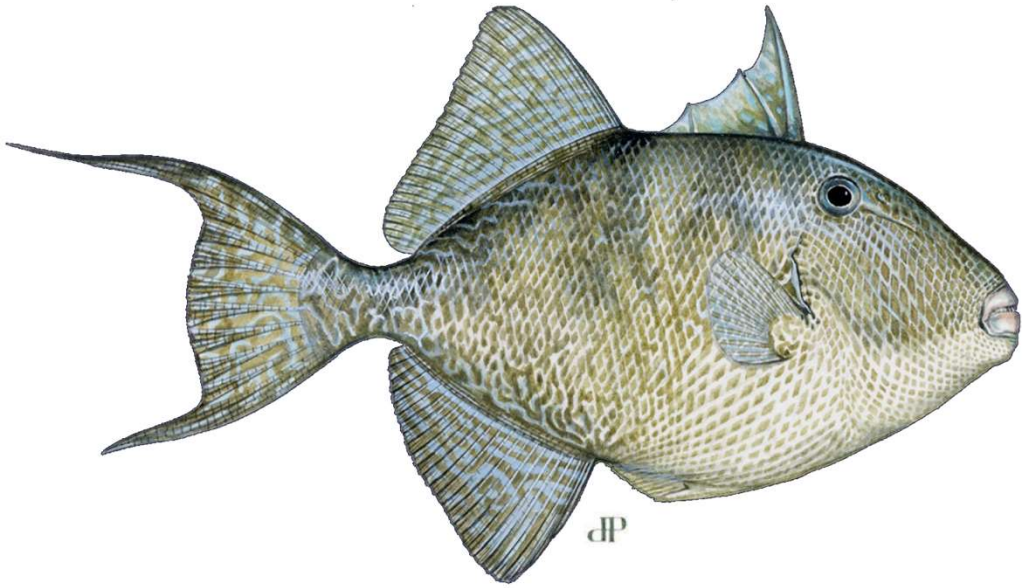
Validating Gray Triggerfish Age Estimates Derived from Otoliths and Spines, and Assessing Effects of Ageing Error on Estimates of Size-at-Age, Growth, and Stock Status Benchmarks



Will Patterson, Derek Chamberlin, Zachary Siders

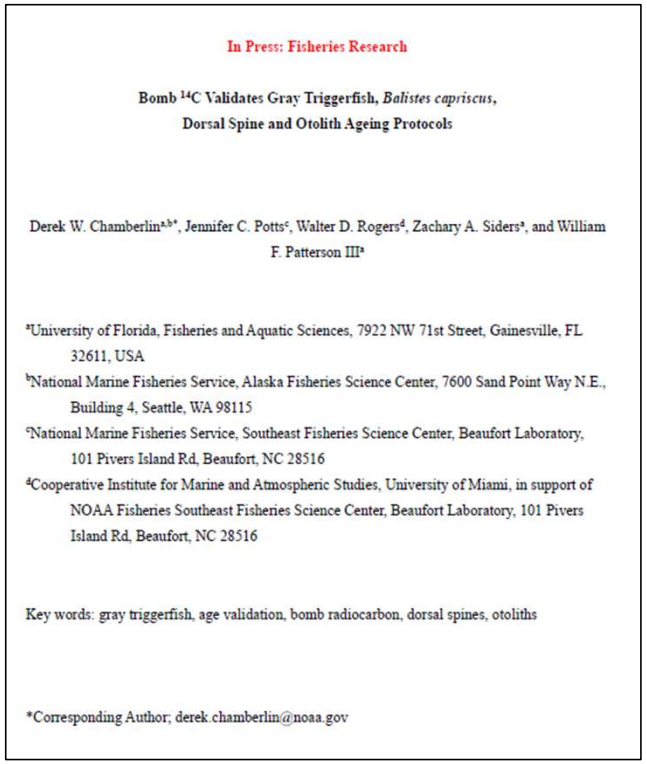
UF IFAS UNIVERSITY of FLORIDA

UNIVERSITY of FLORIDA UF Marine Fisheries Laboratory

NOAA NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION U.S. DEPARTMENT OF COMMERCE

Report Organization and Study Contributors

Jennifer Potts, Walt Rogers, Miaya Taylor, Nick Fisch, Kelli Johnson, Katie Siegfried, Shannon Cass-Calay



In Press: Fisheries Research

Bomb ^{14}C Validates Gray Triggerfish, *Balistes capriscus*, Dorsal Spine and Otolith Ageing Protocols

Derek W. Chamberlin[a,b*], Jennifer C. Potts[c], Walter D. Rogers[d], Zachary A. Siders[a], and William F. Patterson III[a]

[a]University of Florida, Fisheries and Aquatic Sciences, 7922 NW 71st Street, Gainesville, FL 32611, USA
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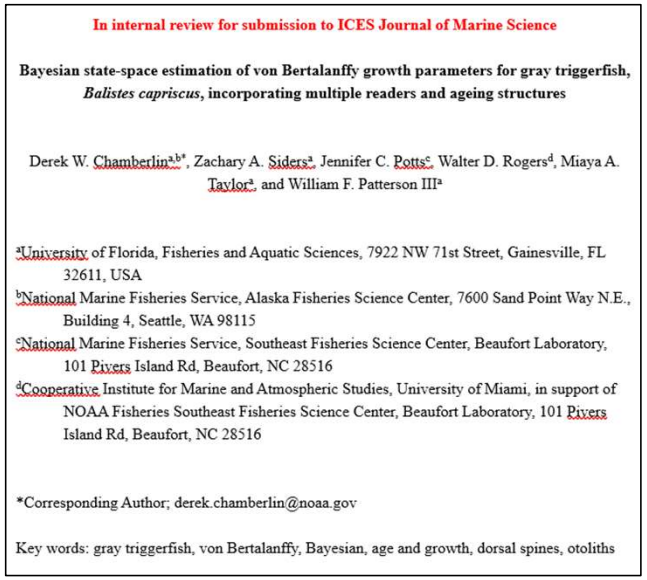
[c]National Marine Fisheries Service, Southeast Fisheries Science Center, Beaufort Laboratory, 101 Pivers Island Rd, Beaufort, NC 28516
[d]Cooperative Institute for Marine and Atmospheric Studies, University of Miami, in support of NOAA Fisheries Southeast Fisheries Science Center, Beaufort Laboratory, 101 Pivers Island Rd, Beaufort, NC 28516

Key words: gray triggerfish, age validation, bomb radiocarbon, dorsal spines, otoliths

*Corresponding Author; derek.chamberlin@noaa.gov



In internal review for submission to ICES Journal of Marine Science

Bayesian state-space estimation of von Bertalanffy growth parameters for gray triggerfish, *Balistes capriscus*, incorporating multiple readers and ageing structures

Derek W. Chamberlin[a,b*], Zachary A. Siders[a], Jennifer C. Potts[c], Walter D. Rogers[d], Miaya A. Taylor[a], and William F. Patterson III[a]

[a]University of Florida, Fisheries and Aquatic Sciences, 7922 NW 71st Street, Gainesville, FL 32611, USA
[b]National Marine Fisheries Service, Alaska Fisheries Science Center, 7600 Sand Point Way N.E., Building 4, Seattle, WA 98115
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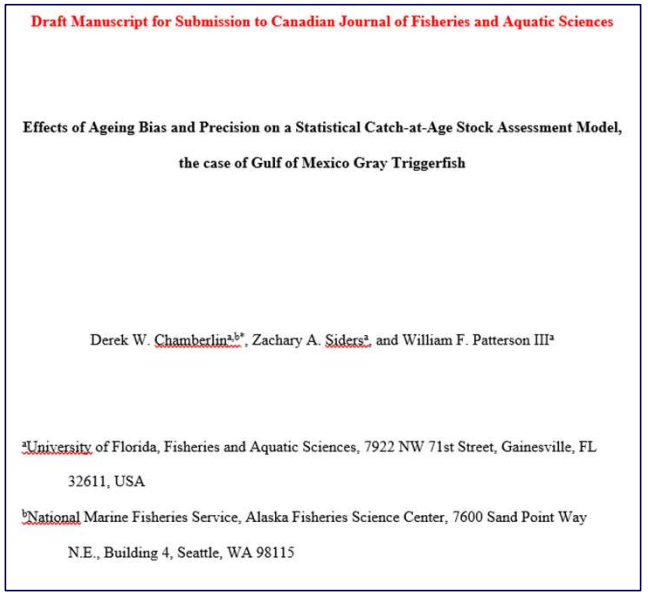
*Corresponding Author; derek.chamberlin@noaa.gov

Key words: gray triggerfish, von Bertalanffy, Bayesian, age and growth, dorsal spines, otoliths



Draft Manuscript for Submission to Canadian Journal of Fisheries and Aquatic Sciences

Effects of Ageing Bias and Precision on a Statistical Catch-at-Age Stock Assessment Model, the case of Gulf of Mexico Gray Triggerfish

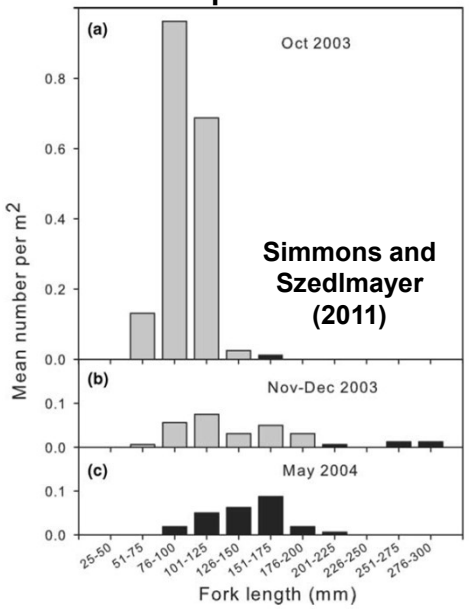
Derek W. Chamberlin[a,b*], Zachary A. Siders[a], and William F. Patterson III[a]

[a]University of Florida, Fisheries and Aquatic Sciences, 7922 NW 71st Street, Gainesville, FL 32611, USA
[b]National Marine Fisheries Service, Alaska Fisheries Science Center, 7600 Sand Point Way N.E., Building 4, Seattle, WA 98115

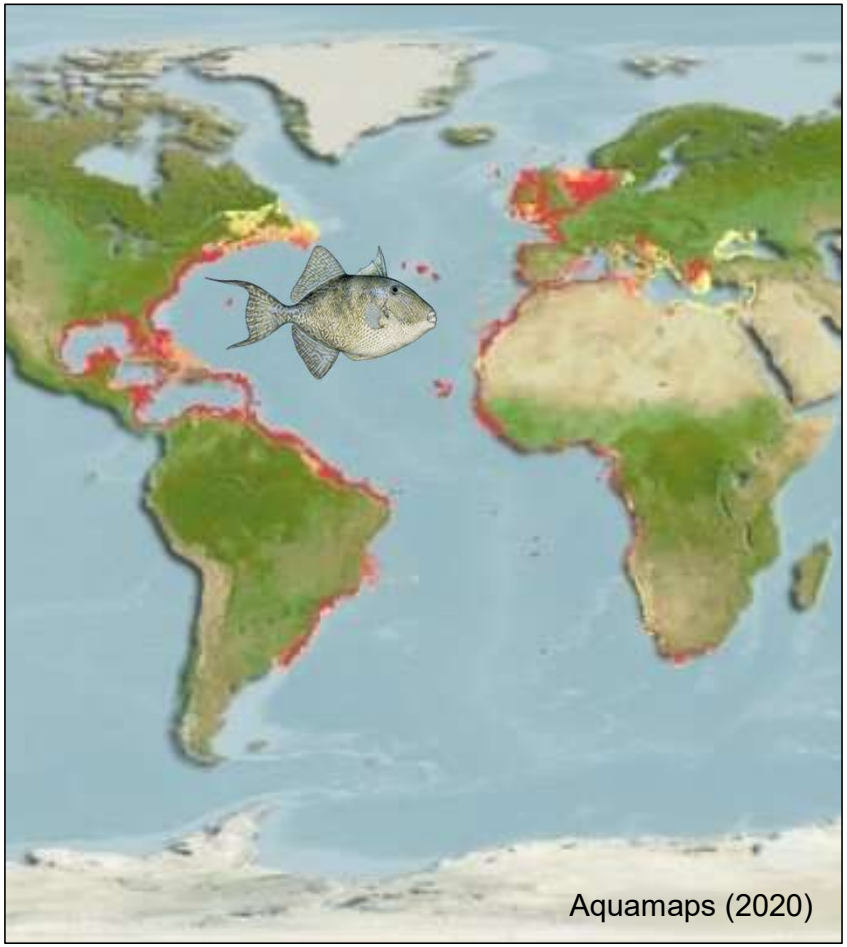
Gray Triggerfish, *Balistes capriscus*

- **Distributed in tropical to temperate waters on both sides of the Atlantic Ocean**
- **Spend up to a year of life associated with *Sargassum*, then settle onto reef habitat**
- **Not highly targeted in U.S. waters of Atlantic or Gulf of Mexico until 1980s or later**

Settlement on AL Experimental Reefs

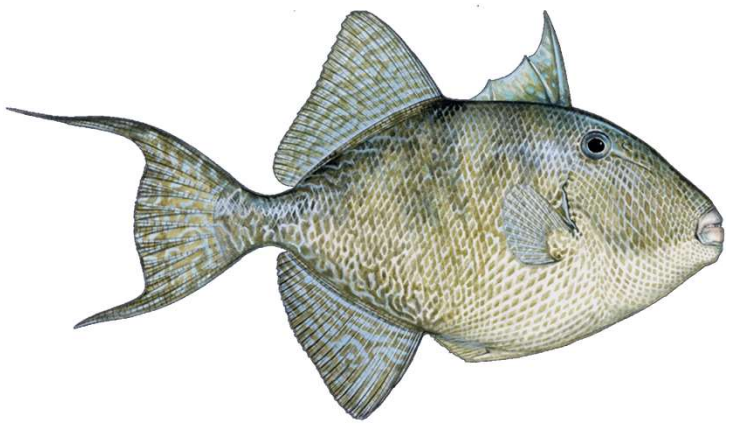


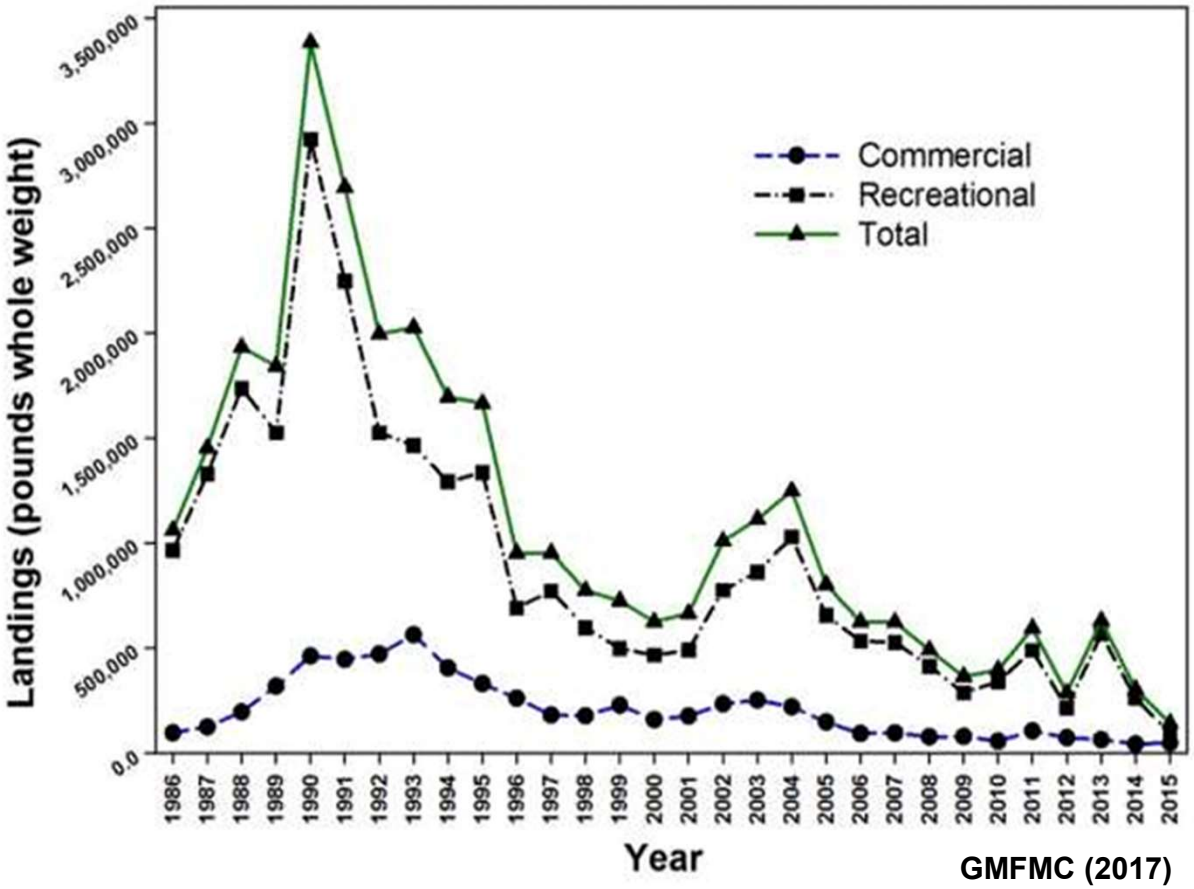
Simmons and Szedlmayer (2011)



Gulf of Mexico Gray Triggerfish Fishery Sectors and Estimated Landings

- **Two main fishery sectors: recreational (private, headboat, charter) and commercial handline**
- **Gray triggerfish also captured in commercial longline fishery and as shrimp trawl bycatch**

