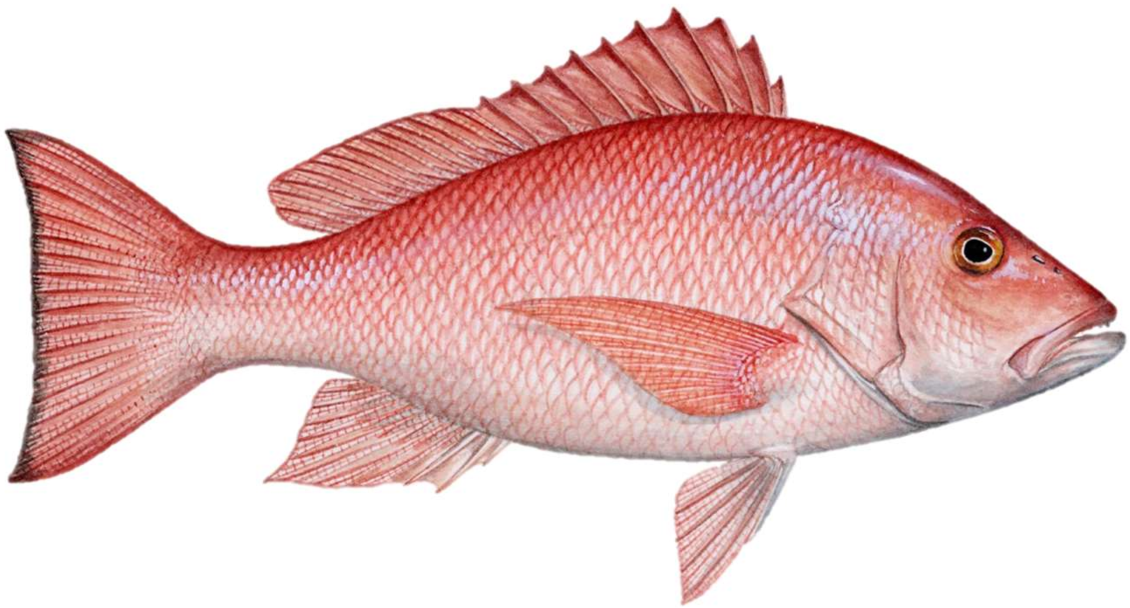
Estimation of US Atlantic Red Snapper Abundance



UF UNIVERSITY of FLORIDA

NC STATE UNIVERSITY

TEXAS A&M UNIVERSITY CORPUS CHRISTI

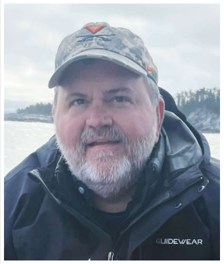
NOAA

FLORIDA FISH AND WILDLIFE CONSERVATION COMMISSION

SOUTH CAROLINA DEPARTMENT OF NATURAL RESOURCES

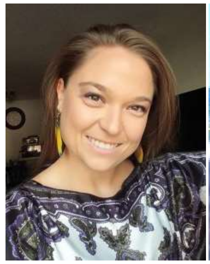
GEORGIA DEPARTMENT OF NATURAL RESOURCES COASTAL RESOURCES DIVISION

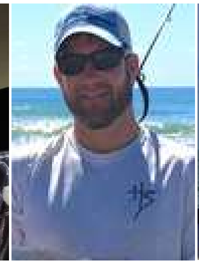
Study Team


Will Patterson


Joe Tarnecki

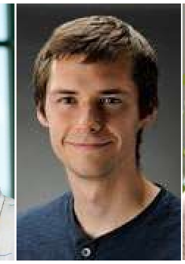

Sam Ricketts


Miaya Taylor


Dave Chagaris


Liam Kehoe


Dave Portnoy


Chris Hollenbeck


Alison Monroe


Kat Lanoue


Lizz Hunt


Jeff Buckel


Paul Ruderhausen


Nathan Hostetter

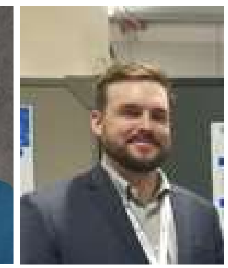

Krishna Pacifici


Dan Gwinn


Viviane Zulian


Erin Schliep


Brian Reich


Chris Custer


Nate Bacheler


Kyle Shertzer


Eric Anderson


Chris Taylor


Matt Damiano


Bev Sauls


Ted Switzer


Wally Bubley


Dawn Franco

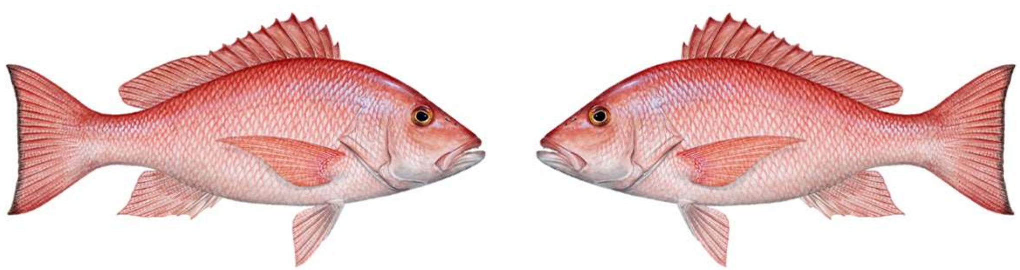
South Atlantic Red Snapper Research Program Study Objectives

1) Estimate the distribution and density of red snapper across the US Atlantic shelf from North Carolina through the Florida Keys with ROVs in unknown or unconsolidated habitats

2) Develop a hierarchical Bayesian integrated abundance model to estimate age-2+ red snapper population size based on Southeast Reef Fish Survey trap-camera and ROV survey data

3) Conduct genetic close-kin mark recapture (CKMR) analysis to estimate age-2+ red snapper population size

4) Integrate/reconcile study results with the Atlantic red snapper stock assessment model



Bayesian Hierarchical Integrated Modeling

Objective:

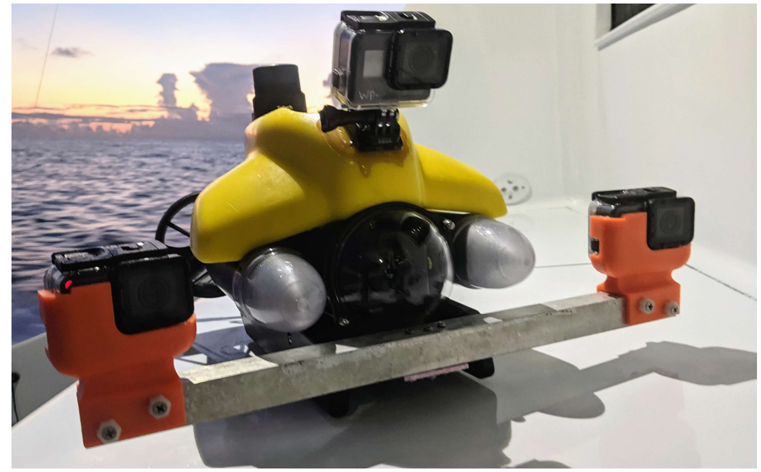
1) Estimate Atlantic red snapper population size with a CV of ≤0.3 from trap-camera, ROV, and habitat data

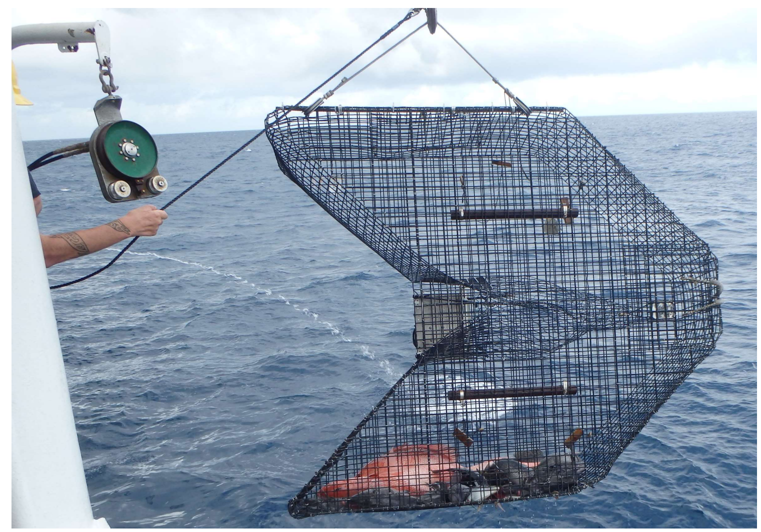
Approach:

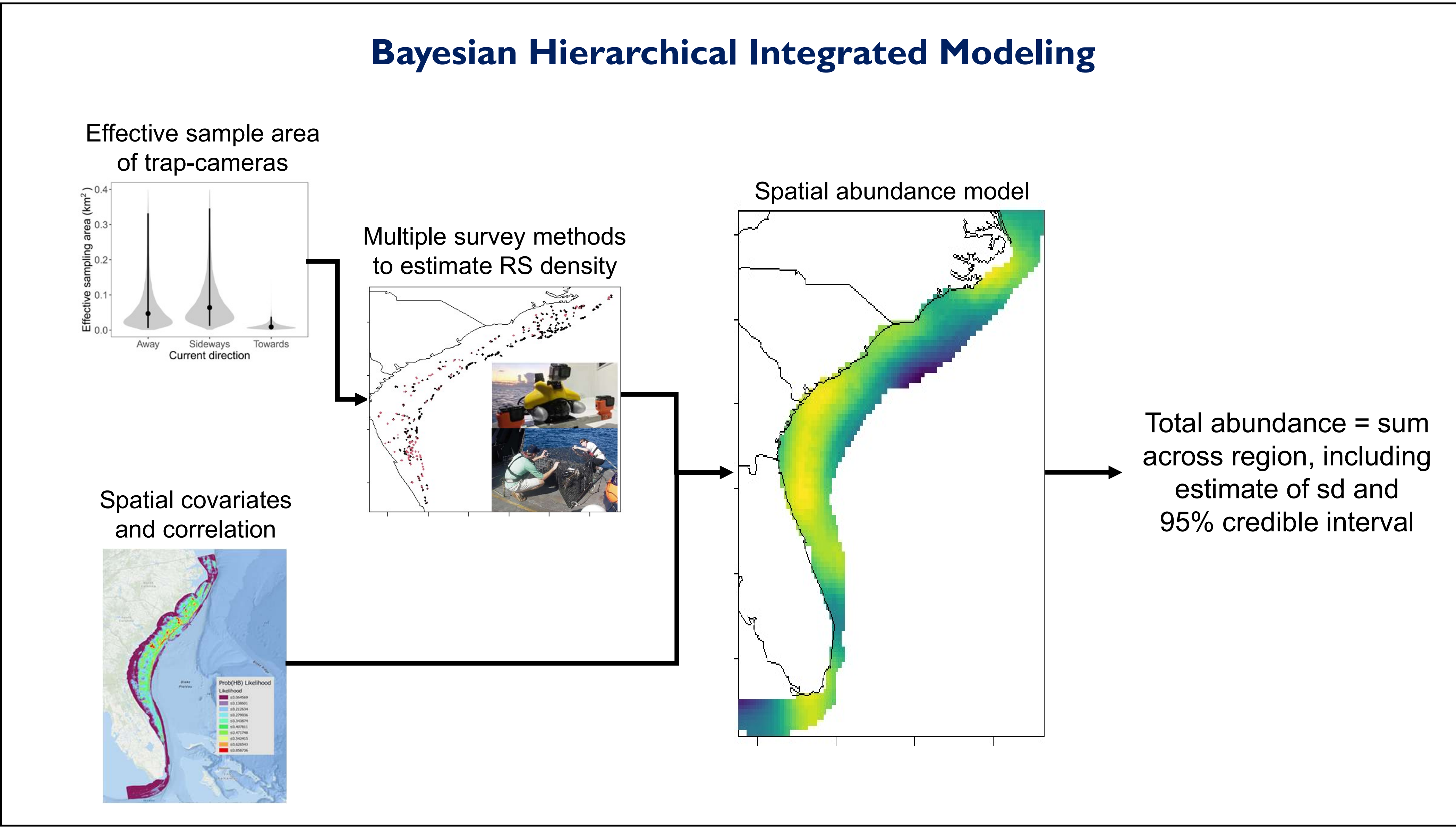
1) Integrate red snapper density estimates from multiple survey methods to jointly estimate red snapper abundance at three spatial scales: i) survey site (~10^3 m^2), ii) grid cell (25 km^2), and iii) study area (~100 x 10^3 km^2)

2) Habitat suitability informed by study video data, fishery-dependent data, and informed priors from previous studies and mapping

3) Separate observation models to account for different detection probabilities and effective sampling area of ROV, traps, and cameras mounted to traps






Bayesian Hierarchical Integrated Modeling
Effective sample area of trap-cameras
Effective sampling area (km²)
0.4
0.3
0.2
0.1
0.0
Away
Sideways
Towards
Current direction
Multiple survey methods to estimate RS density
Spatial covariates and correlation
Prob(HB) Likelihood
Likelihood
Spatial abundance model
Total abundance = sum across region, including estimate of sd and 95% credible interval

Red Snapper Reaction to Trap-Camera or ROV

Vol. 517: 1–14, 2014
doi: 10.3354/meps11094
MARINE ECOLOGY PROGRESS SERIES
Mar Ecol Prog Ser
Published December 15

FEATURE ARTICLE

FREE ACCESS

Environmental conditions and habitat characteristics influence trap and video detection probabilities for reef fish species

Nathan M. Bacheler[1,*], David J. Berrane[1], Warren A. Mitchell[1], Christina M. Schobernd[1], Zebulon H. Schobernd[1], Bradford Z. Teer[1], Joseph C. Ballenger[2]

[1]National Marine Fisheries Service, Southeast Fisheries Science Center, 101 Pivers Island Road, Beaufort, NC 28516, USA
[2]Marine Resources Research Institute, South Carolina Department of Natural Resources, 217 Fort Johnson Road, Charleston, SC 29412, USA

458

Canadian Science Publishing

ARTICLE

Fine-scale behavior of red snapper (*Lutjanus campechanus*) around bait: approach distances, bait plume dynamics, and effective fishing area

Nathan M. Bacheler, Brendan J. Runde, Kyle W. Shertzer, Jeffrey A. Buckel, and Paul J. Rudershausen

Fisheries Research 246 (2022) 106155

Contents lists available at ScienceDirect

Fisheries Research

journal homepage: www.elsevier.com/locate/fishres

ELSEVIER

Check for updates

A multidisciplinary approach to estimating red snapper, *Lutjanus campechanus*, behavioral response to mobile camera and sonar sampling gears

Steven B. Garner[a,*], Robert Ahrens[a], Kevin M. Boswell[b], Matthew D. Campbell[c], Daniel Correa[b], Joseph H. Tarnecki[a], William F. Patterson III[a]

[a] University of Florida, Fisheries and Aquatic Sciences, 7922 NW 71st St, Gainesville, FL 32653, USA
[b] Florida International University, Biological Sciences, Biscayne Bay Campus, 3000 NE 151st St, North Miami, FL 33181, USA
[c] National Marine Fisheries Service, Southeast Fisheries Science Center, Mississippi Laboratories, 3209 Frederic St, Pascagoula, MS 39567, USA

