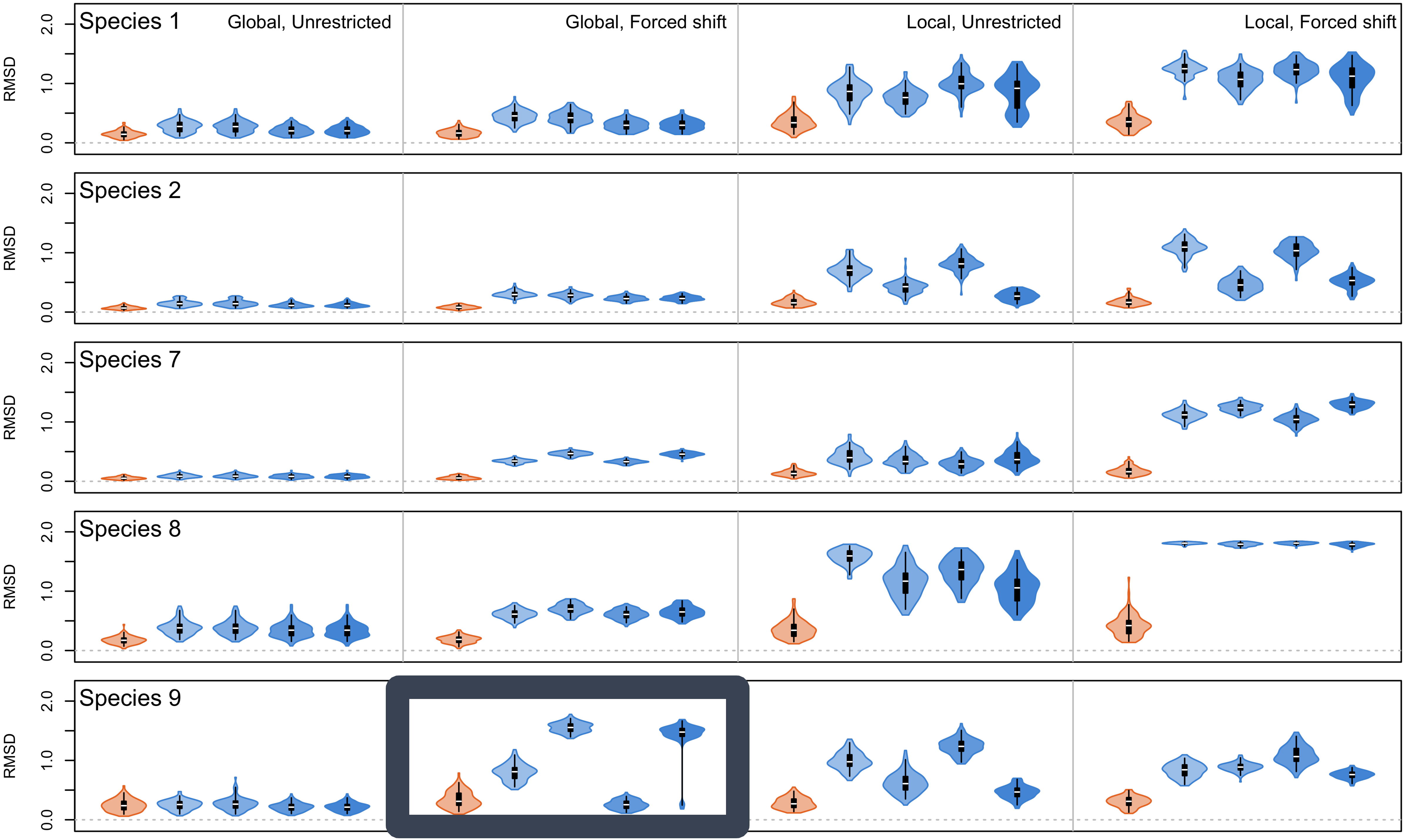

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Species 7
Species 8
Species 9
RMSD
0.0
1.0
2.0