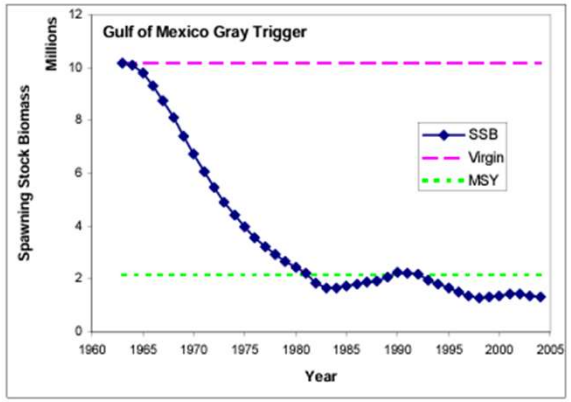


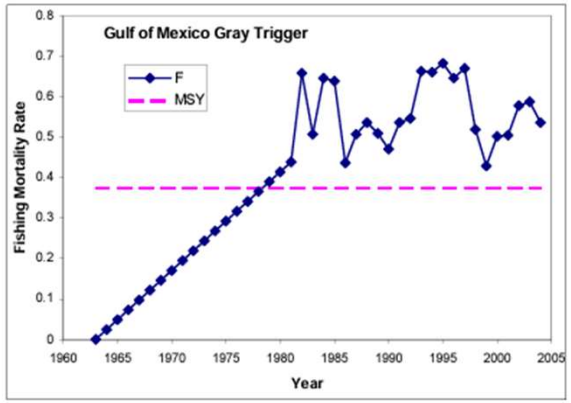


GMFMC (2017)

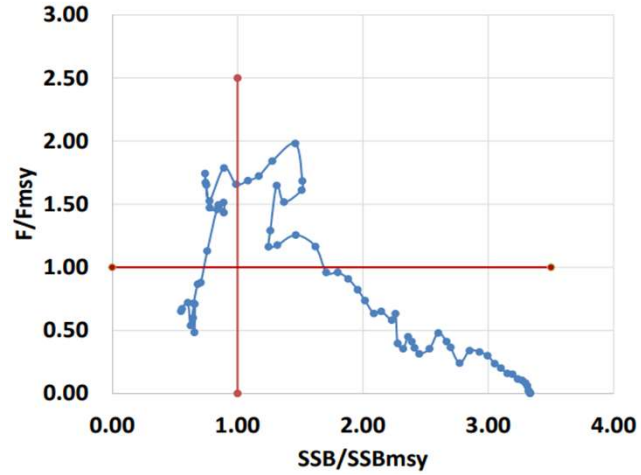
Gulf of Mexico Gray Triggerfish Assessment and Stock Status

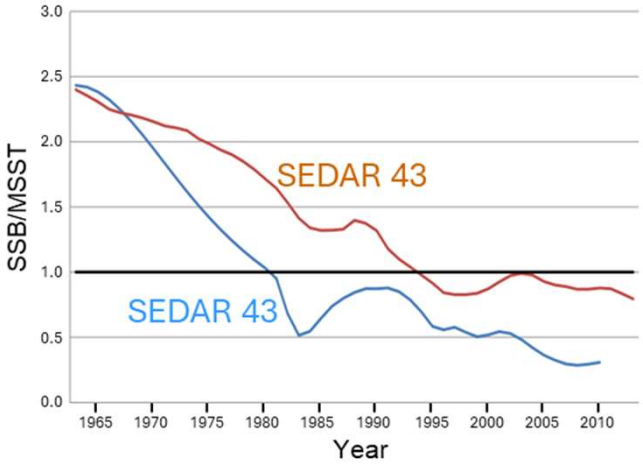
SEDAR 9 (2006)
GOM GT Stock Status





SEDAR 43 (2015)
GOM GT Stock Status





SEDAR 62 (2019)
GOM GT Stock Status

Assessment terminated:
No stock status estimates produced

Gulf of Mexico Gray Triggerfish Rebuilding Plans

FINAL

REEF FISH AMENDMENT 30A:

GREATER AMBERJACK - REVISE REBUILDING PLAN, ACCOUNTABILITY MEASURES

GRAY TRIGGERFISH - ESTABLISH REBUILDING PLAN, END OVERFISHING, ACCOUNTABILITY MEASURES, REGIONAL MANAGEMENT, MANAGEMENT THRESHOLDS AND BENCHMARKS

Including Supplemental Environmental Impact Statement, Regulatory Impact Review, and Regulatory Flexibility Act Analysis

February 2008

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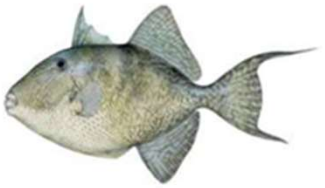
This is a publication of the Gulf of Mexico Fishery Management Council Pursuant to National Oceanic and Atmospheric Administration Award No. NA05NMF4410003.

Gray Triggerfish Rebuilding Plan



Final Amendment 46 to the Fishery Management Plan for the Reef Fish Resources of the Gulf of Mexico

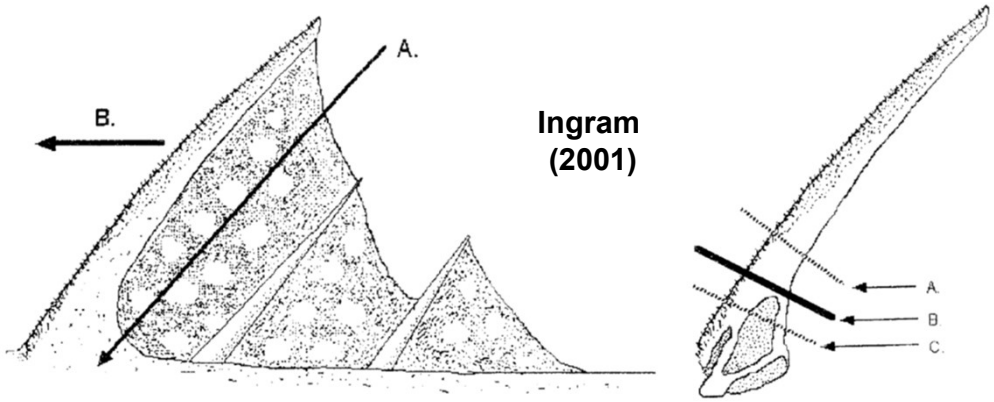
Including Environmental Assessment, Fishery Impact Statement, Regulatory Impact Review, and Regulatory Flexibility Act Analysis

May 2017

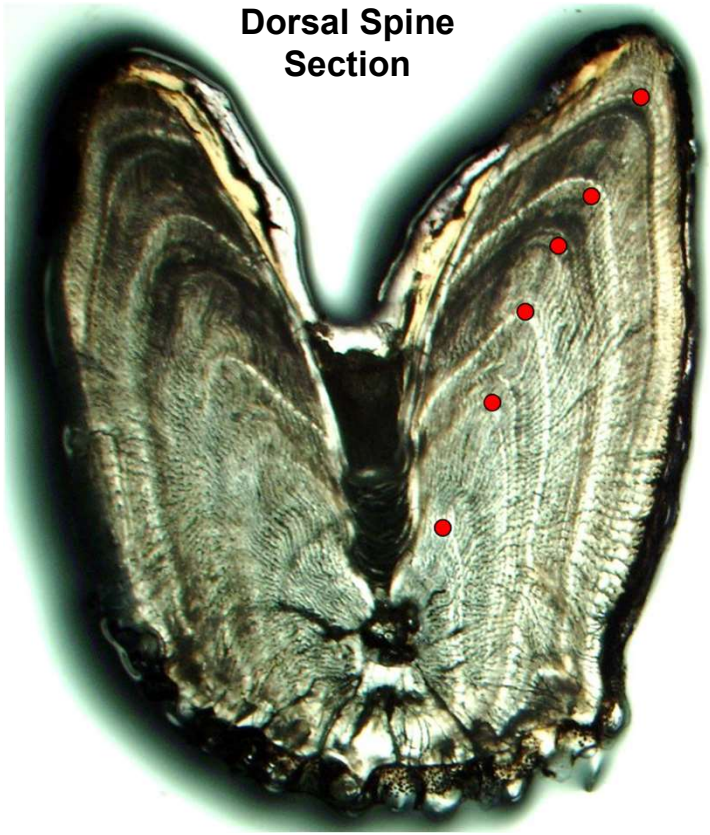
This is a publication of the Gulf of Mexico Fishery Management Council Pursuant to National Oceanic and Atmospheric Administration Award No. NA15NMF4410011.

Generating Age Comps: Traditional Gray Triggerfish Ageing with Dorsal Spines

Extracting and Sectioning Dorsal Spine

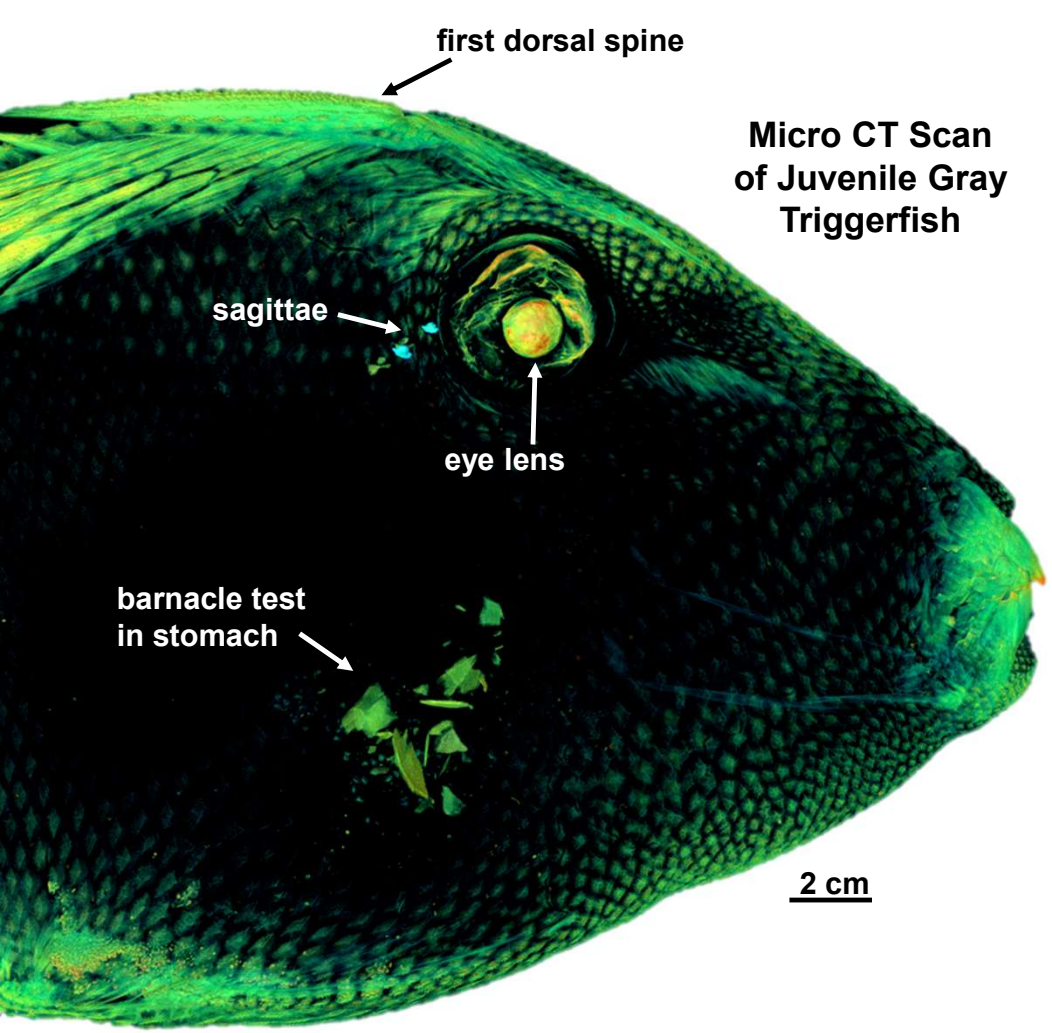


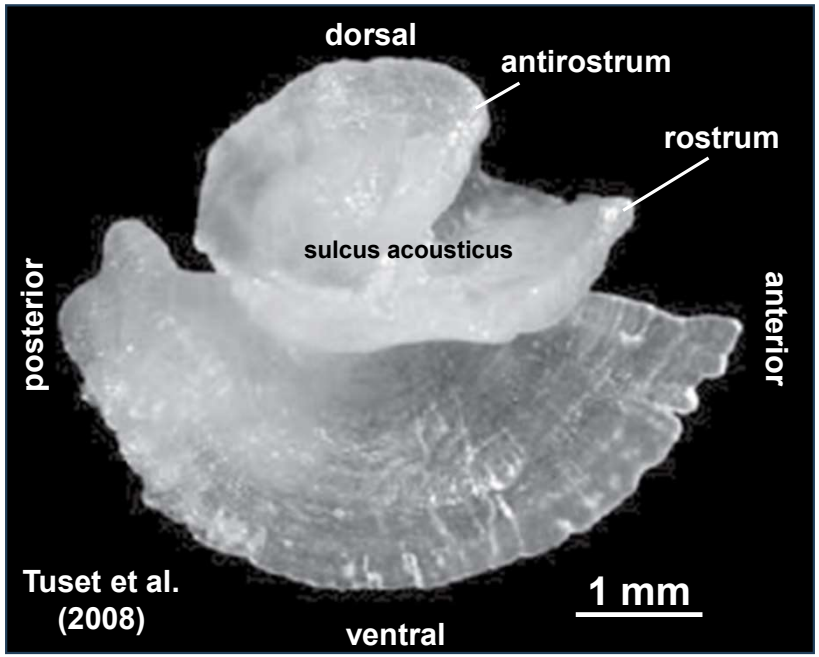
Ingram (2001)

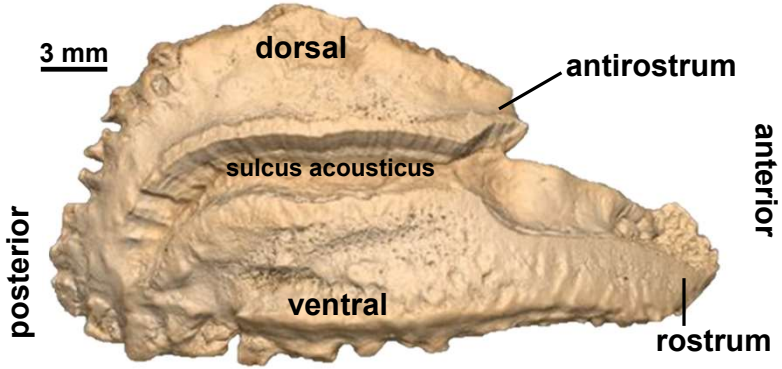


- First dorsal spine = historical ageing structure of choice
- Relatively easy to extract and section
- Concerns raised about ageing error, both imprecision and bias
- Important implications for population ecology and stock assessment

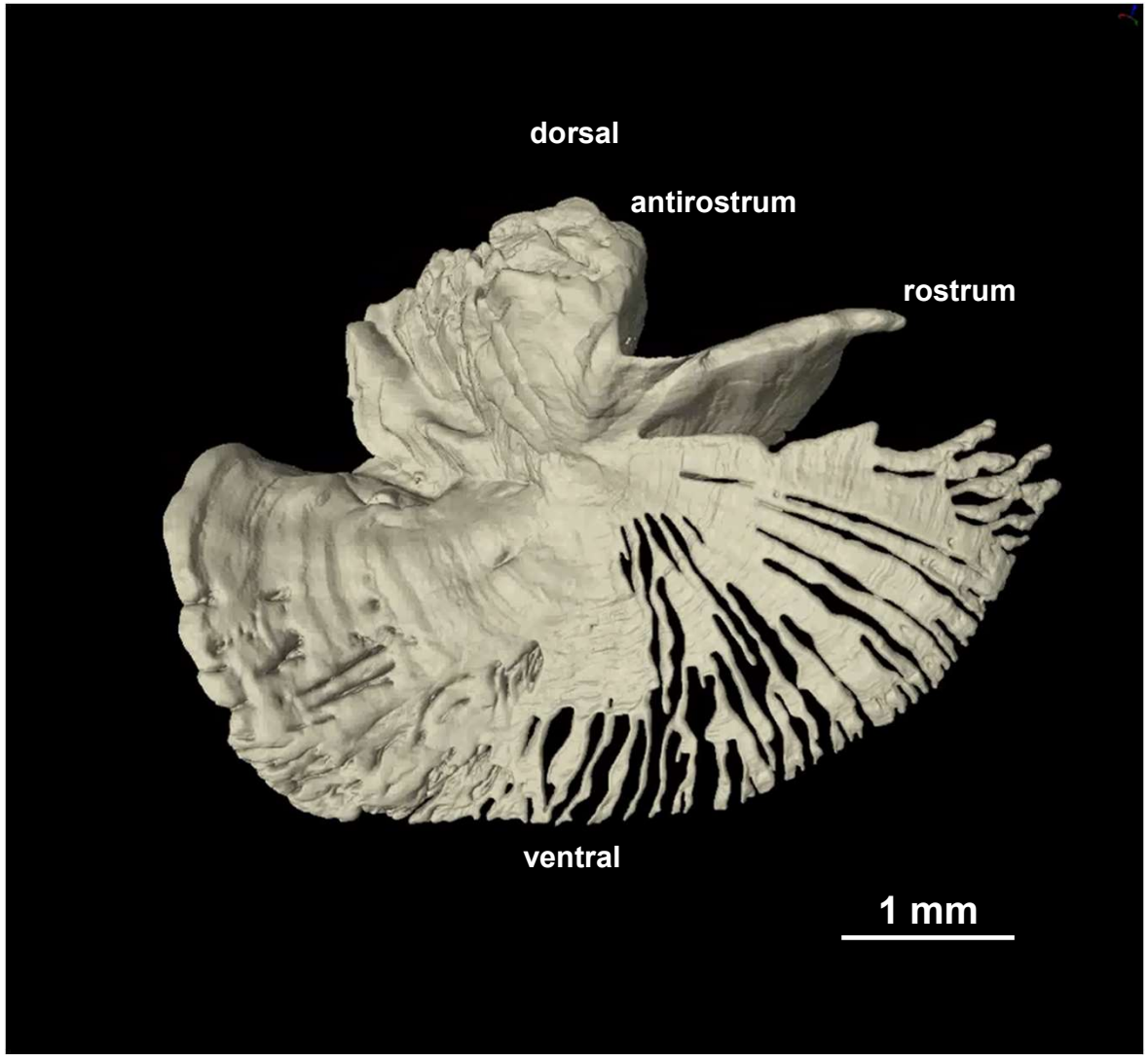
Gray Triggerfish Otoliths: Small, Delicate, Difficult to Extract