PLOS ONE

Check for updates

OPEN ACCESS

Citation: Garner SB, Olsen AM, Caillouet R, Campbell MD, Patterson WF, III (2021) Estimating reef fish size distributions with a mini remotely operated vehicle-integrated stereo camera system. PLoS ONE 16(3): e0247985. https://doi.org/10.1371/journal.pone.0247985

Editor: Hudson Tercio Pinheiro, California Academy of Sciences, UNITED STATES

Received: July 23, 2020

Accepted: February 17, 2021

Published: March 4, 2021

RESEARCH ARTICLE

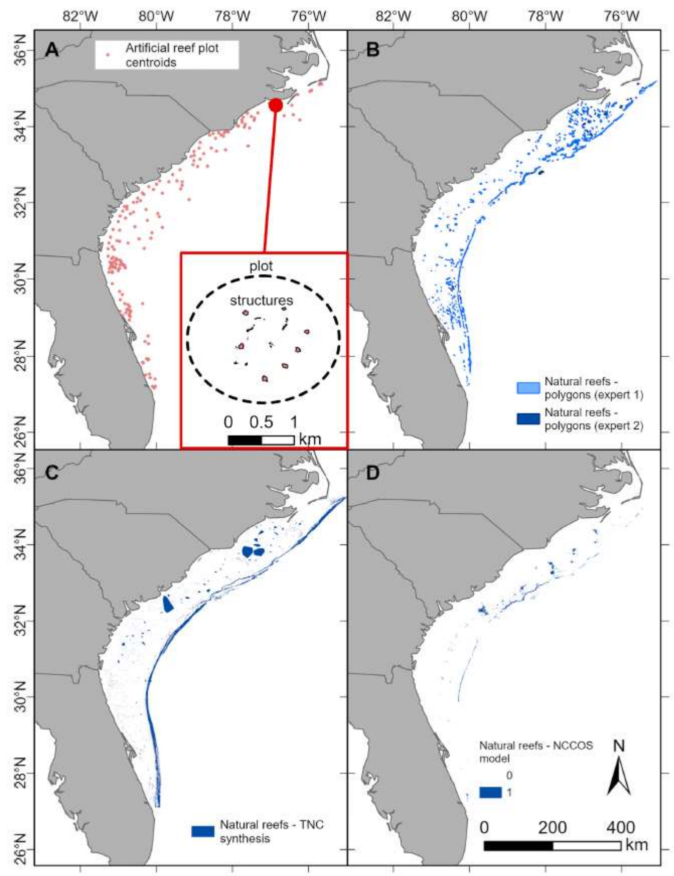
Estimating reef fish size distributions with a mini remotely operated vehicle-integrated stereo camera system

Steven B. Garner[1]*, Aaron M. Olsen[2], Ryan Caillouet[3], Matthew D. Campbell[3], William F. Patterson, III[1]

1 Fisheries and Aquatic Sciences, University of Florida, Gainesville, Florida, United States of America, **2** Department of Ecology and Evolutionary Biology, Brown University, Providence, Rhode Island, United States of America, **3** Mississippi Laboratories, Southeast Fisheries Science Center, National Marine Fisheries Service, Pascagoula, Mississippi, United States of America

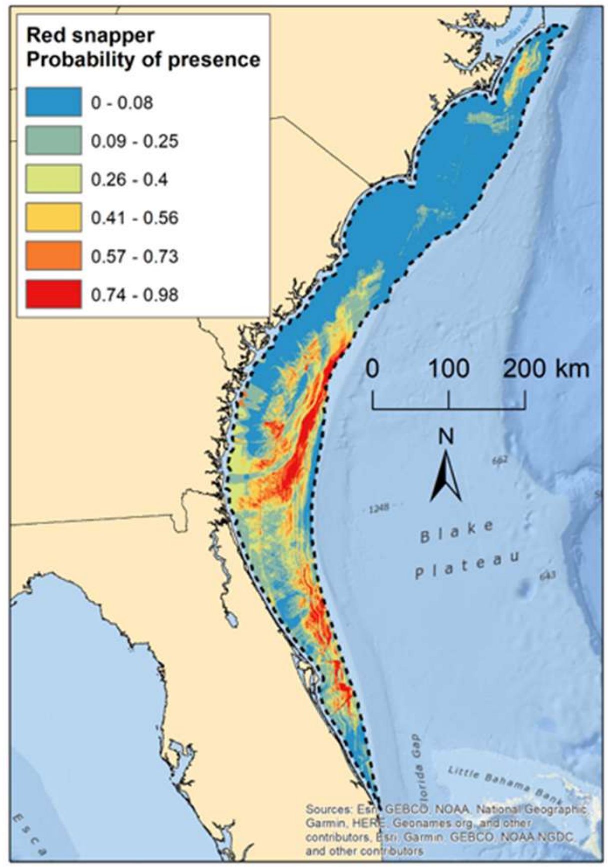
Analysis of Spatial Covariates

Regional NR and AR Distribution



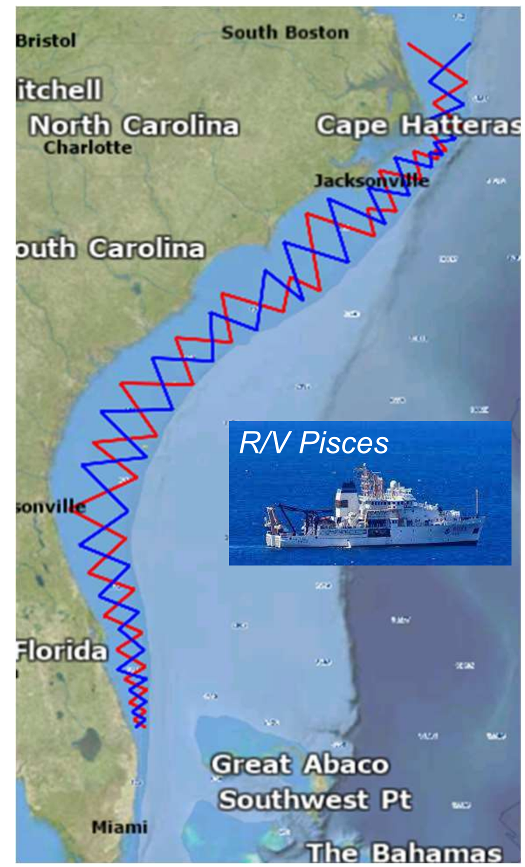
Steward et al. (2022)

RS Habitat Suitability

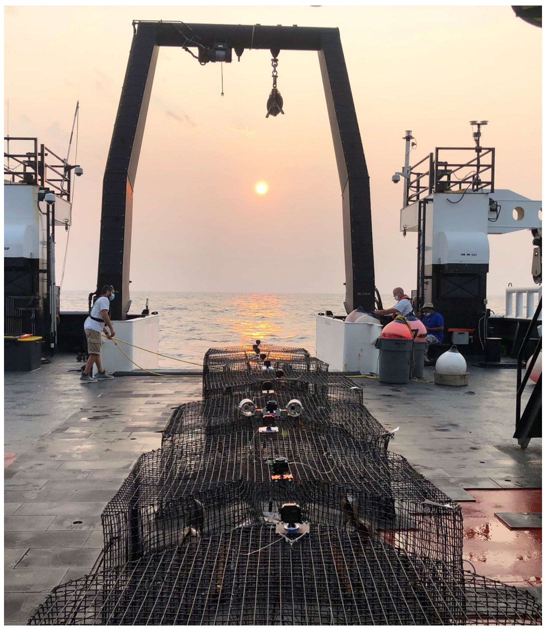


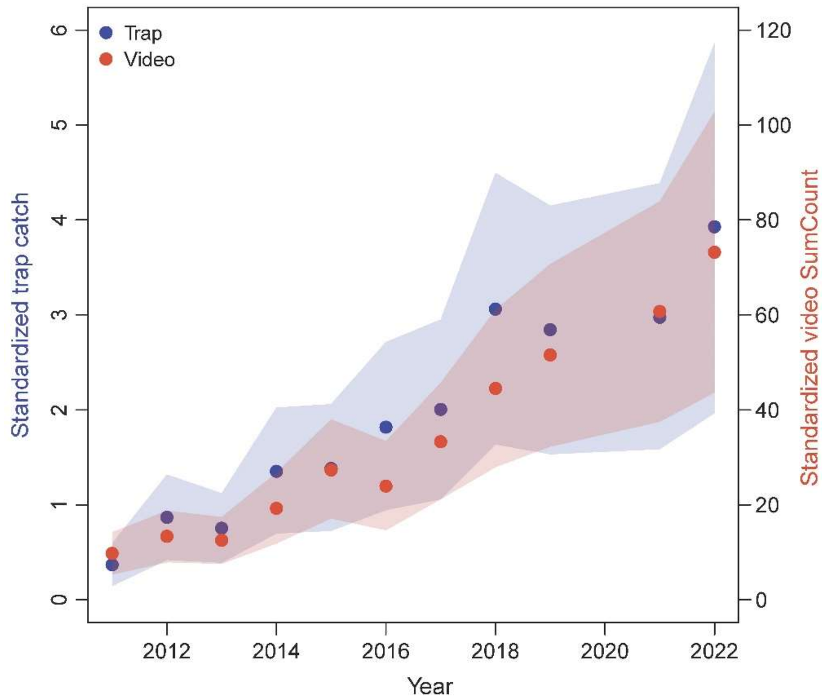
Pickens and Taylor (2020)