Comparison #2

VMS

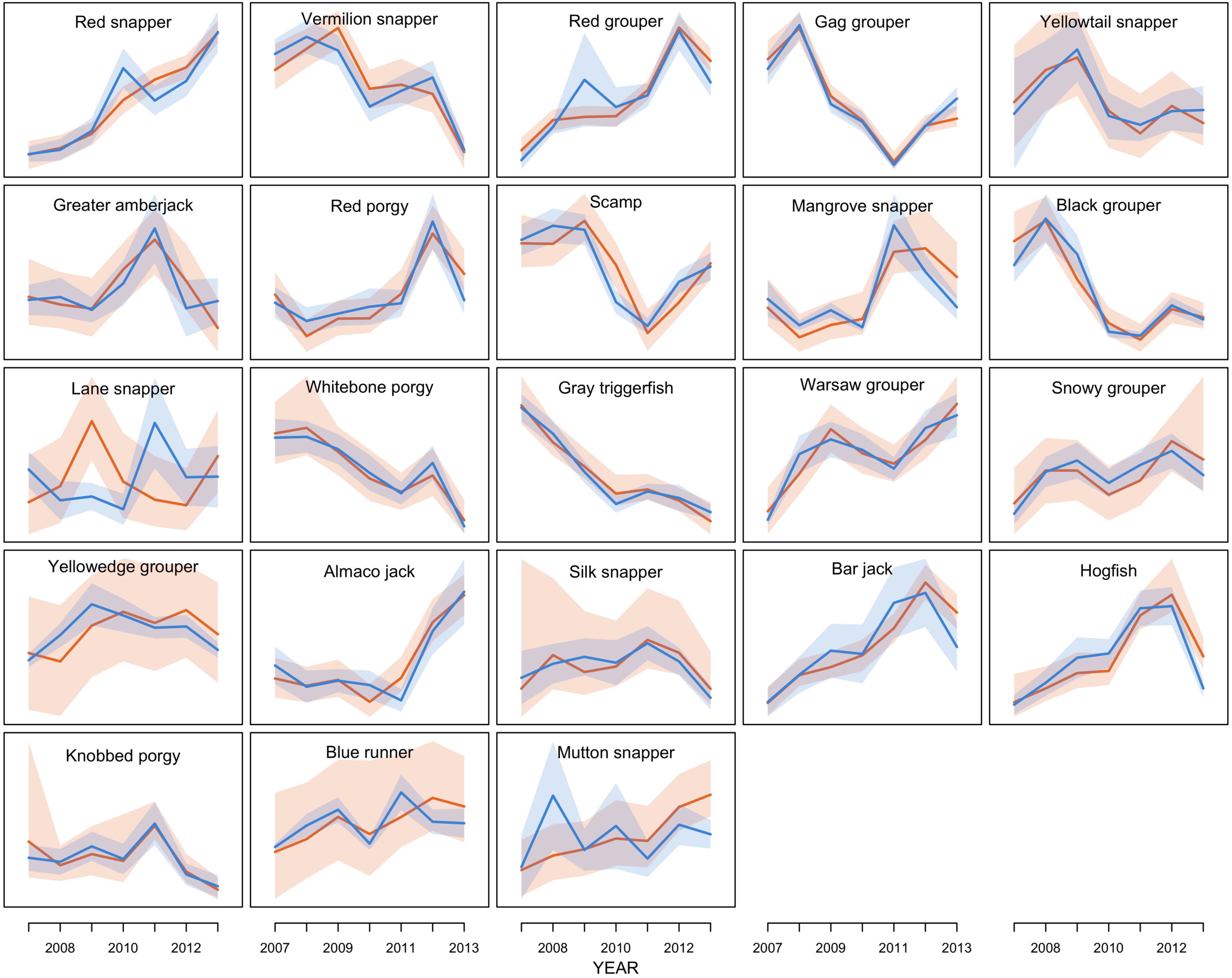
Same method as described previously. Unfished areas imputed as the temporal average of previous two occurrences.

dGLMM

Geostatistical extension of delta-GLMs implemented using the VAST package (Thorson et al 2015 *ICES J Mar Sci*; Thorson and Barnett 2017 *ICES J Mar Sci*).

Unfished areas are automatically imputed based on information from nearby samples.