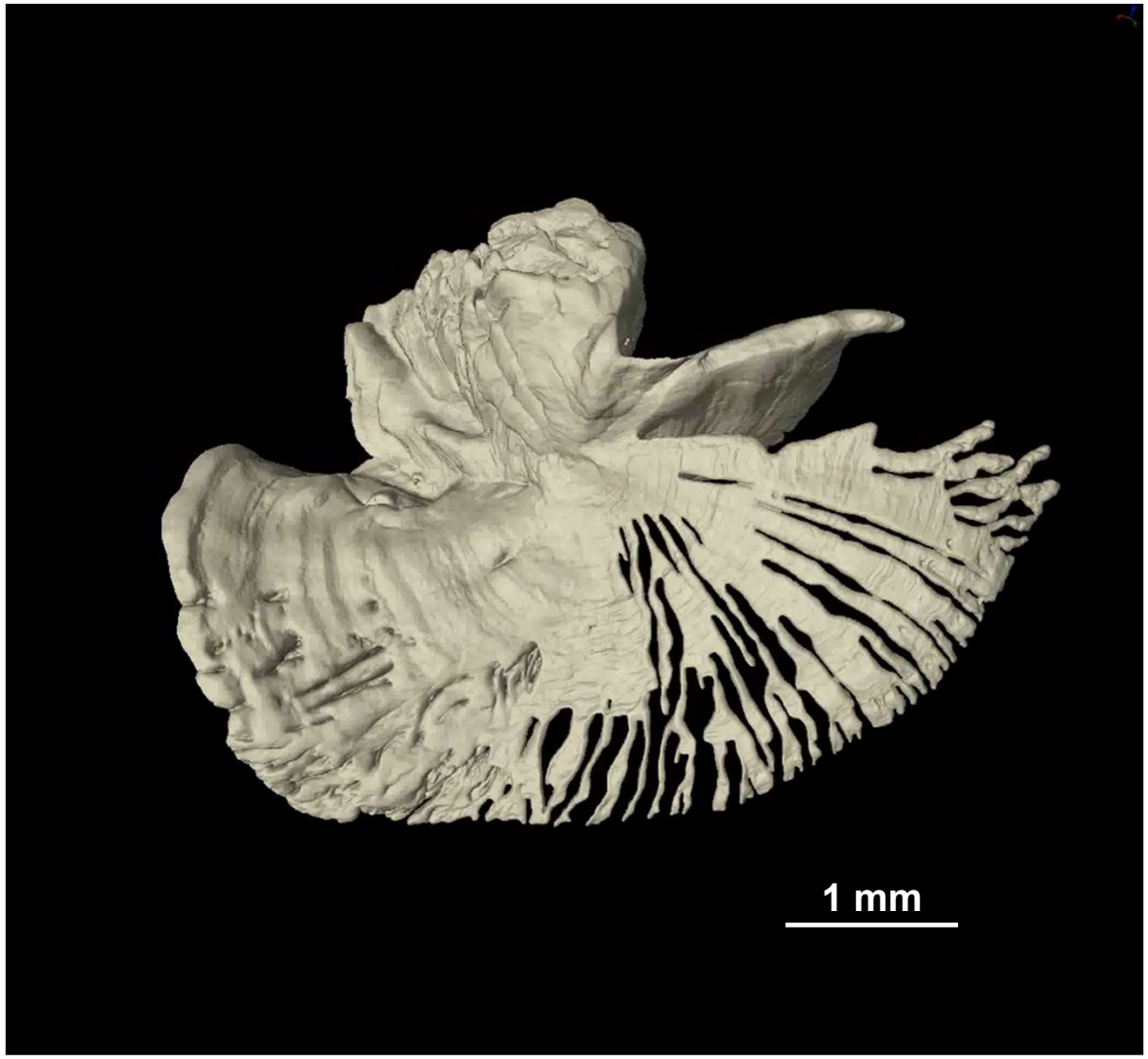




Gray Triggerfish Otoliths: Small, Delicate, Difficult to Extract

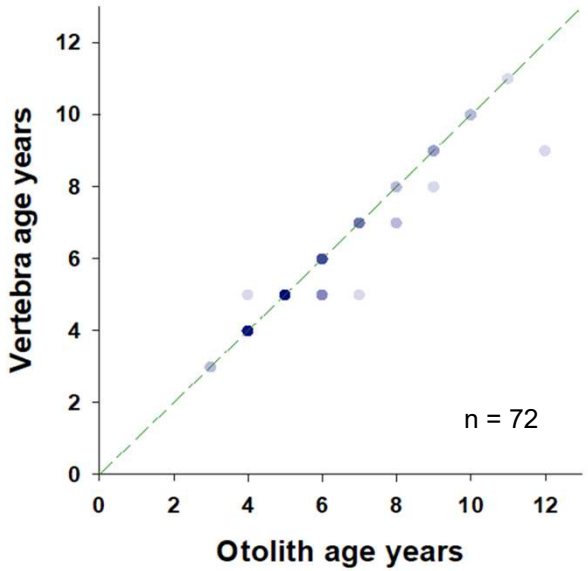


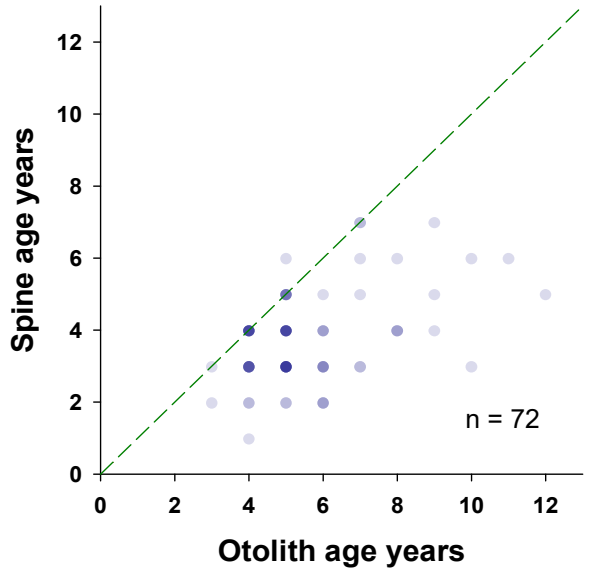
Gray Triggerfish Otoliths: Small, Delicate, Difficult to Extract



Utilizing Otoliths to Age Gray Triggerfish: Shervette and Dean (2015)

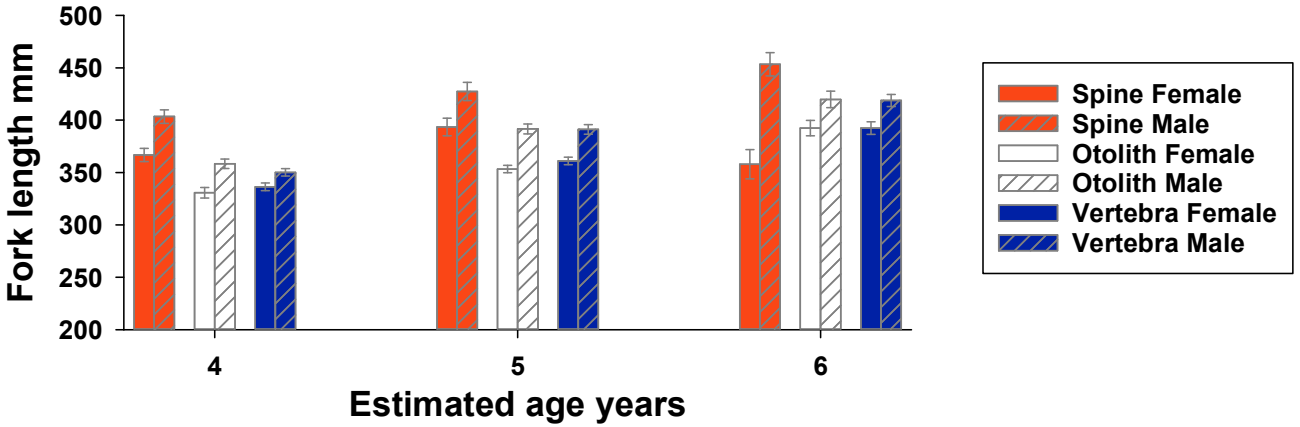
Comparing ageing structures:





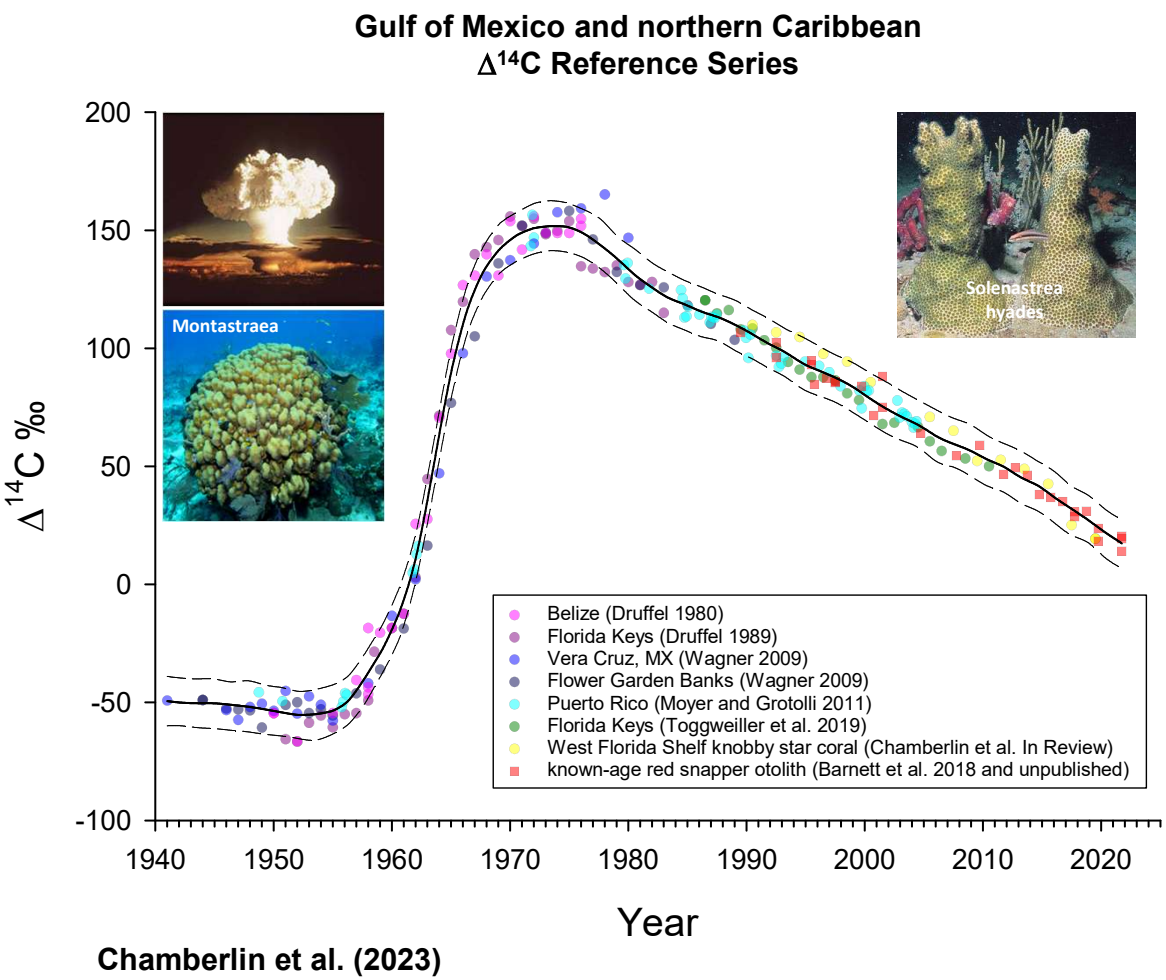
Poor agreement between otoliths and spines

Estimated mean (95%CI) size at age:

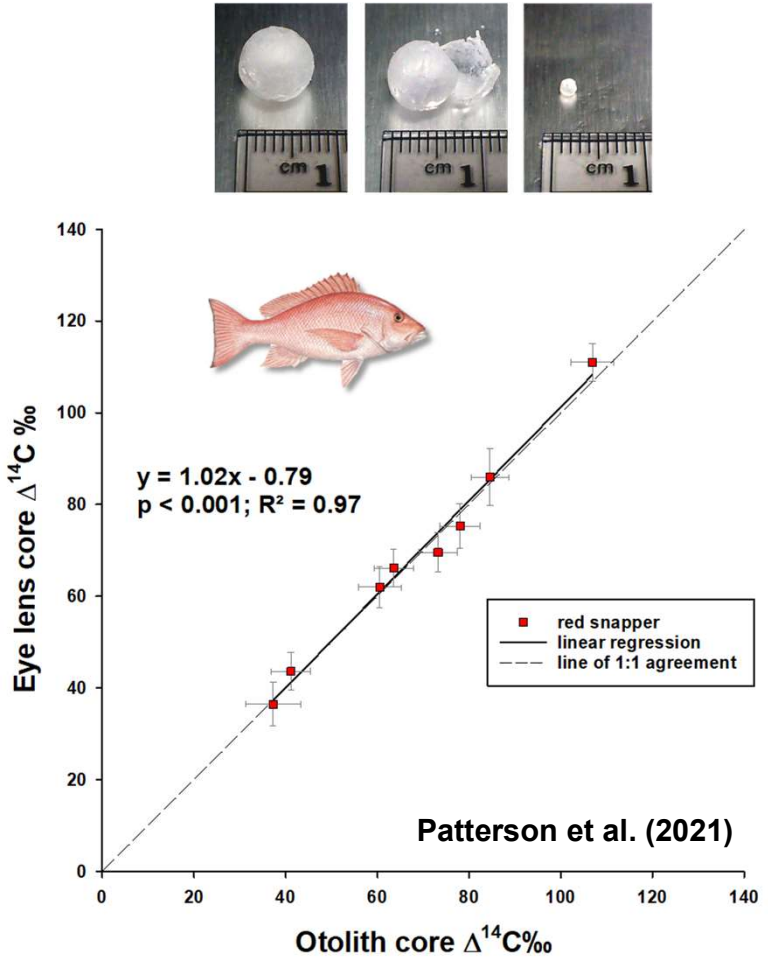


Important implications for growth as well as age comp estimates

Eye Lens-Based Bomb ^{14}C Fish Age Validation



Chamberlin et al. (2023)



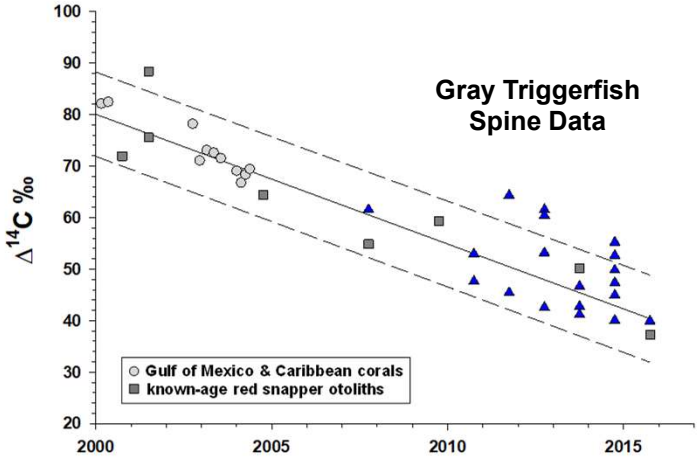
Preliminary Validation of Gray Triggerfish Spine- Versus Otolith-Derived Ages

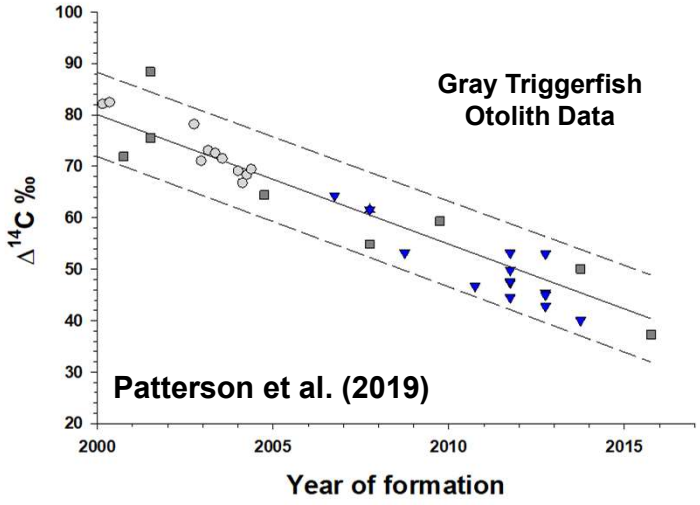
Do Sagittal Otoliths Provide More Reliable Age Estimates Than Dorsal Spines for Gray Triggerfish?