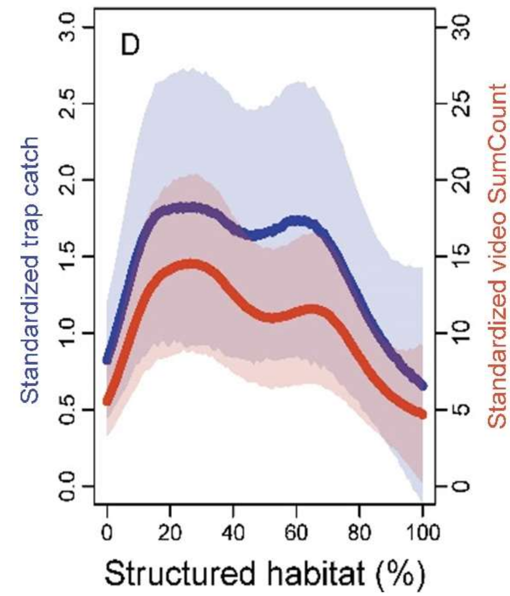
Ongoing Habitat Mapping



SERFS Trap-Camera Red Snapper Trends

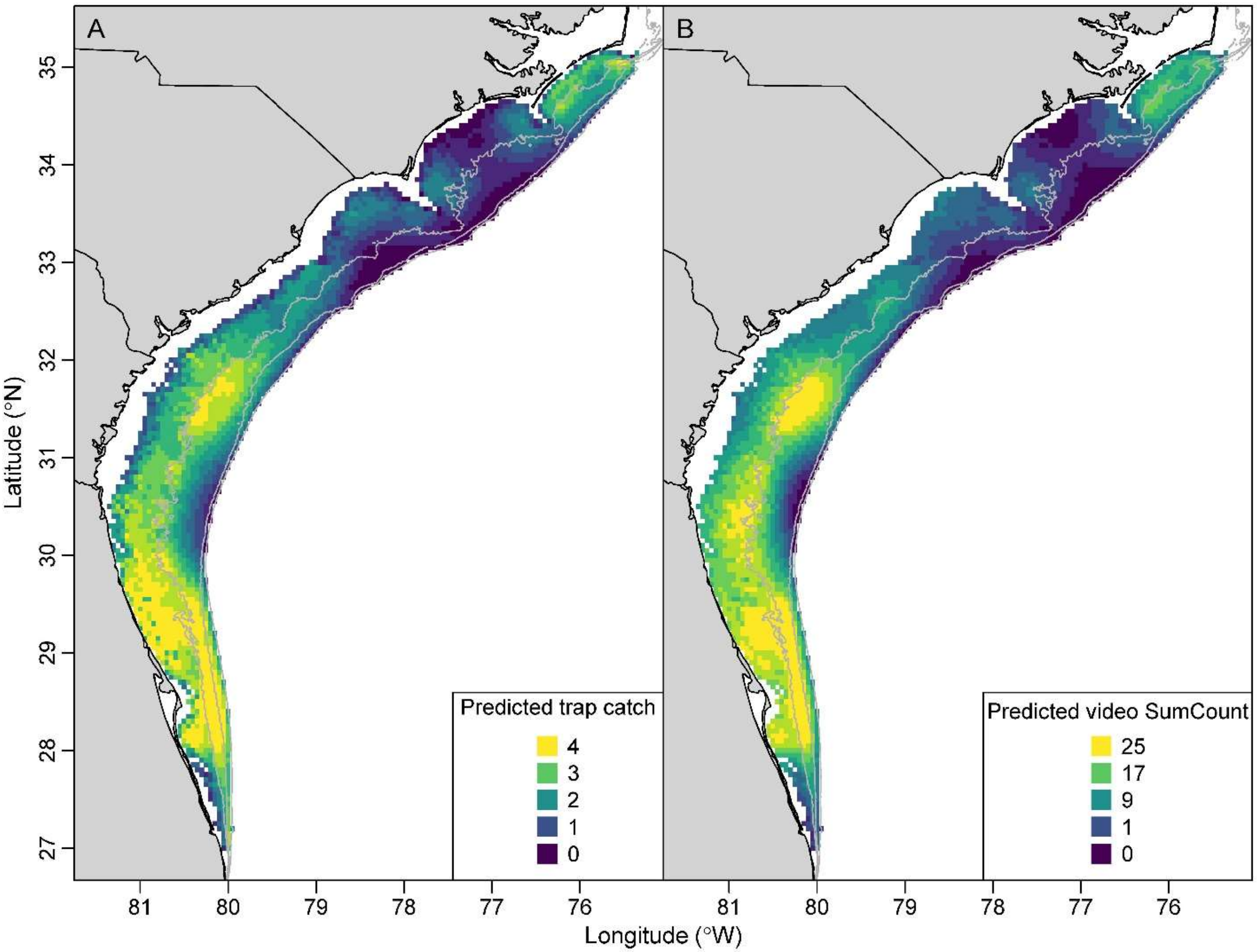






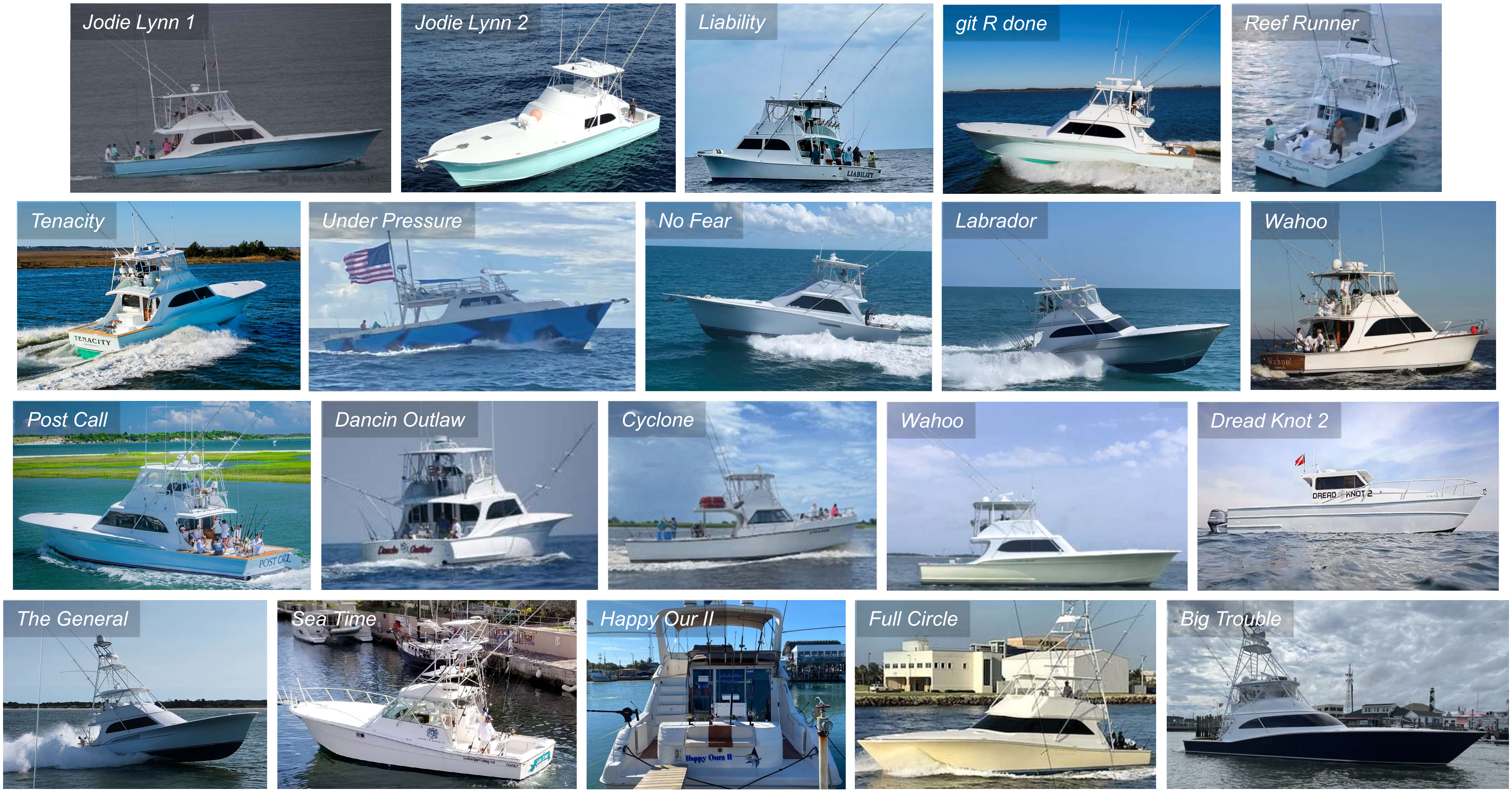
Bacheler et al. (in review)

SERFS Camera-Trap Red Snapper Trends

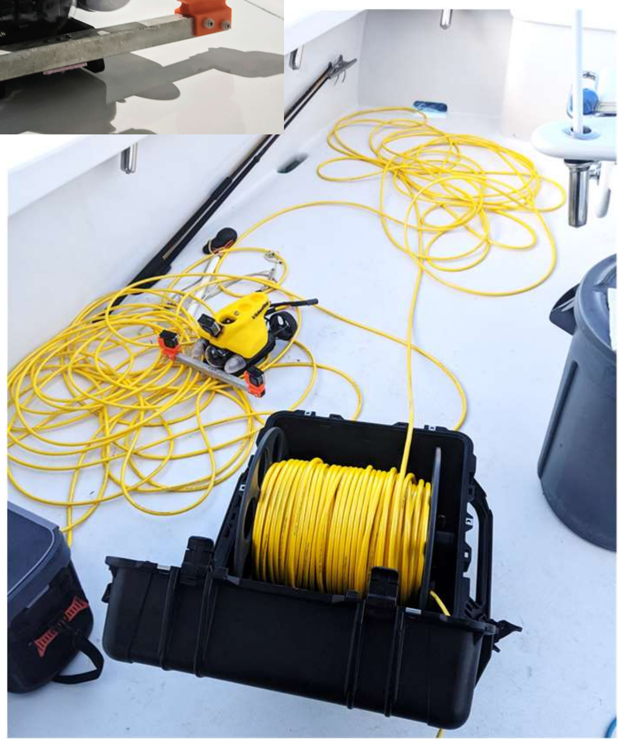


Bacheler et al.
(in review)

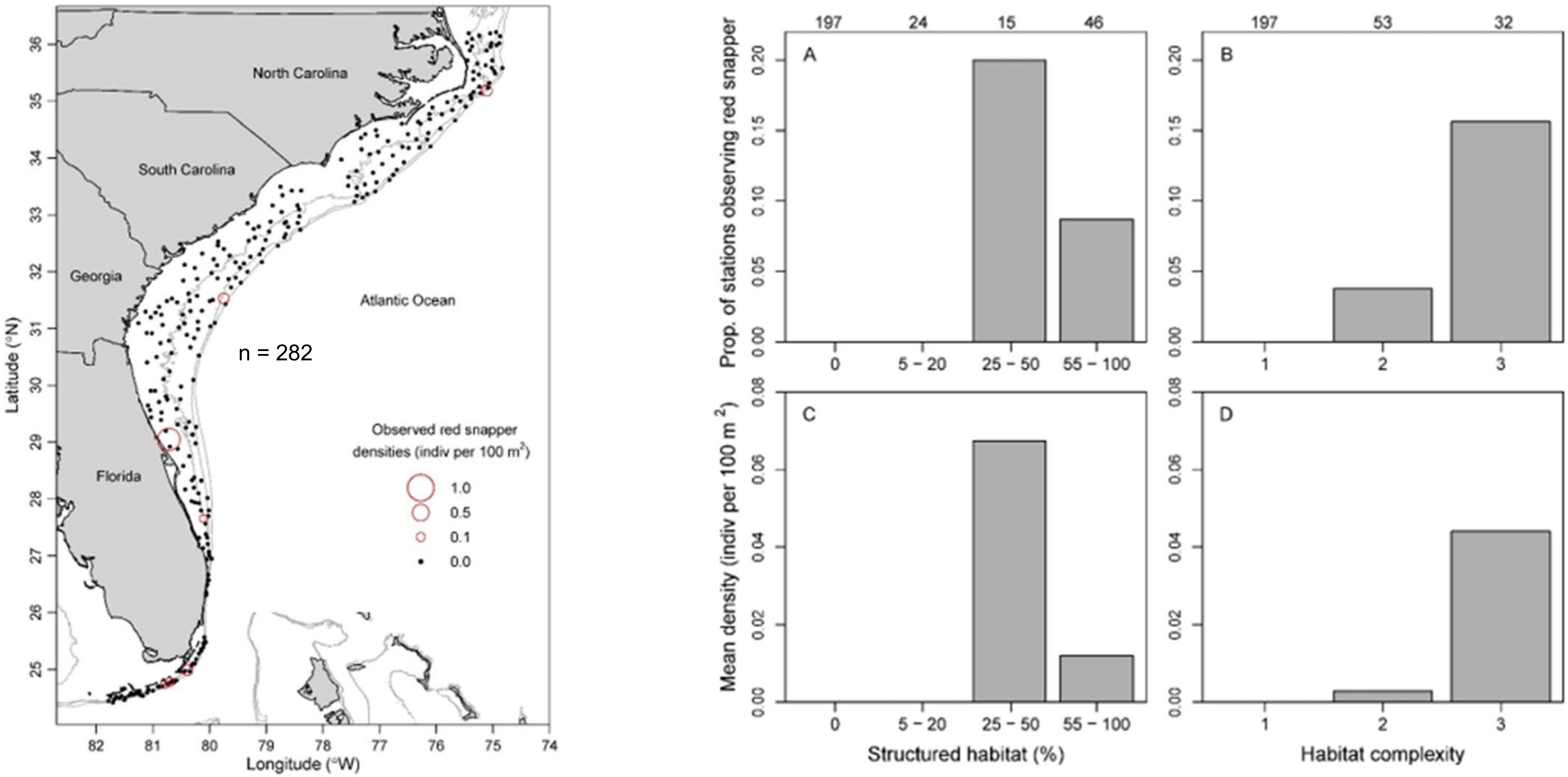
Remotely Operated Vehicle Surveys: Cooperative Research



Remotely Operated Vehicle Sampling Across the US Atlantic Shelf



ROV Sampling 2021-2023

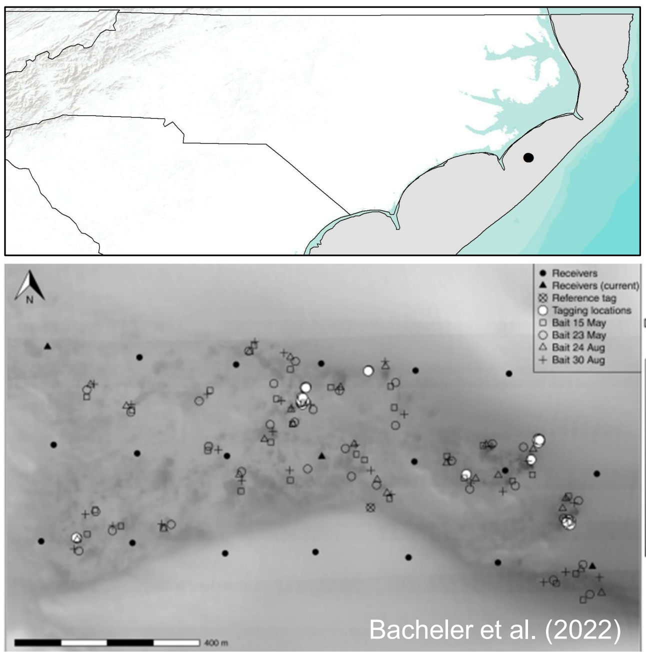


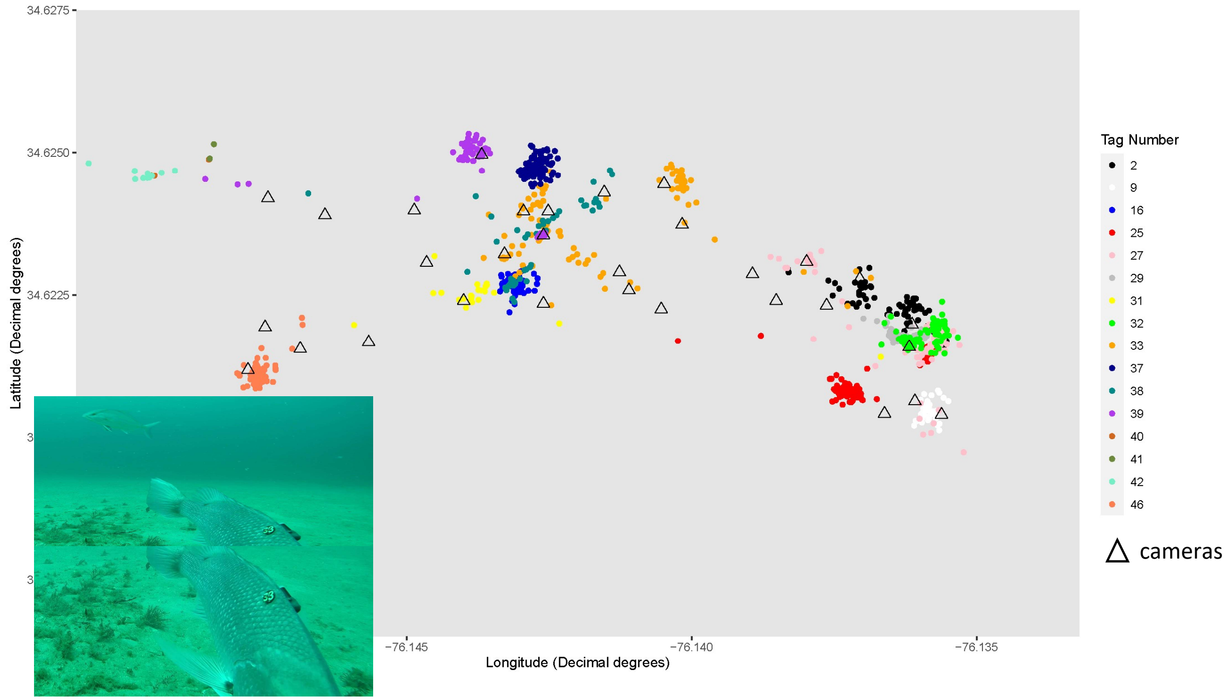
Bacheler et al. (in review)

Estimating Effective Sampling Area and Fish Density from Camera Data

Data:

- North Carolina, 2019
- VPS array
- 16 tagged red snapper → marked individuals
- 31 camera samples: repeated counts of marked, unmarked, and unknown red snapper
- Developed N-mixture + Marked approach; tested via simulation applied to case study data





Estimating Effective Sampling Area and Fish Density from Camera Data

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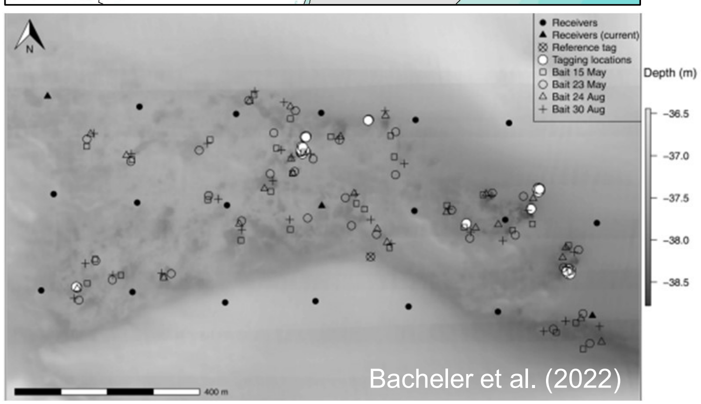
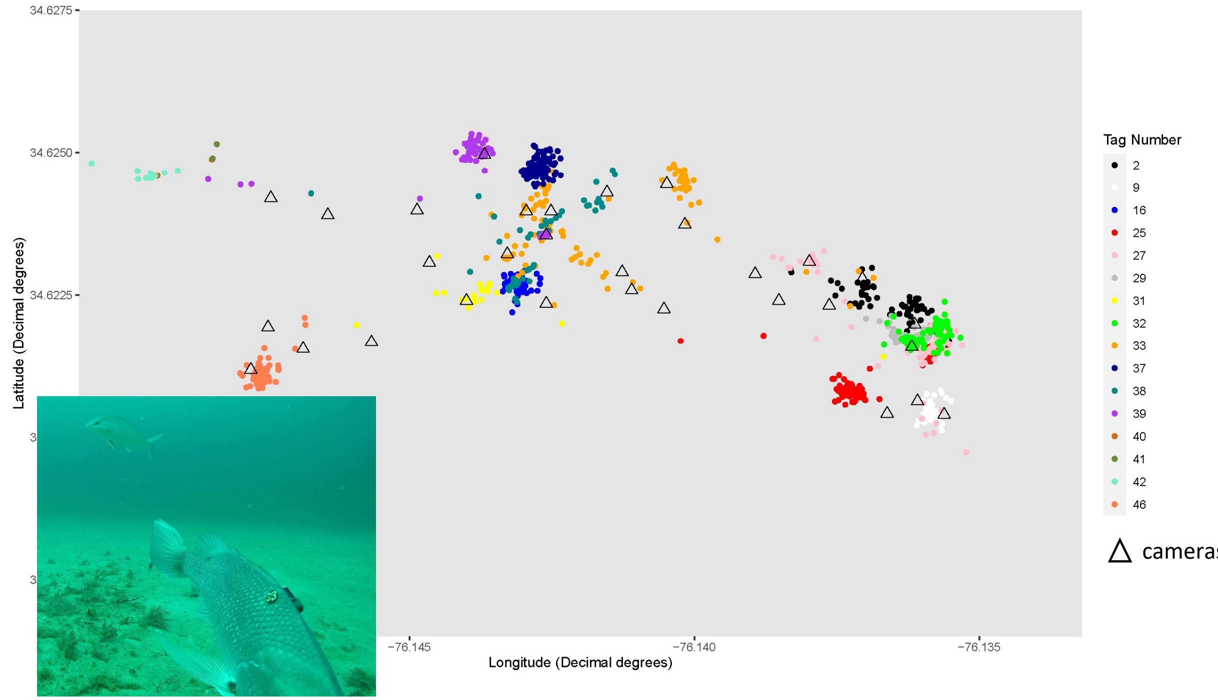
- 16 tagged red snapper ⟶ marked individuals
- 31 camera samples: repeated counts of marked, unmarked, and unknown red snapper
- Developed N-mixture + Marked approach; tested via simulation applied to case study data

Detections of marked individuals allow us to estimate ESA.