Used 100 knots to approximate the random field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Silk snapper
Bar jack
Hogfish
Knobbed porgy
Blue runner
Mutton snapper
2008 2010 2012
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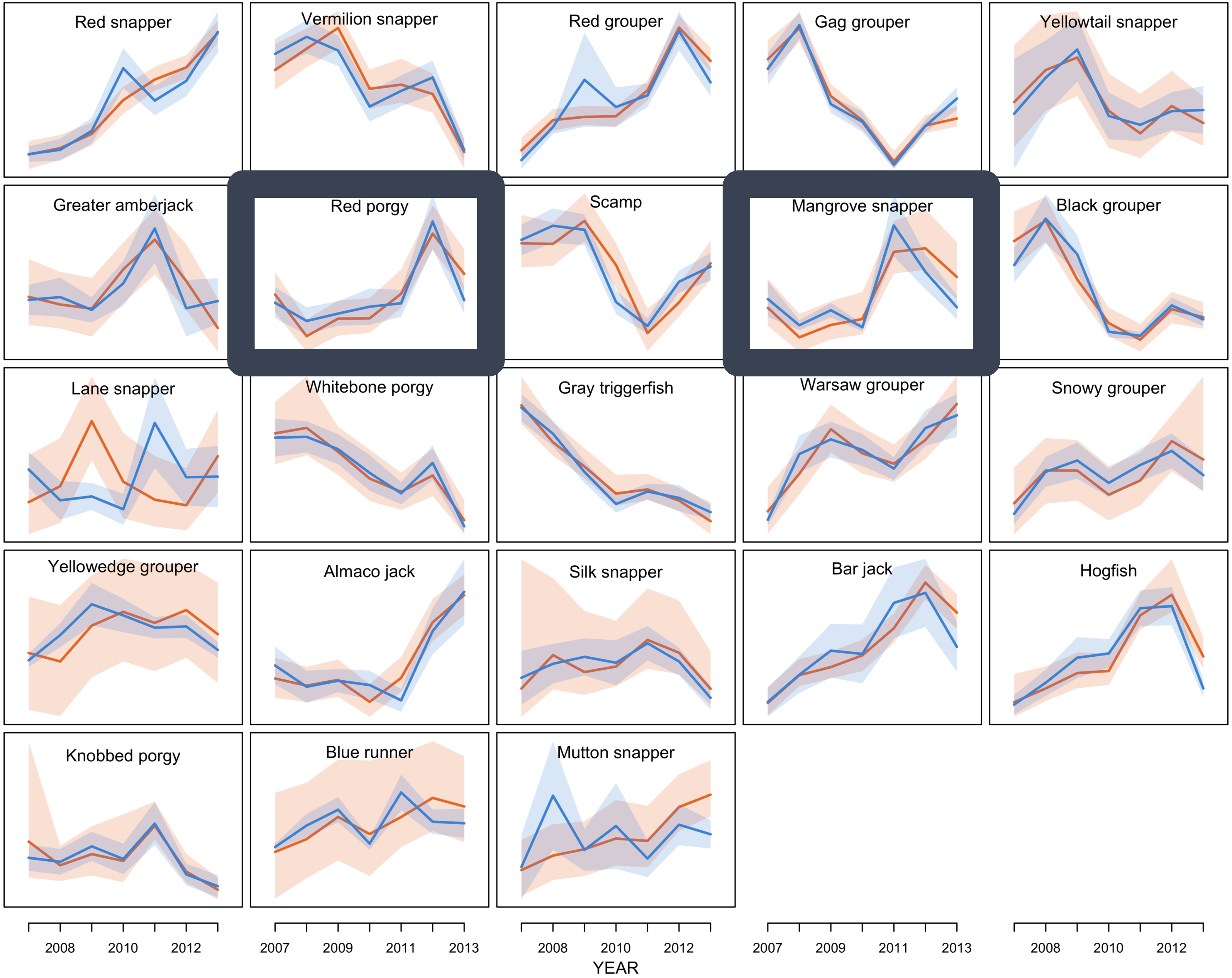
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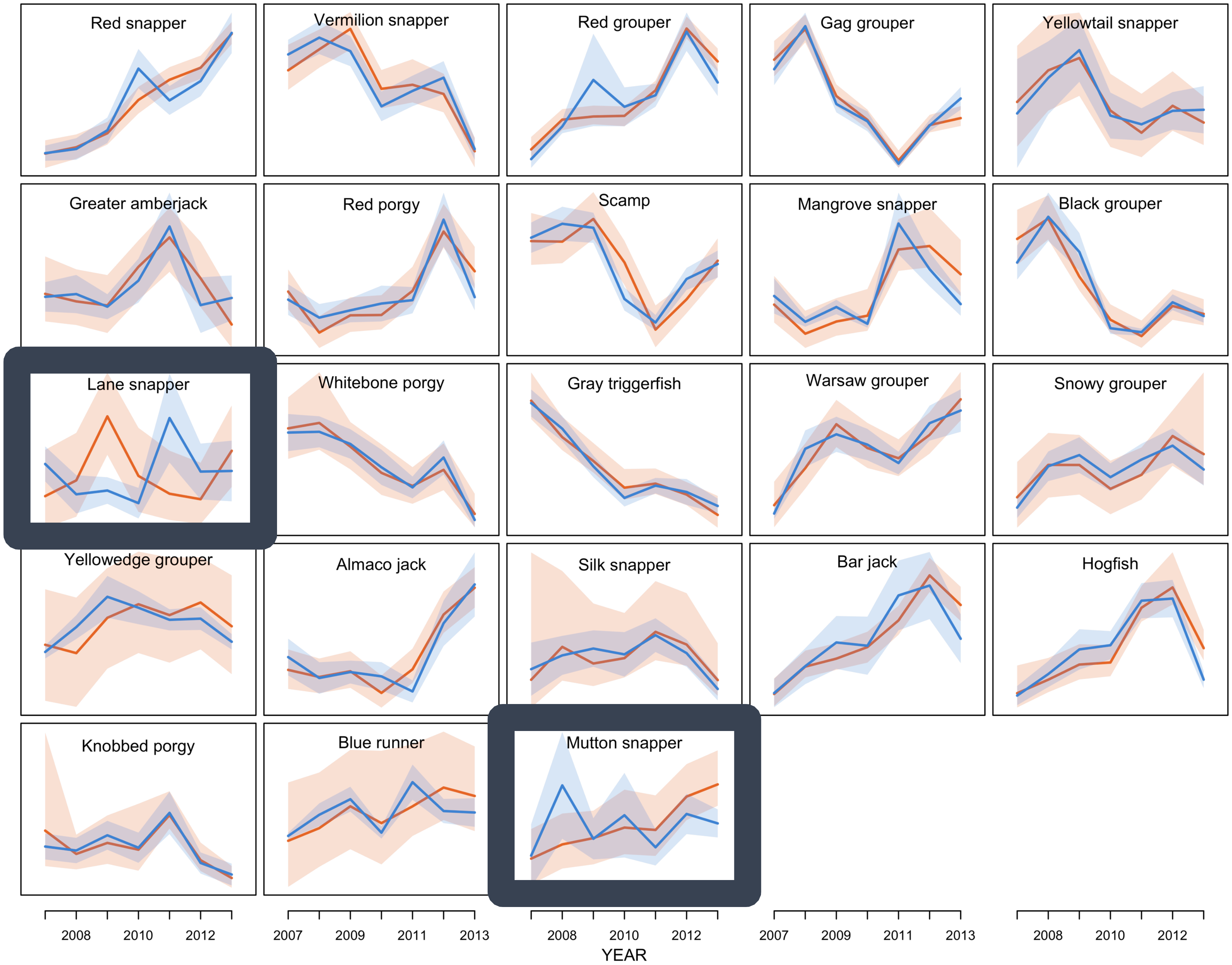
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Fisheries dependent data