William F. Patterson III, Virginia R. Shervette, and Beverly K. Barnett, and Robert J. Allman[3]

SEDAR62-WP-17

21 May 2019
Updated: 23 May 2019





Advocating for Otolith-Derived Age Estimation in Gray Triggerfish

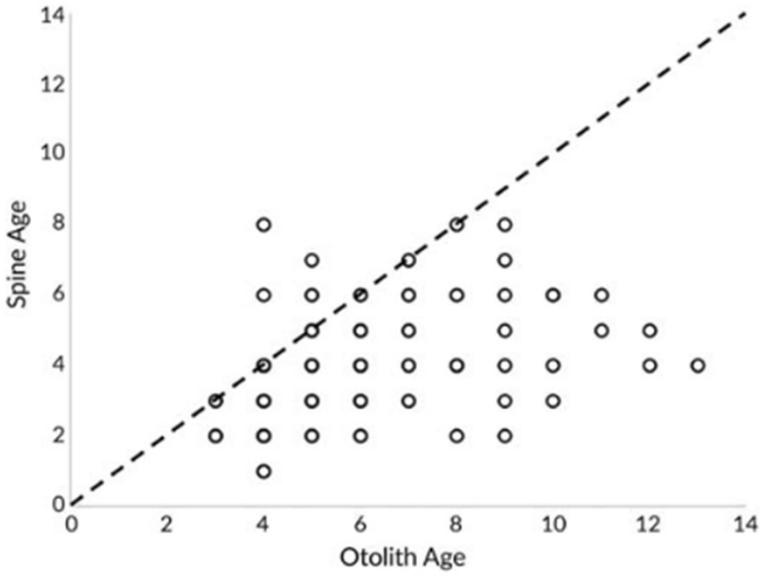
Received: 8 August 2020 | Accepted: 9 December 2020
DOI: 10.1111/jfb.14644

REGULAR PAPER

JOURNAL OF FISH BIOLOGY fsbi

Age and growth of grey triggerfish *Balistes capriscus* from trans-Atlantic populations

Virginia R. Shervette[1,2] | Jesús M. Rivera Hernández[1,2] | Francis Kofi Ewusie Nunoo[3]



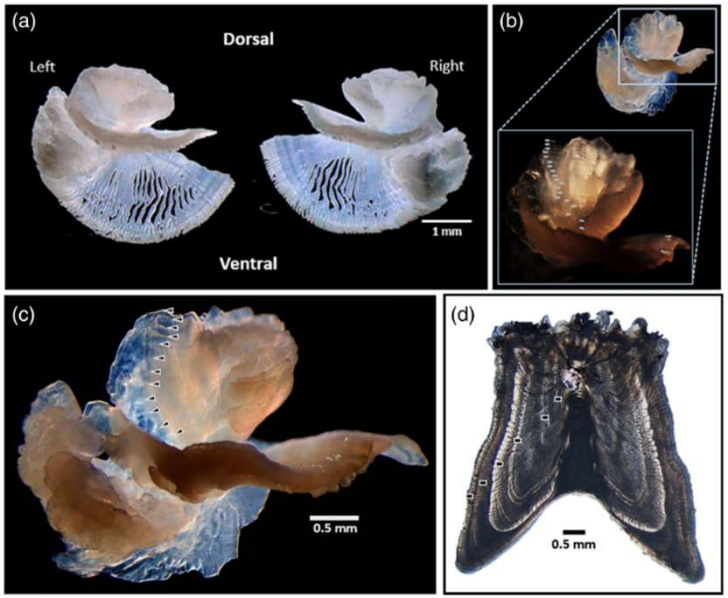
JOURNAL OF FISH BIOLOGY fsbi

REGULAR PAPER | Open Access

Illuminating otoliths: New insights for life history of *Balistes* triggerfishes

Virginia R. Shervette | Jesús M. Rivera Hernández

First published: 01 October 2022 | https://doi.org/10.1111/jfb.15233



Gulf of Mexico Gray Triggerfish 2025-26 Stock Assessment

- **Significant issues to address:**
  - **population structure**
  - **model spatial structure**
  - **stock-recruit relationship**
  - **release mortality**
  - **ageing error**

Examining Aspects of Gray Triggerfish Ageing Error and Their Implications

- **Three-year study funded by the GMFMC ahead of the 2025 GOM gray triggerfish stock assessment to address ageing error issues**

- **Original study objectives:**

  1) sample gray triggerfish from landings in the southeastern, northeastern, and western GOM

  2) estimate fish age via opaque zone counts in sagittal otoliths and translucent zone counts in dorsal spines

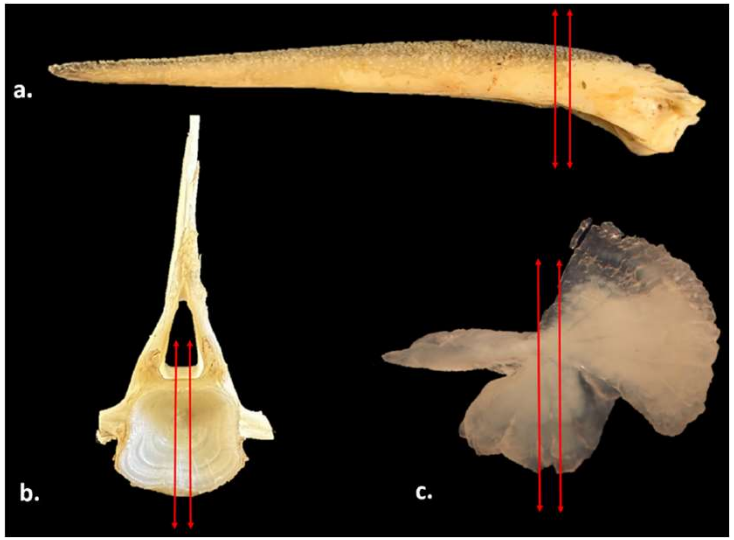
  3) validate age estimates for a subset of samples via application of the bomb ^{14}C chronometer to eye lens core (age-0 portion) $\Delta^{14}C$ values;

  4) test for differences in sex-specific size-at-age and growth estimates among regions and between commercial and recreationally harvested fish

  5) compute age-length keys (ALKs) by sex, and potentially by region and fishery sector, pending results under objective 4.

A Modified Spine-Based Method to Estimate Gray Triggerfish Age

- **Potts et al. (2023): modified spine-based GT ageing protocol produced similar age estimates as sectioned otoliths.**



Fisheries Research 267 (2023) 106809

Contents lists available at ScienceDirect

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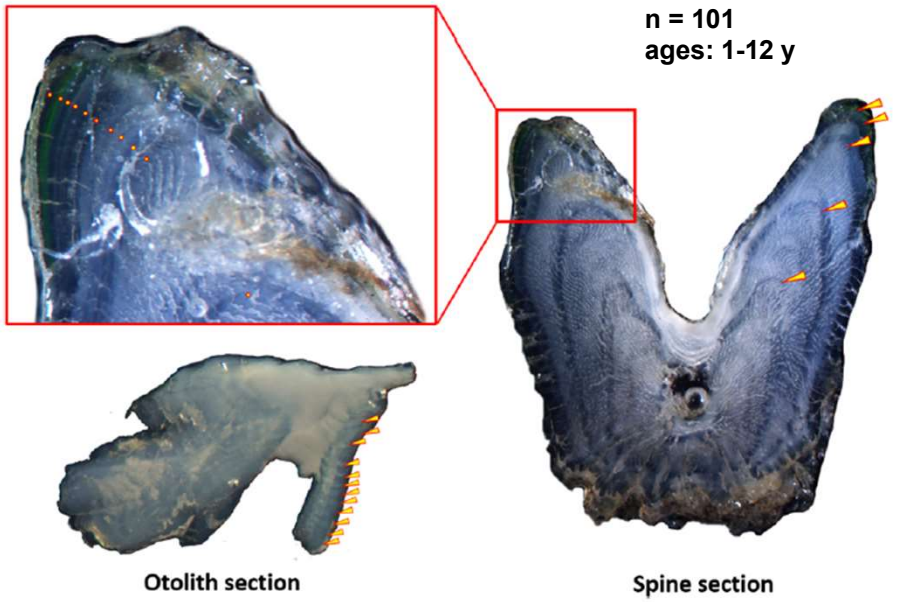
journal homepage: www.elsevier.com/locate/fishres

Full length article

Validation of annual growth zone formation in gray triggerfish *Balistes capriscus* dorsal spines, vertebrae, and otoliths

Jennifer C. Potts [a,1], Walter D. Rogers [b,*,2], Troy C. Rezek [c], Amanda R. Rezek [d]



Chapter 1: Gray Triggerfish Age Validation

In Press: Fisheries Research

Bomb ^{14}C Validates Gray Triggerfish, *Balistes capriscus*, Dorsal Spine and Otolith Ageing Protocols

Derek W. Chamberlin[a,b*], Jennifer C. Potts[c], Walter D. Rogers[d], Zachary A. Siders[a], and William F. Patterson III[a]

[a]University of Florida, Fisheries and Aquatic Sciences, 7922 NW 71st Street, Gainesville, FL 32611, USA

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[d]Cooperative Institute for Marine and Atmospheric Studies, University of Miami, in support of NOAA Fisheries Southeast Fisheries Science Center, Beaufort Laboratory, 101 Pivers Island Rd, Beaufort, NC 28516

Key words: gray triggerfish, age validation, bomb radiocarbon, dorsal spines, otoliths

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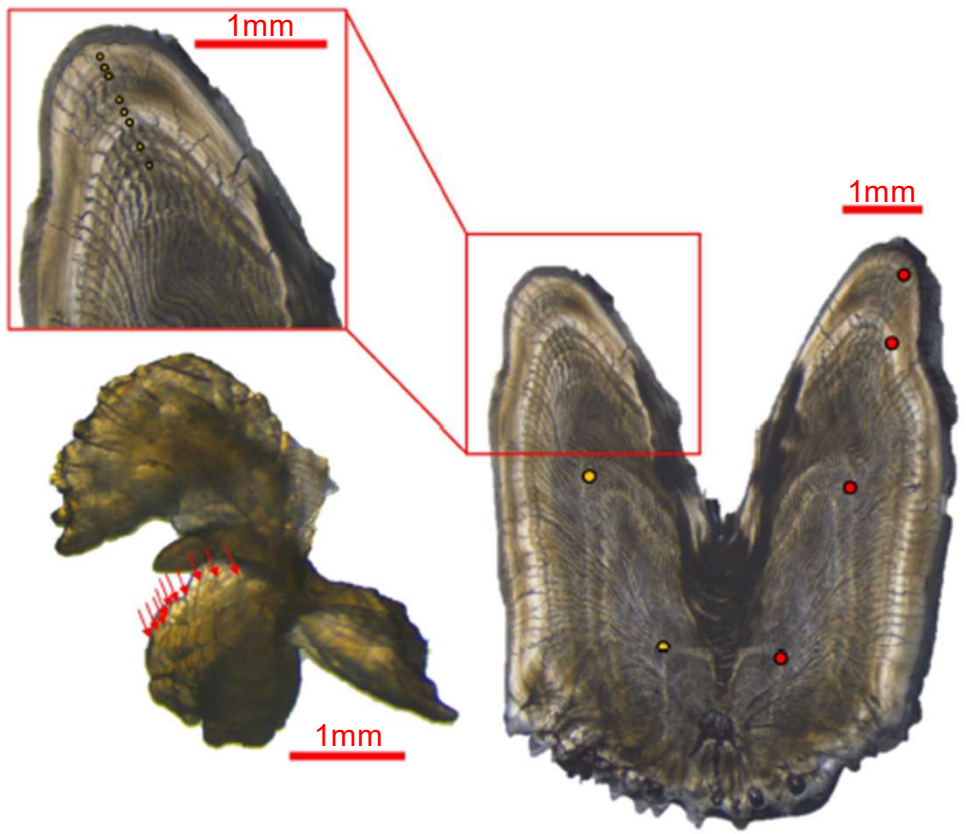
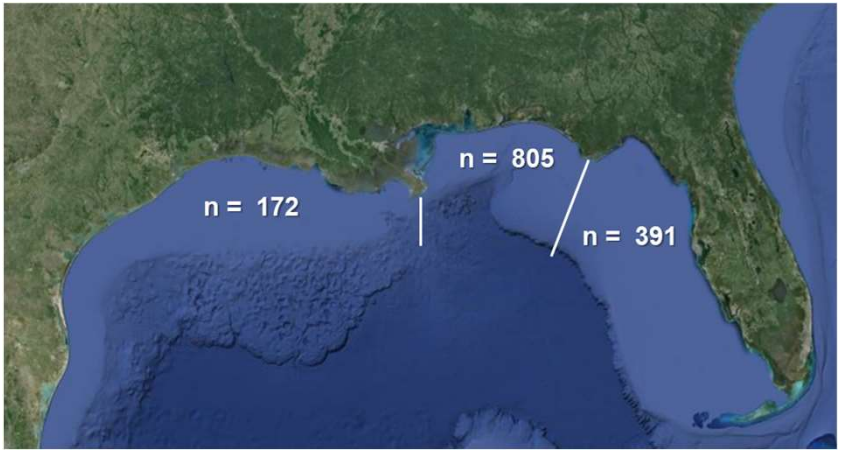
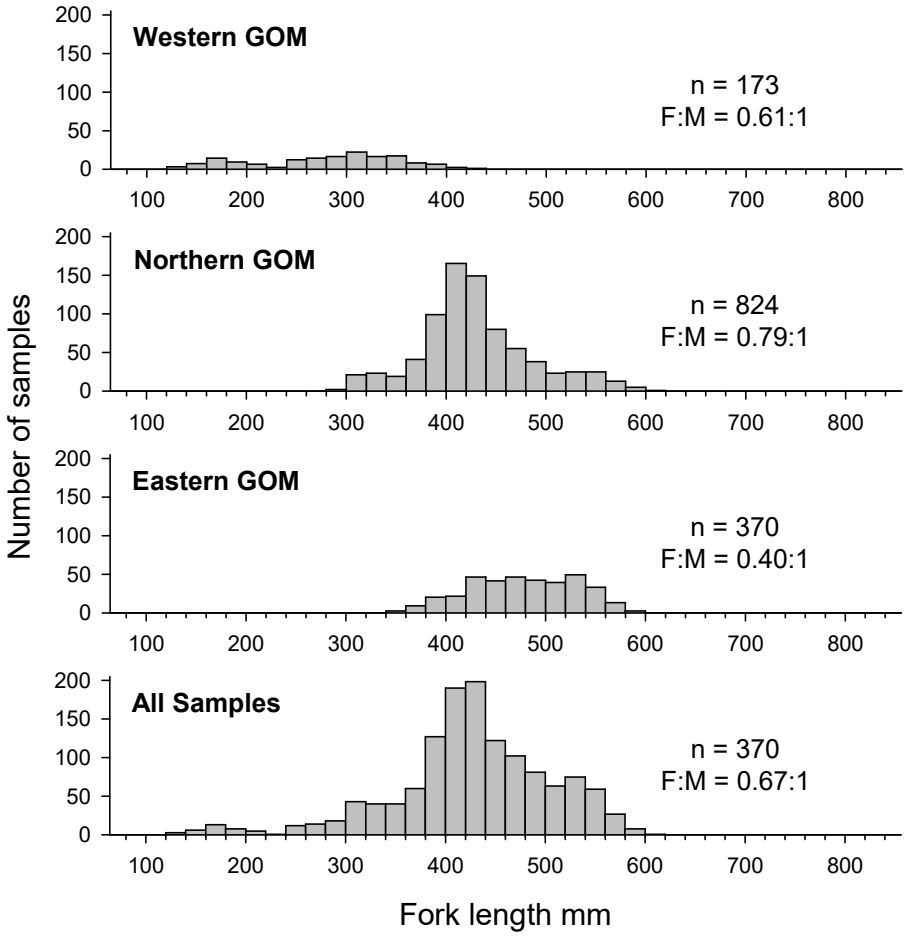


Gray Triggerfish Sample Distributions

- **Total samples: 1,370 samples among commercial handline and longline, recreational landings, and spearfishing and trawl fishery-independent sampling**



- **First 100 samples treated as a training set among three readers:**
  R1: Derek Chamberlin
  R2: Jennifer Potts
  R3: Walt Rogers



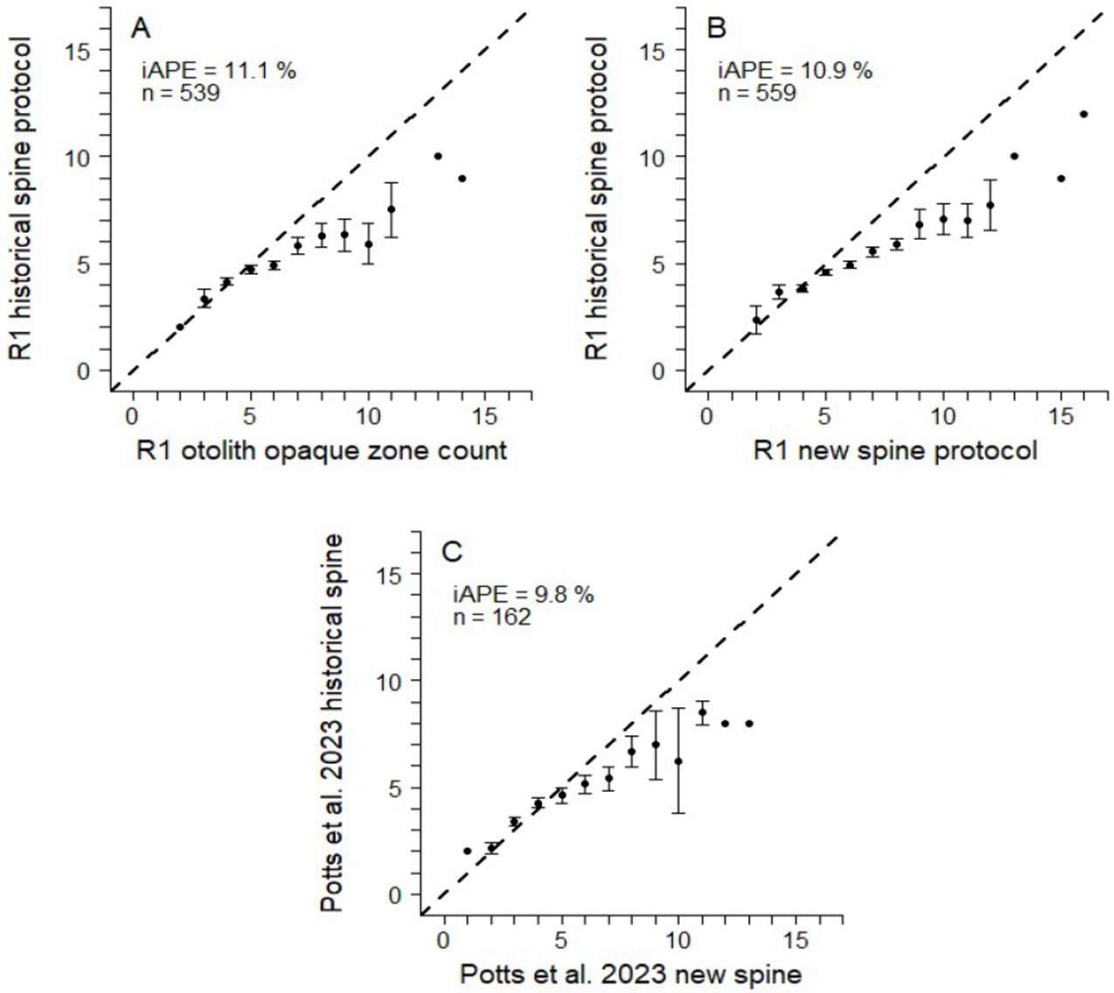
Gray Triggerfish Sample Distributions

- **Skewed sex ratio in each sample region, but 27.1% of samples could not be aged due to missing gonads**

FL mm	Unknown	Female	Male	F:M
<250	39	11	18	0.61:1
251-300	19	33	21	1.57:1
301-350	19	59	34	1.74:1
351-400	98	123	150	0.82:1
401-450	96	100	167	0.60:1
451-500	69	32	106	0.30:1
501-550	31	34	83	0.41:1
551-600	3	5	20	0.25:1