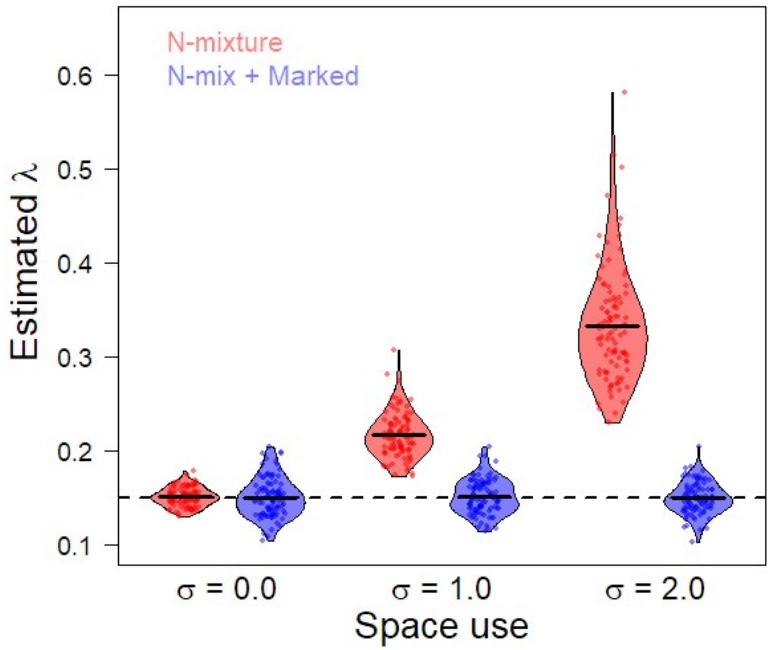


Estimating Effective Sampling Area and Fish Density from Camera Data

Simulation study:

Count data alone: Biased, density estimate increases as fish movement increases

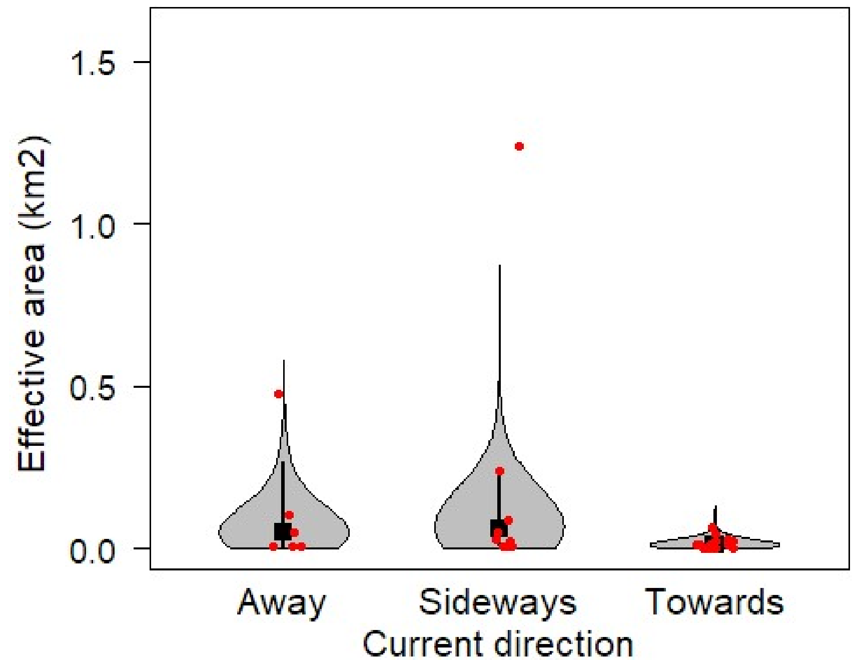
Integrated Approach: Unbiased density estimation across multiple levels of fish movement (e.g., differing ESA)



Case study:

ESA varies as a function of current direction.

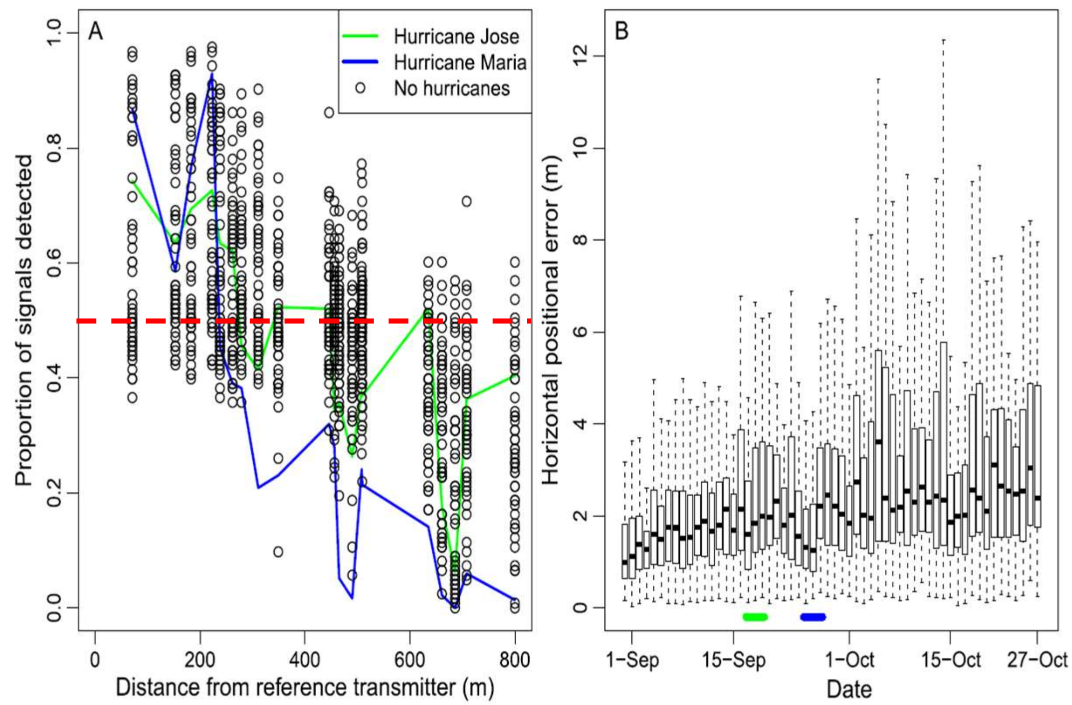
Estimated 150 (102-235) individuals on reef (1.6 km^2) or ~66 snapper km^{-2}



Zulian et al. (in revision)

Red Snapper Telemetry ESA Experiments Summer 2023 and 2024

- Spatial capture-recapture experiments to estimate the effective sample area of trap-cameras for red snapper
- 3D telemetry arrays deployed off seNC (2023) and neFL (2024) to conduct experiments
- Adult red snapper captured with hook and line, tagged with acoustic tags with depth sensors, and tracked in 3D
- Paired sampling with ROV and trap-cameras to conduct spatial capture-recapture analysis



Bacheler et al. (2021)

ECOLOGY
ECOLOGICAL SOCIETY OF AMERICA

ARTICLE | Open Access

Modeling spatiotemporal abundance and movement dynamics using an integrated spatial capture–recapture movement model

Nathan J. Hostetter, Eric V. Regehr, Ryan R. Wilson, J. Andrew Royle, Sarah J. Converse

First published: 28 May 2022 | https://doi.org/10.1002/ecy.3772 | Citations: 3

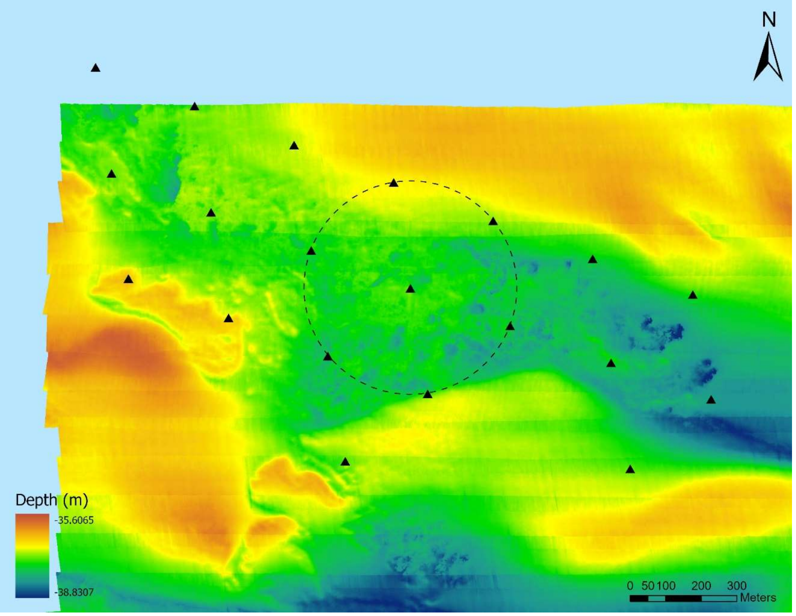
3D Telemetry and Estimation of ESA via Spatial Capture-Recapture Modeling

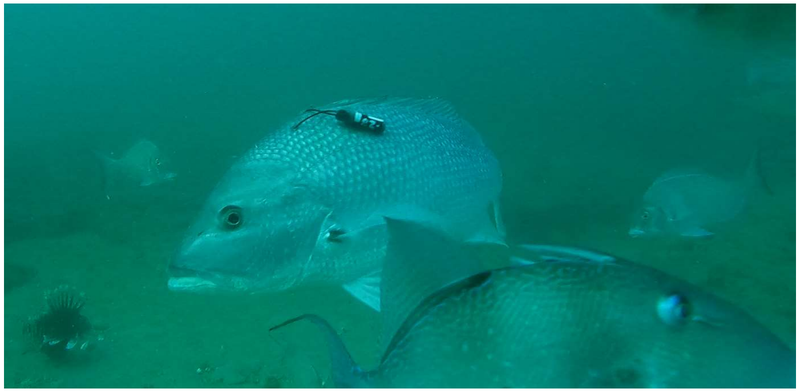
- NC 2023: VPS array (n = 20 receivers) deployed in August 2023,
  - -300 m receiver spacing
  - -45 red snapper tagged with external telemetry tags
  - -mean TL= 604 mm (range 428-780 mm)

- Sampling:
  - 8/22: 18 SERFS chevron traps on Pisces, paired ROV
  - 9/8: 18 NCSU light chevron traps
  - 10/30: 14 NCSU light chevron traps

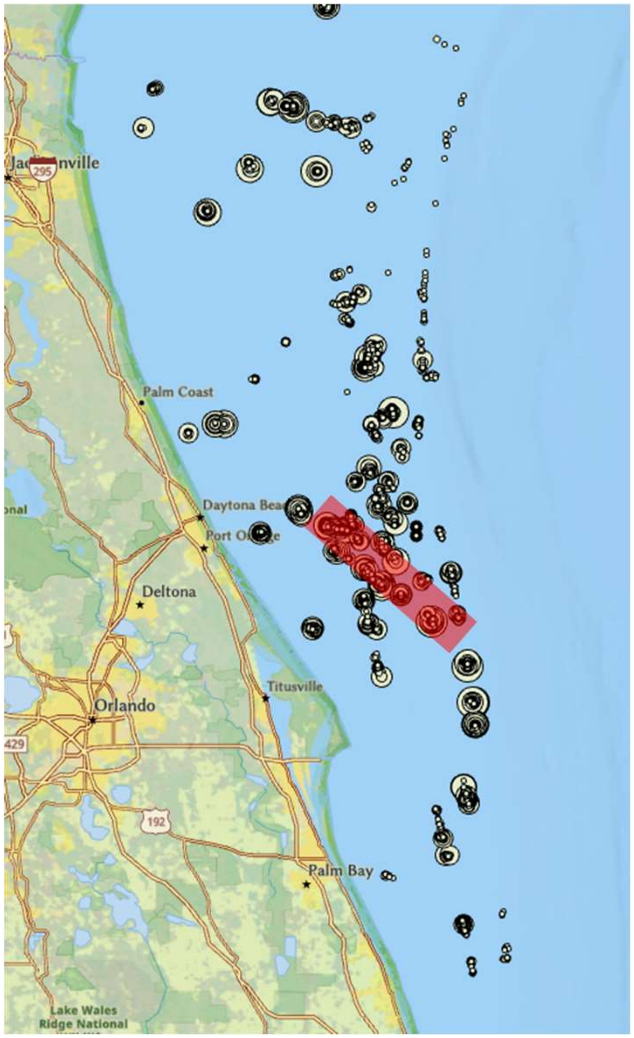
- Receivers recovered Nov 2023
  - -1.3M detections of tagged RS
  - -196,856 GPS position estimates