Simulation Design

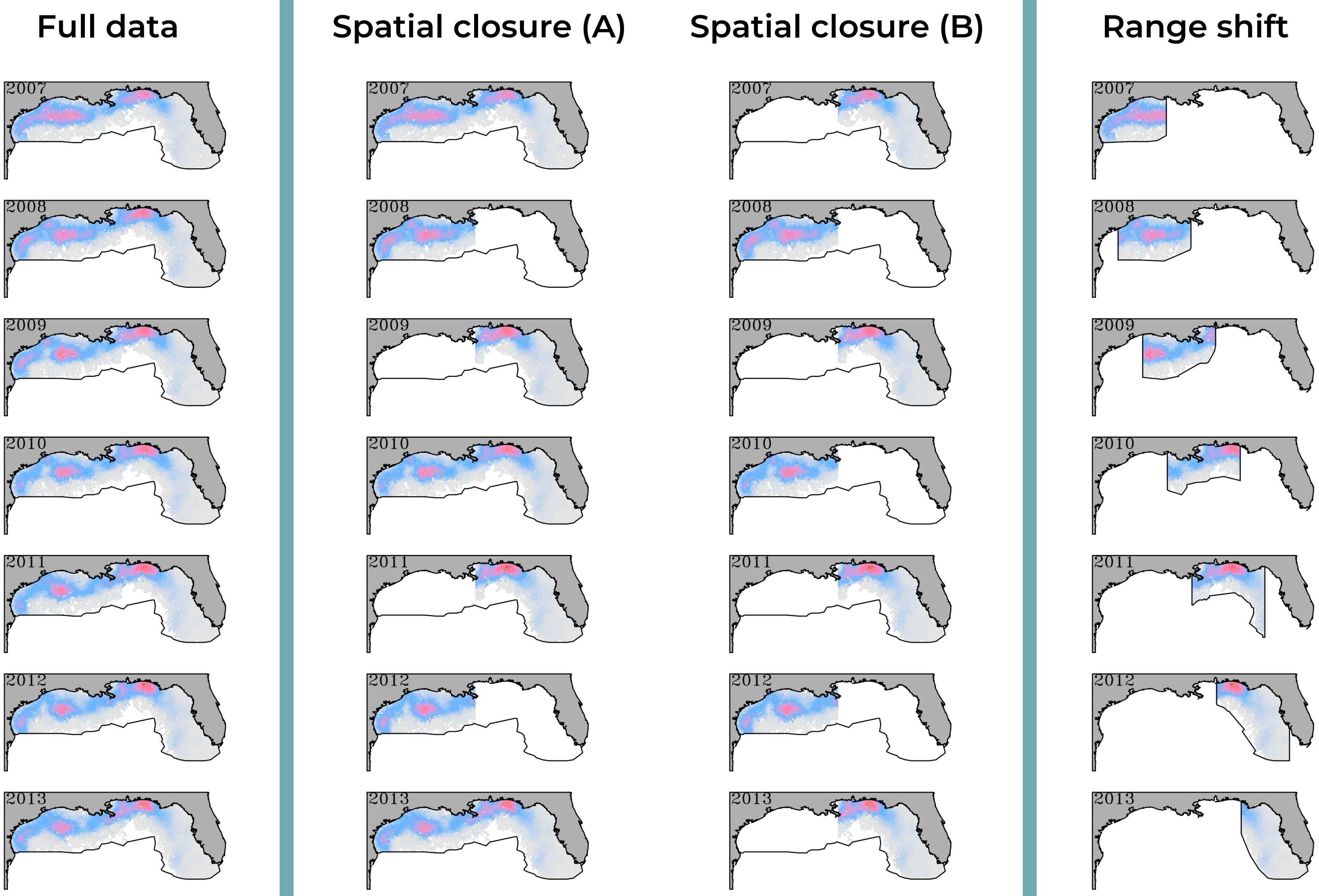
Using previously simulated species (**8**) and scenario (**localized abundance trends** and **unrestricted effort distribution**) data, explore how data quality and imputation rules effect predicted indices.

Data quality

Consider two patterns in data quality: **full spatial coverage** and **reduced spatial coverage**.

Spatial sampling

Consider three patterns in data availability: **fully sample distribution, spatial closures,** and **range shift**.