Reader Agreement among Ageing Structures

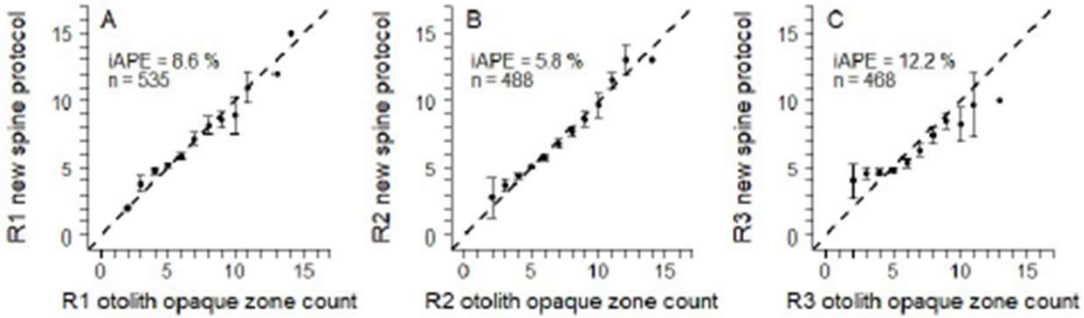
- **Total sample size for reader and protocol comparison: n = 573**
- **Historical spine method age estimates lower than otolith or new spine protocol estimates after age-5**
- **R1: Derek Chamberlin**
- **Index of average percent error relatively high for all ageing approaches**



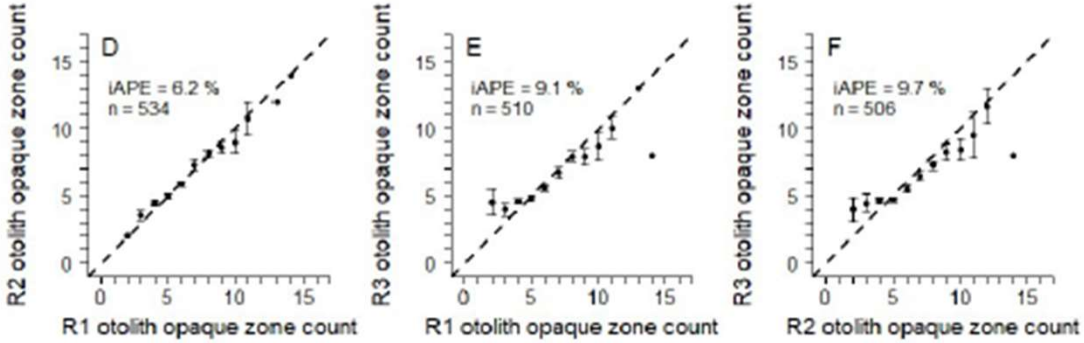
Reader Agreement among Ageing Structures

- **Reader 1: Derek Chamberlin**
  Reader 2: Jennifer Potts
  Reader 3: Walt Rogers

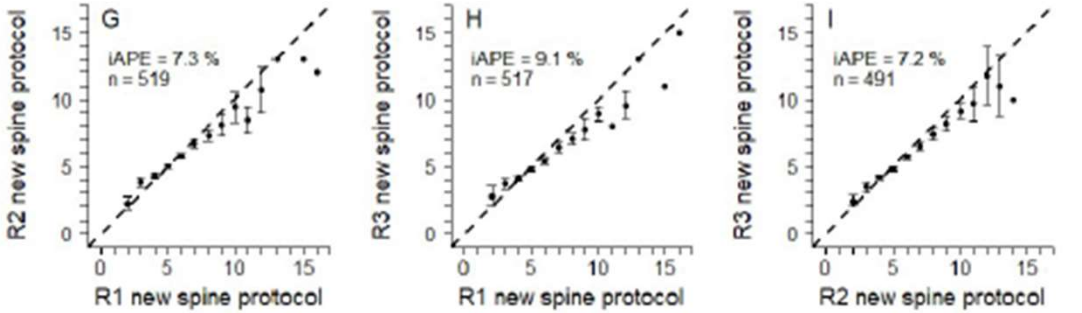
Within reader: otolith versus new spine



Among readers: otolith ages



Among readers: new spine ages



Eye Lens-Based Bomb ^{14}C Age Validation

scientific reports

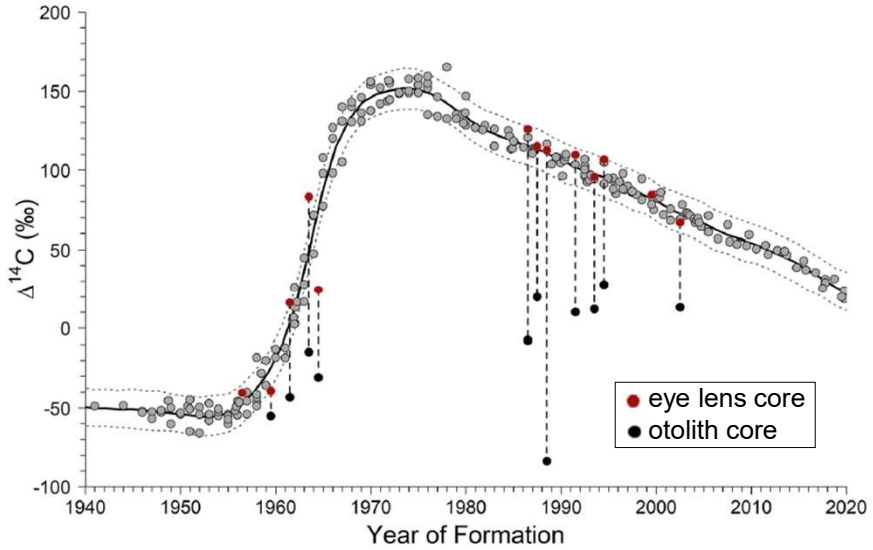
Check for updates

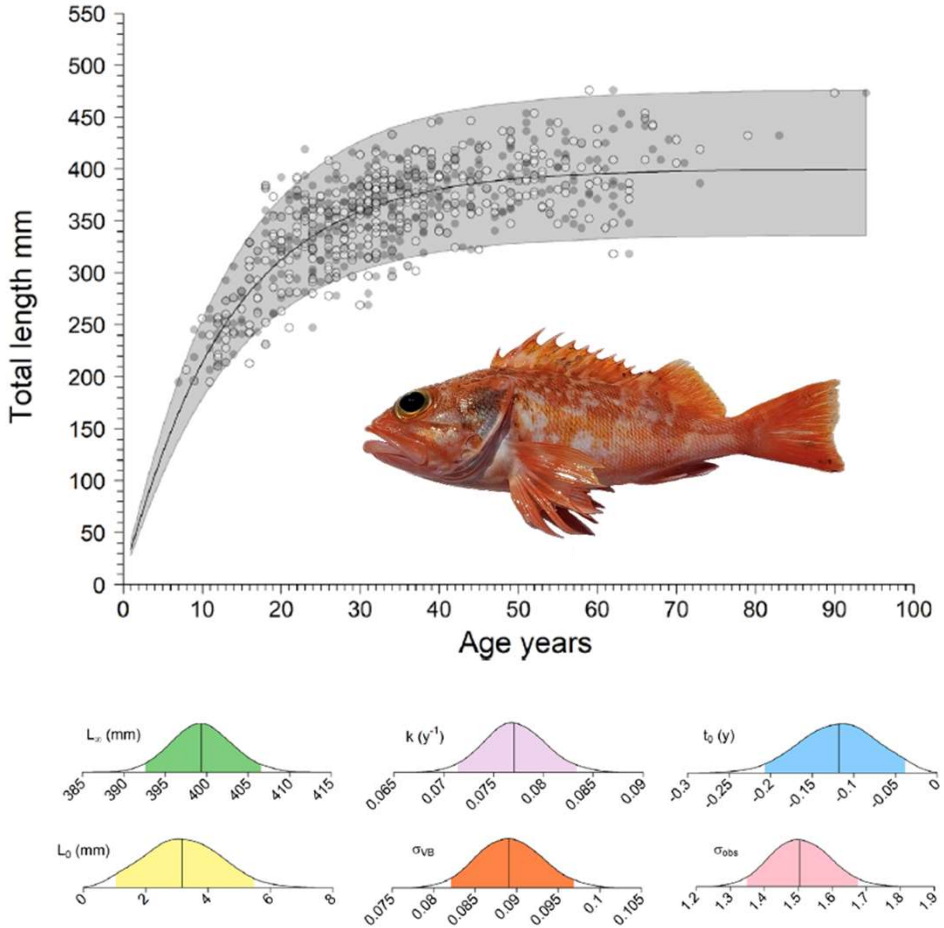
OPEN

Eye lens-derived $\Delta^{14}C$ signatures validate extreme longevity in the deepwater scorpaenid blackbelly rosefish (*Helicolenus dactylopterus*)

Derek W. Chamberlin[1*], Zachary A. Siders[1], Beverly K. Barnett[2] & William F. Patterson III[1]

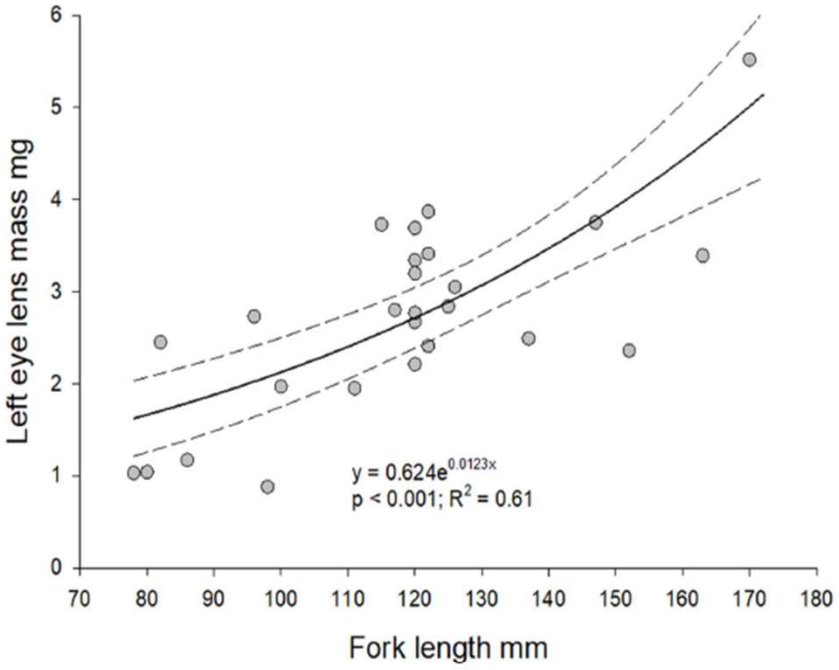
Scientific Reports | (2023) 13:7438 | https://doi.org/10.1038/s41598-023-34680-0 nature portfolio

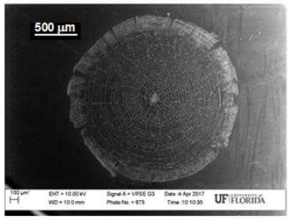


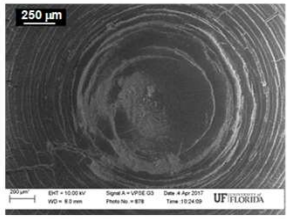


Gray Triggerfish Eye Lens-Based Bomb ^{14}C Age Validation

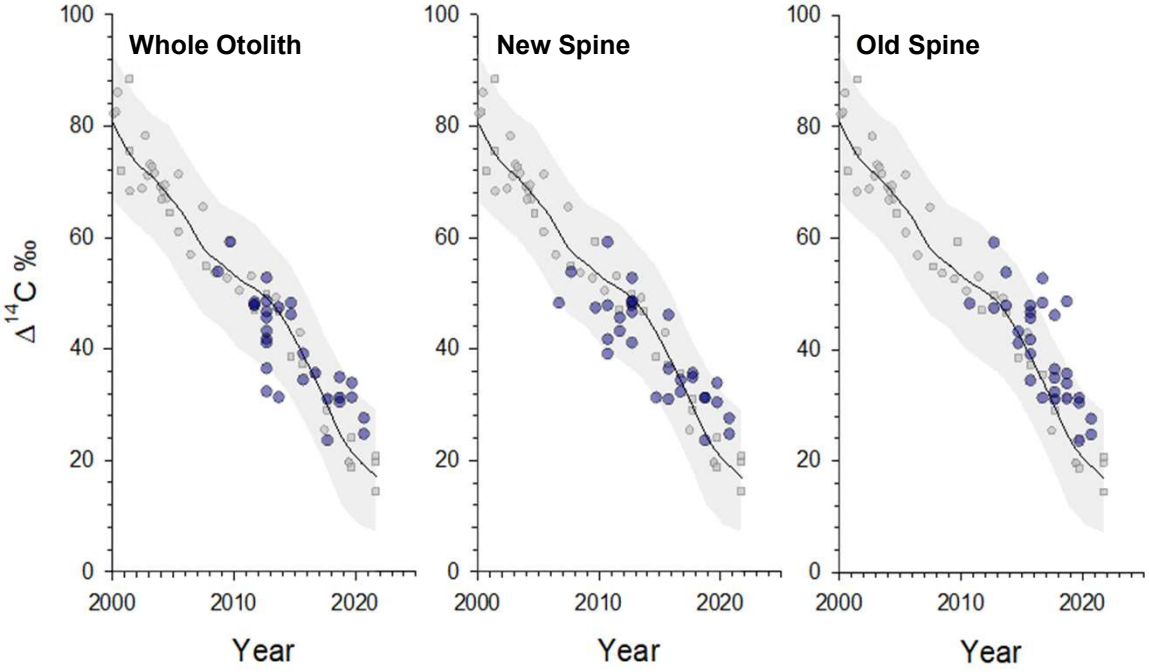
Juvenile GOM Gray Triggerfish Eye Lens Mass Versus Fork Length Relationship







Bayesian Spline-Based Test of Ageing Accuracy



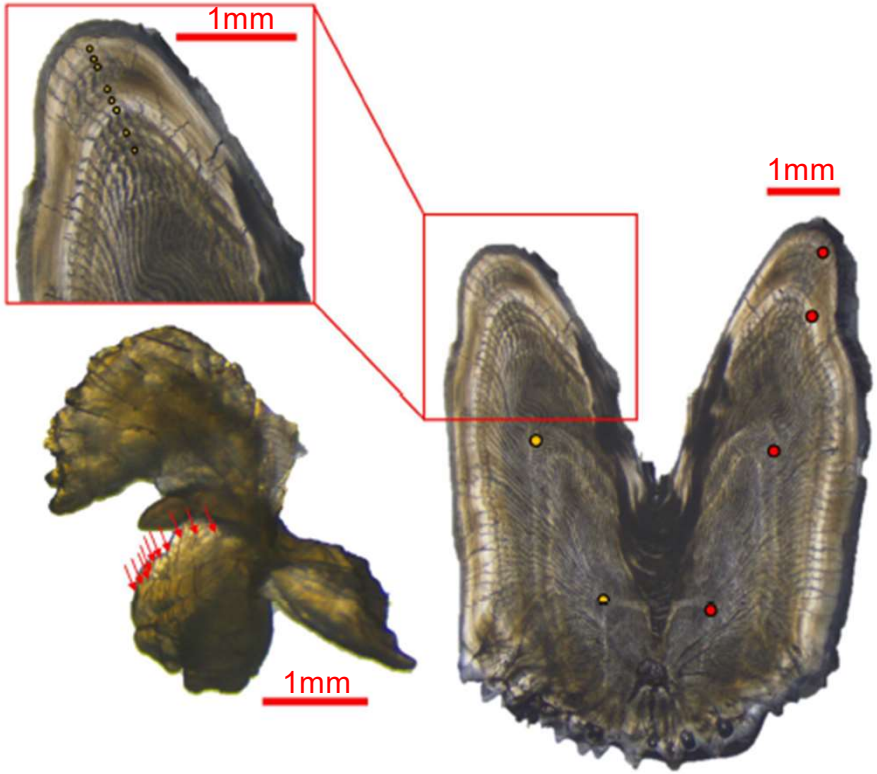
- **Age estimates significantly biased for old spine method; median bias: -1.72 y**
- **No significant ageing bias for new spine method or whole otolith method**

Chapter 1 Conclusions

- **Age estimates derived from whole otoliths or the new spine ageing protocol are unbiased, but precision issues persist with both methods.**

- **New dorsal spine protocol ageing was slightly more precise among readers (iAPE = 9.4%) than otolith ageing (iAPE = 10.1%) and read times were 2-3x faster for dorsal spine sections than whole otoliths.**

- **For 2025 assessment, re-ageing archived spine sections for fish >age-5 is an appropriate solution to produce unbiased age composition estimates.**



Chamberlin et al. (In Press)

Chapter 2: Gray Triggerfish Growth Estimation

In internal review for submission to ICES Journal of Marine Science

Bayesian state-space estimation of von Bertalanffy growth parameters for gray triggerfish, *Balistes capriscus*, incorporating multiple readers and ageing structures

Derek W. Chamberlin[a,b*], Zachary A. Siders[a], Jennifer C. Potts[c], Walter D. Rogers[d], Miaya A. Taylor[a], and William F. Patterson III[a]

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[b]National Marine Fisheries Service, Alaska Fisheries Science Center, 7600 Sand Point Way N.E., Building 4, Seattle, WA 98115

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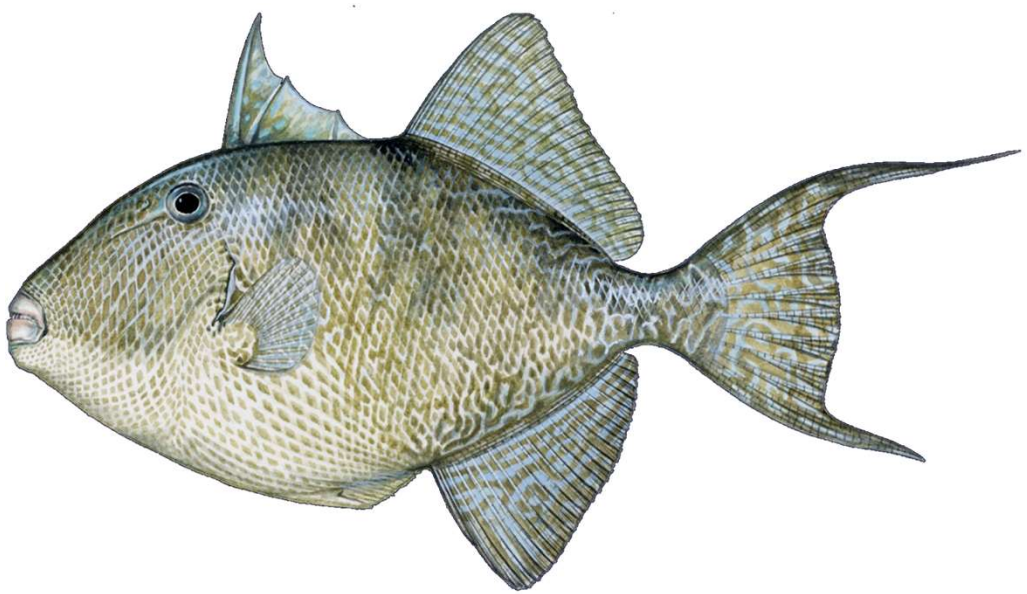
*Corresponding Author; derek.chamberlin@noaa.gov