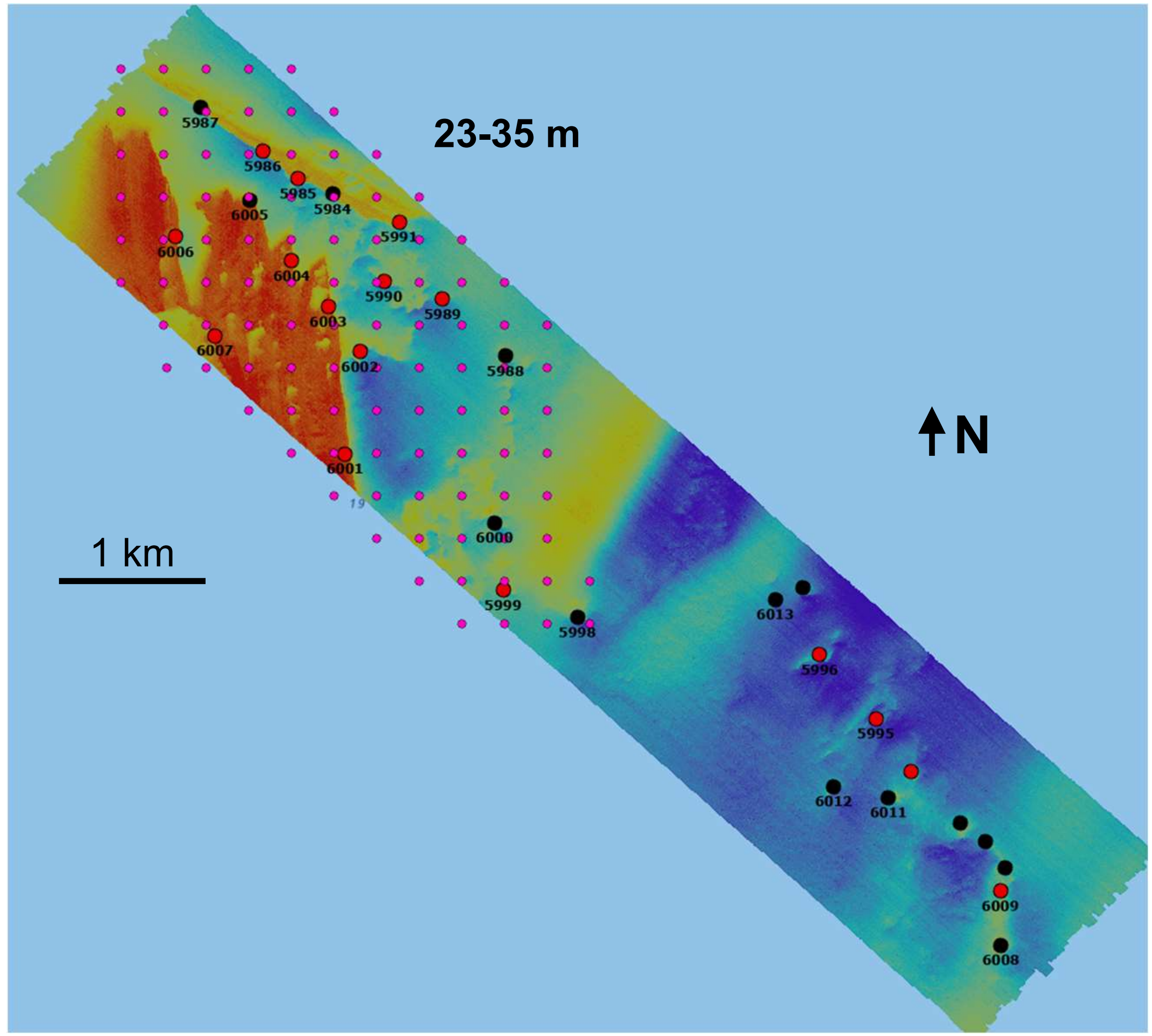
- 2023 video analysis completed:
  - -RS observations: 8/22 (n = 1), 9/8 (n = 10), and 10/30 (n = 13)





Red Snapper Telemetry ESA Experiments Summer 2024





Close-Kin Mark-Recapture

Objectives:

1) To estimate red snapper population size in US Atlantic

2) To estimate red snapper genetic population structure

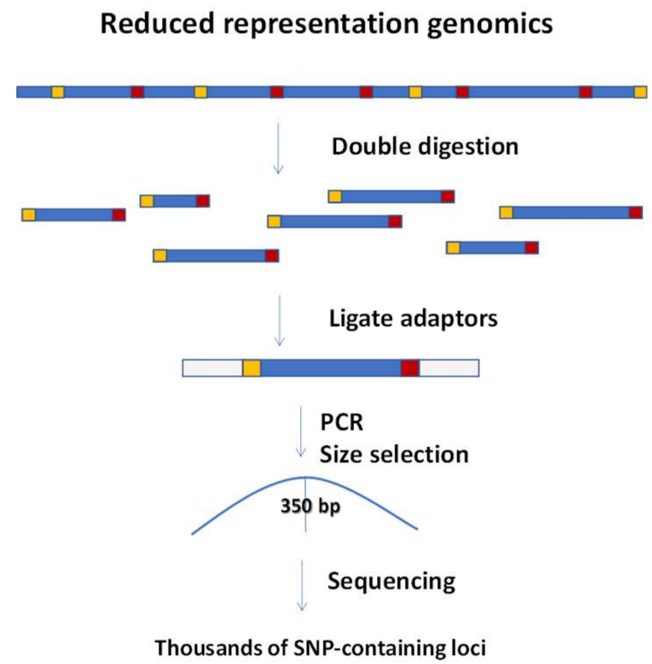
MarineGenomics Laboratory
Texas A&M University - Corpus Christi

Approach:

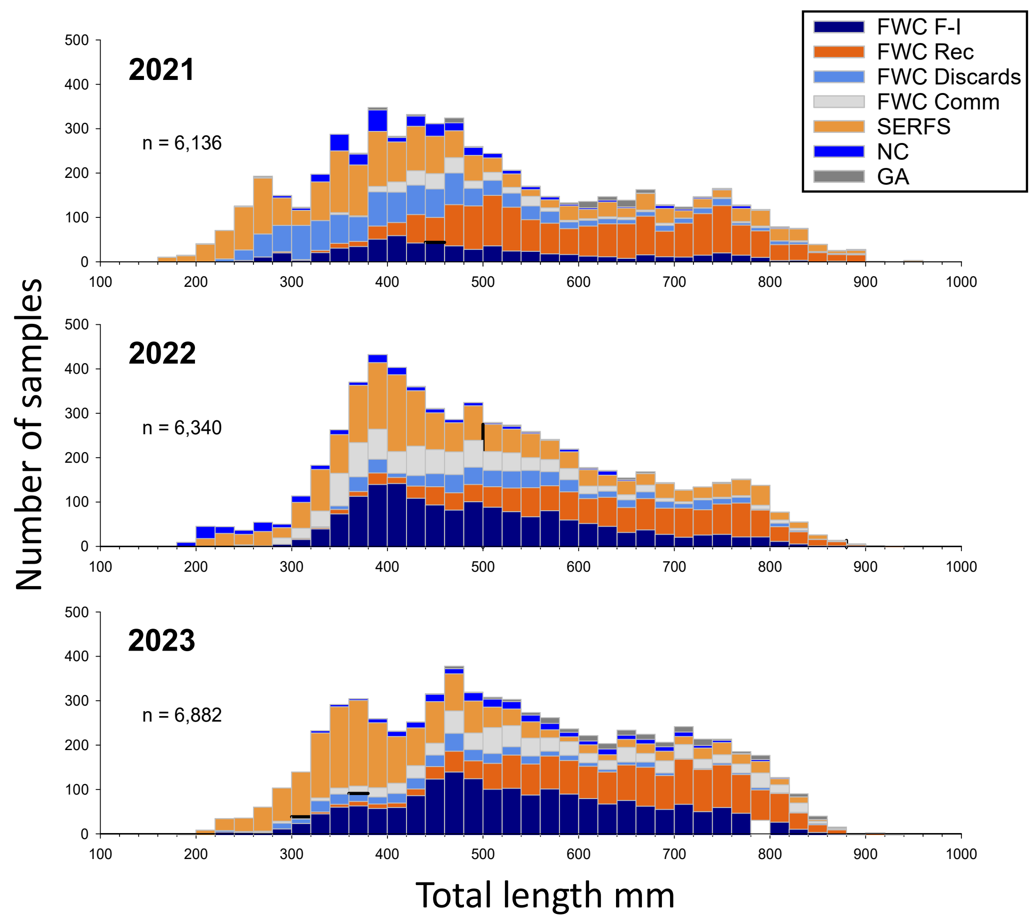
1) Fin clip sampling of Atlantic red snapper; up to 5k per year for 3 years

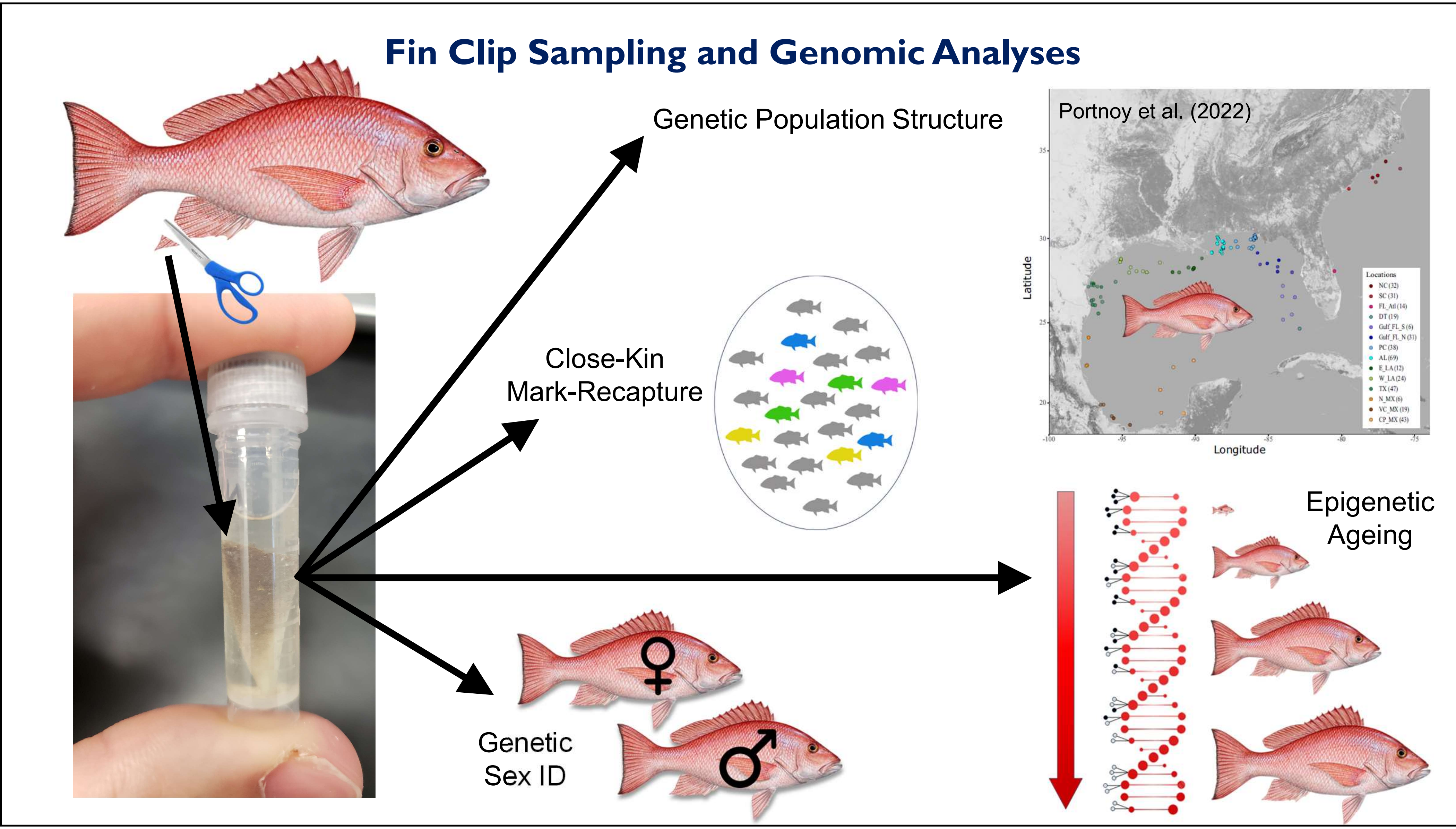
2) Development of genotyping in the thousands (GT-seq) panels to allow high through-put sequencing of 400 microhaplotypes (SNP-containing loci)

3) Sequencing of fin clip samples and population size estimation with CKMR model

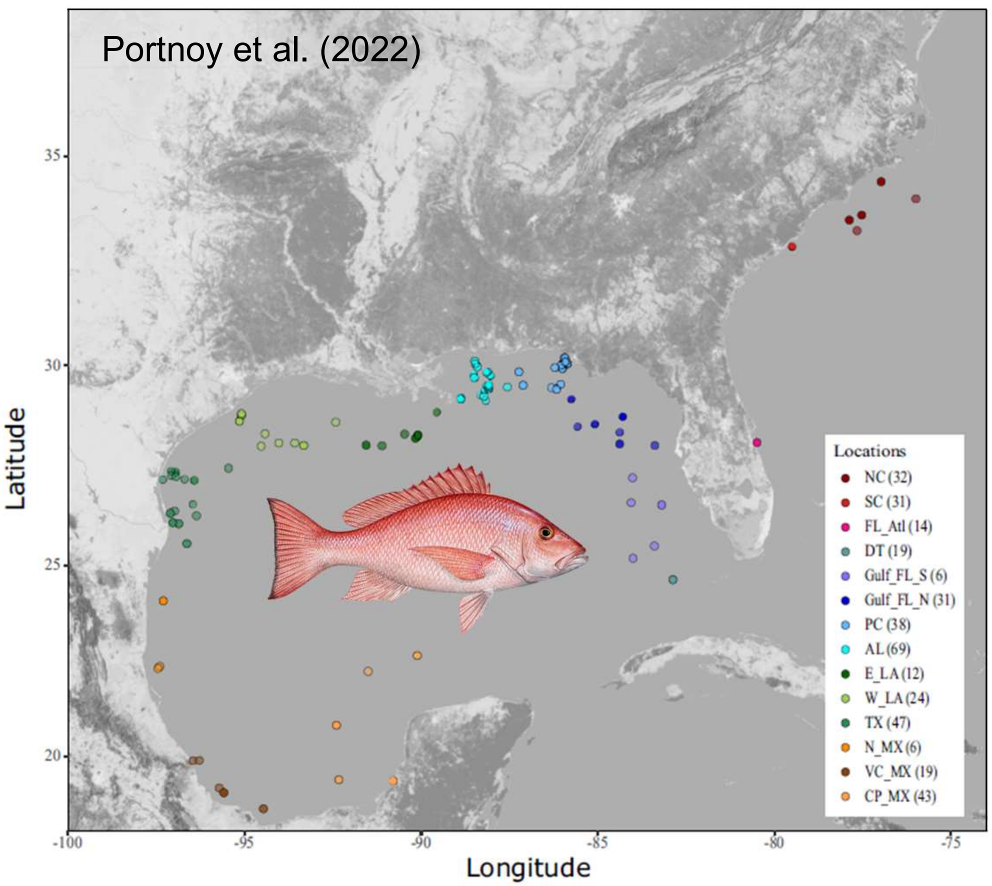


Fin Clip Sampling for Genomic Analyses




Fin Clip Sampling and Genomic Analyses
Genetic Population Structure
Portnoy et al. (2022)
Latitude
Longitude
Close-Kin
Mark-Recapture
Epigenetic
Ageing
Genetic
Sex ID

Red Snapper Atlantic Population Structure and Connectivity with GOM



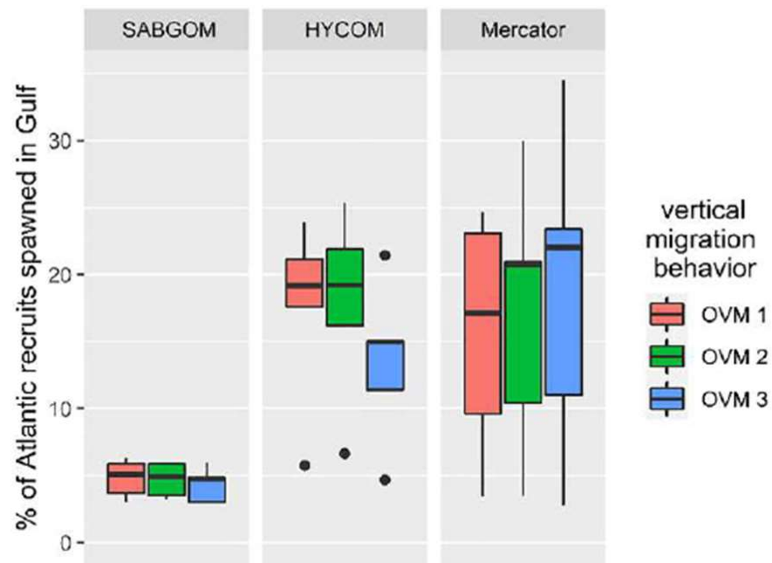

Received: 16 December 2021 | Revised: 27 July 2022 | Accepted: 31 July 2022
DOI: 10.1111/fog.12607