Full data
Spatial closure (A)
Spatial closure (B)
Range shift
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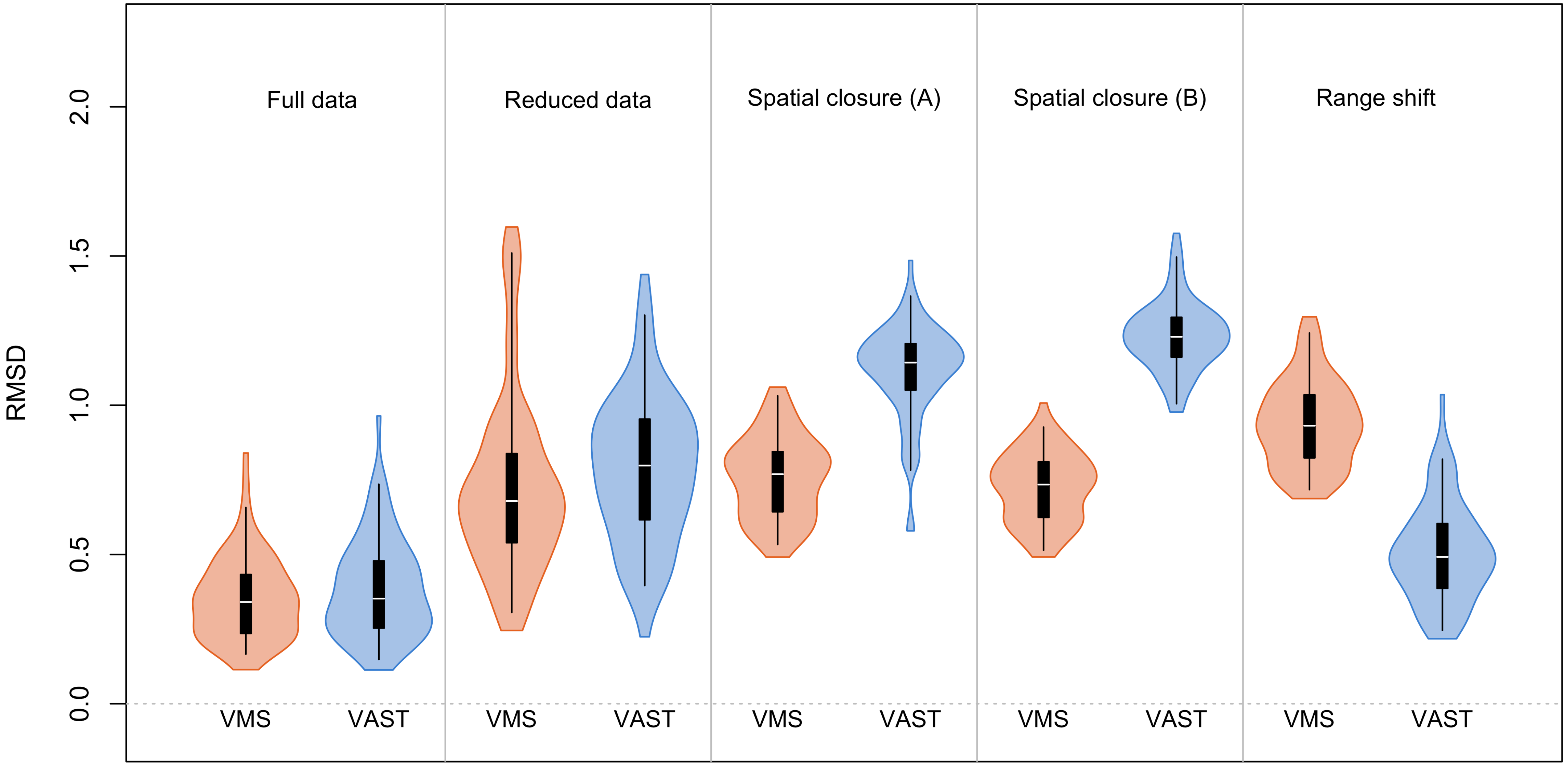
2009
2010
2011
2012
2013


RMSD
0.0
0.5
1.0
1.5
2.0
Full data
Reduced data
Spatial closure (A)
Spatial closure (B)
Range shift
VMS
VAST
VMS
VAST
VMS
VAST
VMS
VAST
VMS
VAST

Discussion

How we impute matters

dGLMM

May have poor performance in situations when effort distribution changes relative to the underlying distribution for reasons not tied to abundance (regulations, spatial closures, economic impacts, etc).