Key words: gray triggerfish, von Bertalanffy, Bayesian, age and growth, dorsal spines, otoliths

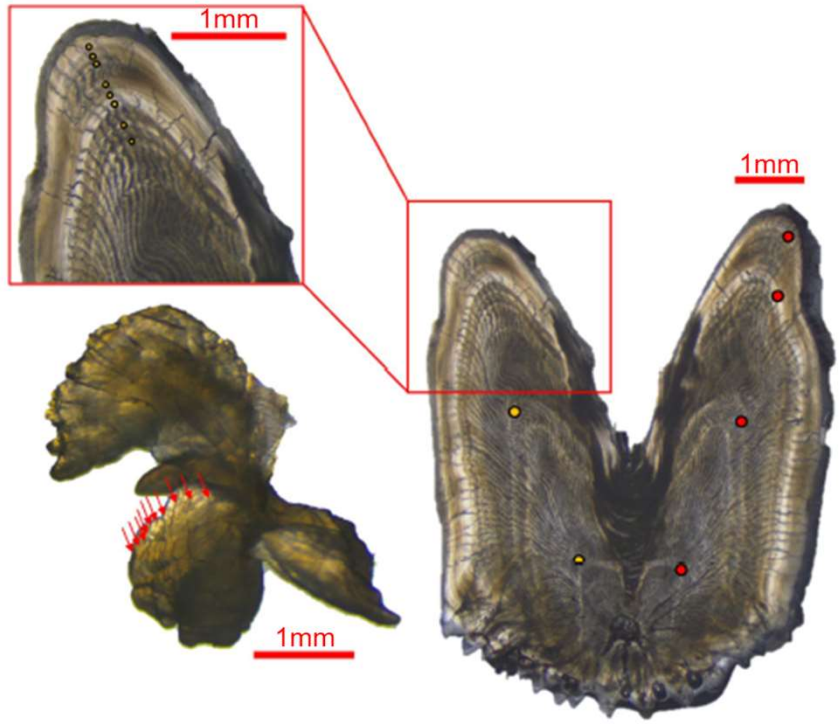


Chapter 2: Gray Triggerfish Growth Estimation

- **Total sample size for age and growth analysis:**
  n = 1,270

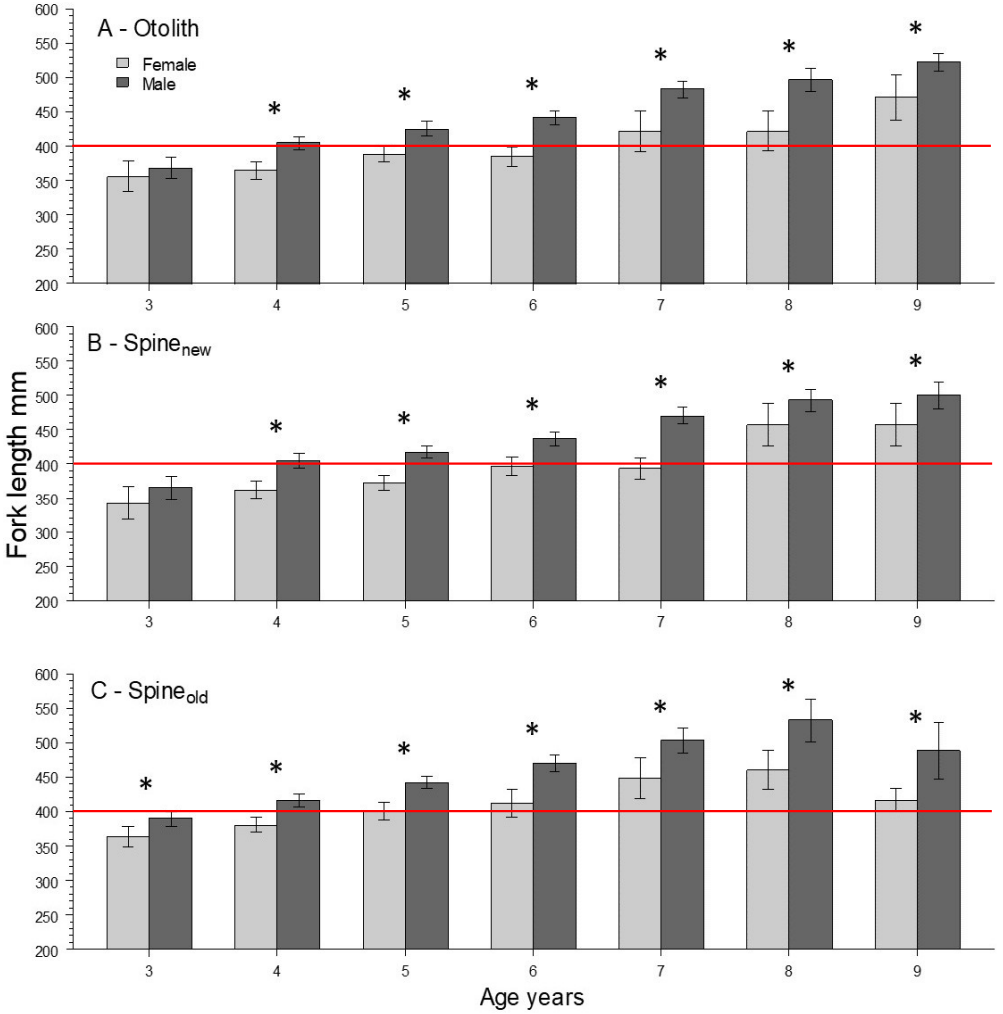
- **Ageing protocols:**
  1. **whole otolith**
  2. **spine section: old protocol**
  3. **spine section: new protocol (Potts et al. 2023)**

- **Three readers:**
  R1: Derek Chamberlin
  R2: Jennifer Potts
  R3: Walt Rogers



Sex-specific Gray Triggerfish Size-at-Age

- Three-factor ANOVA run to test for differences in size-at-age for R1 ages
- Factors: ageing structure, age, and sex
- structure*age*sex interaction sliced by structure and age to test for sex-specific differences in size-at-age



Bayesian State-Space Gray Triggerfish Growth Estimation

- **Bayesian state-space model developed to estimate of gray triggerfish von Bertalanffy growth model (VBGM) parameters and test for differences between sexes and ageing protocols**

- **Size-at-birth formulation of the VBGM (von Bertalanffy 1934)**

- **State-space approach allows for more effective separation of process error (σ_{VB}) from observation error (σ_{obs}) by including multiple readers**

$$L_{i,t} = L_{\infty}(L_{\infty} - L_0)e^{-kt_i}$$

where:

$L_{i,t}$ = length at age t

L_{∞} = asymptotic length

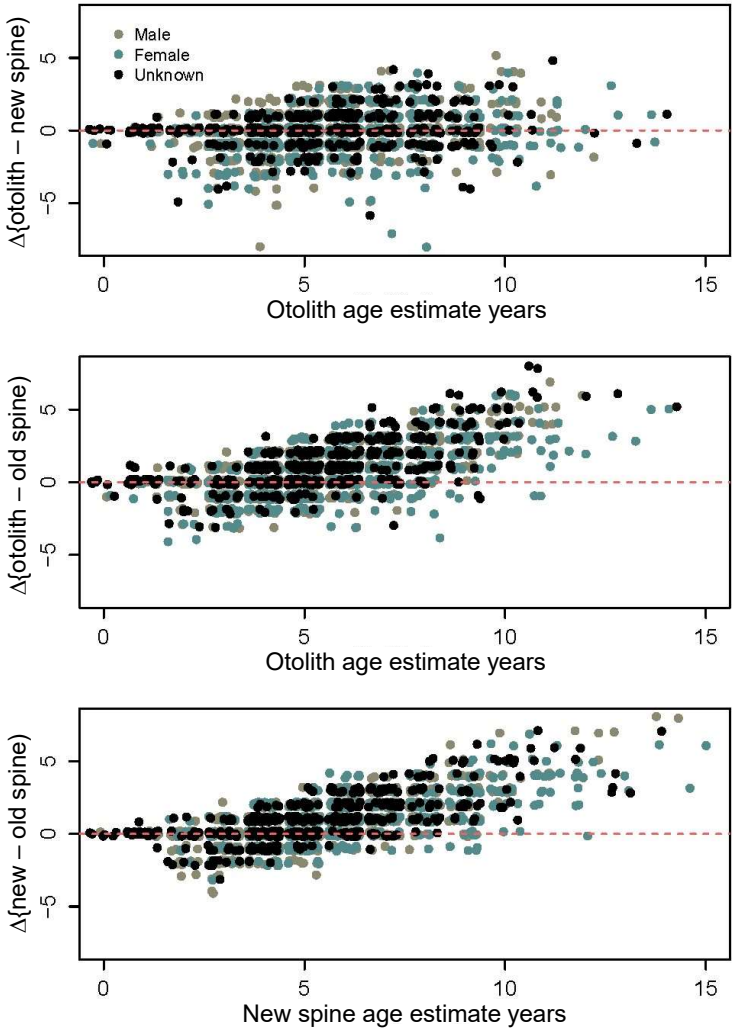
L_0 = size at birth

k = Brody's growth coefficient

t_i = age

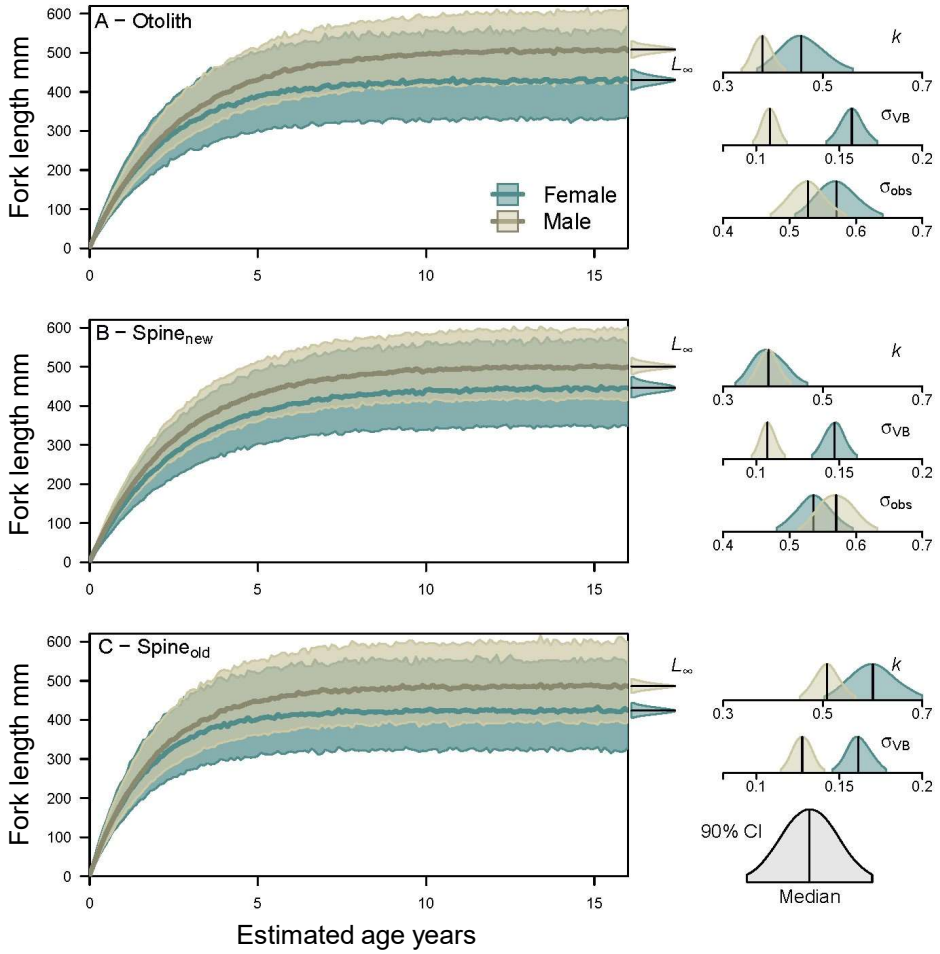
Bayesian State-Space Gray Triggerfish Growth Estimation

- **Clear differences in estimated age between otolith or new spine estimates versus the old spine method regardless of sex**



Bayesian State-Space Gray Triggerfish Growth Estimation

- **Significant differences in VBGMs among ageing protocols and between sexes**
- **No significant differences in VBGM parameters between otolith and new spine ageing protocols**
- **Significant differences in t_0 and k between otolith or new spine versus old spine age estimates, but very small absolute differences in t_0 (<0.01 y)**



Bayesian State-Space Gray Triggerfish Growth Estimation

- **Significant differences in VBGMs among ageing protocols and between sexes**
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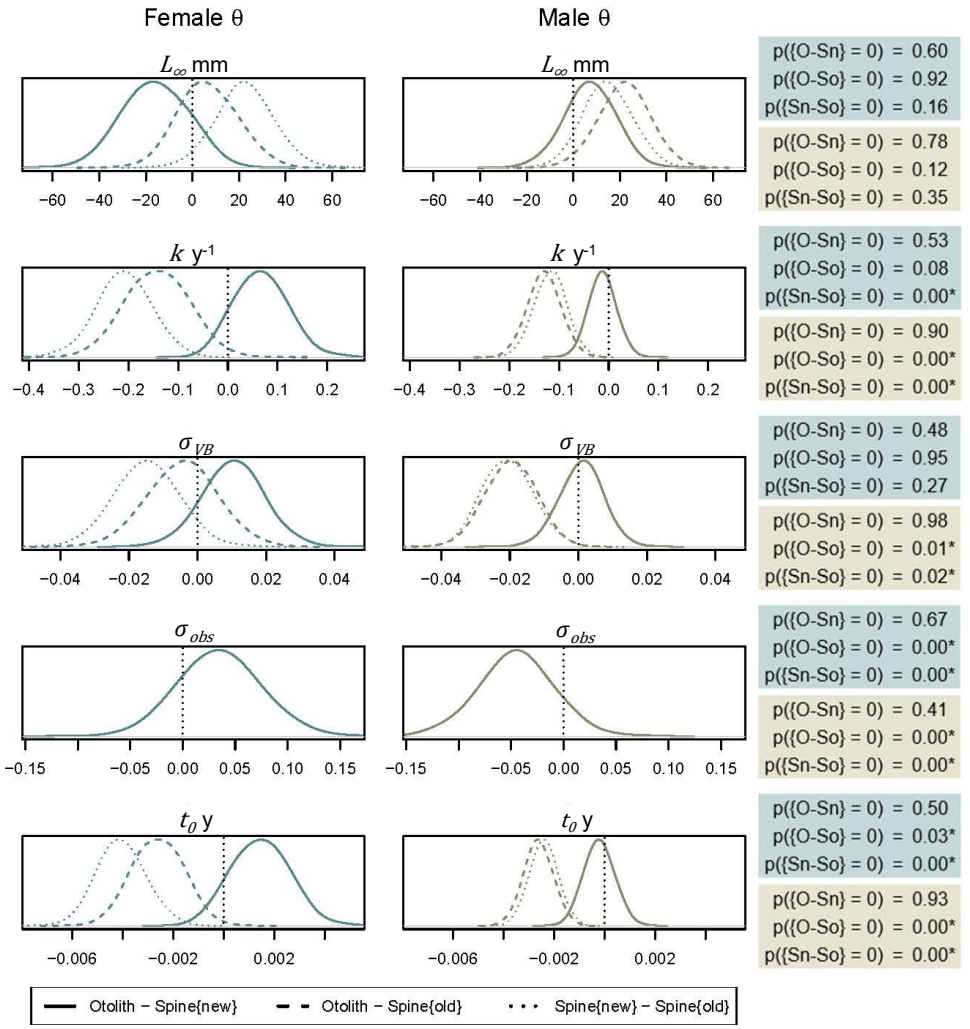
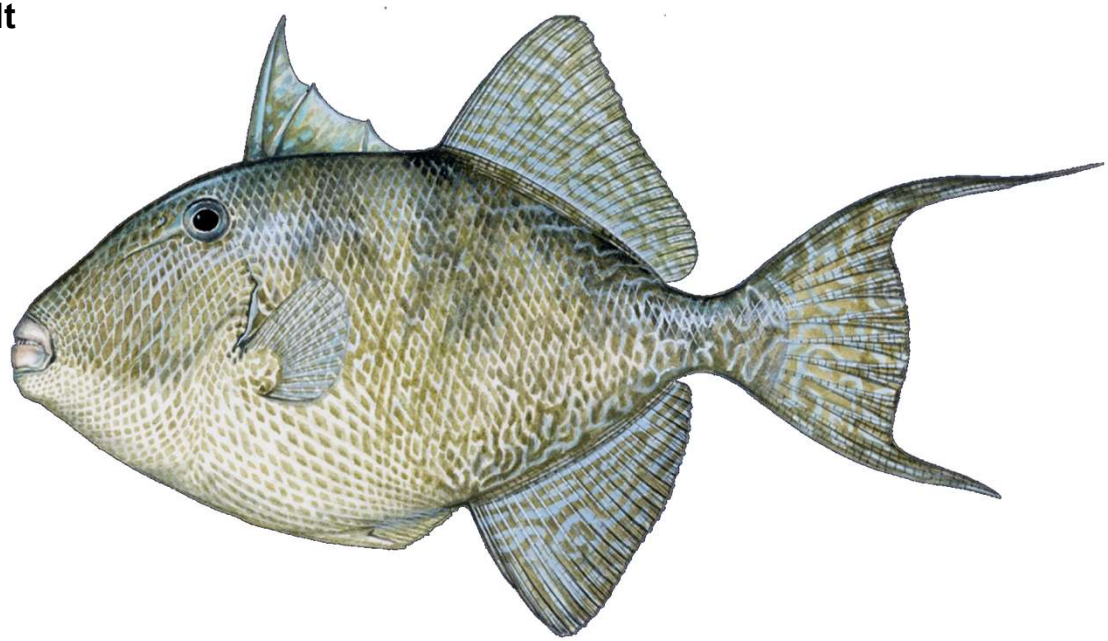