ORIGINAL ARTICLE

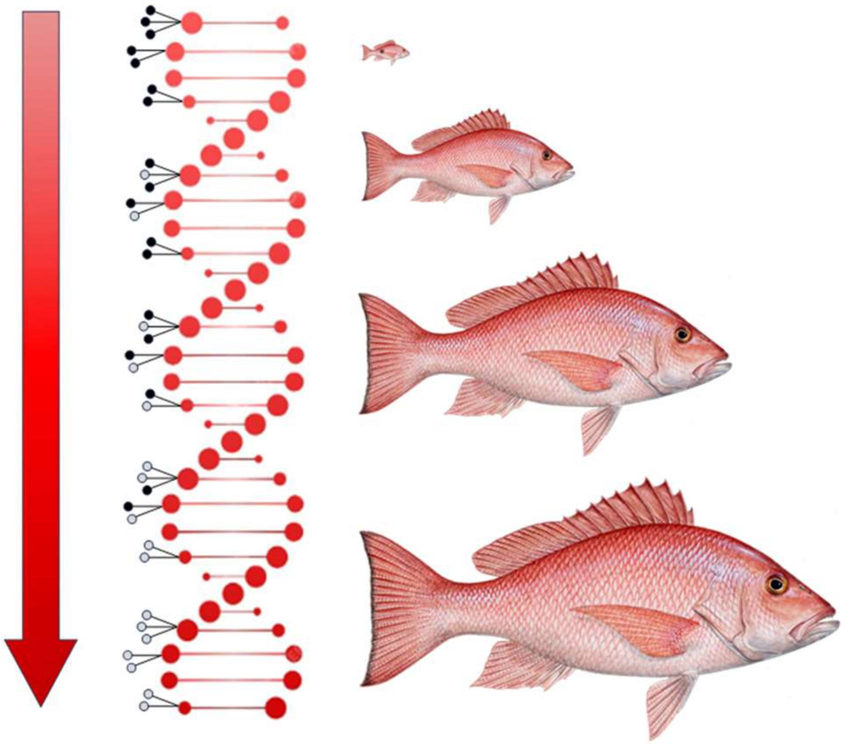
WILEY

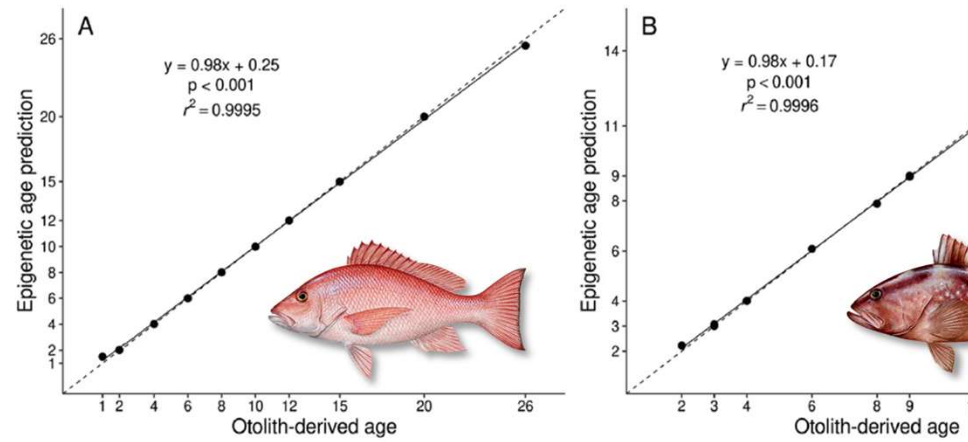
Source–sink recruitment of red snapper: Connectivity between the Gulf of Mexico and Atlantic Ocean

Mandy Karnauskas[1] | Kyle W. Shertzer[2] | Claire B. Paris[3] | Nicholas A. Farmer[4] | Theodore S. Switzer[5] | Susan K. Lowerre-Barbieri[6] | G. Todd Kellison[2] | Ruoying He[7] | Ana C. Vaz[1,3]

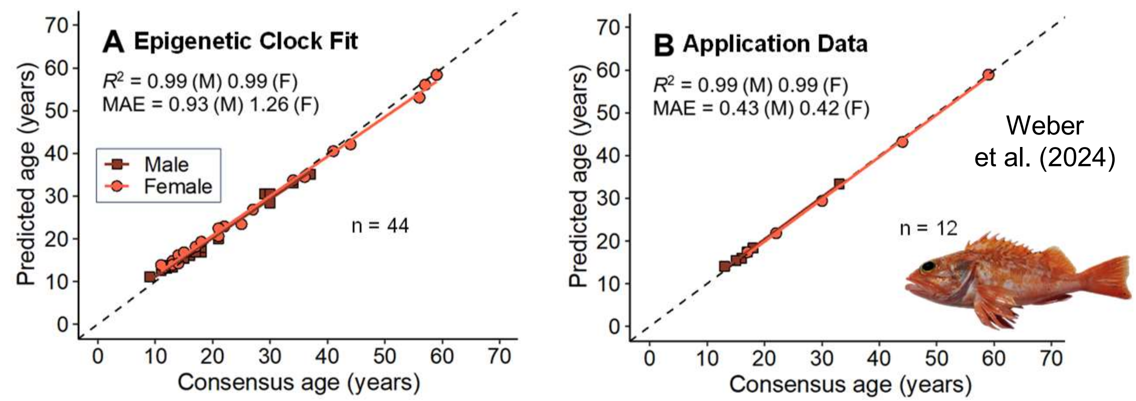


Epigenetic Ageing



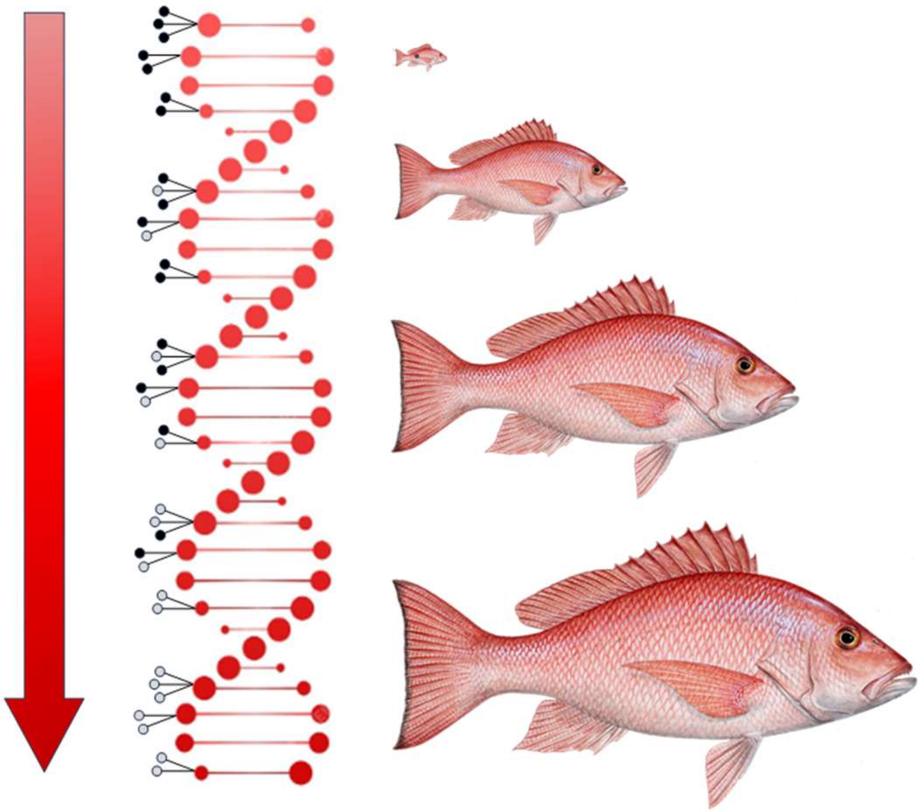


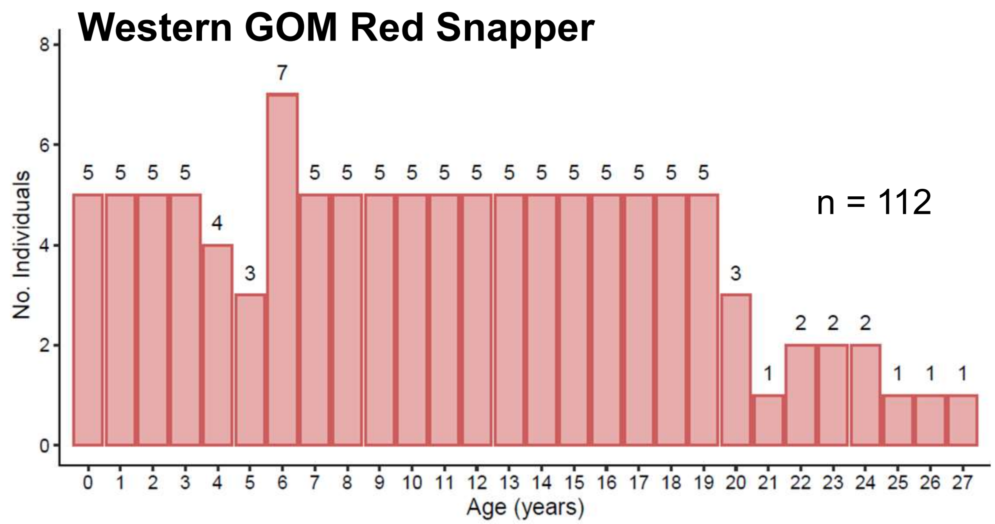
Weber et al. (2022)



Weber et al. (2024)

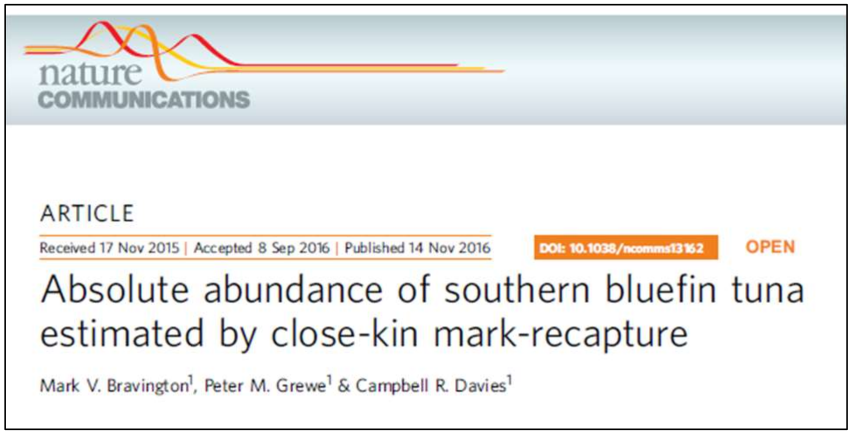
Expanded Red Snapper Epigenetic Clock Development





- 5.79 billion raw reads (each 150 bp long)
- 3.96 million CpG sites identified
- 224,883 CpG present in >80% of individuals
- 11,254 age-correlated CpG sites identified

Genetic Close-Kin Mark-Recapture



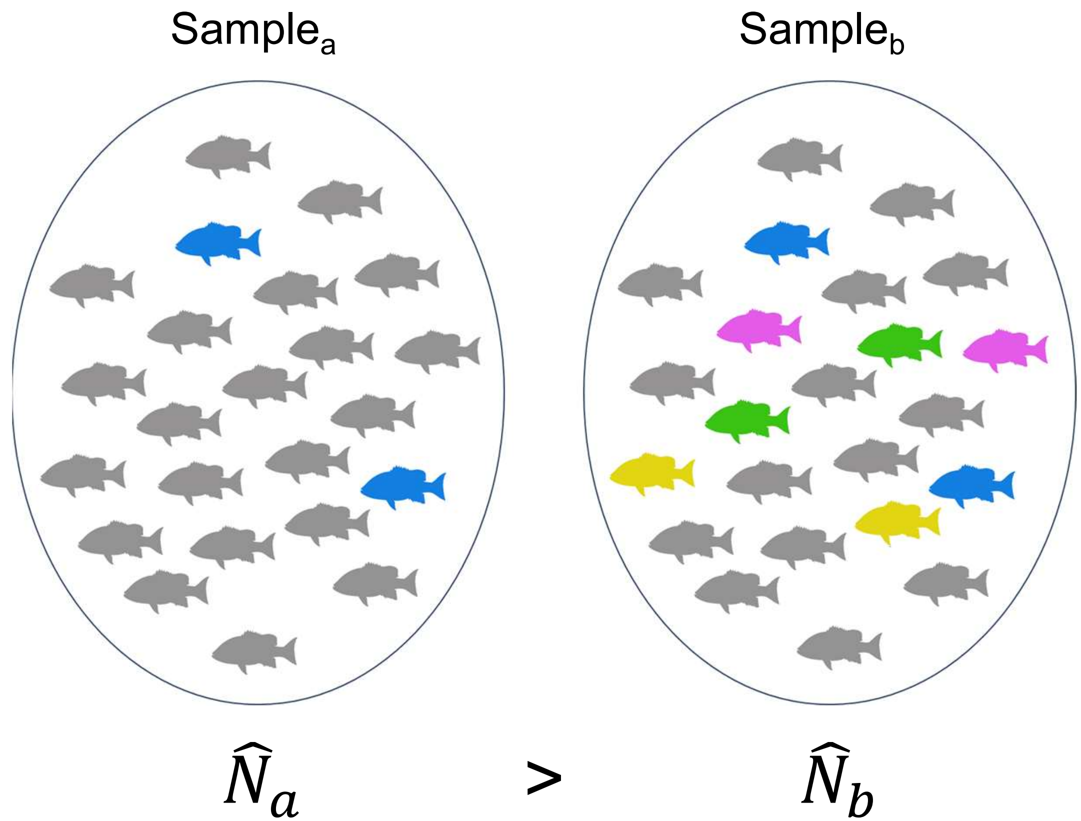
nature COMMUNICATIONS

ARTICLE

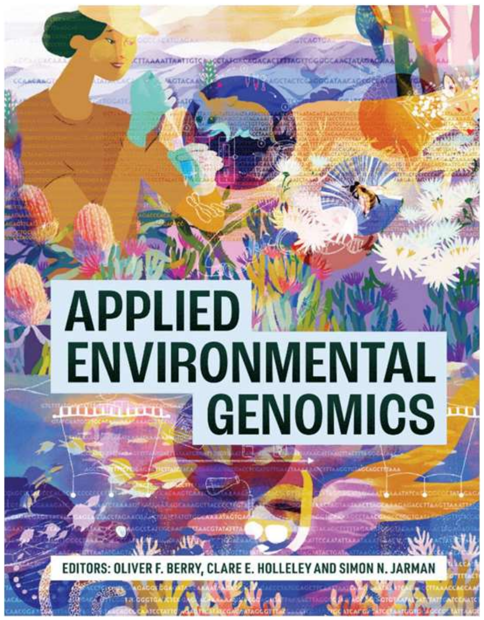
Received 17 Nov 2015 | Accepted 8 Sep 2016 | Published 14 Nov 2016 DOI: 10.1038/ncomms13162 OPEN