VMS

Simple temporal imputation is likely to fail in situations where the underlying abundance distribution is shifting out of previously fished areas and into unfished areas.

Additionally, temporal imputation is likely to be most effective for non-transient species with strong associations to underlying habitat.

Future directions

Explore additional settings in VAST: number of knots and spatiotemporal error structures.

Add additional methods for imputing “holes” in spatiotemporal CPUE distributions.

Continue mapping limiting scenarios for interpolation methods.

delta-GLM

Logbook standardization can accurately capture the true trend if abundance and effort patterns are simple.

AIC sometimes selected overly complex model structures, so care needs to be given to appropriately match the scale and dynamics of the underlying structure.

Inverse trends can be predicted under worst case scenarios of abundance and effort dynamics.

delta-GLMM VAST

Accurately captures true trends from fisheries dependent data when spatial coverage is complete and matches the underlying abundance distribution.

Comparatively worse performance when the fleet only samples portions of the underlying abundance distribution and imputation of unsampled fished areas required.

VMS

Simple temporal imputation and spatial averaging of VMS is fairly robust method across simulated scenarios, and can accurately track abundance trends.

Comparatively worse under range shift scenario.

Summary

Acknowledgements

Many thanks to Jim Thorson for help with VAST.

Thank you to the NOAA Fisheries-RTR program as well as the NOAA Fisheries – Sea Grant Population Dynamics Fellowship for funding this research.

Thank you to the following current and former NOAA Fisheries scientists for helping me work with and access the data: Carlos Rivero (Beaufort), Neil Baertlein (Miami), and Liz Scott-Denton (Galveston).

Photographic images came from the National Marine Sanctuaries Media Library and fish illustrations were drawn by Diane Peebles.

Meet the players

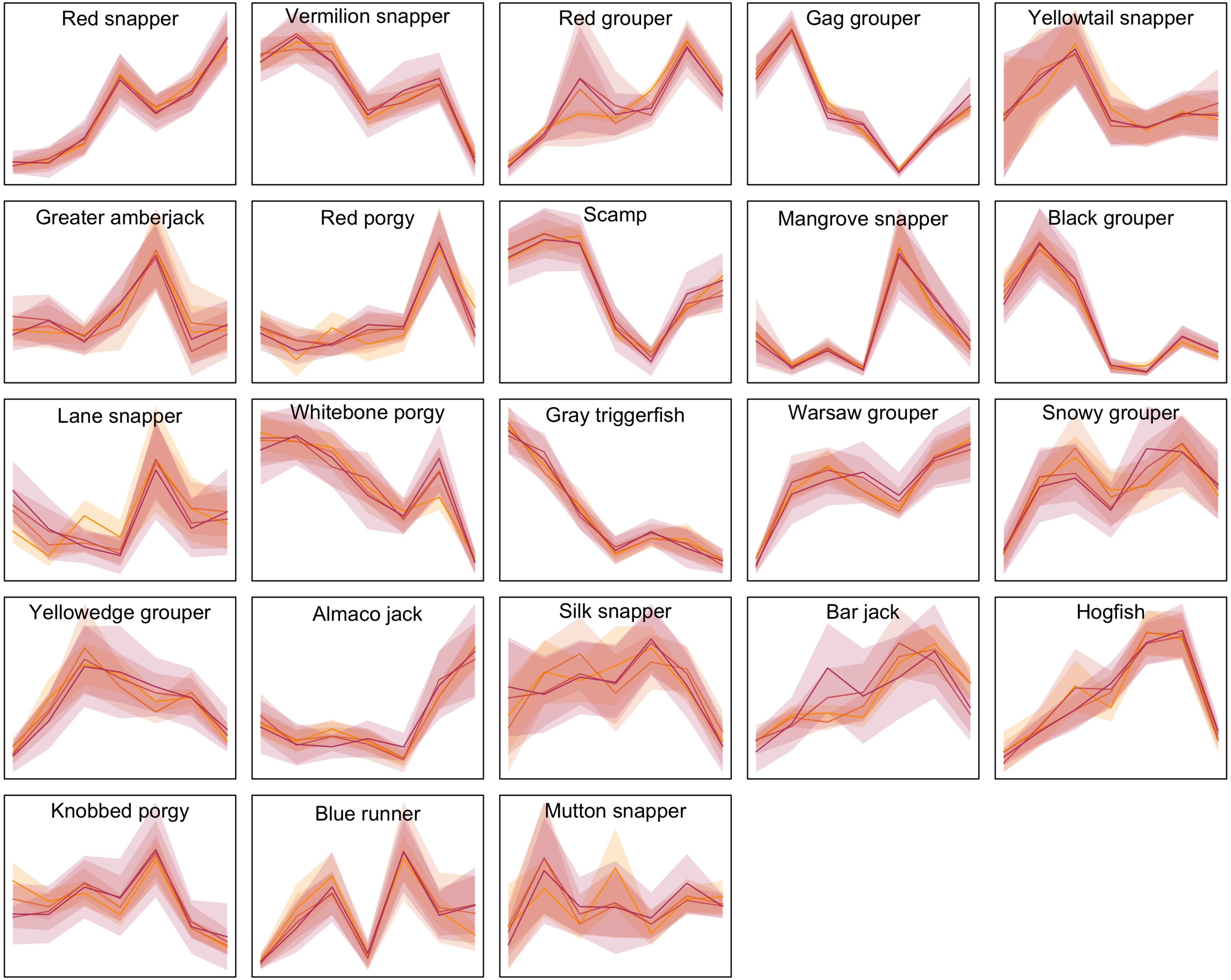
Gulf of Mexico vertical line reef fish fishery