Chapter 2 Conclusions

- **Lack of significant differences in VBGMs between otolith and new spine ageing data is consistent with the result that both methods produce accurate age estimates.**

- **Bayesian state-space approach enabled us to include multiple readers and more effectively separate process error from observation error.**

- **Moving forward, the new spine ageing protocol proposed by Potts et al. (2023) is an effective approach for estimating gray triggerfish growth models, as well as for producing age composition data for statistical catch-at-age stock assessment models.**



Chapter 3: GT Stock Assessment Simulations to Test Effect of Ageing Error

Draft Manuscript for Submission to Canadian Journal of Fisheries and Aquatic Sciences

Effects of Ageing Bias and Precision on a Statistical Catch-at-Age Stock Assessment Model, the case of Gulf of Mexico Gray Triggerfish

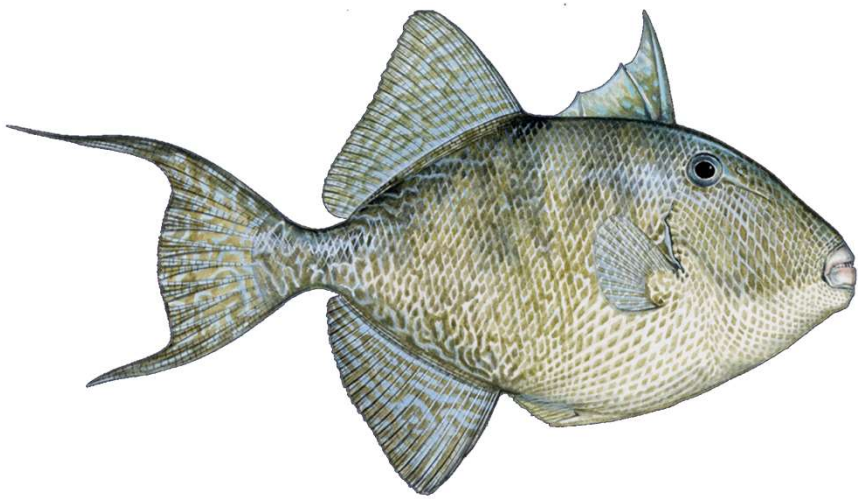
Derek W. Chamberlin[a,b*], Zachary A. Siders[a], and William F. Patterson III[a]

[a]University of Florida, Fisheries and Aquatic Sciences, 7922 NW 71st Street, Gainesville, FL 32611, USA

[b]National Marine Fisheries Service, Alaska Fisheries Science Center, 7600 Sand Point Way N.E., Building 4, Seattle, WA 98115

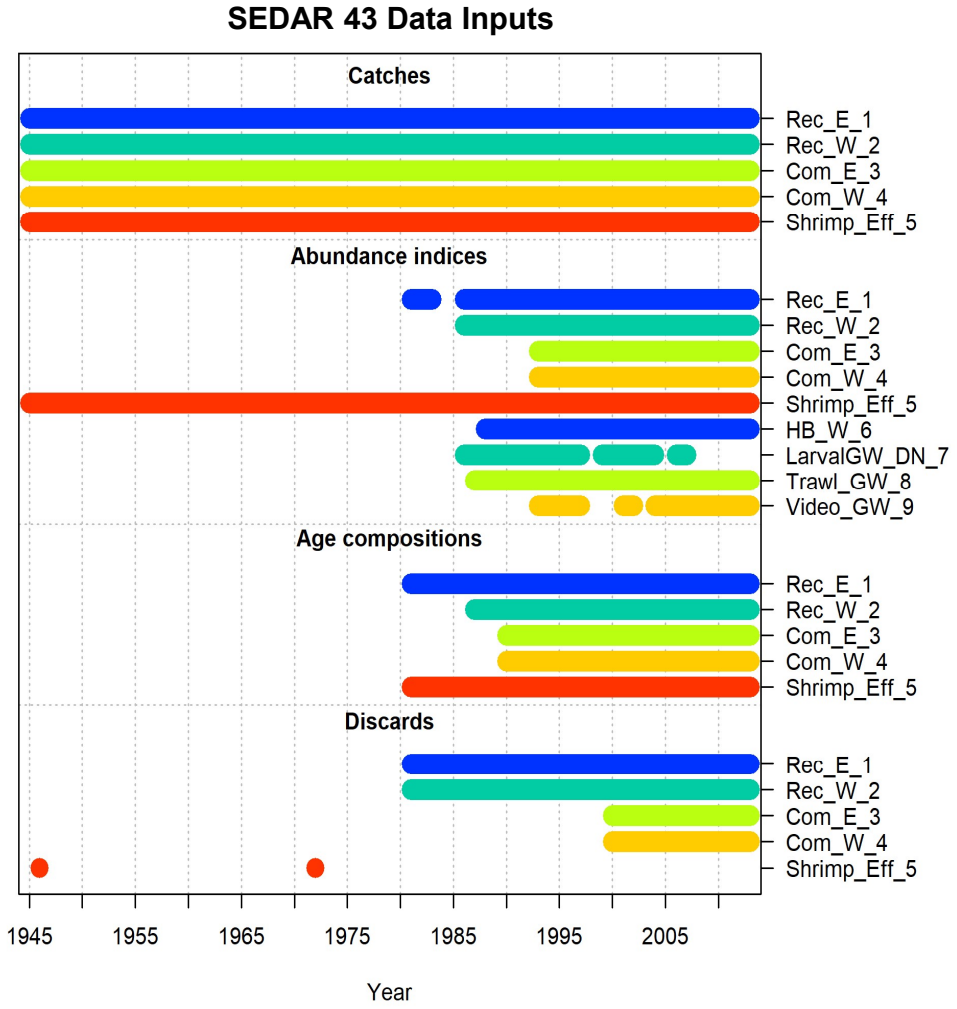
So What?

Does ageing error matter for gray triggerfish stock assessment and management?



Assessment Simulation Approach and Methods

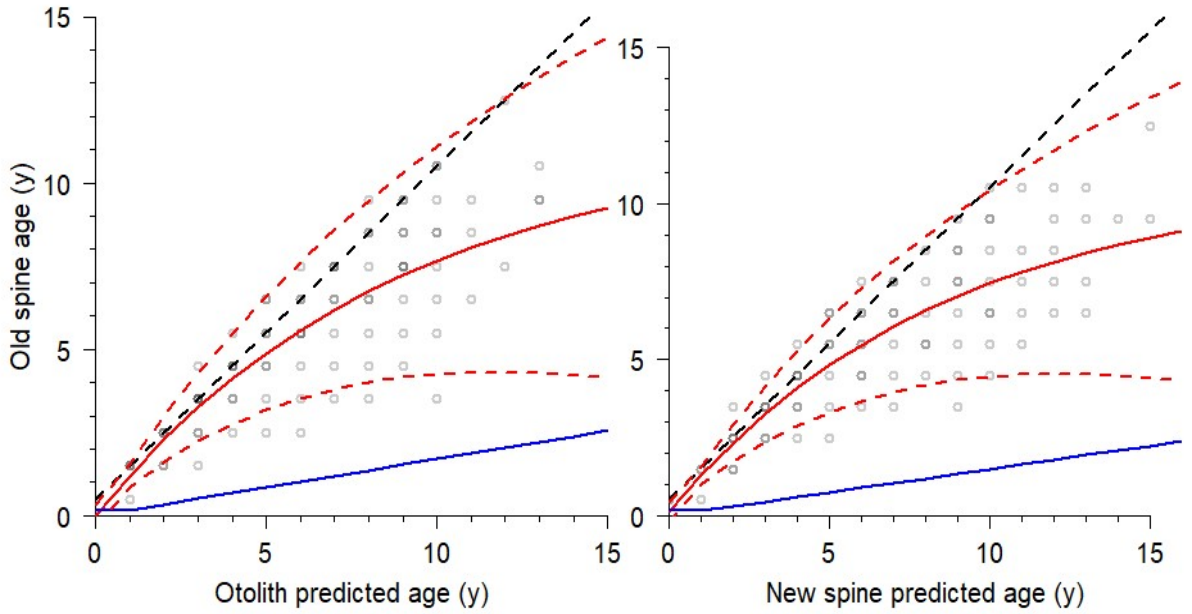
- SEDAR 43 data input files and model code provided to study team by SEFSC personnel
- SEDAR 43 assessment converted from SS v3.24 to SS v3.30
- The 2015 assessment configuration, including the ageing error definition, retained to ensure gray triggerfish dynamics were accurately captured by the model.
- Assessment includes catch and age composition data from five fleets plus nine indices of abundance (six fisheries-dependent and three fisheries-independent); years: 1945-2013



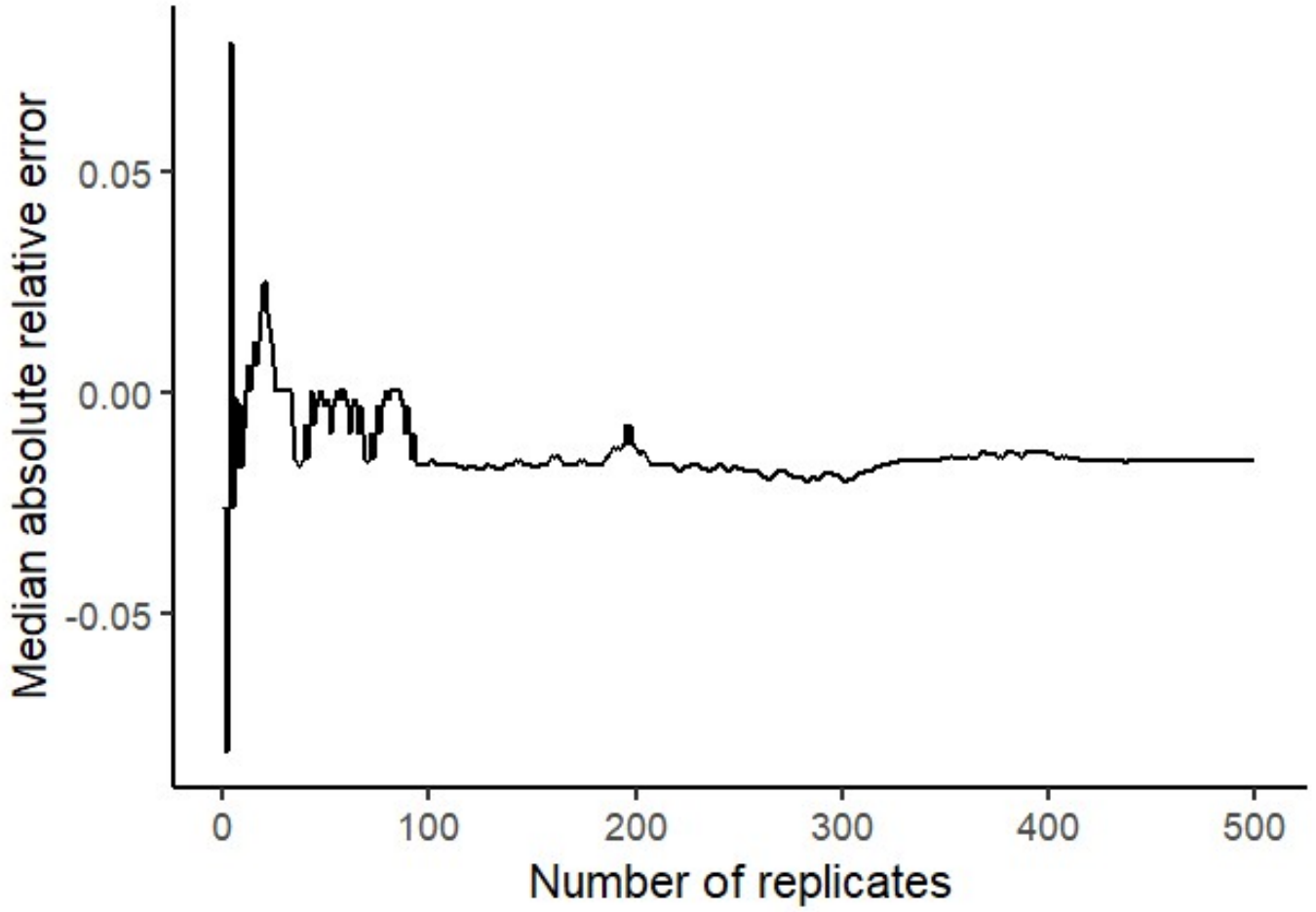
Assessment Simulation Approach and Methods

- **Simulation framework: ss3sim in R**
- **Operating models based on SEDAR 43 gray triggerfish assessment and parameterization**
- **Scenario-specific ageing error matrices applied in the OM**
- **EM operated under assumption that original age comps data generated with old spine protocol were accurate**

Study Scenario	Operating Model	Estimation Model
1	Old spine	Old spine
2	Otolith	Old spine
3	New Spine	Old spine

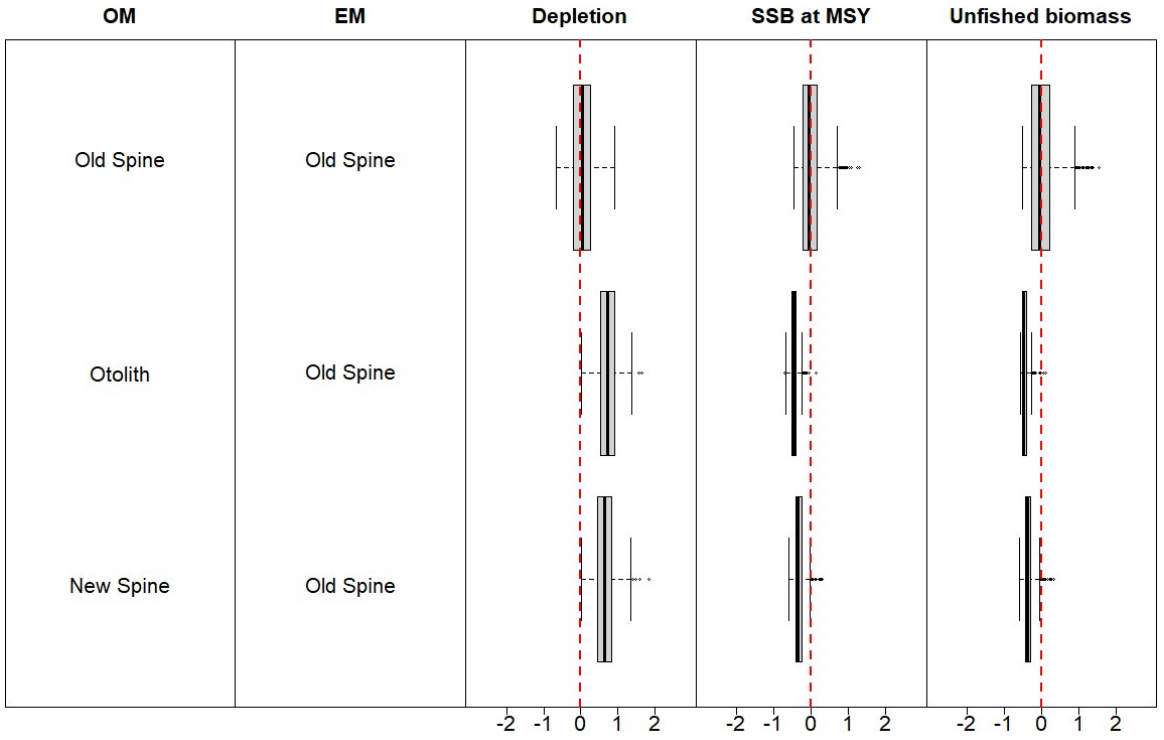


Stock Assessment Simulation Results: Stability in Steepness Estimate

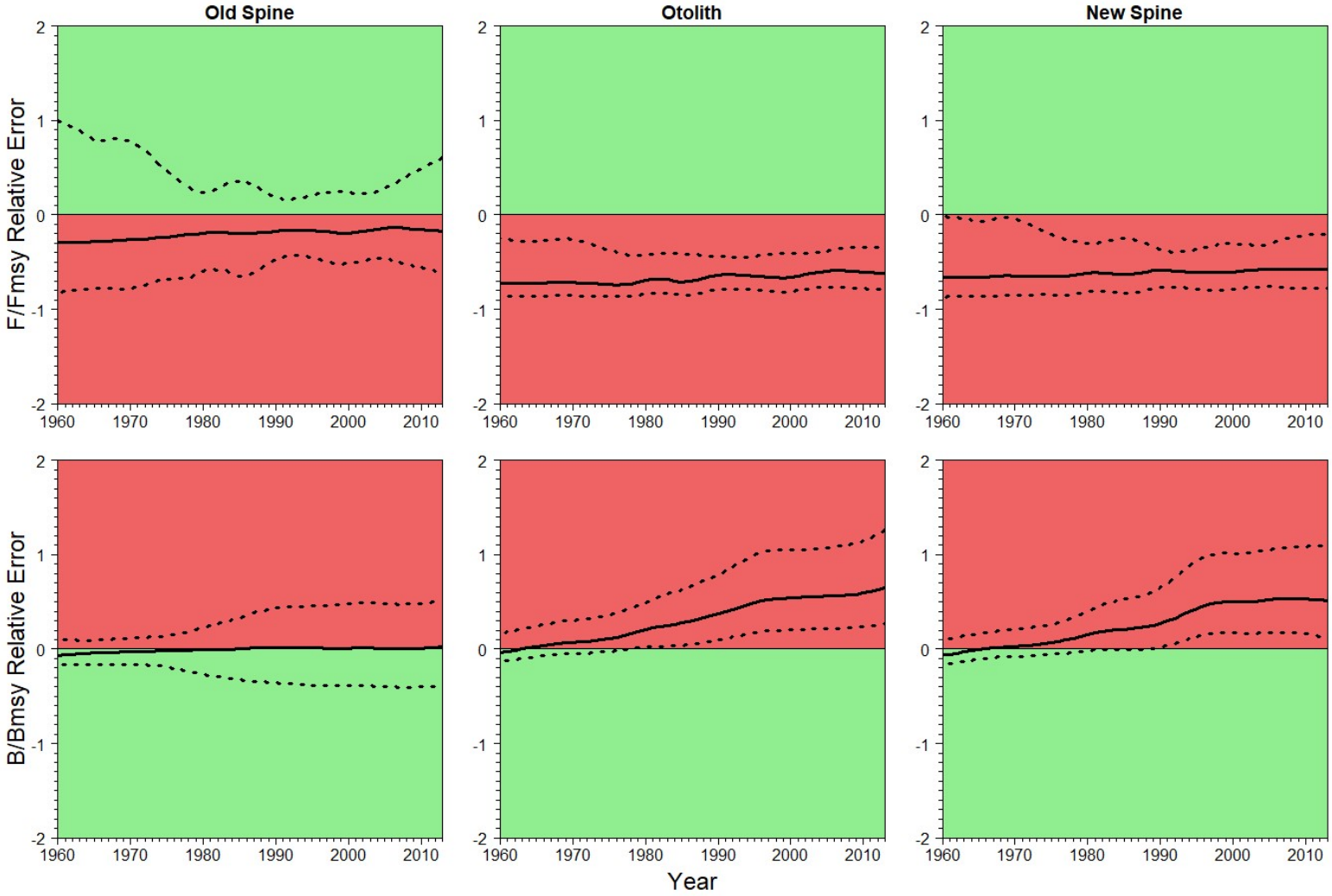


Stock Assessment Simulation Results

Study Scenario	Operating Model	Estimation Model	Convergence	Depletion	SSB at MSY	Unfished Biomass	Terminal Year F/F_{MSY}	Terminal Year B/B_{MSY}
1	Old spine	Old spine	99.8%	0.03	-0.05	-0.06	-0.13	0.02
2	Otolith	Old spine	99.8%	0.72	-0.48	-0.48	-0.58	0.67
3	New Spine	Old spine	99.4%	0.63	-0.35	-0.37	-0.54	0.52