Absolute abundance of southern bluefin tuna estimated by close-kin mark-recapture

Mark V. Bravington[1], Peter M. Grewe[1] & Campbell R. Davies[1]

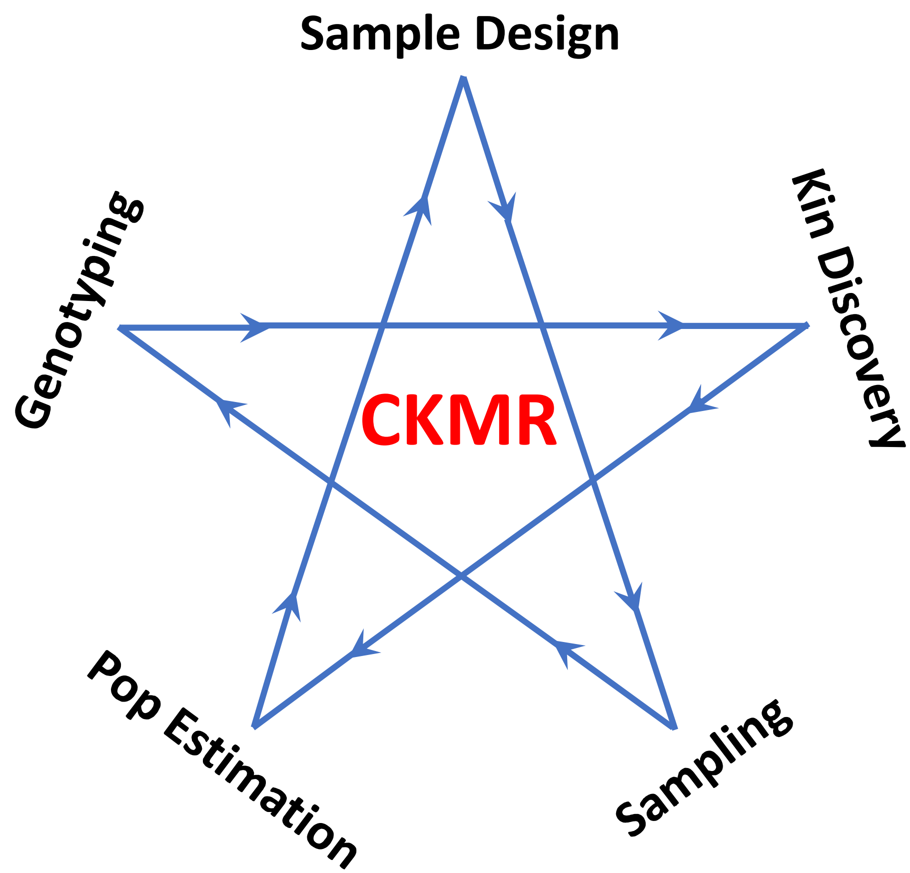


Genetic Close-Kin Mark-Recapture



11 The practical magic of close-kin mark-recapture

Mark V. Bravington and Emma L. Carroll **2023**



Close-Kin Mark Recapture Sequencing

- Successfully genotyped 10,347 individuals with a GT-seq panel
  - 5,532 (90.2%) from year 1 (2021)
  - 4,815 from year 2 (2022)
- Putative related Individuals
  - 9 pairs of parent-offspring
  - 33 pairs of full siblings
  - 107 pairs of half siblings
- Selection of year 1 possible siblings genotyped using ddRAD to confirm kinship
- Confirmed from those individuals:
  - 4 pairs of full siblings
  - 22 pairs of half siblings
- Ongoing ddRAD genotyping of 123 additional putative kinship pairs

Genetic Close-Kin Mark-Recapture: Previous Simulation Studies

Ecology and Evolution Open Access

ORIGINAL RESEARCH | Open Access

Robustness of close-kin mark–recapture estimators to dispersal limitation and spatially varying sampling probabilities

Paul B. Conn, Mark V. Bravington, Shane Baylis, Jay M. Ver Hoef

First published: 05 May 2020 | https://doi.org/10.1002/ece3.6296 | Citations: 18

Received: 25 June 2021 | Revised: 9 September 2021 | Accepted: 15 September 2021

DOI: 10.1111/1755-0998.13513

RESOURCE ARTICLE

MOLECULAR ECOLOGY RESOURCES WILEY

CKMRpop: Forward-in-time simulation and tabulation of pairwise kin relationships in age-structured populations

Eric C. Anderson

FISH and FISHERIES

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Close-kin methods to estimate census size and effective population size

Robin S. Waples, Pierre Feutry

First published: 20 October 2021 | https://doi.org/10.1111/faf.12615 | Citations: 12

Ecology and Evolution Open Access

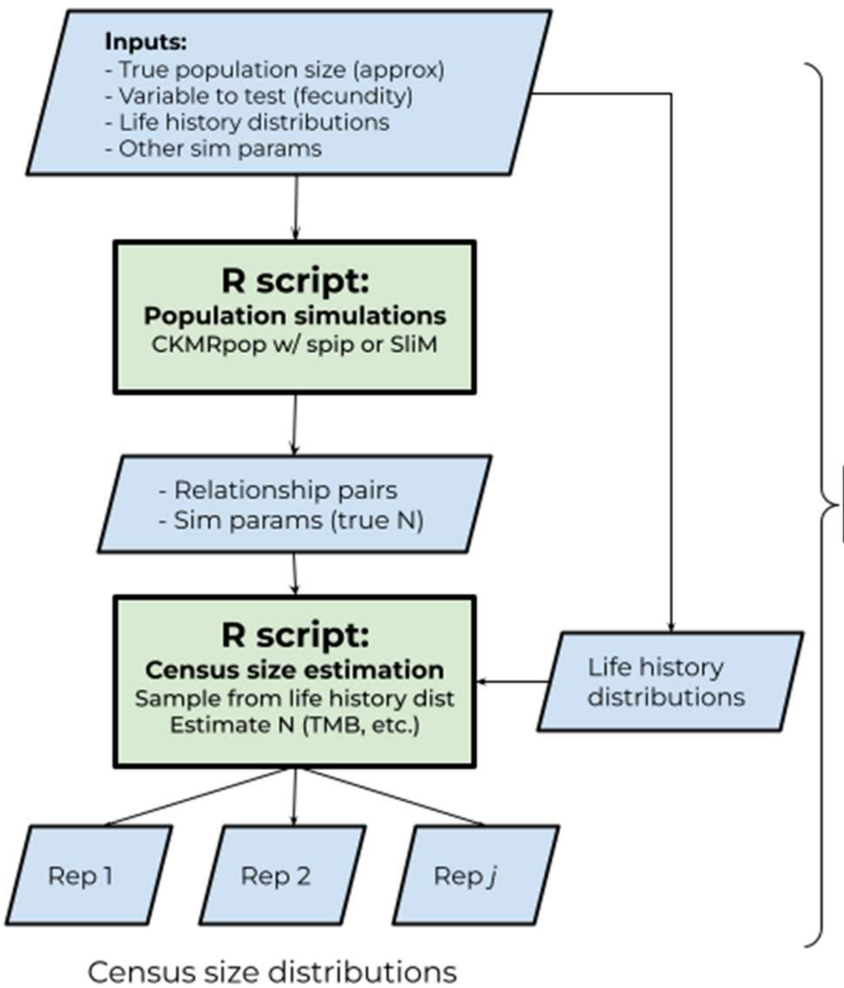
RESEARCH ARTICLE | Open Access

Accounting for unobserved population dynamics and aging error in close-kin mark-recapture assessments

John D. Swenson, Elizabeth N. Brooks, Dovi Kacev, Charlotte Boyd, Michael J. Kinney, Benjamin Marcy-Quay, Anthony Sévêque, Kevin A. Feldheim, Lisa M. Komoroske

First published: 07 February 2024 | https://doi.org/10.1002/ece3.10854

Genetic Close-Kin Mark-Recapture: SARSRP Simulation Study



Study questions:

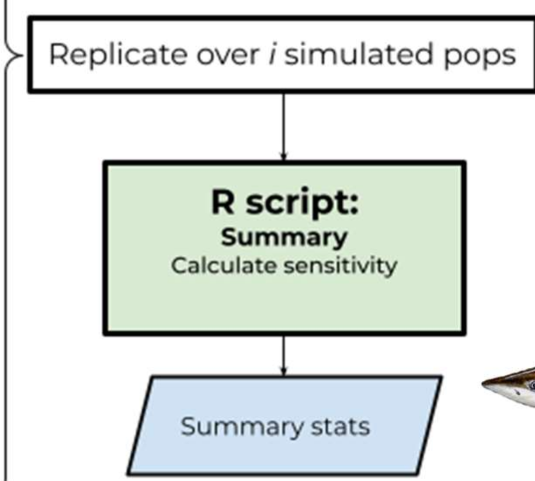
1) How sensitive is population size estimate to:

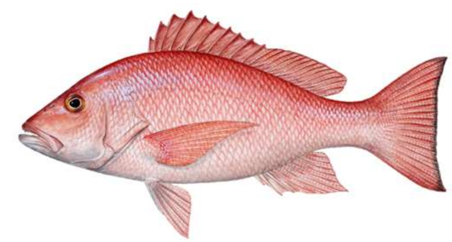
mortality estimates?

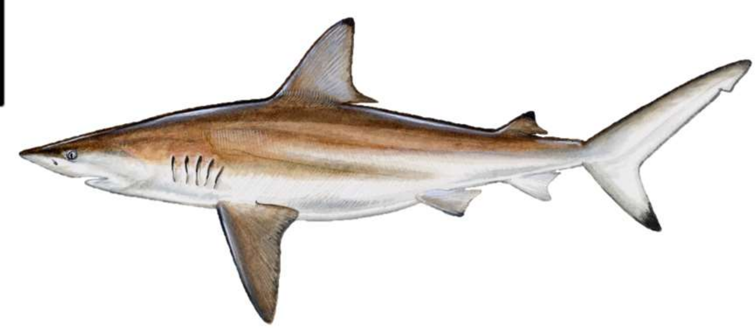
fecundity estimates?

estimated maturity schedule?

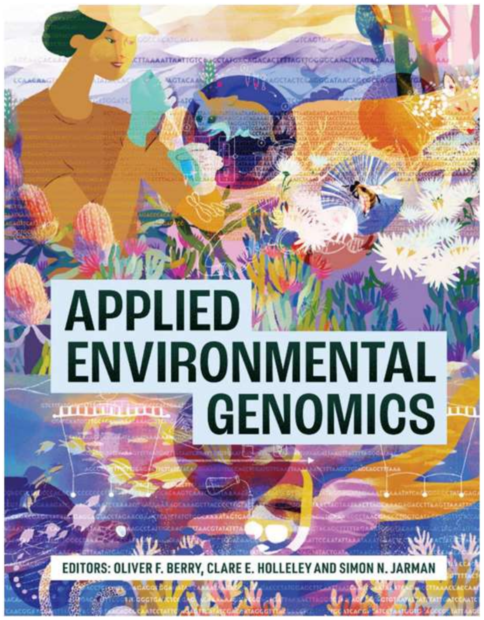
2) Best methods to account for uncertainty?







Genetic Close-Kin Mark-Recapture



11 The practical magic of close-kin mark-recapture

Mark V. Bravington and Emma L. Carroll **2023**

Table 11.1. Summary of completed CKMR studies.

Source: samples from dead (D) and/or alive (L) animals; Genotyping method (Geno): DArTCap^{TM} (Cap), DArTSeq^{TM} (Seq), SNP array or microsatellites (Usat). Model: Fully age structured (Full); Single-cohort adjusted Lincoln-Peterson (Single); exponential change with survival estimated (*N, z, p*); exponential change assuming quasi-equilibrium stable age composition, plus survival estimated (Stable age); exponential change, no survival estimate (*N, z*). Abundance is order-of-magnitude, so $\log_{10}(N_{adult}) = 3$ means closer to 1000 than to 100 or to 10 000.

Species	Source	Geno	POP	HSP	Model	$\log_{10}(N_{adult})$	$N_{samples}$	Ageing	Citation
Southern bluefin tuna (*Thunnus maccoyii*)	D	Usat	X		Full	6	13 000	Length (juveniles); Otolith+length (adult)	Bravington, Grewe *et al.* 2016
Southern bluefin tuna	D	Cap	X	X			>25 000		Davies *et al.* 2020
Chinook salmon (*Oncorhynchus tshawytscha*)	D	Usat	X		Single	3	2000	Inspection	Rawding *et al.* 2014
School shark (*Galeorhinus galeus*)	D	Cap		X	Full	5	3000	Vertebra	Thomson *et al.* 2020
White shark (*Carcharodon carcharias*)	L+D	Cap		X	*N, z, p*	2	200	Length	Hilary *et al.* 2018
Grey nurse shark (*Carcharias taurus*)	L+D	Seq	X	X	Stable age	3	378	Length	Bradford *et al.* 2018
Speartooth shark (*Glyphis glyphis*)	L	Seq		X	*N, z, p*	3	226	Length	Patterson *et al.* 2022
Northern River shark (*Glyphis garricki*)	L	Cap		X	*N, z, p*	3	300	Length	Bravington *et al.* 2019
Brook trout (*Salvelinus fontinalis*)	L	Usat	X		Single	3	300	Length	Ruzzante *et al.* 2019
Thornback ray (*Raja clavata*)	D	SNP array	X		*N, z*	4	>7000	Length	Trenkel *et al.* 2022

Estimating South Atlantic RS Discards: Tagging Simulations

Objectives:

1) To design a tagging study that can estimate exploitation and the magnitude of discards in the private recreational fleet.