Encountered species typically exhibit aggregating behavior, high site fidelity, and/or association with hard bottom structure.

Characterized by:
snappers (*Lutjanidae*),
groupers (*Epinephelinae*),
jacks (*Carangidae*),
grunts (*Haemulidae*), and
porgies (*Sparidae*).

Fishing effort targets hard bottom structure through multiple short sets. Fishing is done using multiple baited hooks deployed on vertical lines from a stationary or slowly drifting vessel.

From May 2007 to December 2013, **890 vessels** took **31,650 trips** resulting in **2,750,000 VMS locations**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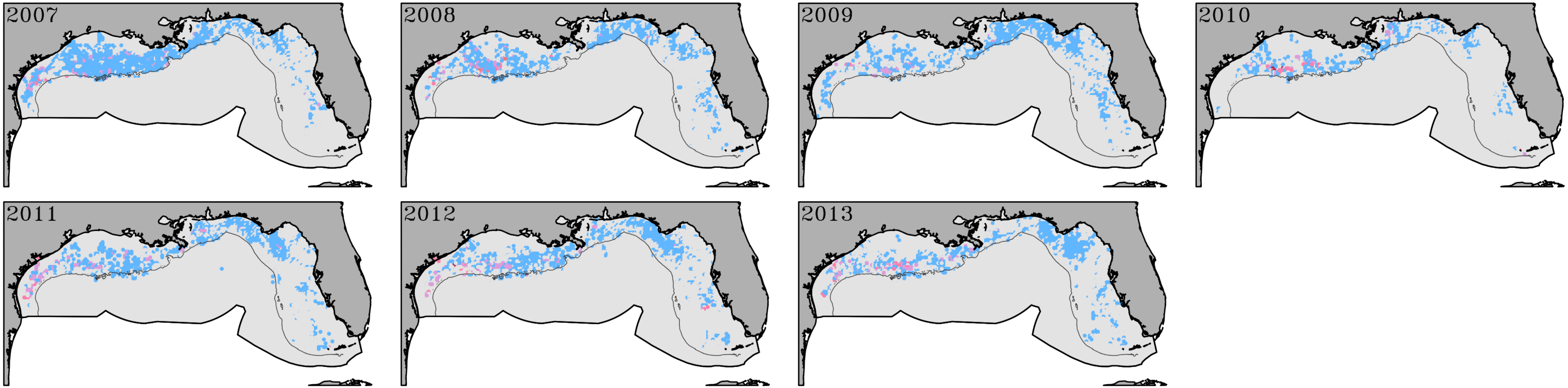

Mutton snapper