Stock Assessment Simulation Results

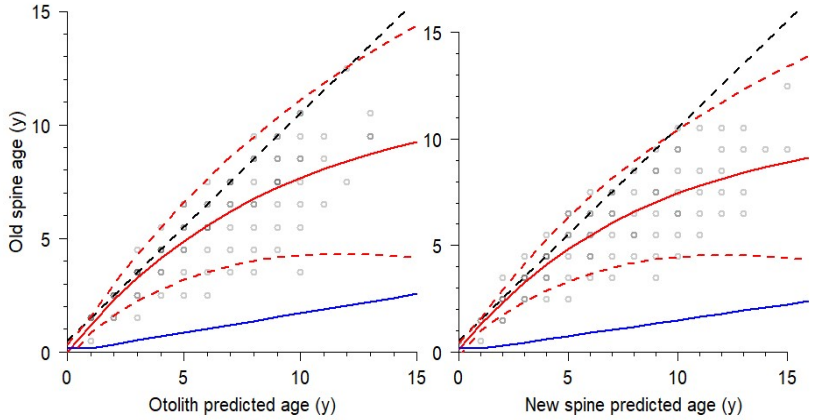


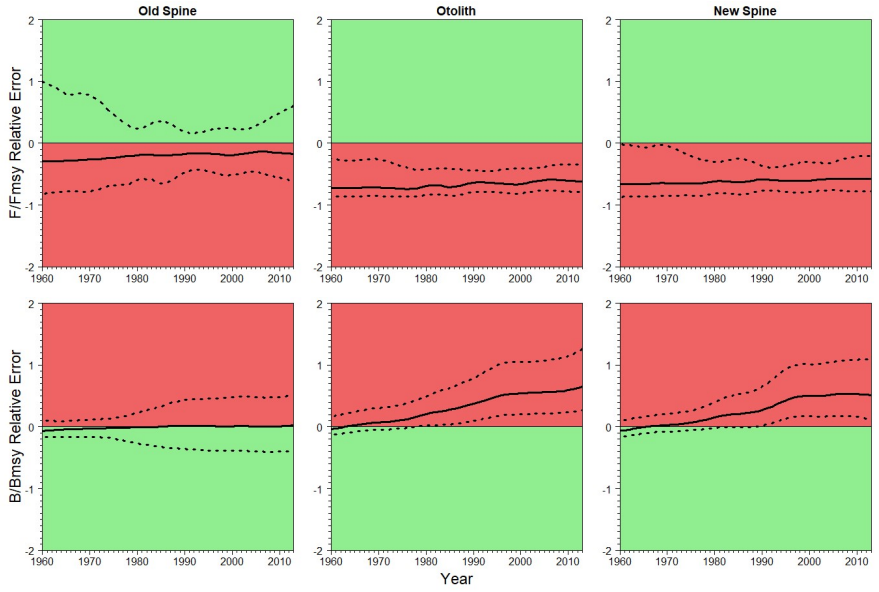
Chapter 3 Conclusions

- **Ageing bias imparted from old spine ageing protocol age comps had a substantial effect on stock assessment results.**

- **It is unclear to what extent, but ageing error likely contributed to the lack of recover observed in gray triggerfish during the 2000s and 2010s.**

- **There are several issues to address in the next gray triggerfish SEDAR assessment, but re-ageing archived spine samples for fish >age-5 with the Potts et al. (2023) protocol should alleviate ageing error issues revealed during this study.**



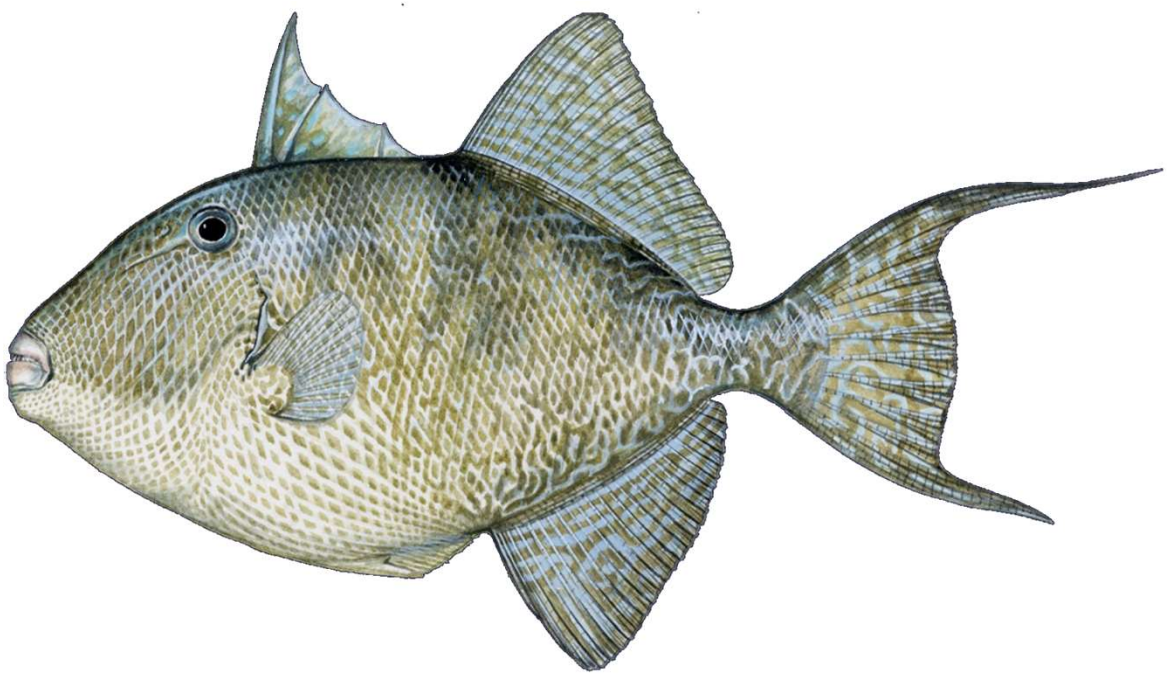


Overall Study Conclusions

- **Ageing error DOES matter for gray triggerfish stock assessment and management, and quite a bit.**

- **State-of-the-art eye lens-based bomb ^{14}C age validation was used to test for gray triggerfish ageing bias, but a relatively simple solution exists to correct for that bias in future assessments.**

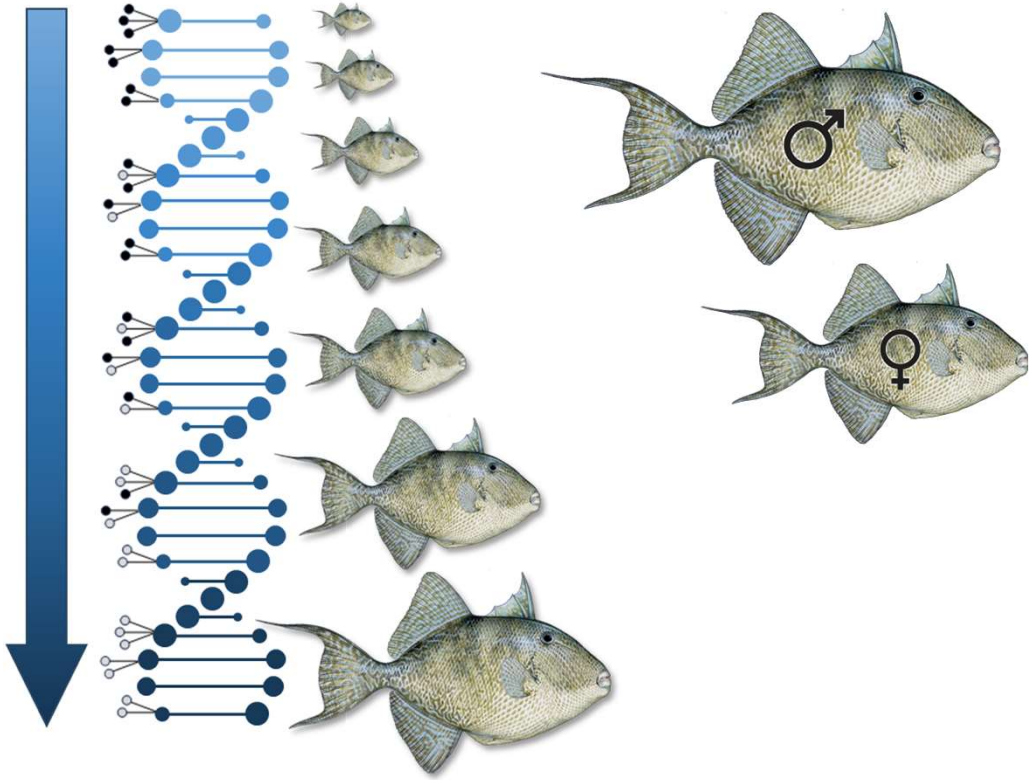
- **Issues related to sexually dimorphic growth in gray triggerfish are likely to persist in the next stock assessment.**

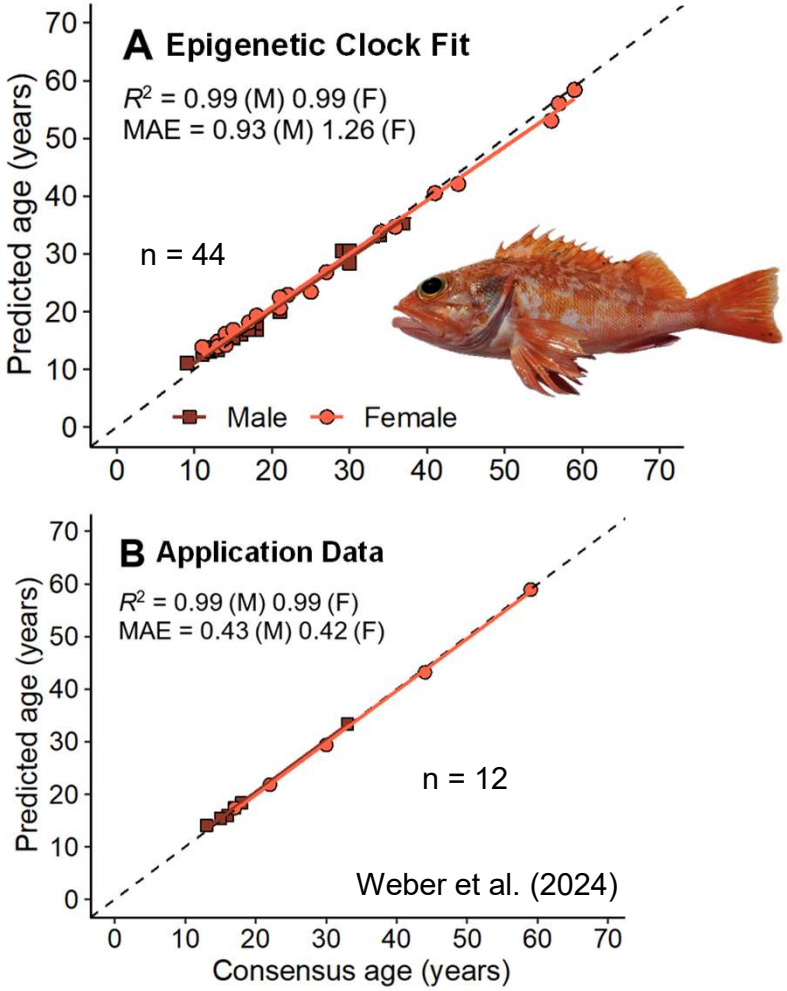


Ongoing Research and Potential Future Directions

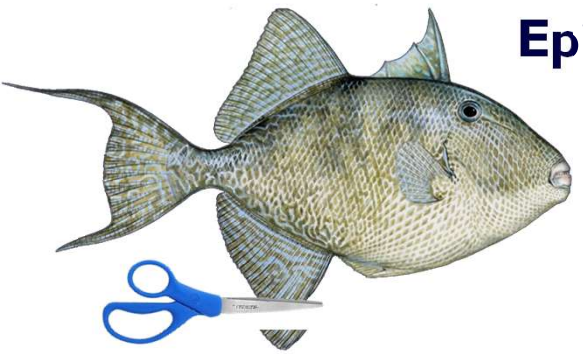
Epigenetic Ageing

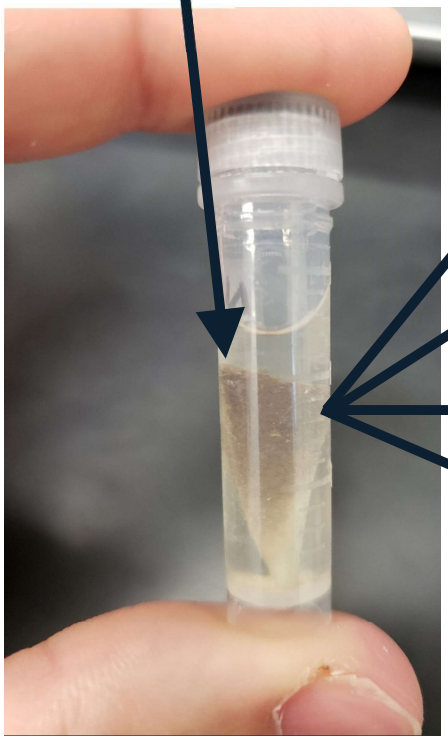
Genetic Sex ID



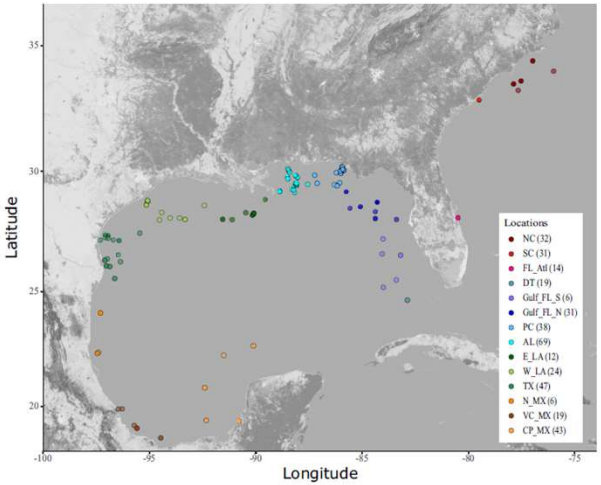


Epigenetic Ageing and Other Genomic Tools

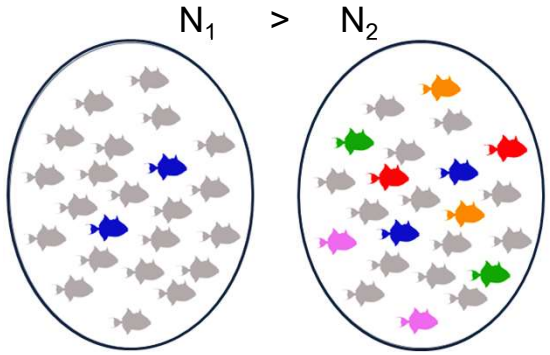


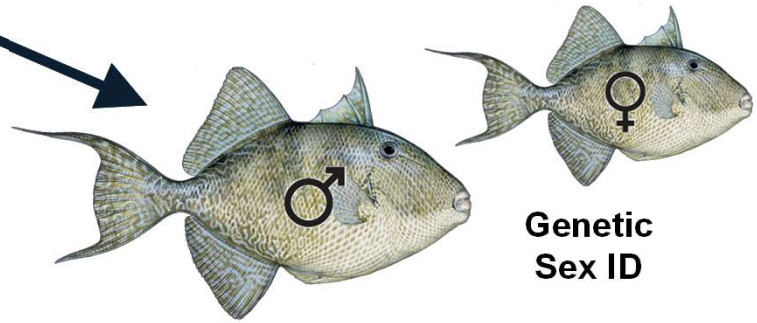


Genetic Population Structure



Close-Kin Mark-Recapture





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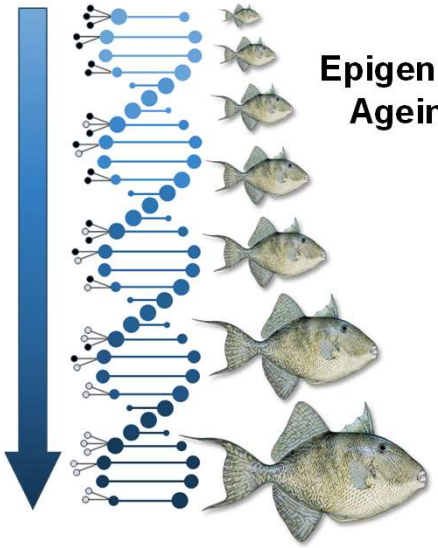

Epigenetic Ageing

Acknowledgements

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Kristen Dahl
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Steve Rash
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Nachman's Seafood
Dewey Destin's Seafood
Star Fish Company
Waterstreet Seafood
Wild Seafood Company

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Questions???