Approach:

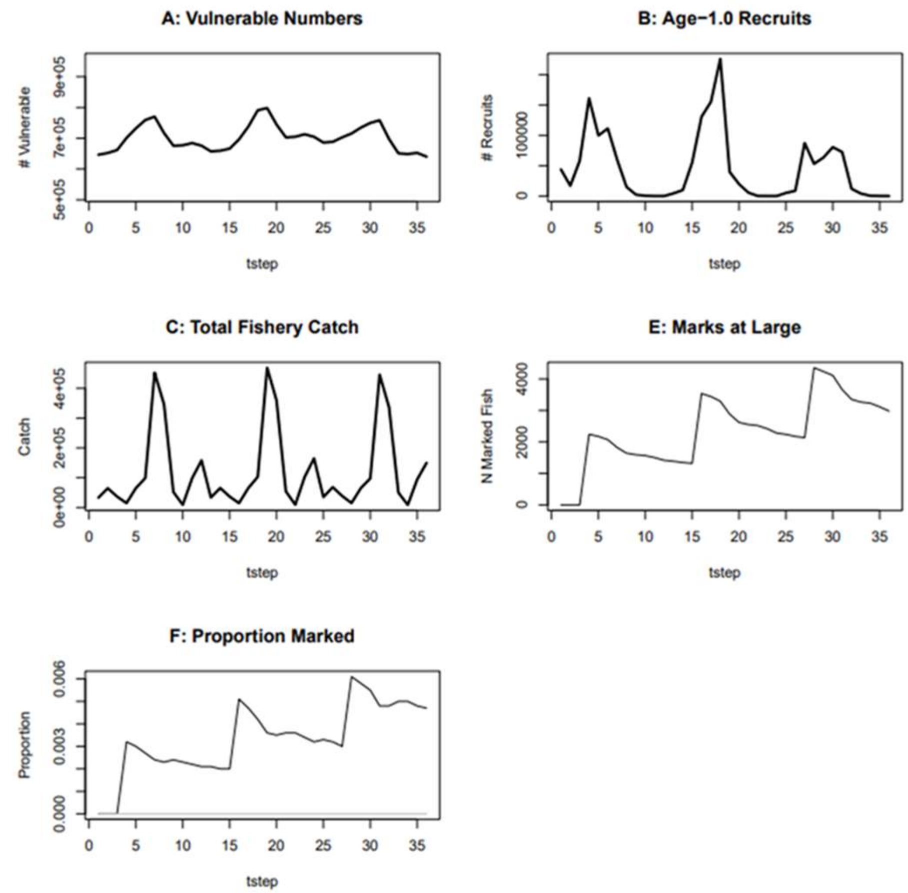
1) Focus on NE Florida, where >90% of harvest and discarding occurs

2) Explore both conventional and genetic tags in a simulation framework

3) Operating model: monthly population dynamics with individual based tagging simulation model

4) Develop and code Barker joint encounter (i.e., live and dead recoveries) estimation model

5) Evaluate precision in catch-release and harvest probability estimates across tag numbers and reporting rates



Estimating South Atlantic RS Discards: Tagging Simulations

- Workshop held in Cedar Key, FL in June 2023 to discuss modeling approach, initial model development, and tagging logistics

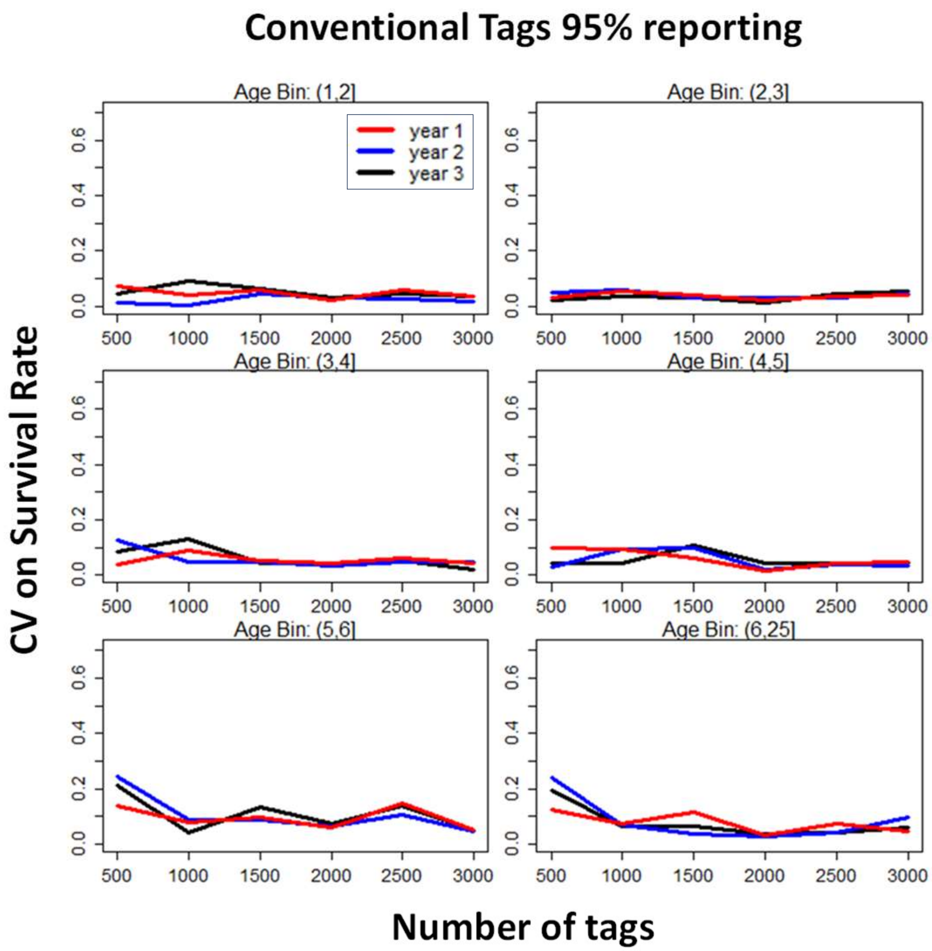
- Follow-up online workshop scheduled for May 2, 2024 to review models and discuss simulation results

- Preliminary findings:

  -High precision (CV<0.2) and low bias in age-specific survival rate estimates from simulations based on conventional tagging, but affected by reporting rate uncertainty

  -Gene tagging feasible but would require obtaining tissues samples from private, recreational discards

  -Gene tagging challenges: angler participation, training, materials, and sample preservation; a large portion of the total catch likely to be inaccessible



Integrating Red Snapper Pop Estimates into Assessment and Management

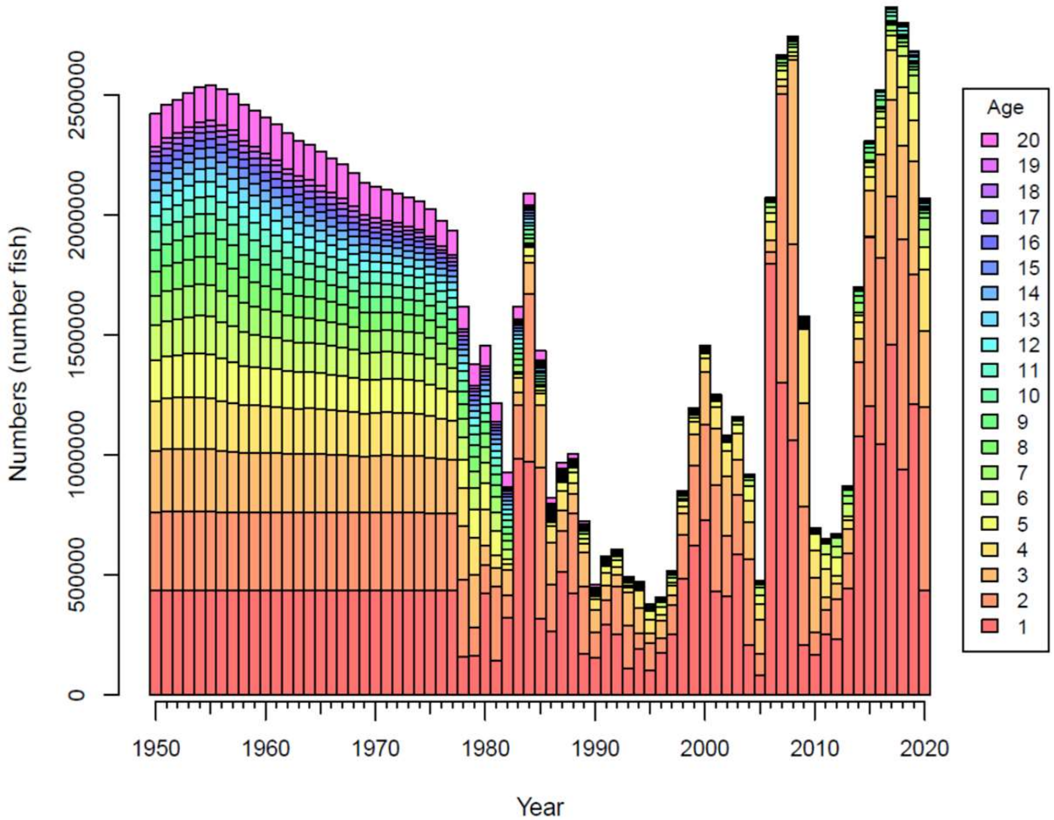
1) Evaluate two assessment approaches:
   A. Scale the current assessment model to the externally derived abundance estimates
   B. Integrate new data and pop estimation into the assessment model

2) Matt Damiano was funded through NOAA-MARFIN to work with Kyle Shertzer at NOAA Fisheries-Beaufort Laboratory as post-doctoral scholar on CKMR integration into BAM assessment model

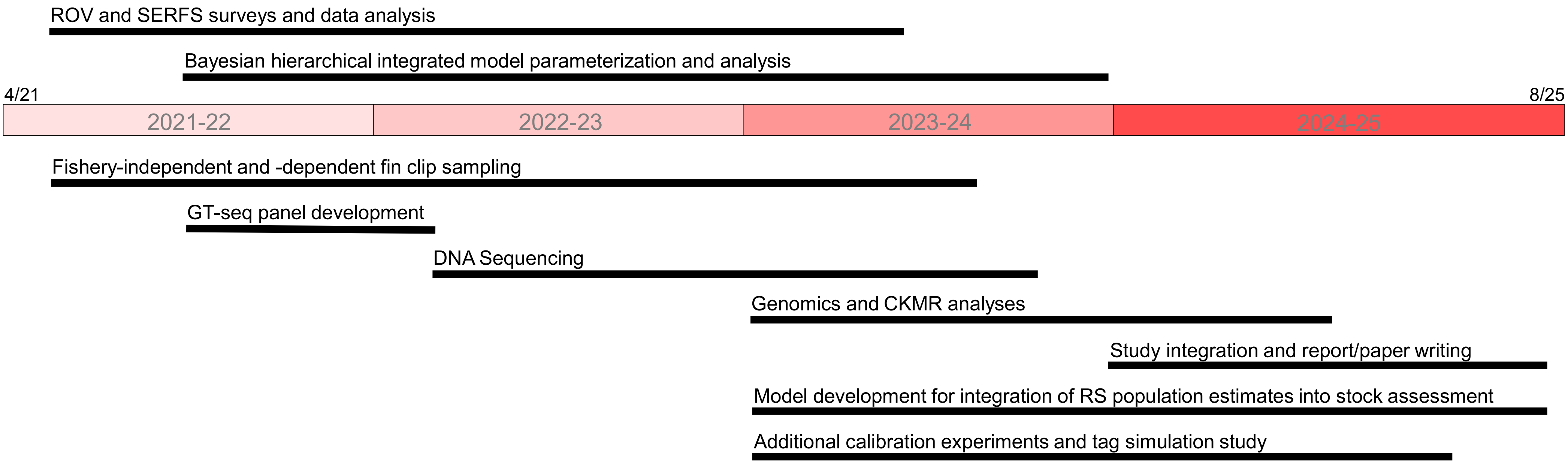
3) Incorporate estimates into next Research Track Assessment, scheduled to start in 2025

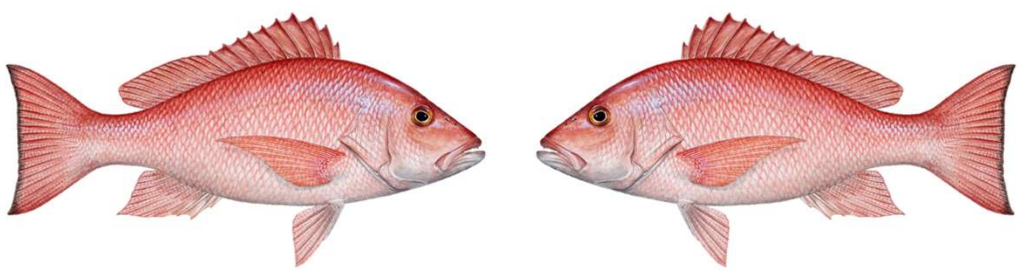
Kyle Shertzer

Matt Damiano



Timeline of Study Components





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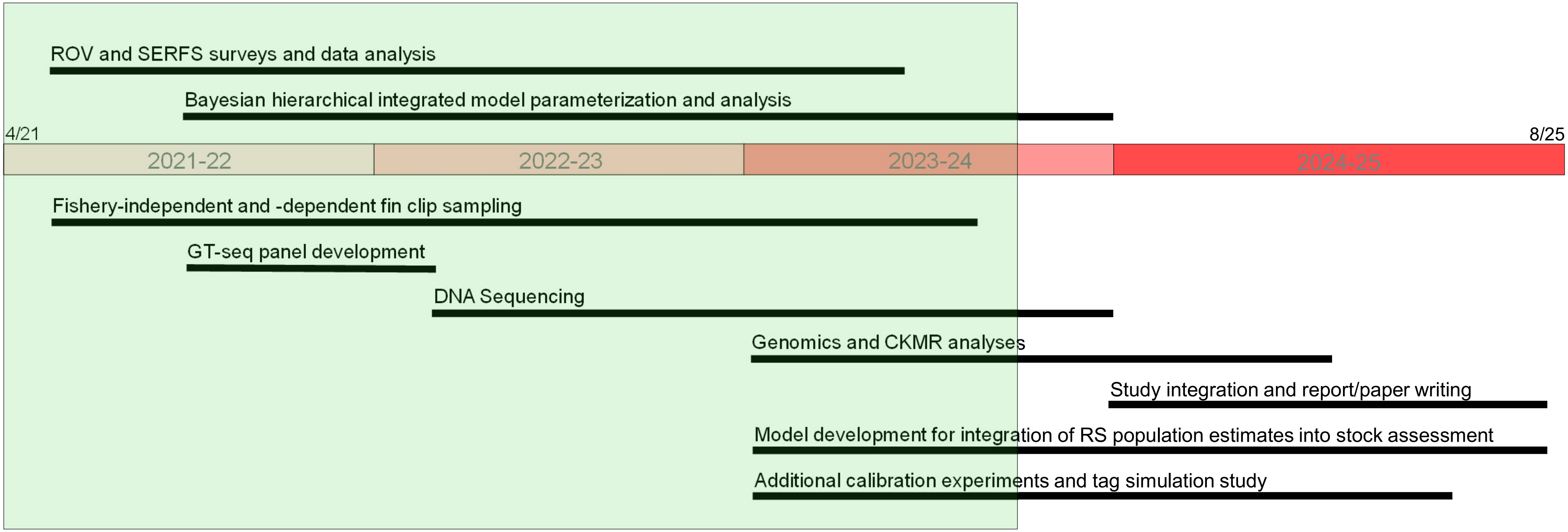

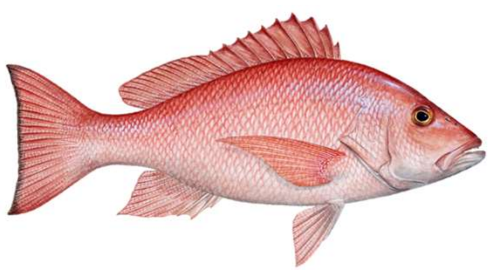

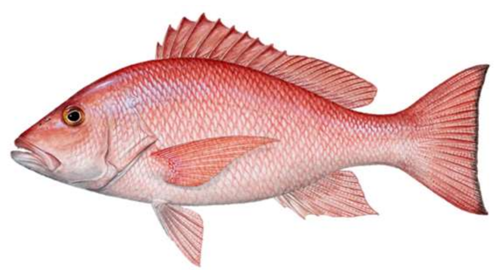

Acknowledgements

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Robert Williams
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Hans Kraaz
Paul Johnson
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Drew Demaree
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Keith Green
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and FWC accounts personnel